5 Surface water

This chapter outlines the issues associated with management of surface waters for the Project, including the relationship with other developments through the Draft Interim Water Allocation Plan for the Ord River. In particular, the management of water on farms is examined, including the effects water runoff from the croplands would have on receiving waters downstream of the Project Area. The chapter also outlines anticipated changes in local hydrology that may result from the proposed development.

5.1 OVERVIEW

As with ORIA Stage 1, releases of water from Lake Argyle, flowing via Lake Kununurra would be the source of irrigation water for the Project. The distribution of water from Lake Kununurra to the Project Area would be via the purpose-built M2 Channel.

The Keep River, located between the Ord and Victoria river catchments, is the most significant watercourse draining the Project Area. In addition to the Keep River, Sandy Creek drains the easternmost fringes of the Keep River Plain. The entire Project Area would be contained within the lower reaches of the Keep River and Sandy Creek catchments. Both the Keep River and Sandy Creek discharge into Joseph Bonaparte Gulf.

Nearly all rivers and streams in the region flow only in the wet season. Permanent water is therefore restricted to sheltered pools and billabongs that retain water during the dry season, and the tidal reaches near the river mouths. Pools and springs are important refuge areas for fauna in an otherwise seasonally dry environment.

Wet-season flows in all rivers and streams typically have high turbidity levels reflecting high sediment loads. The exception is the Ord River downstream of the Ord River Dam. This dam acts as a sediment trap, and hence water released downstream of the lake is low in suspended solids.

5.2 ORD RIVER

The Ord River rises near Halls Creek and has a catchment area of some 64,000 km^2. It is approximately 650 km long and flows via Lake Argyle and the Kununurra Diversion Dam on route to the Cambridge Gulf. The Dunham River, a major tributary of the Ord River, enters the latter approximately 2 km downstream of the Kununurra Diversion Dam. The Dunham River is unregulated.

Prior to construction of the Ord River Dam in 1971, the lower Ord River normally ceased flowing for at least two or three months at the end of each dry season between June and October. River regulation since dam construction has resulted in perennial flow downstream of Lake Argyle.

The farm area associated with the Project would be contained entirely within the catchments of the Keep River and Sandy Creek, and hence drainage waters from the Project Area would not be discharged into the Ord River. Consequently the only impact of the Project on the Ord River would be through the diversion of water for the irrigation scheme. This diversion of water is included in the Draft Interim Water Allocation Plan (Water and Rivers Commission 1999) for the Ord River (Sections 5.2.1, 5.2.2 and 5.2.3 refer). The scope of this ERMP/draft EIS does not include consideration of this diversion of water from the Ord River.

5.2.1 The Draft Interim Water Allocation Plan for the Ord River

The Water and Rivers Commission is the authority in Western Australia responsible for managing the allocation of water resources. The Water and Rivers Commission ensures that water is used efficiently within sustainable limits, and that the needs of people and the environment are balanced.

An important aspect of the allocation process is the preparation and implementation of allocation plans for each water management system, for example a river catchment. These plans define the upper limit of water to be made available for consumption use based on ecological sustainability (ie. after water is allocated for environmental flows), and allocate that water equitably between the different forms of use. That is, they define the amount of water that is allowed to be diverted from river systems and groundwater aquifers, while ensuring sufficient water is maintained to meet the needs of key water-dependent ecosystems. Allocation plans prepared by the Water and Rivers Commission are implemented through licensing under the *Rights in Water and Irrigation Act 1914*.

Licences formalise the allocations and are subject to conditions deemed necessary for good management of the resource. As Western Australia's water allocation system evolves to meet the requirements of the Council for Australian Governments (COAG) Water Reform Framework Agreement, the licences will become the means of identifying water allocations and their holders.

The Ord River has been used for irrigation for more than thirty years, but this use has only involved a small proportion of the available water resource during that time. A hydroelectric power station has been in operation since early 1996, and planning for a major expansion of the irrigation area, including the Project and other components of ORIA Stage 2, is now under way. In order to assist the planning of these projects, the Water and Rivers Commission has prepared a Draft Interim Water Allocation Plan (Water and Rivers Commission 1999) for the Ord River. The Draft Interim Water Allocation Plan was forwarded for review by the EPA in May 1999.

5.2.2 Assumptions made relating to the Draft Interim Water Allocation Plan

The following assumptions have been made by Wesfarmers–Marubeni and the Water Corporation regarding the Draft Interim Water Allocation Plan:

- The water allocation planning process being adopted by the Water and Rivers Commission will provide adequate assessment over time of the effects of the Project on the ecology and other values of the lower Ord River. For this reason, this issue is not addressed directly in this ERMP/draft EIS.

- The final (long-term) water allocation to the Project will be consistent with the interim allocations currently proposed by the Water and Rivers Commission.

5.2.3 Water allocation and licence provision

The Draft Interim Water Allocation Plan tables an interim water allocation of 1,235Gl/year as being acceptable for all existing and proposed irrigation uses in the Ord River Irrigation Area. The proposed water allocation for the Project Area is 740Gl/year. In assessing the irrigation allocation, the Water and Rivers Commission has had to ensure that there would be sufficient water for all other uses, including water for hydroeletric power generation and Environmental Water Provisions (EWP). A summary for the proposed allocation of water from the Ord River Dam is in Table 5.1.

Table 5.1 The use of water released or flowing from Lake Argyle - for full irrigation development and the generation of 100GWhr of hydro-power per year.

Water released or flowing from Lake Argyle	Average yearly amount (GL/a)
Divertible Allocations for Irrigation Purposes:	
• ORIA Stage 1*	300
• ORIA M2 Development Area (the Project)	740
• ORIA - Other Stage 2 developments	195
Water that contributes to meeting the Interim EWPs⊙	510
Hydro-electric power generation only**	150
Overflow⊙⊙	930
Total	2825

* *May be increased to 355 GL/a under certain conditions*

⊙ *Water that flows over the spillway, through the scour values or through the Hydro-electric stations and the contributes to meeting the interim EWPs downstream*

** *Releases specificially for hydro power generation - occurs only when hydro-power demand is greater than that needed to meet any other demand.*

⊙⊙ *Overflow only - water that flows over the spillway and is in excess of the downstream needs of irrigation or the interim EWPs.*

Source: Water and Rivers Commission 1999.

In preparing the Draft Interim Water Allocation Plan, the Water and Rivers Commission has made an assessment of the appropriate EWP, prior to making an assessment of the suitable water allocations for irrigation and other purposes. The Draft Interim Water Allocation Plan states that "Until more details study can be carried out, the Water and Rivers Commission considers that the monthly flow volumes in the Ord River just below the Dunham River confluence should be maintained at levels that at least equal the 20^{th} percentile value, which is the monthly flow volume that is not likely to be exceeded on 20% of occasions. The plan also states that the interim Environmental Water Provision (EWP) was largely "to ensure recognition of the need for some level of provisions of water to the environment and to provide a starting point for a more clearly justified EWP". In preparing the Draft Interim Water Allocation Plan, the Water and Rivers Commission has acknowledged the need for more detailed study of EWP's, and has adopted a precautionary approach in relation to the proposed consumptive use allocations.

The Water and Rivers Commission is planning for the Interim Plan to be formalised by 2003.

The Draft Interim Water Allocation Plan states that an allocation of 1,235 GL/a is adequate for irrigation purposes, whilst also maintaining flexibility for future allocation decisions. The allocation for irrigation represents approximately 44% of long term average releases from Lake Argyle, at full development of ORIA Stage 2, under the draft Interim Water Allocation Plan.

For the existing irrigation area (ORIA Stage 1), a licensed allocation of an annual average of 300 GL would be issued subject to certain conditions relating to the operation of the distribution system. The Water and Rivers Commission states that it is prepared to allocate up to a further 55 GL for ORIA Stage 1 if clear evidence for the irrigation demand can be demonstrated. This would require evidence that over 90% of the area irrigated is to be planted to sugarcane, and clear field evidence that research estimates of high sugarcane crop water demands were critical for economic production. Improvements in on-farm and distribution efficiencies, and commitments to a sustainable land and water management plan, must also be demonstrated before additional water would be allocated.

In the past, allocation licences have been issued for a maximum of ten years in accordance with established policy, and with an expectation of renewal subject to water being available and licence conditions having been complied with. However, the policy on licence duration and the expectation of renewal are under review as part of the implementation of the COAG Water Reform Framework Agreement. Proposals for longer duration licences, and the Water and Rivers Commission's powers to amend licence conditions during their life, have been considered in this overall reform context over the last twelve months.

It is the intention of Wesfarmers–Marubeni and the Water Corporation to secure a water licence with a duration commensurate with the economic life of the Project.

5.3 KEEP RIVER, SANDY CREEK AND THEIR TRIBUTARIES

5.3.1 Hydrology

Overview

The Keep River rises south-east of Kununurra and has a catchment of some 5,000 km^2, equivalent to approximately 8% of the Ord River catchment. The headwaters of the Keep River begin just south of the Victoria Highway (see Figure 5.1). After passing through the gorges and low hills of the Keep River National Park, the river emerges on to the cracking-clay plains and flows north and then north-east to drain into the Joseph Bonaparte Gulf.

Major tributaries of the Keep River include Knox Creek, Border Creek and Oakes Creek, which have the majority of their catchments within Western Australia. The areas of these catchments are presented in Table 5.2.

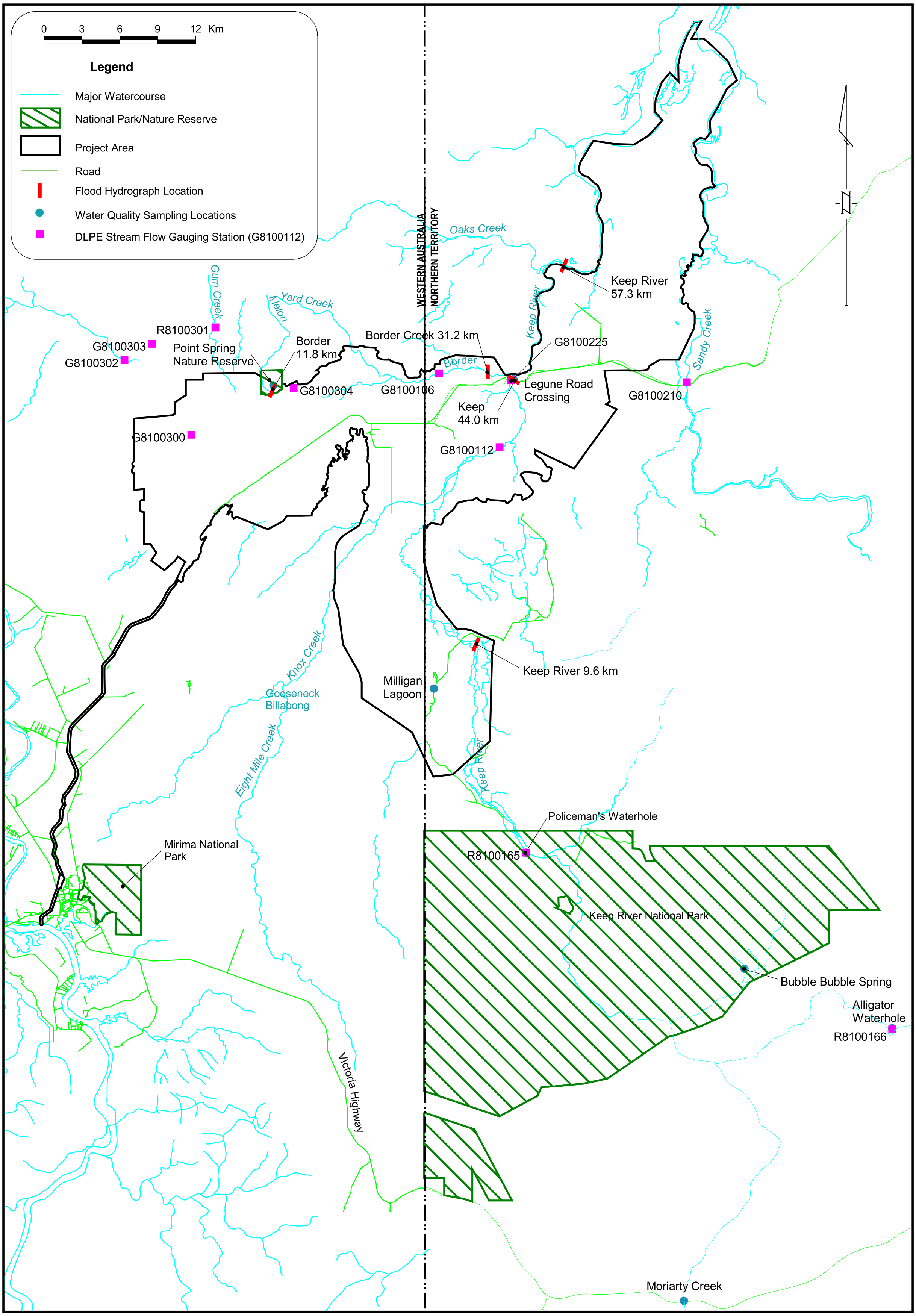

Figure 5.1 Regional Hydrology

Table 5.2 Keep River catchment areas

Catchment	Area (km^2)
Keep River	3,190
Border Creek	1,032
Oakes Creek	243
Knox Creek	577
Total	**5,042**

Sandy Creek flows into the Keep River estuary. The catchment of Sandy Creek, which has an area of 1,240 km^2, lies entirely within the Northern Territory.

Hydrological data are collected by the DLPE at several gauging stations on the Keep River and its tributaries and on Sandy Creek. Table 5.3 summarises the stream flow data available for the DLPE guaging stations shown in Figure 5.1.

Table 5.3 DLPE stream flow recording

Site Number	Name	Length of record	Start – End
G8100106	Border Creek	15 years	1971–1986
G8100112	Keep River (N.B. Gridline)	7.5 years	1971–1977
R8100165	Keep River	16 years	1970–1986
R8100166	Keep River	2 years	1972–1974
G8100210	Sandy Creek	2 years	1977–ongoing
G8100225	Keep River	21 years	1964–1986
G8100300	Weaber Plains West	3.5 years	1971–1974
G8100301	Gum Creek	3.5 years	1971–1974
G8100302	Sandy Creek*	2 years	1971–1973
G8100303	Cockatoo Creek	2 years	1971–1973
G8100304	Weaber Plains North	3.5 years	1971–1974

* *Tributary of Border Creek in Western Australia*

Keep River—upper reaches

While the main watercourse of the Keep River upstream of the Legune Road crossing is reasonably well defined, secondary flood channels parallel to the river exist along most of the river length. This is particularly noticeable at the junction of Knox Creek with the Keep River where there is a series of braided channels approximately 2–3 km wide.

A number of billabongs and lagoons occur on the floodplain of the Keep River, particularly within former drainage lines or anabranches of the river. The largest natural waterbody of this type in or near the Project Area is Milligan Lagoon (Figure 5.1).

Flow data collected by the DLPE at the Legune Road crossing, summarised in Table 5.4, indicates there is virtually no flow in the upper reaches of the Keep River from June through October. The data also indicates a high variation in annual flows.

Table 5.4 Recorded monthly flows in Keep River at Legune Road Crossing

	Mean (GL)	10th Percentile (GL)	median (GL)	90th Percentile (GL)
Jan	56.1	4.7	21.7	170.0
Feb	104.8	5.2	57.4	310.7
Mar	131.3	10.4	68.2	313.6
Apr	4.6	0.0	0.8	10.1
may	0.5	0.0	0.0	0.8
Jun	0.0	0.0	0.0	0.0
Jul	0.0	0.0	0.0	0.0
Aug	0.0	0.0	0.0	0.0
Sep	0.0	0.0	0.0	0.0
Oct	0.0	0.0	0.0	0.0
Nov	8.4	0.0	0.0	5.6
Dec	5.7	0.0	2.4	13.4

Source: DLPE data for Site Number G8100225 for period 1971–1986 as interpreted by Sinclair Knight Merz.

Border Creek and the Weaber Plain

The Weaber Plain is relatively flat and large parts are subject to inundation during the wet season. A number of intermittent watercourses from the surrounding hills, including Cockatoo Creek, Gum Creek and Melon Creek, discharge on to the plain. This water spreads out into indistinct sheet flow as the greater part of the plain has no incised channel. Only at the northern extremity of the plain is there defined drainage, and here Border Creek carries water eastwards into the Keep River. However, relatively little runoff reaches Border Creek except in very wet periods. The Pincombe and Cave Spring ranges to the south of the Weaber Plain produce runoff that is generally lost by infiltration or evaporation on the Weaber Plain, with little runoff reaching the downstream gauging point on Border Creek.

Data collected by the Department of Lands, Planning and Environment indicate that no flows have been recorded in Border Creek between June and September. The data also indicate that the Border Creek catchment contributes approximately 12% of the Keep River flows, although representing approximately 20% of the catchment area. Data from stations located further upstream in the Border Creek catchment indicate only sporadic flows after heavy rains late in the wet season.

Point Spring and Cave Spring are two small but permanent waterbodies that occur at the foot of the Weaber Range and the Cave Spring Range respectively. Both are surface expressions of groundwater, fed by infiltration higher up in the respective ranges.

A shallow surface waterbody has formed on the western portion of the Weaber Plain as a consequence of drainage releases from ORIA Stage 1. This waterbody varies in size with climatic conditions and volume of discharge; however, at times it is about 5 km long and 2 km wide.

Knox Creek and the Knox Creek Plain

Knox Creek enters the Keep River some 13 km upstream of the Legune Road crossing. The major tributary of Knox Creek is Eight Mile Creek, which rises just south of the Victoria Highway in the vicinity of Matheson Ridge. An unnamed major tributary of Knox Creek drains Mt Cecil and Abney Hill immediately north of Mirima National Park. The main drainage line of Knox Creek runs within a kilometre south-west of the Pincombe Range before turning east to the Keep River confluence in the vicinity of the border between Western Australia and the Northern Territory. There are no known flow records for Knox Creek.

The Knox Creek Plain is mostly well drained due to its uniform but gentle slope.

Keep River—lower reaches

Downstream from the Legune Road crossing, the Keep River becomes a series of permanent waterholes separated by rockbars. At the confluence with Border Creek the river opens into a tidal waterbody some 50–100 m wide, which is connected to the Keep River mouth. Oakes Creek discharges into the Keep River in this reach, which becomes progressively wider and tidal to the river mouth. The tidal range at the mouth is approximately 8 m.

Sandy Creek

Sandy Creek is immediately east of the Keep River Plain. At this location its bed is relatively wide and sandy containing sand beds 100 m and 200 m in width both downstream and upstream of Legune Road. Small semi-permanent lagoons or billabongs and sandy strips occur close to the creek. These are primarily associated with old meanders and are most apparent in the vicinity of Legune Road.

Sandy Creek becomes tidal approximately 10 km downstream of the Legune Road.

5.3.2 Water quality

Water quality data in the vicinity of the Project Area have primarily been collected by the DLPE. Sampling has also been conducted by the Power and Water Authority, the Water Directorate (Field 1988), the Water Corporation (December 1995 to July 1996 and February 1998), CSR (April 1996 to November 1996) and the OIC (April 1996 to February 1997), and during the aquatic fauna survey for the Project (Larson 1999). The water quality data available from the surveys are presented in Appendix G.

The range of water quality data collected in and near the Project Area during the wet and dry seasons is presented in Table 5.5 for the Keep River and associated waterholes and in Table 5.6 for other watercourses, including the M1 Channel. The majority of the Keep River samples have been taken from lagoons or pools either at the start or the end of the wet season, when the river was not flowing.

During the wet season the salinity levels in the non-tidal sections of the Keep River are similar to those in the Ord River, with conductivities generally less than 200 µS/cm. During the dry season higher salinity levels (up to 740 µS/cm) have been recorded in pools upstream of Legune Road crossing, indicating the effect of evaporation on this water-quality parameter.

Salinity levels in the Keep River become progressively higher closer to the river mouth as the tidal influences become more substantial.

Concentrations of nutrients sampled in the Keep River and its tributaries during the wet season have ranged from 0.01 mg/L to 0.54 mg/L total phosphorus and 0.12–0.48 mg/L total nitrogen. Land uses in the Keep River catchment involve conservation in the Keep River National Park and pastoral activities. Some of the naturally occurring total phosphorus levels are above the national guidelines (ANZECC 1992) of 0.01–0.1 mg/L for the protection of freshwater ecosystems.

Only one sample has been collected from the Keep River during the dry season and analysed for nutrients. The level of total phosphorus (0.018 mg/L) in this sample is comparable to the lower values measured during the wet season.

5.4 PREDICTED CHANGES TO THE HYDROLOGY OF THE KEEP RIVER

The hydrology of the Keep River and its tributaries adjacent and downstream of the Project Area would be affected by several features of the Project, including:

- alteration of flow levels and velocities, through containment of flood waters within flood protection levees;
- alteration of surface runoff volumes and timings, through land and drainage modification;
- alteration of dry season flow patterns, due to intermittent, but minimal, releases of irrigation water during periods of equipment failure or during maintenance;
- possible alteration of seasonal flows resulting from groundwater management strategies (section 5.4.4 refers).

5.4.1 Influence of the flood protection levees

Flood protection levees would be constructed around most of the perimeter of the farm development area to prevent flooding of the cropped areas and associated infrastructure in all but extreme conditions. These flood protection levees, described in Chapter 3, would influence the flow levels and velocity within the Keep River, Border Creek and to a lesser extent in Sandy Creek as a consequence of containing floodwaters to a reduced area of floodplain.

The extent of the changes to the hydrology of the Keep River and Border Creek during flood conditions is shown in Figure 5.2. This figure shows typical hydrographs on these two watercourses for both the existing and the post-development scenarios for the following flood conditions:

- frequently occurring flood events, denoted by the 1-year Average Recurrence Interval (ARI) flood hydrograph. By definition, the 1-year ARI flood would occur, on average, once every year;
- infrequent flood events, denoted by the 25-year ARI flood hydrograph. The 25-year ARI flood would be the design flood for the levees; hence it would be contained by the levees;
- extreme flood events, denoted by the 100-year ARI flood hydrograph. The 100-year ARI flood need not be contained by the levees; hence some flooding of the cropped area would be expected.

Of interest are the effects that the levees would have on peak flow levels and velocities as summarised in Table 5.7. This information was derived from the hydrology models used to define the existing and post-development hydrographs (Figure 5.2). The hydrology models were also used to optimise the proposed location of the flood protection levees with respect to minimisation of increases in peak flood levels and velocity.

Table 5.5 Range of water quality data for the Keep River and associated waterholes

Parameter	Keep River		Policeman's Waterhole		Milligans Lagoon		Alligator Waterhole		Bubble Bubble Spring	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Conductivity (µS/cm)	45–313	182–740	173–209	127–134	73	45–82	77	49–112	316	210–298
pH	7.2–8.4	7.2–8.6	8.1–8.3	7.8–7.9	6.8	6.7–7.2	5.8	4.7–6.8	7.9	7.6–8.2
Turbidity (NTU)	22	1–39	11–12	8–13	11	1-10	10	3–10	2	0–10
Dissolved oxygen (% saturation)	–	85–150	–	–	–	–	–	–	–	–
Dissolved oxygen (mg/L)	6.55	6.60–9.05	6.63–6.65	7.91–8.00	4.30	2.90–7.72	6.03	–	5.25	4.58–8.45
Total nitrogen (mg/L)	0.281	0.355	0.245	0.339	0.712	0.444	0.481	0.352	0.123	0.084
Total Kjeldahl nitrogen (mg/L)	0.280–2.250	0.350	0.240	0.280	0.710	0.440	0.480	0.350	0.120	0.080
Nitrate and nitrite (mg/L)	0.001–19.000	0.005–1.000	0.005–0.426	0.059	0.002–0.492	0.004	0.001	0.002	0.003	0.004
Total phosphorus (mg/L)	0.008–0.540	0.018	0.013	0.013	0.024	0.028	0.031	0.030	0.009	0.013
Free reactive phosphorus (mg/L)	0.003–0.057	0.002–0.056	0.006–0.040	0.002	0.004–0.044	0.007	0.010	0.009	0.007	0.004

– *Signifies no data available.*

Sources: *Department of Lands, Planning and Environment monitoring July 1995 to October 1996, and December 1997 to March 1998;, Ribbons of Blue January 1995 and February 1997; Water Corporation December 1995 to July 1996, and February 1998; OIC April 1996 to February 1997; CSR April 1996 to November 1996; Field 1988; and Larson 1999.*

Table 5.6 Range of water quality data for other watercourses

Parameter	Knox Creek	Border Creek	Sandy Creek		M1 Channel		Oakes Creek	Moriarty Creek
	Wet season	Wet season	Wet season	Dry season	Wet season	Dry season	Dry season	Dry season
Salinity (ppt)	–	–	41–61	0	–	–	47–49	–
Conductivity (µS/cm)	–	21–94	34–180	< 5–420	–	–	–	440–560
pH	–	–	5.7	7.2–9.1	–	–	–	7.5–8.3
Turbidity (NTU)	–	–	11	1–8	–	–	–	1
Dissolved oxygen (% saturation)	–	–	–	82–110	–	–	–	73–88
Dissolved oxygen (mg/L)	–	–	–	–	–	–	–	–
Total nitrogen (mg/L)	–	–	–	–	–	–	–	–
Total Kjeldal nitrogen (mg/L)	–	0.51–3.88	–	–	–	–	–	–
Nitrate and nitrite (mg/L)	0.500	< 0.2–15.7	< 0.2–7.1	< 1–1.0	0.155–0.505	0.150–0.396	–	< 1
Total phosphorus (mg/L)	–	0.047–0.226	0.010–0.050	–	–	–	–	–
Free reactive phosphorus (mg/L)	0.039	0.150	–	0.011–0.025	0.004–0.027	0.003–0.060	–	0.023–0.045

– *Signifies no data available.*

Sources: *Department of Lands, Planning and Environment monitoring July 1995 to October 1996, and December 1997 to March 1998; Ribbons of Blue January 1995 and February 1997; Water Corporation December 1995 to July 1996, and February 1998; OIC April 1996 to February 1997; CSR April 1996 to November 1996; Field 1988; and Larson 1999.*

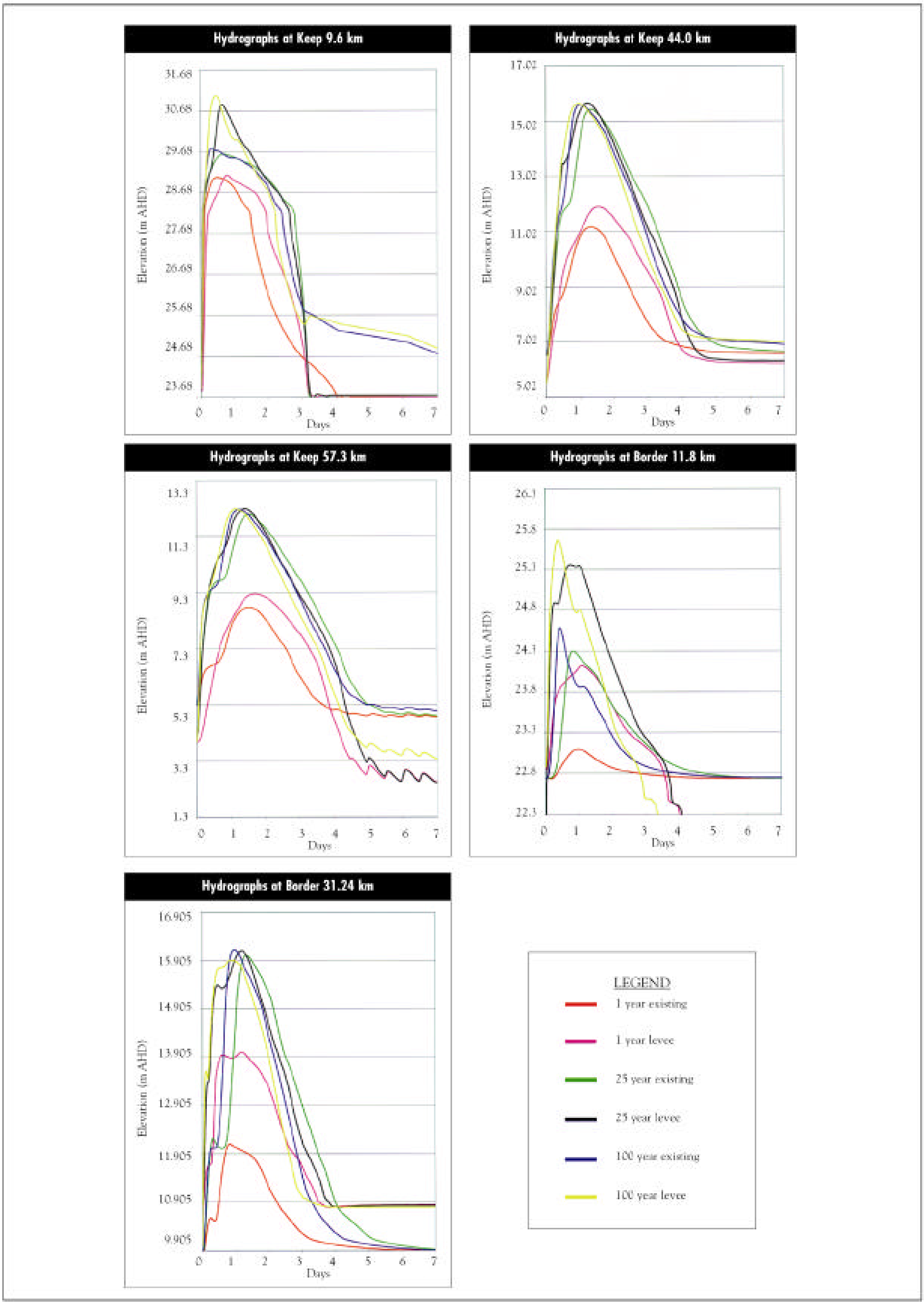

Figure 5.2 Predicted flood hydrographs

Table 5.7 Summary of the influence of flood protection levees on Keep River and Border Creek peak flood height and peak average velocity

Location*	Predicted changes following development					
	Increase in peak flood height (m)			Increase in peak average velocity (m/s) **		
	1-year ARI	25-year ARI	100-year ARI	1-year ARI	25-year ARI	100-year ARI
Keep River 9.6 km (upper development)	Nil	1.2	1.3	Nil	0.2	–0.2
Keep River 44 km (mid-development)	0.7	0.2	Nil	Nil	Nil	Nil
Keep River 57.3 km (lower development)	0.5	0.2	Nil	0.2	Nil	Nil
Border Creek 11.8 km (mid-development)	1.0	1.1	1.1	0.3	0.4	–1.0
Border Creek 31.2 km (lower development)	1.9	0.1	–0.2	1.6	0.8	0.2

* *Refer to Figure 5.1 for locations.*

** *Average velocity is flow rate divided by area of flow.*

A criterion adopted for the optimisation process was to restrict peak flood levels from the 1-year ARI development scenario to those defined by the 25-year ARI existing scenario. In other words, peak flood levels from frequently occurring floods were restricted to a less frequently occurring level. In particular, this criterion resulted in flood protection levee FPL1 (shown in Figure 3.4) being moved approximately 200 m south at Border Creek 11.8 km (near farm block W321 and Point Spring). FPL1 would contain Border Creek along the northern edge of the Weaber Plain.

The revised location of FPL1 is also satisfactory because it avoids frequent inundation of Point Spring, located at the foot of the Weaber Range. The natural levee between the wetland associated with Point Spring and the Weaber Plain has a measured elevation of 24.3 m AHD, the same as the predicted peak flood elevation for the 1-in-25-year ARI flood for the development scenario.

In regard to water velocity, the hydrology models predict minor or no increases in peak average velocity at most locations and even a reduction for some of the 100-year ARI scenarios following development. The exception is the location Border Creek 31.2 km on the lower reaches of Border Creek, with significant increases of peak average velocity of up to 1.6 m/s predicted for the modelled scenarios at this location. However, erosion problems are not anticipated due to the rocky nature of the Border Creek substrate at this location.

At the other locations the minor increases in peak velocities would result in predicted velocities in the range of 0.2–0.8 m/s. These velocities are generally less than the value of 1.5 m/s recommended by ID&A (1996) and Chang (1988) as the maximum permissable velocities for streams with substrates of colloidal stiff clays and alluvial silts and fine gravels, which are characteristic of the Keep River and Border Creek. This factor, together with the riparian vegetation that would be maintained along the natural watercourses, would mitigate any erosion effects.

Localised areas of high water velocity may occur at structures constructed across natural watercourses, such as the siphon and bridge crossings of Knox Creek and the Keep River. Appropriate erosion protection measures such as stone pitching and bridge abutments would be developed for these areas as part of the detail design for the Project.

Monitoring of erosion along all watercourses, including constructed drains, would be undertaken as part of the EMP for the Project. Localised management of any erosion would be undertaken on an as-needed basis by the Environmental Management Entity that would be established as part of the Project (see Chapter 16).

5.4.2 Influence of improved drainage of the farm development area

The black-soil plains of the Project Area currently have relatively poor drainage characteristics due to a combination of their low slopes and localised depressions, or gilgai, that hold surface water. In addition, the black soil develops extensive surface cracks over the dry season, and these cracks retain rainwater until the soil expands sufficiently to close the cracks.

Development for irrigated farming would change the rainfall runoff characteristics from these areas in terms of quantity and timing of flows, as a result of the following features:

- the laser planing of the farm units to remove gilgai (localised depressions) features that would provide uniform slopes to facilitate flood irrigation;
- irrigation water application that would prevent soils from drying and forming surface cracks;
- the growing of sugarcane, a perennial crop with high water requirements, over most of the Project Area;
- on-farm water management systems that would trap and hold, for subsequent use as irrigation water, the first-flush runoff from the farm units. The number of times that the first-flush systems would operate during the wet season would vary with the size and timing of storms;
- the construction of drainage infrastructure that would efficiently remove rainfall runoff from the farm units and convey it to streams and rivers.

Quantification of the rainfall runoff from farms planted to sugarcane was undertaken using the LEACHM model. This model, described further in Chapter 6, was utilised to predict the various proportions of irrigation water and rainfall that result in runoff, infiltration or use by the crop. For average years, the LEACHM model predicts that approximately 25% of the average annual rainfall of 776 mm would run off from the sugarcane crop. Of this 194 mm of runoff, approximately 48 mm of runoff, can be assumed to be captured and returned as irrigation water. Hence, approximately 146 mm of runoff (194 mm less 48 mm), or approximately 20% of the average rainfall, is predicted to leave the farms in average years. A similar proportion is predicted for the areas occupied for road and drainage infrastructure.

The net effect on surface water as a result of the proposed development proceeding would be an increase in the volume of runoff reaching streams and rivers over a typical wet season. In the natural state, there is approximately 5% of rainfall (40 mm) run off from the black-soil plains. Hence, on average, the increase in run off would be approximately 106 mm, about 37 GL/a from the total Project Area, resulting in an annual flow increase of about 25% (based upon median flow of 150.5Gl/a given in Table 5.4) in the lower reaches of the Keep River.

The timing of runoff flows leaving the Project Area would also change following development due to the cropped areas entering the wet season in a moist state and the improved efficiency of the drainage infrastructure. The magnitude of this change would vary during the wet season as a result of natural variation in rainfall intensity and the operation of the first-flush runoff capture systems. However, assuming that the first 50–100 mm of rainfall is currently required to 'wet up' the black-soil plains prior to runoff occurring, it is probable that in some seasons the runoff from the cropped areas would occur around one month earlier than is currently the case.

It is noted that there is a high degree of natural variability of surface-water flows due to the variable nature of rainfall in the region. The changes to flows in the Keep River and Border Creek brought about by improved drainage of the Project Area, as described above, are unlikely to be significant in all but extreme years as they would be within the range of natural variability for these watercourses. Changes to flows in drier years would be the most significant and, at these times, the higher and earlier flows from the Project Area are considered likely to be beneficial to the environment supported by these watercourses.

5.4.3 Alteration of dry season flow patterns

Management of water levels within irrigation channels would be via automated gates controlled from a centralised control centre utilising a SCADA system. This system would be more efficient at minimising spillages than a manual control system. Nevertheless, some intermittent releases of good quality water may occur to the drainage system during maintenance activities such as cleaning of weed-control structures, and periodic draining of channels to facilitate killing of weeds through exposure to the sun.

Releases of water from irrigation channels could also occur during emergency events such as channel-control gates jamming, software failure, or the system being struck by lightning. Any of these events may cause water to back up in channels and overflow to the drainage system, but in a controlled manner. During such an event, the electronic SCADA system would provide warning signals to supervisors. Field crews would then be notified and manual control of gates would be employed until the emergency event had been rectified.

The capture and reuse of tailwater are expected to virtually eliminate discharges from farming areas to the drainage system in the dry season. This would be consistent with the existing natural conditions where surface runoff does not occur from the plains area during the dry season. Tailwater discharges would only occur during periods of mechanical or other operational failures of the tailwater return systems. The magnitude of the releases in these circumstances would be restricted by storage of tailwater in the first-flush storage system and by the irrigation water supply being terminated upon detection of any problems with the tailwater return system.

5.4.4 Influence of groundwater management strategies

Groundwater levels throughout the Project Area would be managed to ensure waterlogging of cropped areas does not occur (Chapter 6 refers). A consequence of this management would be that groundwater would generally be maintained at sufficiently low levels to avoid rising groundwater causing any incremental permanent base flow in watercourses throughout the Project Area.

5.5 WATER QUALITY ISSUES

Water quality issues may arise from a number of areas, as follows:

- ground-disturbing activities during construction;
- farm operations, including possible movement of farm chemicals beyond the boundaries of the cropped areas;
- discharges from the raw-sugar mill of cooling water and treated process water;
- maintenance operations in the irrigation supply channels and balancing storage dams for the control of aquatic weeds;
- in the longer term, possible discharges from the groundwater management system comprising groundwater that is too saline for use in irrigation systems.

These issues are discussed further below, with specific reference to the management measures proposed to mitigate water quality impacts in the receiving waters. Predicted changes to water quality in the Keep River and the water quality monitoring programme proposed for the Project are described in Section 5.6 and Appendix O.

5.5.1 Construction activities

Construction operations would include the clearing and planing of farm areas and extensive earthworks associated with construction of the irrigation, drainage and road infrastructure. The movement of construction machinery over these areas during the wet season would be extremely difficult; hence construction of these components of the Project would be restricted to the dry season, usually between the months of May to October, inclusive.

Construction activities would also be associated with the raw-sugar mill. These construction activities would commence with the establishment of an all-weather access road to allow uninterrupted construction during the wet season.

The primary water quality issue during construction would be the control of sediment that would otherwise enter waterways. Management of sediment during construction would involve a combination of the following measures:

- wherever practicable, restricting ground-disturbing operations to the dry season;
- restricting ground-disturbing operations to the minimum area required to facilitate construction;
- collecting and storing for future use any topsoil from areas to be disturbed;
- installing and maintaining temporary sediment traps downstream of any areas to be disturbed;
- progressive clearing, developing and rehabilitating, wherever possible using locally won topsoil, of any areas that are no longer going to be disturbed.

Monitoring of water quality in the receiving watercourses would also be undertaken during construction.

5.5.2 Farm operations

Management measures would be provided to counter each of the potential mechanisms that exist for the movement of agricultural chemicals off the farms and into the environment. Research into these mechanisms has been undertaken previously for pesticides, particularly endosulfan from cotton farms (Schofield et al. 1998). Although endosulfan is not used on sugarcane, the transport mechanisms identified by the research are useful for devising the management measures proposed for the cane fields and for other crops that may be grown in the Project Area. The management measures proposed for each transport mechanism are described below in decreasing order of importance to off-farm impacts.

Surface water and suspended sediment

Stormwater runoff from irrigation farms can transport eroded soils, nutrients and pesticides. Installation of adequately sized first-flush runoff storages minimise these impacts by trapping and reusing some of these elements on the farm. For the Project, the following approach representing current best practice in farm water management (adopted from a review of the Environmental Protection Authority of New South Wales 1995 and Barrett et al. 1991 as developed by the NSW State Pollution Control Commission, the Queensland Department of Environment and Heritage, and the Department of Primary Industries) would apply;

- Irrigation tailwater return systems would be provided to all cropped areas.
- A first-flush storage capacity of 12 mm of rainfall runoff would be provided to all sugarcane farms.
- A first-flush storage capacity of 25 mm of rainfall runoff would be provided to any farms using endosulfan or any other chemicals perceived to be of high risk to the aquatic environment.
- Collected irrigation tailwater and first-flush stormwater would be reused for irrigation.
- Fertilisers or chemicals would not be applied to cropped areas when the first-flush basin capacity is not available.
- The storage capacity of the first-flush basin would be maintained through regular inspection and removal of sediment.

Sediment retrieved from the first-flush systems would be spread on the cropped areas.

Spray drift

Spray drift is the airborne movement of fine spray droplets away from the crop being sprayed. Results of research throughout Australia indicate that spray drift from the aerial application of pesticides on cotton is potentially a significant contributor to riverine contamination (Schofield et al. 1998).

Sugarcane has a minimal requirement for pesticides to grow successfully in the ORIA (Chapter 2 refers). However, the management measures that would be adopted for the Project to minimise the effects of any spray driftwould be as follows:

- adoption, where appropriate for the crops being grown, of the integrated pest management strategy developed by AGWEST for ORIA Stage 1 (Section 2.3.1 refers) to minimise the amount of pesticides used;

- strict control on the use of pesticides, including mandatory adoption by all farmers of the spray calendar developed annually for ORIA Stage 1;
- minimisation of the use of aerial spraying, by using tractor-based spraying to the maximum extent possible;
- avoidance of unsuitable weather conditions such as surface temperature inversions and unstable conditions during aerial spraying whenever possible;
- utilisation of a large droplet size settings for spray equipment during aerial spraying;
- a requirement that all commercial spray operators be accredited to a national registration programme.

In addition to the above measures, it should be noted that the Project layout includes the provision of conservation areas between cropped and riparian areas (Chapter 10 refers). The width of these areas would be determined on a case by case basis, but as a minimum would be:

- 250 m from the incised channels of rivers;
- 250 m from the outer edge of the riparian zone of wetlands;
- 100 m from the incised channels of significant creeks.

Airborne dust

Soil particles on which pesticides can be deposited can also be subject to suspension in the atmosphere by wind and by activities such as tillage and vehicular traffic. Research has clearly shown that dust movement on farms can relocate pesticides (Schofield et al. 1998). However, this pathway is likely to be far less important than spray drift, in the off-farm aerial transport of pesticides.

Management measures that would be adopted for the Project to minimise the effects of airborne dust include:

- provision of dedicated on-farm access tracks that would not have agricultural chemicals applied directly to them;
- wherever possible, adoption of 'minimum tillage' farming practices.

Volatilisation

Pesticides can volatilise from plant surfaces, the soil surface, from within the soil pore spaces and from pesticides adsorbed on to soil particles. Volatilisation is affected by the saturation vapour pressure of the pesticide, adsorption to substrates, wind velocity, temperature, soil water content, pesticide diffusion and advection through the soil, and the application method (Schofield et al. 1998). Research has established the potential of volatilisation of pesticides to contaminate nearby rivers. However, the contribution from volatilisation is likely to be significantly less than the other transport mechanisms described above. Management would involve minimising the use of pesticides by adoption, wherever possible, of the integrated pest management strategy.

5.5.3 Sugar mill effluents

The raw-sugar mill would produce two effluent streams: a cooling water stream sourced and returned to the irrigation supply system, and a process effluent stream. Each of the these streams would only occur during the crushing (dry) season.

The cooling water stream would consist of approximately 288 ML/d of irrigation water sourced from the irrigation supply system upstream of the sugar mill. An equivalent volume, with its temperature elevated by some 3°C would be returned to the irrigation supply system downstream of the sugar mill.

The process effluent stream would be produced at a rate of about 4.8 ML/d during the crushing season. Because of its high BOD it would be treated in an activated sludge treatment plant to achieve a BOD level of less than 20 mg/L. The effluent would then be utilised on sugarcane fields where it would replace some of the crop's irrigation water requirement.

5.5.4 Weed control in the irrigation channels

Control of aquatic weeds in the irrigation channels and balancing storage dams would be by a combination of mechanical weed removal and periodic dosing with a chemical such as acrolein. The latter is currently used for the control of aquatic weeds in the irrigation channels in ORIA Stage 1.

Chemical management would be in accordance with best-practice procedures as outlined below:

- emptying the channel, locking offtakes, erecting warning signage and notifying farmers prior to injection of the chemical;
- releasing a known flow of water to obtain a water depth of approximately 0.5 m into the channel and releasing the chemical from a controllable release point to maintain an initial concentration (15 ppm in the case of acrolein);
- releasing a marker dye to denote the chemical front;
- shutting flow to the channel and holding the chemical in the channel for a minimum of forty-eight hours before diluting by release of additional water and use of the water for irrigation;
- monitoring of watercourses downstream of the Project Area for acrolein and if detected, review the above procedure in conjunction with the Water and Rivers Commission and the DLPE

5.5.5 Groundwater disposal

Chapter 6 describes the groundwater management strategy that would be implemented as part of the Project. This strategy makes provision for the future extraction of groundwater by bores in order to control groundwater levels.

Disposal of the extracted groundwater would preferentially be into the irrigation channels, to supplement the water obtained from Lake Kununurra. However, it is anticipated that some of the groundwater may be too saline for use in the irrigation system and may therefore require separate disposal. At this stage, Project planning assumes that groundwater unsuitable for use as irrigation water would be collected by pipelines and discharged into the tidal reaches of the Keep River and Sandy Creek. The groundwater collection and disposal system is described further in Chapter 6.

5.6 PREDICTED CHANGES TO WATER QUALITY

5.6.1 Water quality in the Keep River

The potential for the Project to result in elevated nutrient levels in receiving waters has been assessed by the comparison of nutrient levels in drains from ORIA Stage 1, with recorded levels in the Keep River (Table 5.8 refers). The comparison, when the proposed water management practices for the Project are taken into account, would imply a low potential for impact on the nutrient levels in receiving waters. In fact, only a minor reduction in the concentrations of nutrient runoff recorded from farms in ORIA Stage 1 would be required to reduce nutrient levels to levels currently occurring in the Keep River.

Table 5.8 Comparison of nutrient levels in ORIA Stage 1 drains and the Keep River

Nutrient	Irrigation runoff†	Rainfall runoff†	D4 drain*	Keep River
Total nitrogen (mg/L)	0.48	0.68	0.60–1.13	0.28–0.36
Total phosphorus (mg/L)	0.06	0.12	0.21–0.23	0.01–0.54

* *Sampling September 1997 (Doupé et al. 1998).*

† *Mean concentrations for 1996 (Sinclair Knight Merz 1998).*

There would be a low requirement for pesticide use in the Project Area. The majority of the farmed area would be devoted to sugarcane, a crop that has a low requirement for pesticides, and no requirement for endosulfan, to grow successfully in the ORIA.

Crops other than sugarcane could possibly be grown on areas farmed by independent farmers. Experience in ORIA Stage 1 has indicated that these other crops may require a greater use of pesticides than sugarcane, and possible use of endosulfan. Endosulfan is extremely toxic to some aquatic fauna species. The ANZECC (1992) recommendation for the upper limit of endosulfan concentration in the aquatic environment is 0.01 μg/L.

Water quality sampling undertaken in September 1997 in drains discharging from ORIA Stage 1 indicated endosulfan levels in the range of less than 0.001–0.025 μg/L (Doupé et al. 1998). Other sampling has indicated endosulfan concentrations in the ORIA Stage 1 drains in the range of 0–1.1 μg/L (H.G. Gardiner & Associates 1998). The high level was recorded only once, with the majority of levels in the ORIA Stage 1 drainage system ranging from undetectable to 0.2 μg/L.

The potential endosulfan concentrations in the Keep River have been assessed by assuming endosulfan concentrations in the drains of the independent farming area of the Project would be similar to those monitored in the drains of ORIA Stage 1. This assessment has ignored the beneficial effects of the water management measures proposed for the Project, and is therefore considered conservative. It is predicted that endosulfan concentrations, following dilution with Keep River flows, may be within the range 0–0.04 μg/L and generally less than 0.006 μg/L.

As a consequence of the predicted endosulfan concentration being of similar magnitude to the recommended limit, a precautionary approach of adopting interim restrictions is proposed on the use of endosulfan in the Project Area.

The interim restrictions would require each application of endosulfan to receive prior approval from the Environmental Management Entity that would be established in conjunction with the Project (see Chapter 16). The interim restrictions would include monitoring of farm drains, tailwater return systems and drainage flows to confirm the effectiveness of the proposed management measures.

The interim restrictions on the use of endosulfan in the Project Area would be in addition to other commitments made in this ERMP/draft EIS with regard to the use of pesticides. Modification of the interim restrictions, if supported by monitoring results, would be made via the periodic reviews and updating of the Project's EMP.

5.6.2 Water quality in Sandy Creek

Sandy Creek currently drains approximately half of the Keep River Plain and this would continue following Project development.

The potential for the Project to impact upon water quality in Sandy Creek would be less than the generally acceptable levels predicted for the Keep River as described in the previous section. The reasons for this are as follows:

- A smaller proportion of the Sandy Creek catchment (about 4%) would be developed for farmland than for the Keep River (about 6%).
- Drainage discharges from the farm development area would be at, or below, the tidal limit on Sandy Creek, thereby providing additional dilution and flushing of drainage flows.
- It is likely that all the farmland on the Keep River Plain would be devoted to growing sugarcane, thereby avoiding the pesticide issues associated with the cultivation of other crops.

5.6.3 Water quality monitoring

Water quality monitoring would form an important component of the environmental management programme proposed for the Project. Data collected by the monitoring programme would be assessed regularly in conjunction with management practices with the aim of minimising impacts on the receiving environment.

The water quality monitoring programme would be developed in detail as part of the Project's EMP and comprise chemical and physical parameters as well as long-term monitoring of biological impacts on fish and macro-invertebrates (see Appendix O). At this stage it is proposed that the water quality monitoring programme would be implemented by the Environmental Management Entity (Chapter 16) that would be established as part of the Project, and as a minimum involve regular sampling and analysis of the parameters nominated in Table 5.9.

Table 5.9 Outline water quality monitoring programme

Parameter	Location							
	Farm soil	Farm drains	Tailwater dams	Drainage channels	Border Creek	Keep River*	Sandy Creek*	Irrigation channels
Flow	–	–	–	✓	✓	✓	✓	✓
Suspended solids	–	✓	✓	✓	✓	✓	✓	✓
TDS	–	✓	✓	✓	✓	✓	✓	✓
Nutrients	–	–	✓	✓	✓	✓	✓	✓
Insectides	✓	–	✓	✓	✓	✓	✓	
Herbicides	✓	–	–	✓	✓	✓	✓	✓
Turbidity	–	✓	✓	✓	✓	✓	✓	✓
Heavy metals	✓	–	✓	–	✓	✓	✓	–
Chlorophyl *a*	–	–	–	–	✓	✓	✓	✓
Dissolved oxygen	–	–	–	–	✓	✓	✓	–
Erosion and sedimentation	–	–	✓	✓	✓	✓	✓	✓
Biological impacts	–	–	–	–	✓	✓	✓	–

✓ *Indicates regular sampling and analysis.*

– *Indicates no sampling.*

* *Includes upstream and downstream of Project Area.*