1. Introduction

1.1 Background

The groundwater resource used by the irrigation industry within the Callide Valley of Central Queensland is declining as a result of recharge failure in the past 20 years, and overuse since initial development began in the 1960s. As a result irrigators have adopted management strategies to more efficiently utilise the resource. However, as this situation worsens, they have had to consider a range of alternative activities as a means of maintaining profitability. These activities have included intensification of production systems through the use of annual horticultural crops, table grapes and redclaw crayfish. At the same time, new irrigation technology such as subsurface drip irrigation (SDI) appears to offer significant benefits through more efficient water use and increased yields.

1.2 Research problem

Continued overuse of the groundwater resource will further reduce the available supply for irrigation in the future. It also reduces that available for use by other water users - the townspeople and power station. Continued high use will lead to a further deterioration in groundwater quality resulting from the ingress of saline water from surrounding rocks and surface salts accumulated through irrigation in the event of surface recharge. Both outcomes would impact significantly upon irrigators and the wider community.

The perceived advantages of irrigated over raingrown farming is the potentially higher net income and greater security that the former provides (Ross and Williamson 1990, p.63). As in all businesses, irrigators seek to obtain an adequate return on their investment. Reduction in supply and deterioration in quality of the groundwater resource directly impacts upon the profitability of an irrigation enterprise. This in turn affects the economic viability of their businesses. As a result, irrigators need to consider alternative approaches to management of their irrigation resources in order to remain viable.

Declining profitability of the irrigation industry through falling groundwater reserves and deteriorating quality impacts on the wider community through the loss of revenue generated. In the Callide Valley the series of poor seasons experienced in the past decade has resulted in low returns from raingrown agricultural production. During this time it has been the irrigation industry which has benefited local businesses through revenue generation. The grazing industry too has benefited through the irrigated fodder produced locally.

Since the 1990 survey of irrigators by Huf (1991) there has been a significant change in the approach they have adopted in dealing with declining groundwater supplies. There has been a shift from minor adjustments in their irrigation strategies while retaining familiar cropping systems and existing irrigated areas to one involving enterprise changes aimed at maximising the returns on their most limiting resource - water. The observed changes have included:

- cropping intensification using crops with greater potential returns than traditional grain crops. Horticultural crops such as cucurbits have been grown because of their perceived greater return per unit of land and water.
- the adoption of subsurface drip irrigation (SDI) technology to irrigate traditional and alternative crops. This relative new technology has now been installed on 560 ha of irrigated crops within the Callide Valley (S Pratt, pers. comm.).
- development of new industries which have a high return per unit of water. These have included aquaculture (redclaw crayfish), floriculture (eucalypt tips) and horticulture (herbs).

Farm ownership within Australia is dominated by family farms - in 1985-86 farm families accounted for 91 per cent of agricultural establishments (Ockwell 1990, p.28). This has significant implications for the objectives of farm businesses. There is often a close relationship between family objectives and farm business objectives. Walsh (1991, p.7) groups the objectives of the farm manager into:

- farm production objectives;
- farm development objectives;
- financial objectives; and,
- personal and family objectives.

In order to meet these objectives an adequate return on investment in the farm business is important. Irrigation farms require sufficient irrigation water to enable farm business objectives to be achieved through an adequate return. The current low groundwater supplies, and past history of the resource, suggests a need by irrigators to reassess their approach to its use in meeting their objectives. This reassessment has begun as evidenced by changes in resource use seen to date.

Changes in enterprises and irrigation systems require irrigators to make significant financial investments. Before proceeding with these economic and financial feasibility evaluation is needed (Thompson, Spiess and Krider 1983, p. 55). The economic feasibility evaluation assesses the economic viability of alternative enterprises and irrigation systems. It enables the selection of alternatives amongst those available. The financial feasibility assessment examines the financial conditions that will be experienced in implementing the selected alternatives.

There has been little evaluation of the economic feasibility of SDI within Australia and alternative industries such as redclaw production. Both these developments within a district of limited groundwater supplies provides an opportunity to not only conduct an economic feasibility study, but also determine the appropriate mix of alternative irrigation technologies and enterprises irrigators should consider when faced with depleted groundwater supplies.

1.3 Study Objectives

The key objectives of this study are to examine the feasibility and profitability of several of the most recent approaches being used by irrigators to deal with the decline in groundwater irrigation supplies. This study will concentrate on three of these approaches for which some information is currently available. These are:

- the inclusion of annual and perennial horticultural crops into existing farming systems;
- the conversion of existing irrigation systems to subsurface drip irrigation for crops traditionally grown; and,
- the inclusion of redclaw crayfish production into existing farming systems.

The production herbs and eucalypt tips by irrigators is at too early a stage for consideration in this study owing to limited agronomic and marketing information at this time (J Parker, pers. comm.).

Given the existing resource constraints of land, labour, capital and water, the farm manager must specify a farm production plan which will meet his or her business objectives. To achieve these the irrigator can use one or more of the possible alternatives. A multiperiod linear programming (MLP) model will be used to assess the implications of adopting subsurface drip irrigation, redclaw crayfish production and/or horticultural enterprises into an existing irrigated farming system within the Callide Valley. A further objective will be the evaluation of the MLP model as a decision tool by the case study clients.

1.4 Hypotheses

The MLP model developed will be used to test the following guiding hypotheses:

1. The inclusion of horticultural crops in existing farm activities will improve profitability as water resources decline.

2. Subsurface drip irrigation is a profitable alternative to existing irrigation system use in growing traditional irrigation crops under conditions of declining water supplies.

3. The inclusion of a redclaw crayfish enterprise into existing farm systems will improve their profitability as water resources decline.

4. Given the resource constraints existing it is possible to develop a more profitable farm model using horticultural crops, subsurface drip irrigation and/or redclaw production than exists with current farm design and operations.

The solution of the MLP model and associated sensitivity analyses will provide the information necessary to accept or reject these guiding hypotheses. The presence of the alternative activities and irrigation technologies within the optimal farm plan will provide evidence to support their use.

1.5 Study outline

The characteristics of the sudy area are briefly outlined, together with a historical perspective on the use and management of the groundwater resource. A case study farm is used in the development of the MLP model. The farm chosen has had some experience with the alternative activities and irrigation technologies evaluated within this dissertation.

The underlying issue for farm managers within this district is the need plan their activity mix and investment decisions in order to maximise their objectives. This study provides an approach to address this issue in the context of the single farm business.

The following stages were followed in undertaking the study:

1. The technical and economic characteristics of the alternative activities and irrigation technologies were ascertained
2. A static LP model was developed to determine which activities were worth inclusion within the MLP model. This step was necessary to avoid the problems associated with the specification of a very large MLP model.
3. A MLP model was developed to determine the optimal farm plan within a five year planning period. This not only provided the optimal year to year plan of activities but also the appropriate investment path for the case study farming business to follow.

Sensitivity testing of several key constraints was performed to examine the impact upon the optimal farm plan and investment path.

2. Description of the study area

2.1 The Callide Valley

The Callide Valley covers an area of 1560 km^2 in sub-coastal Central Queensland, with the principal town Biloela 120 km west of Gladstone. It is bounded by the Dawes, Calliope and Banana ranges. Streams from these ranges drain into the Callide Valley and flow in a north westerly direction until joining with the Don and Dee Rivers, and then into the Dawson River, a major tributary of the Fitzroy River system. The main streams are the Callide, Kroombit, Kariboe, Grevillea, Bell and Prospects Creeks (Appendix 1).

Biloela has a population of approximately 5500 with an economy based on agriculture (raingrown and irrigated grain, fodder and cotton crops, and cattle), coal mining and electrical power generation.

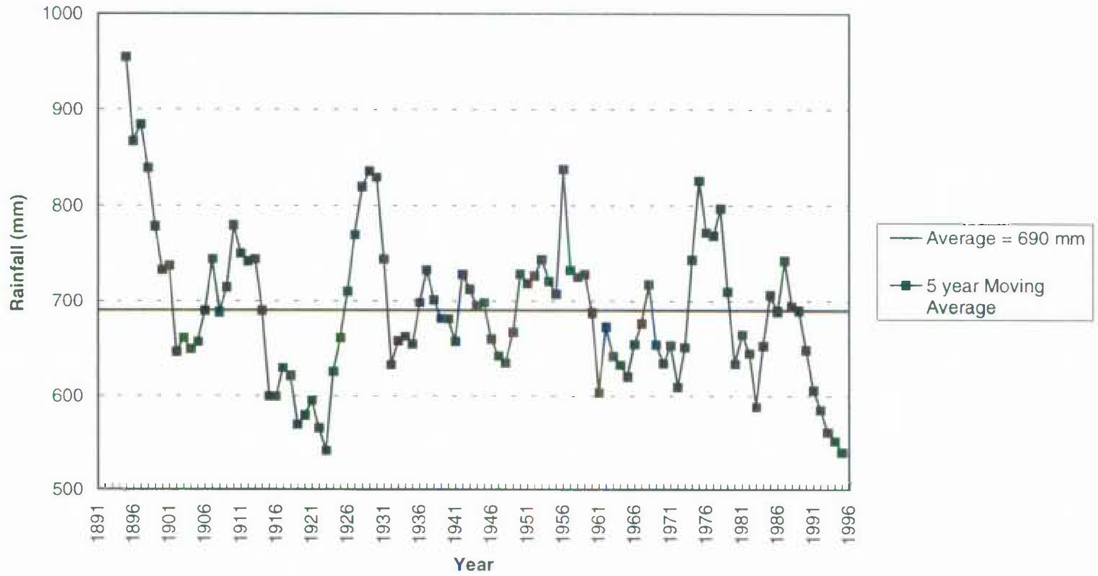
2.2 Resources

2.2.1 Climate

The Callide Valley lies within the 625 to 750 mm rainfall isohyets. Rainfall is summer dominant with two-thirds on average falling from October to March. It is extremely variable owing to the dominance of spring and early summer thunderstorm activity. There is also significant variability in rainfall between years as seen in Figure 2.1 which shows the moving five year average for annual rainfall at Biloela.

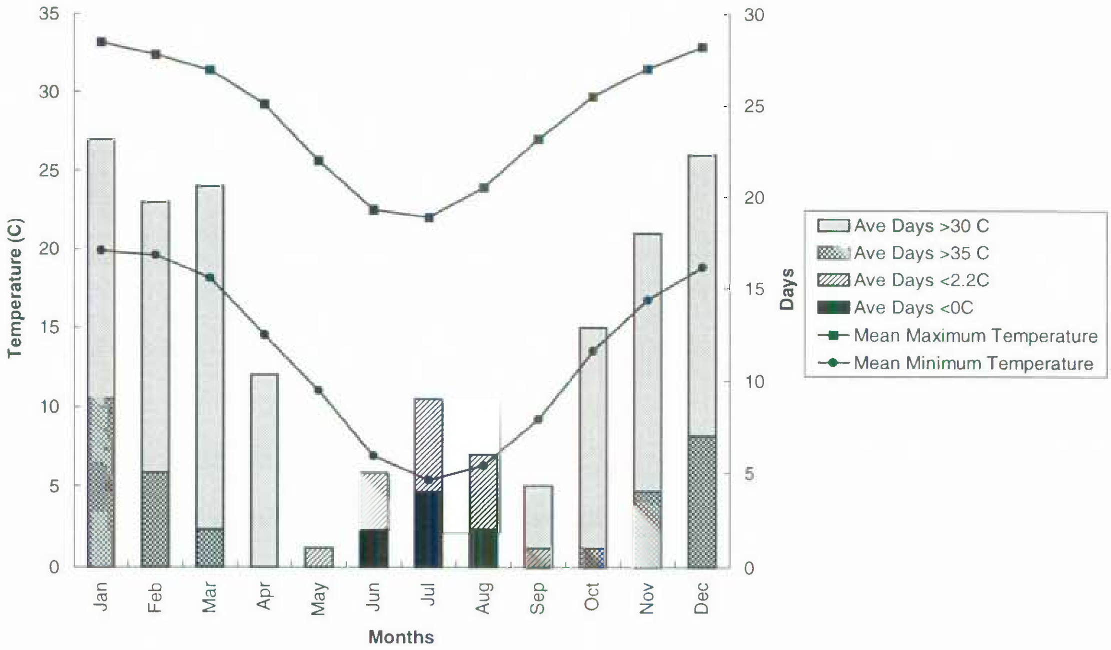
Temperatures are high during the summer months with 136 days from October to March exceeding an average maximum of 30°C, and 28 days on average exceding 35°C. These high temperatures can significantly affect the performance of summer crops, particularly those susceptible to heat damage during flowering and grain filling periods.

Figure 2.1: Five year moving average annual rainfall for Biloela



Source: Clewett et al, 1994

Figure 2.2: Monthly temperature data for Biloela

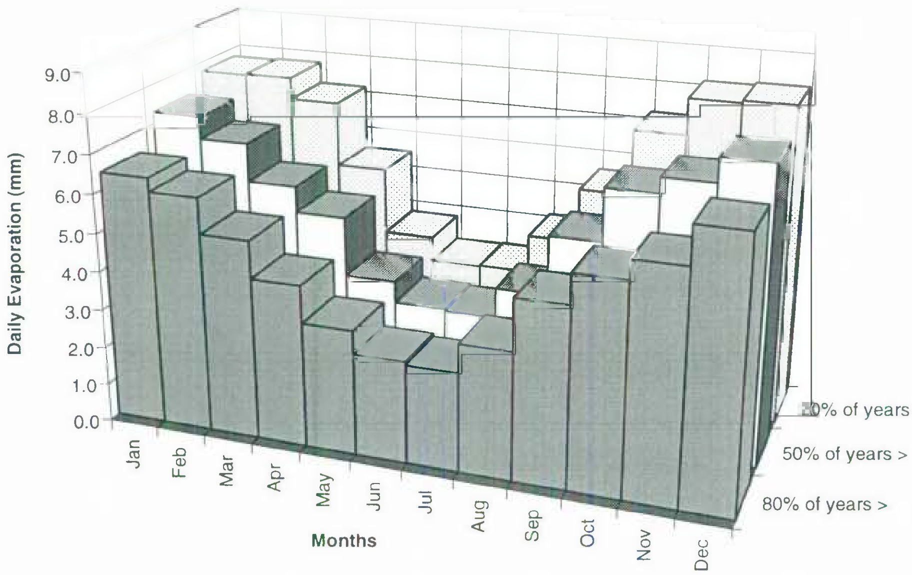


Source: Clewett et al, 1994

Winter temperatures are mild with cool to cold mornings and warm days with maximum temperatures averaging above 22°C. On average 22 frosts occur annually during the main frost period of June to August. Frost incidence is influenced by local topography with low lying areas near creeks most at risk of damaging frosts. The temperature data for Biloela is summarised in Figure 2.2.

Class A Pan evaporimeters are used to measure evaporation rates, which are an index of evaporative demand on plants and the loss of water from open water surfaces. Evaporative demand is greatest during the October to March period, where variability is also the greatest (see Figure 2.3).

Figure 2.3: Variability in monthly Class A Pan evaporation for Biloela



Source: Bureau of Meteorology (pers. comm.) - based on data from 1965 to 1995. Note: 20% evaporation likely to be exceeded twice in 10 years; 50% - 5 times in 10 years; 80% - 8 times in 10 years

2.2.2 Water

Permanent surface water is limited. The major creeks flow intermittently, with semi-permanent waterholes only in the lower reaches of Callide Creek (Isbell 1954, p. 16). There are two major water storages:

- Callide Dam with a capacity of 127 000 ML

- Kroombit Dam with a capacity of 13 300 ML

Callide Dam was constructed as an assured water supply for the Callide A Power Station and the Biloela township, and for periodic groundwater augmentation releases (Anon 1986, p. 31). Kroombit Dam was constructed for groundwater augmentation.

Historical data show that groundwater levels rose by 10 m in the Callide Valley in the period from closer settlement in the 1920s until the 1960s. This rise is attributed to removal of vegetation within the valley. The recharge of the groundwater is dependent upon rainfall within the catchment, with the greatest proportion resulting from the direct absorption of surface flows from stream beds in the upper end of the alluvium.

Groundwater supplies have been extensively developed for irrigation. In early investigations of the groundwater supplies the average depth to bedrock in over 300 bores drilled was 17 m, with the range for the central parts of the alluvium being 12 to 21 m (Anon 1965, p. 10). The average flow of bores drilled during the 1965 investigation was 87000 L/h (with a range of 15 000 to 159 000 L/h - some bores were not tested as they were dry).

2.2.3 Soils

Irrigated cropping is confined to the alluvial plains. These are formed on deposits of alluvium resulting from the weathering and erosion surrounding sedimentary rocks. The soils within the area include cracking and non-cracking clays, duplex soils, gradational soils, loams and sands. Those used for irrigation have moderate to high fertility and water holding capacities. They are well suited to a range of irrigated grain, forage and horticultural crops.

2.3 Agricultural Development

In the 1850s several large grazing leases were taken up within the Callide Valley. Following World War I the Queensland Government initiated a closer settlement scheme. From 1924 onwards more than 400,000 ha of resumed Crown lands was offered as Perpetual Lease Selections in small holdings between 64 and 128 ha (Land Administration Commission, 1967). Following an economic investigation in 1929 additional areas were granted to settlers to ensure a sound living based on dairying of 60 cows plus 20 ha available for cultivation (Gill 1972, p. 1-1;Huf 1991, p. 1).

Cotton was the major crop planted immediately following clearing of vegetation. It was grown under raingrown conditions and grew from 400 ha in 1925 to 16 000 ha by 1934. Rhodes grass was sown amongst cotton in late summer and autumn with the aim of establishing a pasture for raingrown dairying production. Dairying was the major agricultural pursuit from the 1920s until the 1960s where the number of dairying operations dramatically declined and were replaced with beef cattle ones.

Pig production developed in conjunction with dairying enterprises and was in part responsible for the expansion in grain production in the years immediately after World War II. Pig enterprise numbers declined in line with dairying during the 1960s.

Drought in the late 1960s resulted in a fall in the number of cattle enterprises. Recovery in cattle enterprise numbers after the drought was followed by a further fall after the 1974 cattle price slump. Mixed cropping and cattle enterprises resulted as landholders sought to diversify production. Since the late 1980s cropping activities have declined as an extended period of drought prevented cropping opportunities.

2.4 Irrigation Industry

2.4.1 Historical

During 1939-43 the Queensland Irrigation and Water Supply Commission (QIWSC) undertook investigative drilling in the Callide Valley alluviums. Ten experimental wells were constructed with the purpose of stimulating irrigated cotton production (Anon 1965, p. 6).

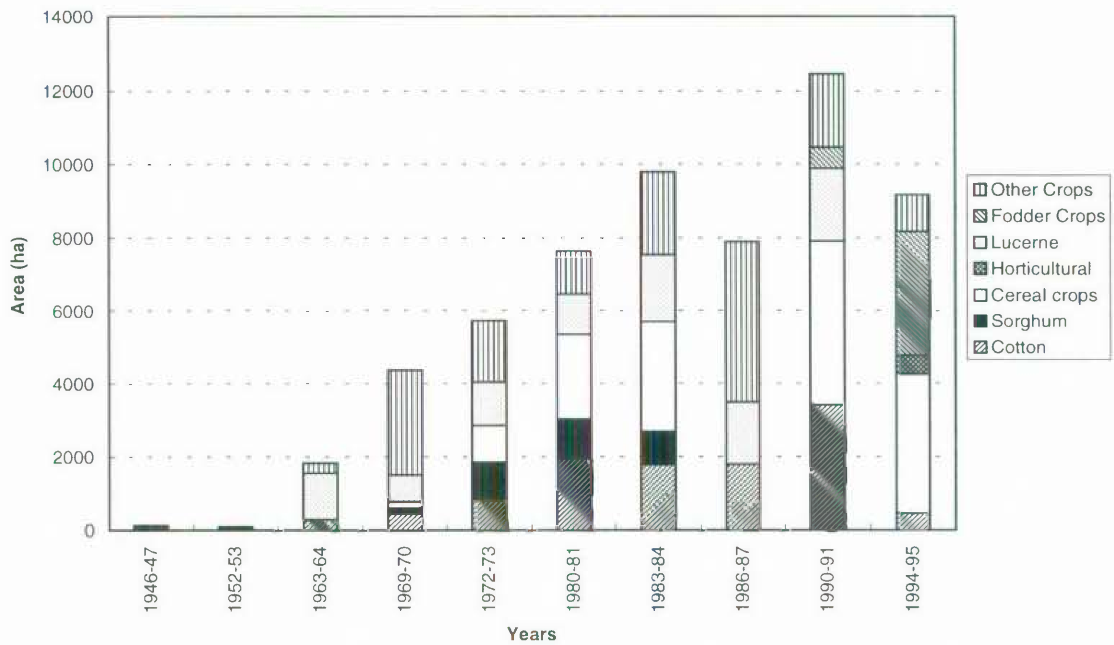
In 1953 R.F. Isbell reassessed the irrigation potential of the Callide Valley. As a result a total withdrawal volume of 37 000 ML was estimated to exist, with an estimated safe annual yield of 6200 ML, sufficient for the irrigation of 1000 ha (Isbell, p. 20).

Irrigation development of the groundwater resource proceeded rapidly in the late 1950s and early 1960s (see Figure 2.4). Anon (1965, p. 6) attributed this development to:

- the dry periods following 1956;
- attractive fodder prices;
- cheap land; and
- availability of groundwater.

The total area of irrigation development increased from around 100 ha in 1946-47 to around 12 000 ha by 1990-91. The lower estimates of irrigated areas in 1986-87 and 1994-95 are the result of diminished groundwater supplies.

Figure 2.4: Irrigated cropping areas in the Callide Valley 1946-47 to 1994-95



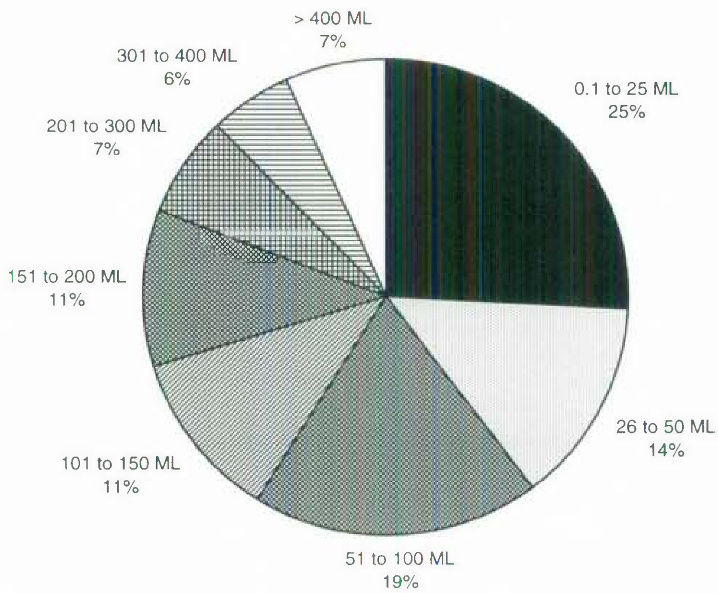
Source: Queensland Water Resources Commission, pers. comm.

Spray irrigation is the most commonly used irrigation method. Furrow irrigation is generally limited to cotton production areas, and crops grown in rotation with cotton or on land formerly planted to cotton.

The Callide alluvium is divided into 11 sections for monitoring and management purposes by the Queensland Water Resources Commission (QWRC). Groundwater use for irrigation averages 83 percent of total metered water use since installation of water meters in 1978-79 (QWRC, pers. comm.).

A large proportion of the 289 irrigation farms have nominal allocations below 100 ML (59 percent, see Figure 2.5). Based on an average crop water use of 3 ML/ha (Anon. 1986, p. 39) this equates to less than 33 ha of irrigated crops grown on these farms. The low average water use figure reported is due to the limited use of irrigation on some farms. For specific crops the water use is greater than this (see Appendix 2). As a result, the area of some crops that can be irrigated adequately is severely restricted. For example, adequate irrigation of lucerne for hay production requires 10 ML/ha of irrigation water. Farms with allocations below 100 ML are unable to adequately grow an area of lucerne above 10 ha.

Figure 2.5: Distribution of nominal allocations within the Callide Valley



Source: Queensland Water Resources Commission, pers. comm

2.4.2 The Groundwater Resource

2.4.2.1 Supply

There has been a long history of overuse of the Callide Valley groundwater resource. The extent of this varies between sections within the valley as shown by groundwater level and quality monitoring by the QWRC through a network of 243 observation bores. Figure 2.6 shows the downward trend in groundwater supplies for Bore 13030084 (Section 10) since development in the early 1960s as a result of over.use of the resource.

The decline was arrested to some extent by recharge in the late 1970s but levels did not return to those occurring at the start of development. By early 1995 the bore levels had fallen to 14.36 m at which no further supplies could be pumped.

Figure 2.7 shows that Bore 13030089 is more responsive to recharge than 13030084. This bore is characterised by periods of significant drawdown followed by recharge. In the 1960s the bore levels fell significantly and where then replenished by recharge during the wetter 1970s period. Drawdown during the early 1980s was followed by artificial recharge from Callide Dam via the diversion channel in the early 1990s. Since then levels have fallen to their lowest on record (13.4 m below the surface) by February 1996.

These two bores demonstrate not only the decline in the groundwater resource since development but also differences in individual bore behaviour resulting from:

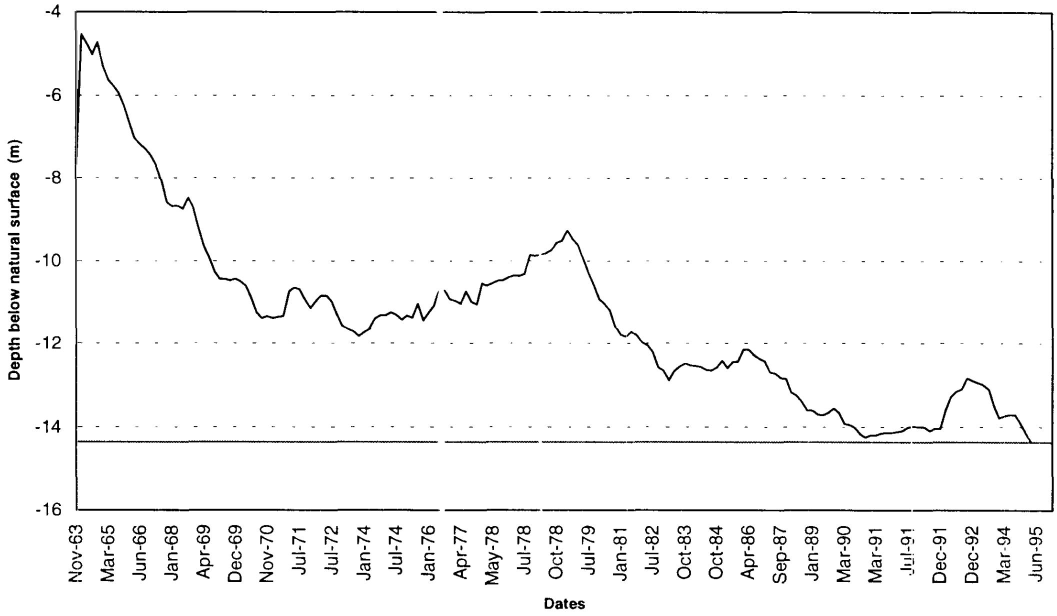
- the extent of over utilisation of the resource;
- responsiveness to drawdown and recharge events;
- benefits of the Callide Valley Augmentation Scheme in different localities.

In 1987 the QWRC stated that `the Valley as a whole is overcommitted, both in terms of allocations and present water use' (Anon 1987, p. 13). This led to the current system of Annual Announced Allocations aimed at getting water use to more closely align with available groundwater supplies. Continued failure of significant recharge emphasises the seriousness of inadequate groundwater supplies for continued irrigation.

2.4.2.2 Water Quality

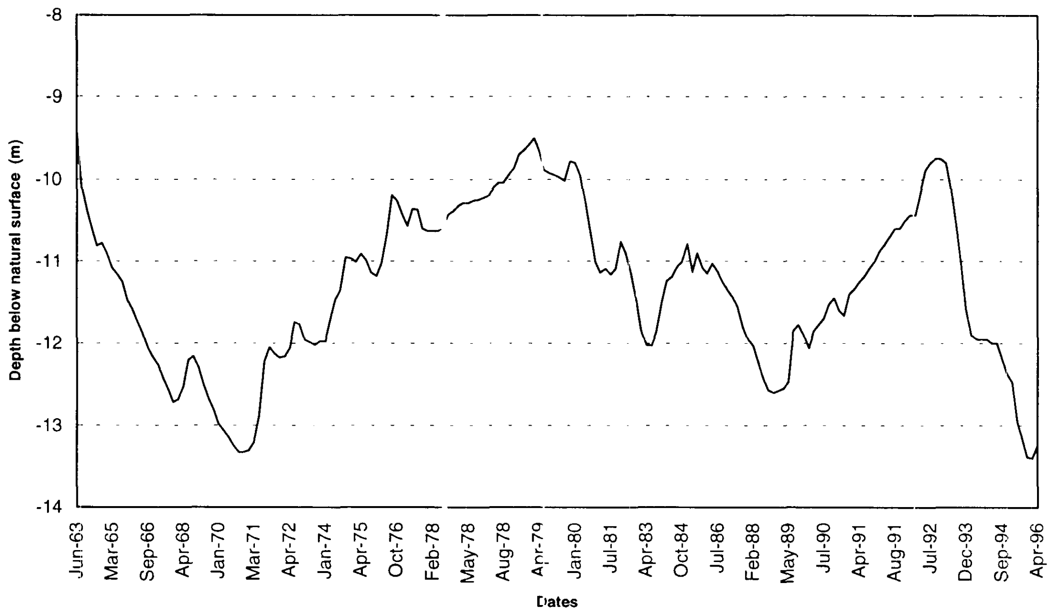
Water quality for irrigation has become an issue as well. Most of the groundwater lies in the salinity range 825 to 3000 $\mu S\ cm^{-1}$. This places it in Salinity Class 2 or 3 (see Appendix 3). Calcium and magnesium salts dominate , so the water is described as being hard. Hard waters form scale deposits which can cause blockages in some irrigation systems (particularly drip irrigation).

Figure 2.6: Water levels for Bore 13030084 (Section 10) for 1963-64 to 1994-95



Source: Queensland Water Resources Commission, pers. comm.

Figure 2.7: Water levels for Bore 13030089 (Section 8) for 1963-64 to 1995-96



Source: Queensland Water Resources Commission, pers. comm.

Crops differ in their tolerance to saline irrigation water which influences the types of crops that can be grown and their yield performance (see Appendix 4). It can also affect the suitability of particular irrigation systems and their management for irrigation. Spray irrigation with saline water may be too damaging for some crops, as can daytime irrigation compared with night time irrigation. Alternative irrigation systems such as drip irrigation enable irrigators to use poorer quality water for irrigation than would be possible with traditional spray systems.

Water quality has changed over time in response to natural and artificial recharge events, and irrigation management of the aquifer. Natural recharge failure in the late 1960s and early 1970s resulted in a deterioration of water quality during that period (median conductivities increased from 1700 to 2700 μS cm^{-1}). During 1980-85 there was an improvement in water quality from Kroombit and Kariboe Creeks attributed to the Augmentation Scheme in operation since 1977. At the same time water quality deteriorated on the western margin of the alluvium due to the infiltration of poorer quality water from surrounding sediments - resulting from withdrawals in excess of sustainable yields.

Poor recharge in the last decade has resulted in continued deterioration of groundwater quality. Much of the alluvium in the upper valley has water quality exceeding 1300 μS cm^{-1} with significant areas below Biloela exceeding 3000 μS cm^{-1}. There is concern that significant surface recharge in some sections will result in a further deterioration in quality as surface salts accumulated from irrigation make their way into the aquifer (I. Baker, pers. comm.).

2.4.3 Management of Groundwater Resource

Management of the groundwater resource has been complicated by the actions of government institutions charged with its management and irrigators directly using the resource. Political considerations have been an additional complication.

The actions of the government institutions responsible for management of the resource can be readily summarised into:

- resource assessment;

- structural works; and
- administrative controls.

2.4.3.1 Resource Assessment

The size and yield of the groundwater resource has been the subject of several reassessments since Isbell's 1953 study. The results of these reassessments have been:

- In 1965 the safe annual supply was estimated to be 30 100 ML (Anon. 1965, p. 15).
- In 1972 the estimated safe annual yield was increased to 38 600 ML. The construction of Callide Dam Stage II and the conjunctive use of water supplies within it with those of the groundwater resource resulted in an estimated combined annual yield of 44 900 ML.
- In 1978 water meters were installed on all bores throughout the Callide Valley, and on surface water facilities located within the augmented sections of the alluvium. As a result it became apparent that the estimates of water use adopted in the 1972 assessment were too high. In 1986 the estimated average availability of groundwater was reduced to 11 790 ML/annum, significantly below the earlier estimate. Additionally, the estimate of average availability of supply from conjunctive use of Callide Dam Stage II and groundwater was reassessed at 21 790 ML/annum.

2.4.3.2 Structural Works

Irrigation development continued throughout the 1960s, while there was no significant recharge of the groundwater supplies. During the early 1960s concerns over the lowered water levels and interference between pumped bores in the upper end of the alluvium prompted interest in artificial replenishment schemes. Small weirs on creeks and larger headwater storages were discounted in the 1965 study in favour of surface storages in conjunctive use with groundwater to alleviate the problem.

In 1965 the QIWSC completed construction of Callide Dam Stage I, an earth and rockfill dam with a storage capacity of 46 600 ML.

In 1969 two weirs were constructed as trial recharge structures - Thangool Weir on Kariboe Creek and Grevillea Weir on Grevillea Creek (see Appendix 1). Both weirs failed to significantly recharge the aquifer owing to siltation and the limited recharge capability of the streams (Anon. 1986, p. 28). In 1975 a series of nine sand dams were constructed along Kariboe Creek with the purpose of raising water levels in the stream to enable greater recharge during periods of low flow. All but one were destroyed in a 1976 flood flow (Anon. 1986, p. 29). In the late 1970s a small diversion structure was built on Kroombit Creek to divert water into the old creek channel which was thought to have better recharge characteristics than the main stream (Anon. 1987, p. 4).

By 1970 the water levels in the groundwater had reached their lowest levels since water level observations had begun in the mid 1940s (Anon 1972, p. 1-1). The situation was most severe in the upper parts of the valley. In 1970 representations by the Callide Valley Irrigators Association led to structural works aimed at augmenting the groundwater supplies. The Callide Valley Augmentation Scheme is designed to augment groundwater supplies by artificially recharging the aquifer from water stored in Callide Dam. The scheme is made up of:

- a channel to divert water from Callide Dam to Kroombit and Kariboe Creeks (completed 1977)
- a recharge weir on Kariboe Creek upstream of Thangool (completed 1977)
- six crump weirs to measure the dam release flows discharged into Callide, Kroombit and Kariboe Creeks
- installation of crest gates on Callide Dam to increase its capacity to 127 000 ML (completed in 1985)

The current aim of the scheme is to provide 3084 ML/annum to the Callide A Power Station, 1200 ML/annum for the township of Biloela and an average of 10 000 ML/annum for groundwater augmentation. In 1987-88 the Queensland Electricity Commission constructed a connecting pipeline to Callide Dam from Awoonga Dam on the Boyne River near Gladstone. This was to ensure water supplies for the newly constructed Callide B Power Station given the unreliable supply provided by Callide Dam. This water is only for use by the power station.

In 1992 Kroombit Dam with a capacity of 13 300 ML was constructed on Kroombit Creek. The safe annual yield of this dam is 3000 ML (I. Baker, pers. comm.).

2.4.3.3 Administrative controls

The QIWSC and QWRC have administered use of the groundwater resource within the Callide Valley since proclamation as an irrigation district in 1968. This administration has included:

- Licensing of all water facilities and the setting of an upper limit on the volume of water which can be used. Restrictions were placed on the issuing of bore licences in March 1982.
- Excess water use charges were implemented to limit water use above allocation (see Appendix 5).
- Prosecution of landholders irrigating without a license, with unlicensed facilities, who interfere with the operation of water meters or use excess allocation more than twice.
- Establishment in 1979 of the Callide Valley Water Advisory Board (CVWAB) to advise the Commissioner of Water Resources on matters relating to management of the resource.

In 1987 the QWRC implemented the concept of Annual Announced Allocations in order to 'reduce the current levels of over allocation and water use and bring them more in line with available supplies' (Anon. 1987, p.21). Irrigators retained their original allocations granted in 1978, but from the 1987-88 water year an announced allocation based on their averaged metered water use in the preceding five years came into effect. The volume made available for irrigation within any one year would be determined by the volume in the groundwater storage at the beginning of the year. As a result the announced allocations for the Callide Valley Irrigation Project in the 1987-88 water year totalled 34 700 ML (A. Bleakley, pers. comm.). Since then the annual announced allocations have been based on the 1987-88 announced allocations and have not been related to the original allocations.

In 1991 the QWRC, under the newly proclaimed Water Resources Act 1990, attached nominal allocations on all licenses within the Callide Valley. The nominal allocations applied were the announced allocations made in the 1987-88 year. At the beginning of each water year announced allocations as a percentage of nominal allocations are made for each section of the valley. The announced allocations have become an important tool in managing the groundwater resource. The restrictions shown in Table 2.1 on irrigators has been necessary given the failure of significant recharge events within the valley in the past decade.

2.4.3.4 Landholder actions

Landholder actions in relation to the groundwater resource have been of two types - political and managerial. Irrigators in the area abpve Thangool sought assessment of artificial replenishment schemes during the early 1960s. These early investigations saw an increase in the estimated safe annual yield of the aquifer. Failure of significant recharge between 1963 and 1970, coupled with continued expansion of irrigation development, resulted in the lowest water levels recorded in bores since observations began in the 1940s.

The QIWSC sought to control use of the aquifer and the Callide Valley Irrigators Association agitated for:

- investigation into replenishment schemes for the aquifer using the services of the Snowy Mountain Authority;
- abandonment of water allocations; and
- desilting of sections of creeks as recharge areas (Anon. 1972, Appendix 5).

Formation of the CVWAB in 1978 formalised the involvement of landholders in the management of the resource. However, there were no statutory powers assigned to this board. Landholders were involved in the development of the Annual Announced

Allocation system, implemented in 1987-88, which saw yet another reassessment of the safe annual yield of the aquifer.

2.4.4 Irrigated agricultural systems

Management by irrigators of the groundwater resource is critical for survival of their businesses. Reductions of 40 per cent in the Announced Annual Allocations in 1988-89, prompted the Queensland Department of Primary Industries (QDPI) to survey irrigators to identify irrigated agricultural systems within the Callide Valley and the

Table 2.1: Announced allocations for Callide Valley groundwater sections 1990-91 to 1996-97

	Announced Allocations (% of Nominal Allocation)							Nominal Allocation
Section	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	(ML)
1	100	100	100	100	100	100	100	2947
2A	80	80	80	80	80	80	80	2903
2B	100	100	100	90	90	90	90	5394
3A	80	80	80	80	80	80	80	3552
3B	80	80	80	80	80	70	80	4416
4A	100	100	100	100	100	100	100	1044
4B	100	100	100	100	100	80	80	468
5	80	90	90	80	80	80	80	3936
7	80	80	80	80	80	80	80	3238
8A	100	120	120	100	100	100	100	1087
8B	80	80	90	90	90	80	80	1000
10A	80	80	80	80	80	80	80	3056
10B	80	80	80	80	80	80	80	2424
11A	80	80	80	80	80	80	80	896
11B	80	80	80	80	80	80	80	1378
Volume Announced	32379	32990	33090	31940	31940	31305	31746	37739
Volume Used	23601	22662	26932	21187	22923	18558		

Source: Queensland Water Resources Commission, pers. comm.

management strategies being used for more efficient irrigation (Huf 1991, p. 2). Four systems where identified:

- Cotton dominated
- Lucerne dominated
- Field crops and horticulture
- Field crops and cattle

The key management strategies to improve irrigation efficiency identified are summarised in Table 2.2.

Table 2.2: Management strategies to improve irrigation efficiency

System	Management strategies
Cotton dominated	• quick, even application of irrigation water • increased fallow moisture storage • match irrigations with crop demand • altering crop agronomy
Lucerne dominated	• avoid irrigation in hottest part of year • altering the duration of irrigation shifts • abandon lucerne to raingrown conditions in last 12 months of its productive life • decrease nozzle size and shorten irrigation runs • irrigate at night
Field crops and horticulture	• reduce peak demands for water • introduce high value horticultural crops
Field crops and cattle	• supplementary irrigation of dual purpose (gain and grazing) crops

Source: Huf, 1991

It was apparent that irrigators at that time were viewing reduced allocations as a short-term problem as the strategies for improved irrigation efficiencies still focused on continuing with familiar crops and retention of existing irrigated crop areas. The introduction of alternative horticultural crops was an exception to this approach. Here irrigators were considering a significant structural change to their operations in response to increased returns from these crops per applied ML.

As the groundwater resource has continued to deteriorate, many more irrigators are now considering significant changes to their farming operations, compared with those observed at the close of the 1980s and first half of the 1990s. The economic evaluation of some of these approaches is the subject of this study.