10. Other environmental issues

10.1 Surface water and groundwater

10.1.1 *Assessment approach*

Surface water

The surface water assessment built on the work undertaken for the *Hume Highway Town Bypasses: Tarcutta, Holbrook and Woomargama — Groundwater and Surface Water Preliminary Assessments* (PB 2008b). The assessment included:

- Flood modelling of Ten Mile Creek to evaluate the impacts of the project on the existing flow regime and on flood levels in the Ten Mile Creek floodplain, taking into account the NSW Flood Prone Land Policy and the policy implementation as detailed in the NSW Floodplain Development Manual (NSW Government 2005).
    - The model was based on a combination of detailed survey data within the main channel of the creek, to the extent of public land (approximately one metre from the creek bank) and ten metre contour information beyond the main creek channel. This provides for accurate prediction of existing and future flood levels, however, there are limitations with regard to the accuracy of the flood extent (as exact ground level information is not available).
- Comparative assessment of modelled existing and future flood extents and prediction of afflux as a result of the project.
- Local catchment survey to identify and assess the potential impacts of the project on water bodies and drainage lines.
- A water supply analysis including an estimation of the water requirements for construction and the impacts on water sources and users.

Water quality testing was also carried out as part of the surface water assessment. Results are summarised and potential impacts on water quality are discussed in Section 10.3.

Groundwater

The groundwater assessment built on the preliminary groundwater and surface water assessments. The assessment included:

- Measurement of groundwater levels, and local and regional flow systems.
- Consideration of the likely impacts on groundwater during construction and operation.

Water quality sampling was also undertaken as part of the groundwater assessment. Results are summarised and potential impacts on water quality are discussed in Section 10.3.

10.1.2 *Existing environment*

Surface water

The project is located in the Ten Mile Creek catchment, an area of some 25000 hectares (CSIRO 2004). The upper south-eastern parts of the Ten Mile Creek catchment are steep, while the western lowland end of the catchment includes a floodplain. The existing Hume Highway and project are within the western lowland end of the catchment and cross the floodplain.

Local catchment

Ten Mile Creek originates near Mount Jergyle in the Woomargama National Park, approximately 15 kilometres south-east of Holbrook. Ten Mile Creek crosses the existing Hume Highway alignment under a bridge. It flows in a north-westerly direction across the project to its confluence with Billabong Creek approximately 10 kilometres west of Holbrook. Billabong Creek continues to flow to the west and ultimately drains to the Murray River some 350 kilometres west of Holbrook.

Flows in Ten Mile Creek are characterised by a seasonal pattern with lower flows generally over summer and autumn. During the site investigation in November 2007, Ten Mile Creek was noted to consist of stagnant pools within the dry creek bed. No flow was observed. The ponds appear to be disconnected at the surface. However, the presence of a shallow water table may indicate sub-surface flow through the alluvium (see below).

Several dams and a spring exist along some of the drainage lines. The drainage lines, dams and spring identified during the site investigation are shown in Figure 10-1. All of the drainage lines, with the exception of one in the northern part of the project, flow to Ten Mile Creek. The northernmost drainage line crossed by the project flows to Billabong Creek.

Hydrology and flooding

Ten Mile Creek has a history of flooding, with significant events being recorded in May, August and October 1968, July 1969, August and September 1970, August 1971, June to October and December 1973, January, April, May and June to October 1974, October 1975, October 1976, September and November 2001, August and October 2003, August and September 2004 and September 2005.

A hydraulic modelling program was used to assess the existing 20, 100 and 2000 year flooding conditions along Ten Mile Creek in the vicinity of Holbrook. In this model, the river channel and floodplain are represented as a series of cross-sections, A to S, with A being the upstream extremity of the model and S being the downstream extremity of the model. This is the flooding assessment area. The flood levels at these 18 cross sections have been used to map potential flood prone land in the Ten Mile Creek floodplain at Holbrook (refer Figure 10-2).

Peak design flows for Ten Mile Creek were estimated for the 20, 100 and 2000 year average recurrence interval (ARI) events, and the probable maximum precipitation (PMP) event. These peak design flows represent the critical duration storm event, which is determined to be six hours. The peak design flows are presented in Table 10-1.

Table 10-1 Peak design flows

Location	Peak design flows (cubic metres per second)			
	20 year ARI	100 year ARI	2000 year ARI	PMP
Holbrook 3 Flow Gauge[1]	122	216	650	2405
Upstream extent of hydraulic model[2]	170	298	945	3475
Proposed bypass crossing[3]	171	299	958	3521
Existing culvert crossing[4]	16	28	85	318

Notes:
1. Located approximately 1.5 kilometres upstream of the existing Hume Highway crossing of Ten Mile Creek.
2. Located approximately 200 metres upstream of the existing Hume Highway crossing of Ten Mile Creek.
3. Located approximately 1.2 kilometres downstream of the existing Hume Highway crossing of Ten Mile Creek.
4. Existing Hume Highway culvert crossing located on an un-named tributary of Ten Mile Creek, approximately 900 metres south-east of the existing Hume Highway crossing of Ten Mile Creek.

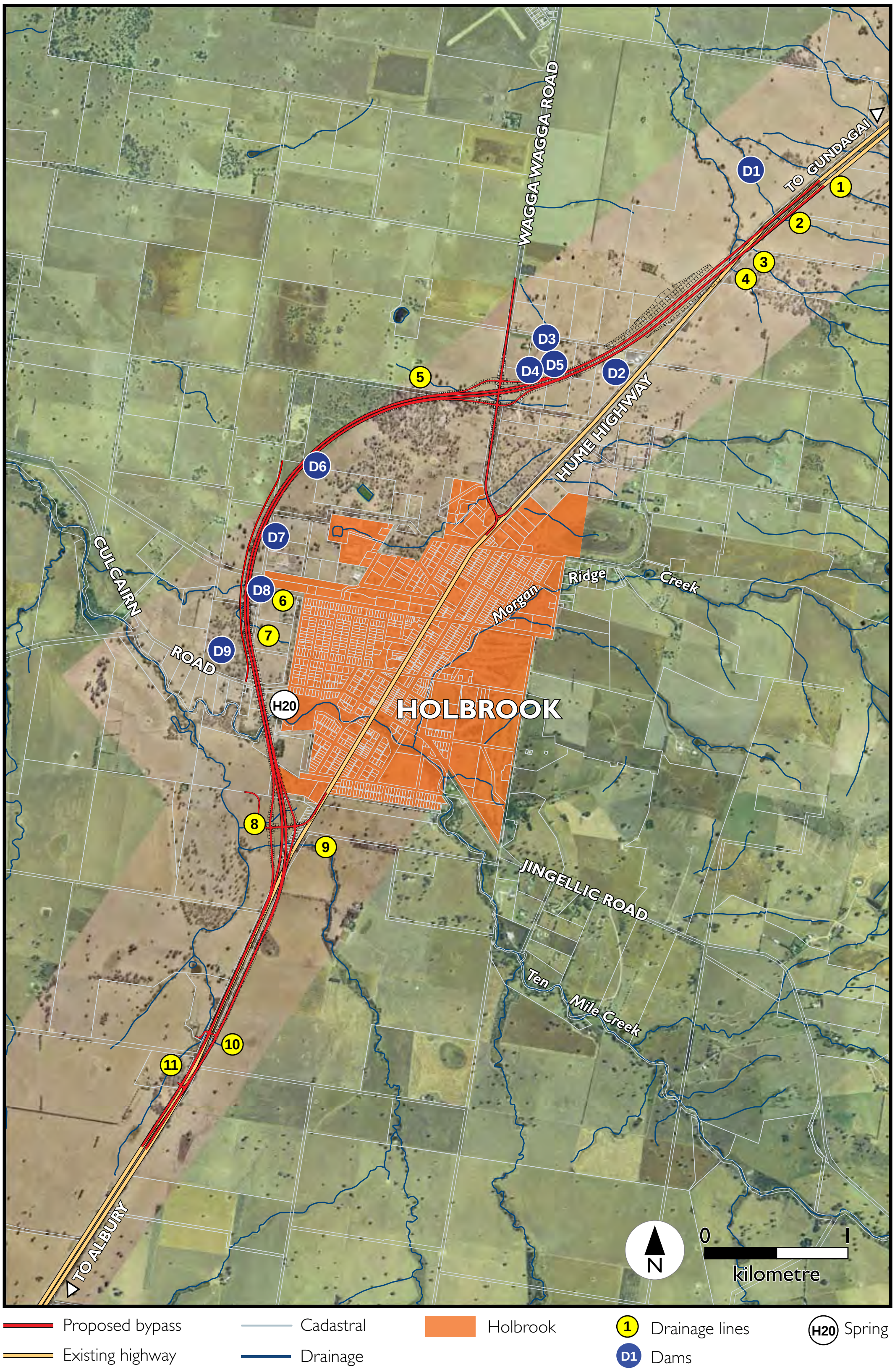

Figure 10-1 **Location of drainage lines and dams**

Peak design flood levels for Ten Mile Creek at each model cross-section within the flood assessment area, under existing conditions, are presented in Table 10-2. The existing 100 year ARI approximate flood extent is shown in Figure 10-2.

Table 10-2 Peak design flood levels at each model cross-section

Cross-section	Peak design flood level (metres AHD)[1, 2]	
	20 year ARI	100 year ARI
A	259.44	260.06
B	258.60	259.21
C	258.20	258.84
D	257.96	258.62
E	257.81	258.46
F	257.59	258.24
G	257.46	258.08
H	257.16	257.85
I	256.6	257.16
J	255.12	255.65
K	254.64	255.17
L	254.21	254.70
M	257.59	258.25
N	257.48	258.12
O	257.15	257.87
P	256.58	257.21
Q	255.18	255.8
R	254.75	255.36
S	254.35	254.94

Notes: 1. metres AHD = metres Australian height datum.

2. While values are listed to the nearest 0.01 metres, for the purpose of this assessment, the accuracy of the model is within the order of +/- 0.1 metres.

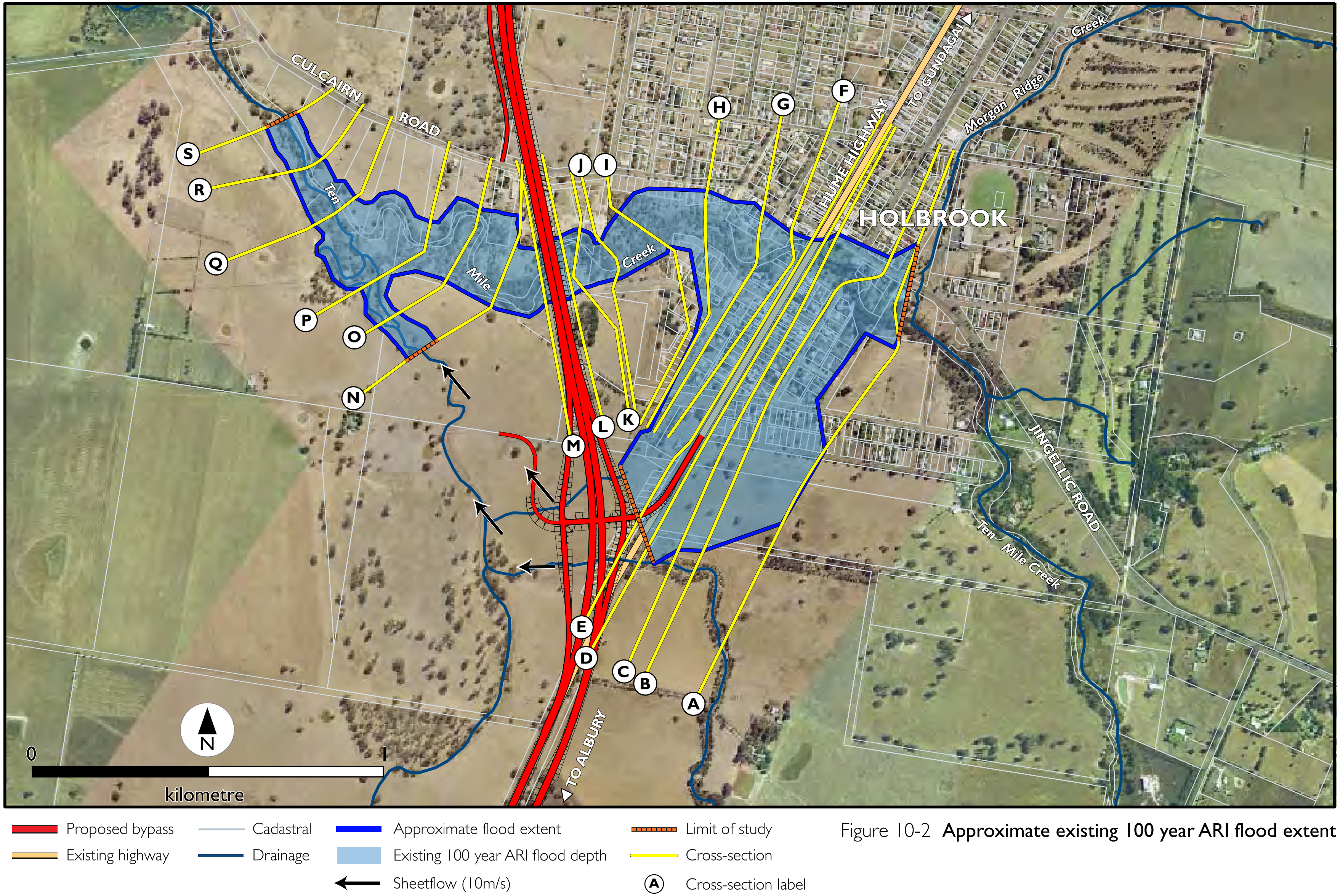

Figure 10-2 **Approximate existing 100 year ARI flood extent**

The 100 year ARI peak design flood event, with a critical rainfall event duration equal to six hours, results in approximately 12 to 14 hours of out-of-bank flooding. Hydraulic modelling of the existing 100 ARI peak design flood predicts the following flood behaviour in the flood assessment area (refer Figure 10-2):

- Flood waters are out-of-bank downstream of the proposed Ten Mile Creek crossing within a relatively narrow flood extent (between cross sections M and S).
- Flood waters are out-of-bank upstream of the proposed Ten Mile Creek crossing (between cross sections A and L).
- Immediately upstream of the proposed Ten Mile Creek crossing (between cross sections H and L) floodwaters remain within a narrow flood extent. From review of the aerial photography available for the area it has been identified that potentially six residential properties (including structures/buildings) located on Culcairn Road, adjacent to Ten Mile Creek may be affected by floodwaters. A structure located on a property off Murray Street, on the southern side of Ten Mile Creek, is also potentially affected by floodwaters.

Existing flooding further upstream of the proposed Ten Mile Creek crossing (between cross sections A and H) is predicted to behave as follows:

- The existing Hume Highway bridge over Ten Mile Creek is set at a higher level than the existing highway south of Holbrook. The existing bridge is not expected to overtop but the existing highway is likely to overtop. As a result, the flood extent in this area is considerably wider than further downstream. These floodwaters likely impact on residential properties adjacent to the existing highway, south of the existing Hume Highway bridge over Ten Mile Creek.
- Flow around the existing highway south of Holbrook would likely travel from Ten Mile Creek south-west as sheet flow, entering Ten Mile Creek downstream of the project. Flow arrows near the southern interchange on Figure 10-2 indicate the approximate route of this sheet flow during larger storm events.

Flooding behaviour is similar during the 20 year ARI event.

Urban flooding

Information on the local drainage system through the town of Holbrook has identified potential local urban flooding. A review of available information and discussions with Greater Hume Shire Council suggests that floodwaters in Morgan Ridge Creek (east of the existing highway) and an unnamed drainage line that drains to dam D7 (refer Figure 10-1), have the potential to break their banks and contribute to local flooding problems between the existing highway and the proposed bypass, north of Ten Mile Creek. The local drainage system would be further investigated during detailed design to ensure that the drainage design accommodates these flow regimes.

Surface water use

The access, taking and use of water is managed under the *Water Act 1912* and the *Water Management Act 2000*. In relation to water licensing and approvals, the *Water Management Act 2000* only applies where a water sharing plan has commenced. No water sharing plans apply to Ten Mile Creek and the Holbrook area. Therefore, the *Water Act 1912* is the main water licensing legislation.

There are no water licences granted within the Ten Mile Creek catchment. There is currently an embargo in place on the granting of new water licences for commercial purposes within the Murray-Darling Basin. The Ten Mile Creek catchment supports large numbers of unlicensed domestic and stock users, which access water under domestic and stock rights.

Local dams provide a source of water for landowners.

Groundwater

Geology

The project is located within the Wagga-Omeo Zone of the Lachlan Fold Belt, which is mapped on the *Wagga Wagga 1:250,000 Geological Series Sheet S1 55-15* (Adamson and Loudon 1960). The Lachlan Fold Belt in this area is characterised by Ordovician Metasediments, with some areas intruded by granites of Silurian and Devonian age. Quaternary alluvium has accumulated in lower lying, major drainage lines and forms flats and floodplains on the valley floors.

The exposed geology of the Holbrook area consists largely of unconsolidated alluvial sediments associated with Ten Mile Creek and its tributaries. The alluvial deposits comprise sand, silt, gravel and clay and the thickness of the alluvium is generally governed by bedrock topography. The thickness of the alluvium typically ranges between 10 and 20 metres, with some deeper areas of alluvium to the west of Holbrook where Ten Mile Creek flows into Billabong Creek. The alluvial deposits are underlain and surrounded by weathered Holbrook granite.

The alluvial deposits at the surface are all of Quaternary age. The Quaternary alluvial deposits associated with the deeper sections of Ten Mile Creek and Billabong Creek are referred to as the Cowra Formation. In the deeper sections, the Cowra Formation may be underlain by the Tertiary alluvial deposits of the Lachlan Formation. The Cowra and Lachlan formations occur in association with the deeper sections of the main alluvial areas and are generally only present in the Billabong Creek catchment. The Tertiary Lachlan Formation sediments consist of grey coloured basal gravels, sands and clays, while the Cowra Formation consists of sands and clays with some gravel, generally brown in colour, deposited during the Quaternary period.

Outcrops of Holbrook Granite occur to the north, north-west and east of Holbrook and weathered granite underlies the alluvial deposits. The Holbrook Granite is Devonian in age and comprises a series of biotite granites, granodiorites, granites and gneiss granite, which have intruded into the surrounding Ordovician sediments. Ordovician sediments outcrop in the upper catchments of Holbrook, approximately 10 kilometres from the town centre, but do not outcrop in the immediate vicinity of Holbrook.

Aquifer characteristics

The assessment area falls within the Billabong Creek groundwater management area. Two main aquifer systems are present:

- Unconsolidated and unconfined alluvial aquifers: The majority of boreholes in the Holbrook area are shallow and obtain their supply from the groundwater within the alluvial systems. The upper alluvium has a lower permeability compared to the underlying lower alluvium. Yields from bores constructed within the alluvial aquifer (Cowra Formation) at Holbrook vary from 0.3 to 1.5 litres per second (Baker et al 2001). The bore depths in the alluvium range from 1.9 to 15.2 metres below ground level (http://www.waterinfo.nsw.gov.au, accessed 2009).

- Semi-confined fractured rock aquifers: The fractured rock aquifers generally produce low and unpredictable groundwater yields, and the groundwater quality is often variable and may be brackish or saline. Yields from bores constructed in the fractured rock range from 0.1 to one litre per second. Only a small number of bores are installed within the fractured rock. Bore depths extend to between 67.1 and 165.5 metres below ground level (http://www.waterinfo.nsw.gov.au, accessed 2009).

The water table in the locality is generally a muted reflection of the land topography and there is hydraulic connectivity between the two aquifer systems. Recharge into the groundwater systems occurs via direct rainfall and runoff and also via connection with overlying creeks. Groundwater discharge is likely to occur in the lower lying areas of the landscape (springs), at the break of slope and as base flow to surface water bodies (creeks). Groundwater movement within the two flow systems is from the south-east to the north-west, which is consistent with the local topography.

Groundwater levels

Bore depths and water level measurements were collected at 11 bores during the October 2008 field investigation. The results indicate that groundwater levels in the alluvium are generally shallow, ranging from 2.74 to 8.5 metres below ground level. The groundwater table in the alluvium was very flat, with a total fall of 5.5 metres between the maximum and minimum groundwater level.

The groundwater levels in the fractured rock aquifer were much deeper than the alluvium aquifer.

The groundwater table within the fractured rock was relatively flat with a total fall of 11.9 metres between the maximum and minimum groundwater level.

Once converted into metres AHD, there was minimal difference between the relative groundwater levels in the alluvium and fractured rock aquifers.

One spring was identified. The spring overlies the alluvial floodplain of Ten Mile Creek. At the time of field investigation the spring contained water. The location of the spring is indicated on Figure 10-3.

Many of the dams inspected are likely to be spring fed. The presence of springs and spring fed dams in the Holbrook area is due to the very shallow water levels in the alluvium.

Areas of low topographic relief (such as Ten Mile Creek and the River Red Gum swampy area located west of the southern end of the project) are likely to receive groundwater base flow and discharge in high rainfall periods.

Groundwater use

The majority of bores in the locality are licensed to supply domestic and stock requirements. There are three registered boreholes in the assessment area (H4, H12, H19) (see Figure 10-3). During the field investigation, only one of the registered bores could be correlated to a borehole on the ground. Additional unregistered bores were identified during the field investigation, used for either stock and domestic supplies or for recreational use (watering of public parks and sportsgrounds).

The majority of high yielding bores in the Holbrook area obtain their groundwater from the alluvial sediments. Within the Groundwater Management Area (GMA014), which includes the Billabong Creek catchment, the total groundwater entitlement is 7364 megalitres, which is distributed between 49 renewable licences (DECCW pers comm. 2009). For the period July 2007 to June 2008, only 1278 megalitres of the total entitlement was actually extracted. Following the highest recorded usage year in 2004 to 2005 an embargo was placed on the Billabong Creek alluvium preventing the granting of any new high yield groundwater extraction licences.

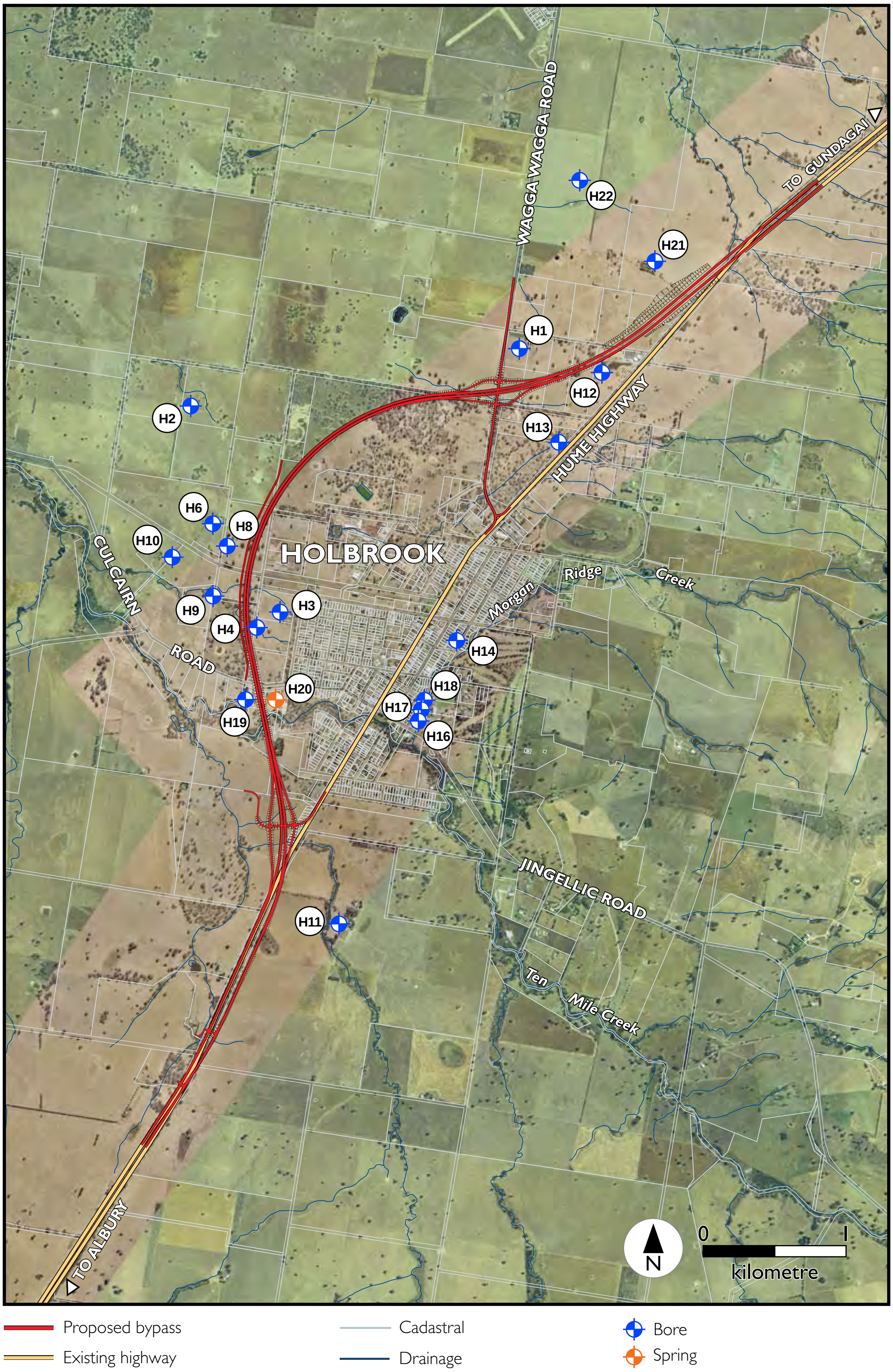

Figure 10-3 **Bore locations**

10.1.3 *Potential surface water impacts*

Construction

Local catchment impacts

The project would cross several local drainage lines. During construction there is potential for drainage lines to be temporarily blocked or diverted. Blocking or diversion of drainage lines may result in localised areas of flooding on the upstream side of the project and may prevent flows from reaching downstream receiving waters or farm dams. Diversion of drainage lines may also create localised areas of flooding and scour. These temporary impacts are expected to be minor and would be managed through the implementation of standard construction techniques.

Management of runoff from the construction site would have the potential to concentrate flows and erode the landscape. These temporary impacts are expected to be minor and would be managed through the implementation of standard construction techniques.

Surface water and flooding and impacts

Construction of the project would include site establishment and preparation works, drainage works (culverts, bridges, sediment basins), pavement construction and some ancillary works across the Ten Mile Creek catchment. During construction blockage of usual flow paths in the case of a flood has the potential to affect flood behaviour and change flood flow distribution. Depending on the location of flow blockages in relation to properties within the floodplain, there is potential that these changes may results in temporary flooding impacts. There is also potential for construction works to be affected by flooding.

These temporary impacts are expected to be minor and would be managed through the implementation of measures as outlined in Table 10-5.

Water supply impacts

Section 6.3.2 discusses the water requirements for the project (approximately 400 megalitres over the two year construction period) and the potential sources of that water.

Extraction of water from dams may impact landowners and agribusinesses. Access to, and the volume of, water to be extracted would only be in agreement with landholders and so impacts are likely to be minor.

Construction of offline water storages (if required) could potentially reduce local runoff that would otherwise flow to existing drainage lines and/or farm dams. This would have little impact on water supply for local users and would be managed through the measures provided in Table 10-5.

There is currently an embargo in place on the granting of new licences for commercial purposes in the Murray-Darling Basin. Water for the project would not be sourced from Ten Mile Creek.

The project would be unlikely to have an overall impact on surface water supplies and surrounding users.

Operation

Local catchment impacts

Impacts on the local catchment during operation of the project are unlikely as the drainage system would be designed to ensure that distribution of flow is maintained to match the existing flow regime as much as possible.

As with the construction phase, the drainage lines that are crossed by the project have the potential to be impacted by blockage (eg debris). Blockage of flow has potential to increase in-flows, which may cause localised flooding both upstream and downstream of the project. An increase in impervious surfaces would potentially generate more runoff. Concentrated runoff may generate increased velocities resulting in potential scour and sedimentation with downstream impacts to receiving surface waters.

Potential impacts would be mitigated through the longitudinal drainage system for the project and the measures outlined in Table 10-5.

Extreme rainfall events due to climate change

'Climate change' refers to future changes in climate that are driven by an increase in heat from the sun, retained in the Earth's atmosphere. There is presently a general consensus amongst climate experts that climate change is occurring and that most of the warming observed over the last 50 years is attributable to human activities that have increased atmospheric concentrations of greenhouse gases (IPCC 2007). In Australia, evidence of climate change has been identified by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2006) to include increased average temperatures, changes in annual rainfall and increased climate extremes (more intense droughts and extreme rainfall events).

In the Murray catchment (within which this project is located), the future climate is likely to experience increased extreme rainfall events. The CSIRO predicts between a seven per cent reduction and a 29 per cent increase in extreme rainfall (40 year ARI one day rainfall event) in this catchment in 2070 (CSIRO 2007). Further flood modelling assessment of potential climate change impacts would be undertaken, as necessary, during the detailed design, in consultation with DECCW. The project would adopt a factor of safety in the design of drainage structures.

Flooding and hydrology impacts

The concept design seeks to minimise change in afflux. The design objectives for the 100 year ARI event are as follows:

- Land without buildings or sensitive structures: minimise impacts.
- Land where buildings or sensitive structures are already below the 100 year ARI flood level: minimise and manage impacts.
- Land where buildings or sensitive structures previously not inundated in the 100 year ARI event would be at increased risk of inundation: no additional impacts.

Hydraulic modelling indicates that the project would alter the distribution of flow within the Ten Mile Creek floodplain both upstream and downstream of the proposed bridge over Ten Mile Creek.

The concept design assumes a multi-span bridge over Ten Mile Creek with a 120 metre opening. Based on the comparative assessment of the existing and future hydraulic model results, the project would generally not alter the flood extent in the 100 ARI event. Additionally, afflux for the 20 year ARI was also assessed to provide further understanding of the existing flooding conditions for more recurrent events. This afflux is due primarily to a reduction in conveyance area associated with the proposed bridge and bridge piers.

Afflux at each model cross-section within the Ten Mile Creek floodplain for the 20 year and 100 year ARI events is summarised in Table 10-3. Figure 10-4 shows the 100 year ARI flood event afflux with the project.

Table 10-3 Afflux at each model cross-section during the 20 year and 100 year ARI events

Cross-section[1]	Existing 20 year ARI[2]	Proposed 20 year ARI[2]	Afflux (metres)	Existing 100 year ARI[2]	Proposed 100 year ARI[2]	Afflux (metres)
A	259.52	259.52	0.00	260.11	260.11	0.00
B	258.55	258.56	0.01	259.16.	259.17	0.01
C	258.13	258.15	0.02	258.78	258.81	0.03
D	257.89	257.92	0.03	258.57	258.60	0.03
E	257.76	257.79	0.03	258.42	258.46	0.04
F	257.59	257.59	0.00	258.25	258.25	0.00
G	257.47	257.48	0.01	258.12	258.12	0.00
H	257.14	257.15	0.01	257.87	257.87	0.00
I	256.58	256.58	0.00	257.21	257.21	0.00
J	255.17	255.18	0.01	255.80	255.80	0.00
K	254.75	254.75	0.00	255.36	255.36	0.00
L	254.35	254.35	0.00	254.94	254.94	0.00
M	257.59	257.59	0.00	258.25	258.25	0.00
N	257.48	257.48	0.00	258.12	258.12	0.00
O	257.14	257.15	0.01	257.87	257.87	0.00
P	256.58	256.58	0.00	257.21	257.21	0.00
Q	255.18	255.18	0.00	255.80	255.80	0.00
R	254.75	254.75	0.00	255.36	255.36	0.00
S	254.35	254.35	0.00	254.94	254.94	0.00

Notes:
1. The river station represents the distance to the downstream extremity of the model (in metres) along the invert of the main channel.
2. metres AHD = metres Australian height datum.
3. While values are listed to the nearest 0.01 metres, for the purpose of this assessment, the accuracy of the model is within the order of +/- 0.1 metres.

Table 10-3 indicates that the proposed bypass would cause some afflux in the adjacent floodplain areas upstream of the proposed bridge for the 20 and 100 year ARI events. For the 20 year ARI design event, afflux would range between 0.00 metres and 0.03 metres.

For the 100 year ARI design event, afflux would range between 0.00 metres and 0.04 metres. The greatest afflux would be located immediately upstream of the proposed bridge and is due primarily to a reduction in conveyance area associated with the proposed bridge and bridge piers.

The project would not result in any additional flood impacts to properties in the 100 year ARI flood event. Potentially six residential properties and a shed (between cross sections H and L) may be affected by flooding in the 100 year ARI flood event (refer Figure 10-2). A maximum afflux of up to 0.01 metres is predicted at these properties. Further detailed survey and modelling of the area immediately upstream of the proposed Ten Mile Creek crossing would be undertaken to determine the exact nature of the proposed flood extent. Detailed design would further seek to minimise the afflux. Management measures, if required, would be developed in consultation with the affected landowner(s) and may include measures such as flood proofing of structures to prevent the ingress of floodwaters.

The final bridge length would be subject to detailed design.

The existing Hume Highway bridge causes floodwaters in Ten Mile Creek to overtop the Hume Highway on the southern approach to the existing bridge. The proposed bypass would not increase the amount of floodwater that flows across this overland flowpath since the capacity of Ten Mile Creek and the terrain upstream of the existing highway govern the amount of floodwaters that contribute to this overland flowpath. However, without sufficient drainage infrastructure, the project could potentially prevent this overland flow from continuing on its current route back to Ten Mile Creek due to the embankment of the project blocking the existing overland flow route. Changes in flow distribution may lead to increased flood levels (afflux), and changes in flood inundation extent and velocity. Potential impacts would be mitigated through the drainage system for the project and the measures outlined in Table 10-5.

The duration of inundation is the amount of time that a property or land experiences flooding during a particular storm event. Frequency is how often a flow event of a particular magnitude impacts a property or land. The project is unlikely to change the duration of inundation or frequency of flooding within the Ten Mile Creek floodplain in the locality.

Changes in velocity as a result of the project may lead to changes in scour and/or sediment movement within waterways and around structures such as bridge piers and abutments. Scouring at structures can lead to undermining and failure of structures. High velocities have the potential to move structures in a downstream direction if not properly designed. Sedimentation can lead to a reduction in flow conveyance area within a waterway or through bridge structures by filling of the channel, raising inverts and vegetation growth. This reduction in conveyance area can potentially lead to increases in water levels during storm events.

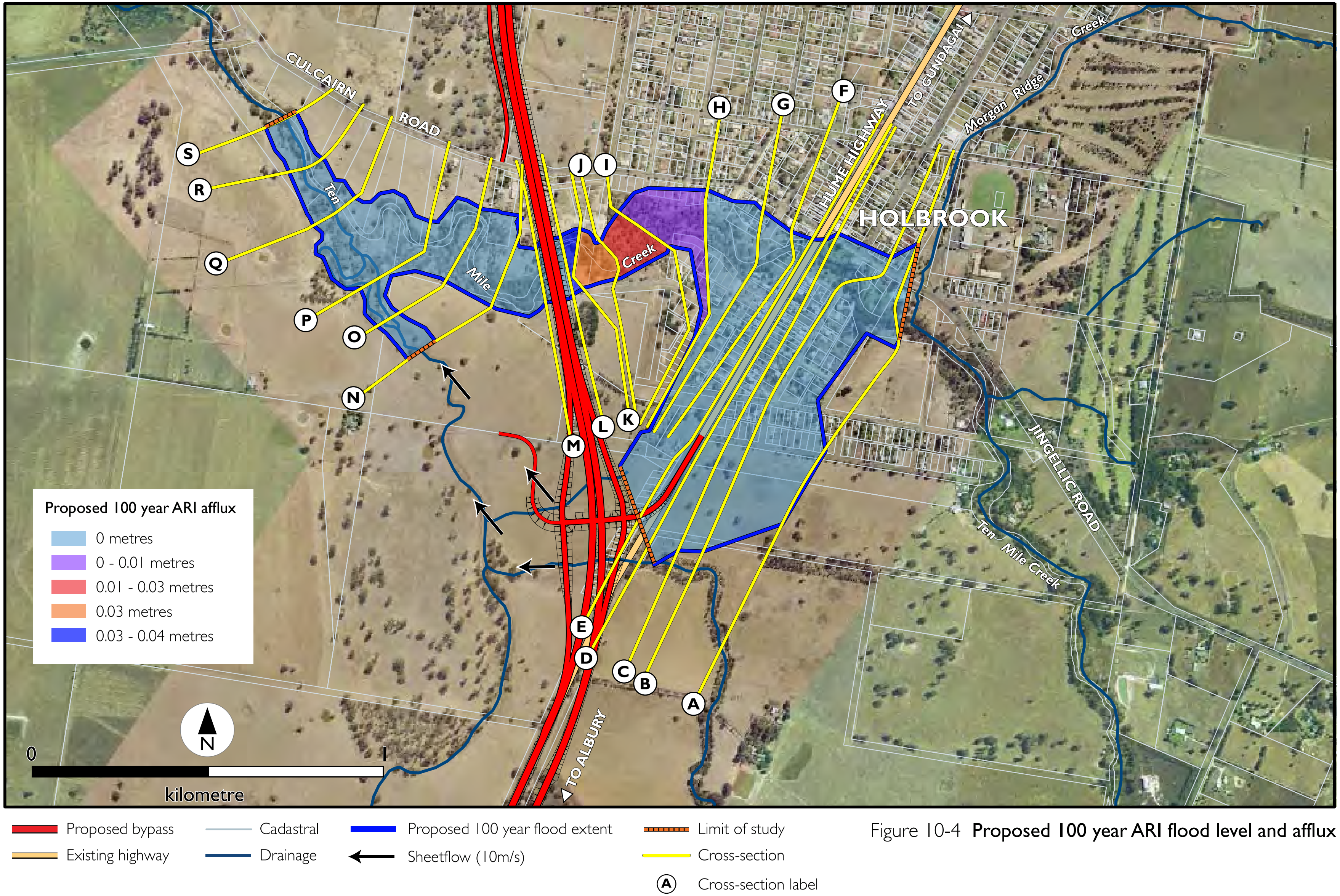

Figure 10-4 **Proposed 100 year ARI flood level and afflux**

The project would change the velocity of water flows. Changes to peak velocities at key structures are summarised in Table 10-4. These changes to velocities would not pose a major risk to the operation of the project or to the main channel of Ten Mile Creek.

Table 10-4 Changes to peak velocities at key structures

Location	Event (ARI)	Existing (metres per second)[1]	Proposed (metres per second)[1]	Impact (metres per second)
Existing Hume Highway bridge	20	1.55	1.41	-0.14
	100	0.66	0.74	0.80
	2000	0.66	0.66	0.00
Existing pedestrian bridge	20	1.05	1.04	-0.01
	100	0.8	0.8	0.00
	2000	0.58	0.58	0.00
Proposed bypass bridge	20	1.27	1.25	-0.02
	100	1.53	1.52	-0.01
	2000	2.33	0.65	-1.68

Note: 1. While values are listed to the nearest 0.01 metres, for the purpose of this assessment, the accuracy of the model is within the order of +/- 0.1 metres.

Flood hazard within a floodplain is defined in the *NSW Floodplain Development Manual* (NSW Government 2005) and is based on flood depth and flood velocities and other relevant factors that affect the safety of structures and/or individuals. These other factors include flood warning, flood awareness, flood readiness and evacuation methods.

From a hydraulic perspective, if flood depths are greater than one metre and or flood velocities are greater than two metres per second, then the degree of flood hazard is considered to be high. Depths and velocities within the over bank areas are less than one metre and two metres per second respectively for both the existing and proposed conditions. Accordingly, the flood hazard is low within this area of the Ten Mile Creek floodplain. The project is not likely to change the existing flood hazard in the vicinity of Holbrook.

10.1.4 *Potential groundwater impacts*

Construction

The works associated with the construction of the project would have short-term impacts on ground conditions, and therefore, potentially groundwater flows. Potential impacts would include:

- Short-term impact to unconfined alluvial aquifers as a result of aquifer compaction caused by construction of controlled fills, structures and other compaction activities. The effects of ground compaction include the following:
  - Aquifer compaction may result in impediment or prevention of the natural groundwater flow to the north-west. This may cause water logging and ponding to the immediate east of the construction site, and may also result in the lowering of the water table to the west and north-west.
  - Increase in the incidence of dryland salinity associated with the changes to flow regime. Dryland salinity may then be introduced into previously unaffected areas.
- Impacts to the spring at H20 (refer Figure 10-3), which is located within the assessment area. Impact to the spring is subject to detailed design.

- Excavations into the alluvium that are deeper than approximately two metres have the potential to receive groundwater inflow.
- Potential impacts on surrounding groundwater users through the use of groundwater supplies for construction of the project (eg reduced groundwater levels).

Water supply impacts

Section 6.3.2 discusses the water requirements for the project (approximately 400 megalitres over the two year construction period) and the potential sources of that water. If groundwater is used, extraction may affect access to local groundwater supplies for adjacent users. If required, a groundwater monitoring program would be implemented to manage potential impacts of groundwater extraction. The monitoring program would consist of the following elements:

- Monitoring of groundwater levels and quality prior to groundwater extraction, monthly during extraction, and for a period after completion of extraction.
- Inspection of groundwater bores for serviceability on a weekly basis.

Should groundwater be accessed for construction, groundwater level and quality data would be assessed monthly. Should impacts be detected, steps to minimise the impacts would be implemented. These would include:

- Reduction in the extraction rate.
- Increase in the rest time between pumping intervals.
- Rotation of pumping bores.
- Temporary use of alternative water supplies.
- Investigation of alternative groundwater bores.

Operation

During operation, the ground conditions have the potential to change permanently. These long-term impacts may include:

- Potential long-term impact to unconfined alluvial aquifers as a result of aquifer compaction under the project. The potential consequences of long-term aquifer compaction are the same as those described above for construction impacts.
- Three groundwater bores (H4, H12 and H19) are located within the construction site boundary (refer Figure 10-3) and may be impacted by the project. Any replacement would be carried out in consultation with the landholder(s)/agency stakeholders as required.
- The spring at H20 will continue to flow during operation of the project. It has the potential to undermine the integrity of the road embankments.
- Changes to the flow regime induced by the project would increase the risk of the development of dryland salinity. The disruption to shallow groundwater flow from compaction of the shallow sediments may contribute to water logging and ponding on the up gradient (eastern) side of the project. Dryland salinity may then be introduced into previously unaffected areas.
- Water logging on the eastern side of the project from raised groundwater levels may impact the town of Holbrook. Potential impacts would include increased water pooling during periods of heavy rainfall and increased risk of dryland salinity.

Impacts on groundwater would be minimised through standard design and construction practices.

10.1.5 *Management of surface water and groundwater impacts*

Table 10-5 identifies mitigation and management measures that would be implemented for surface water and groundwater impacts. Impacts relating to soils and water quality and hazards and risks are detailed in Section 10.3 and 10.6 respectively. These measures have been incorporated into the draft statement of commitments in Chapter 11.

Table 10-5 Surface water and groundwater mitigation and management measures

Potential impact	Mitigation and management measure
Pre-construction	
Ground compaction inducing changes to shallow aquifer conditions and increased incidence of salinity	▪ Consider the impacts of ground compaction on the aquifer conditions through detailed design.
Increased extreme rainfall events due to climate change increasing afflux	▪ As necessary, undertake further flood modelling assessment of potential climate change impacts during the detailed design, in consultation with the DECCW.
Construction	
Flooding caused by blockages to flood flow paths during construction	▪ Maintain major flood flow paths during construction activities. ▪ Design temporary creek crossings to overtop in a large flood event. ▪ Locate material stockpiles outside of the 10 year ARI floodplain. ▪ Use diversion bunds to divert flows around construction works.
Inefficient water use	▪ Implement water efficient work practices, such as water reuse and recycling for road construction and revegetation irrigation.
Interaction with shallow groundwater flows	▪ Develop drainage infrastructure, and as necessary, land management initiatives, to manage any groundwater seepage during construction.
Induced localised dryland salinity	▪ Develop strategies to manage groundwater issues associated with surrounding land uses, including management of recharge areas, in consultation with DECCW as necessary.
Impact on groundwater system and users	▪ Undertake groundwater extraction monitoring (if required). Implement mitigation measures where levels indicate that the project is potentially having an adverse impact.
Water extraction boreholes/dams directly affected by the project	▪ Relocate boreholes/dams to maintain a reliable water supply for landholders, if required.
Operation	
Afflux and increased inundation time at sensitive receivers	▪ Manage change in peak flood levels (afflux) in the 100 year ARI event through detailed design. Measures could include: ‣ Treatment to individual properties in consultation with landowners and other relevant stakeholders, such as flood proofing of structures, house raising, protective earth bunds.
Afflux and increased inundation time at sensitive receivers	Manage change in peak flood levels (afflux) in the 100 year ARI event through detailed design. Measures could include: ▪ Treatment to individual properties in consultation with landowners and other relevant stakeholders.

Potential impact	Mitigation and management measure
Potential blockages, diversions or erosion of waterways or drainage lines	▪ Design drainage structures to convey flows under the project. ‣ Implement appropriate scour protection measures at bridge(s) and drainage structures.
Obstruction of groundwater flow	▪ Install appropriate subsurface drainage infrastructure, for example, blind ditches, in areas identified as having shallow groundwater levels.

10.2 Non-Aboriginal heritage

10.2.1 *Assessment approach*

The non-Aboriginal heritage assessment was undertaken in accordance with the principles of the Australian International Council on Monuments and Sites (ICOMOS) Burra Charter and current heritage best practice guidelines, including the Department of Planning's (Heritage Branch) *NSW Heritage Manual* publication *Statements of Heritage Impact* (Heritage Branch and Department of Urban Affairs and Planning 1996).

The non-Aboriginal heritage assessment built on the work undertaken for the *Hume Highway Upgrade Holbrook Bypass: Preliminary Environmental Assessment* (RTA 2008a) and included:

- Preparing a revised regional historic overview of the locality.
- Searching all relevant statutory and non-statutory heritage registers, including:
  - National Heritage List.
  - Commonwealth Heritage List.
  - NSW State Heritage Register.
  - NSW State Heritage Inventory.
  - RTA S170 Heritage and Conservation Register.
  - State Rail Authority S170 Heritage and Conservation Register.
  - Holbrook Shire Council Interim Development Order (IDO) 1970.
  - National Trust of Australia.
  - Register of the National Estate.
- Desktop primary and secondary historical research, including historical chronological mapping of the assessment area.
- Consulting with the Heritage Branch Library, RTA Document Management Centre and the Greater Hume Shire Council, and the relevant local historical societies, including National Trust of Australia (NSW), local government heritage adviser.
- Non-Aboriginal field survey of the assessment area between 27 October and 29 October 2008 to identify and record known and potential heritage items, archaeological artefacts, sites or features, and to assess the archaeological research potential of the assessment area. The survey included:
  - A systematic transect-based method, whereby transects were located in relation to the proposed bypass. These transects were surveyed on foot by the field team who were spaced at varying intervals based on the level of ground surface visibility.

  - Recording using standard site recording forms and a combination of descriptive, drawn and photographic mediums. Information recorded included location, site type, description, extent of site, approximate age, current land use, visible impacts on site, a site sketch plan and digital photographs.
- Preparing a non-Aboriginal heritage assessment. This included an assessment of significance of the identified items against the NSW Heritage Council assessment criteria and a heritage impact assessment of these items.

10.2.2 *Historic overview*

On their journey to Port Phillip, the explorers Hume and Hovell crossed into the Holbrook area in November 1824. In 1826 Governor Darling established an area known as the 'Limits of location'. The first pastoralists in the Holbrook area originally occupied the land without formal consents. On 1 February 1837 the Government Gazette listed the first grazing licence for the land, which today constitutes the greater district of Holbrook.

Pastoral expansion in the 1830s created an arterial route from Sydney as far as Lower Tarcutta, known as the Great Southern Road. By 1838 the main overland route from Sydney to Melbourne, known as the Port Phillip Road, roughly followed the route that would become the Hume Highway. In 1928 the road was renamed the Hume Highway.

Later village development and population growth was due to the *Crown Lands Alienation and Occupation Acts* of 1861. This land reform allowed for the division of larger pastoral grants into smaller land blocks. From 1866 onwards, floods of settlers from Victoria and South Australia arrived. The village and surrounding district was densely populated by the 1870s.

Prior to 1915 the current town of Holbrook was referred to as 'Ten Mile Creek'. By 1847 'Ten Mile Creek' and the name 'Germans' were interchangeable. The 'Germans' evolved into 'Germantown' by 1875. A town common was reserved in 1876 for use by town residents or small-scale local farmers. It provided an area for grazing, watering of stock and collection of firewood. The town cemetery was established on its southern edge in 1879.

During the 1880s a variety of organisations were founded, which advanced the town's agricultural and pastoral pursuits. By 1888 the Great Southern Railway was built, but bypassed the town. This began to affect the town with fewer travellers passing through and business slowing. By 1891 the population had declined and economic depression was widespread. Another factor contributing to the economic downturn was a significant decrease in the price of wool.

Between 1886 and 1907 a number of Travelling Stock Reserves were created around the township, where cattle could obtain water and pasture overnight. In 1902 the railway reached Holbrook, leading the Travelling Stock Reserves to be established close to the station to facilitate holding of stock prior to transportation.

By the turn of the 20th century, businesses in the town included general stores, butchers, blacksmiths, a bakery, a chemist and a boot shop, a flour mill, two cordial factories and a saw mill.

10.2.3 *Presence of heritage sites/items in the assessment area*

Six non-Aboriginal heritage items were identified in the assessment area through historical research and site inspections. No listed non-Aboriginal heritage items exist within the assessment area. These heritage sites/items include:

- HHI-1 — Montpellier Shearer's quarters.
- HHI-3 — Hereford Stud Homestead.
- HHI-4 — Historic dairy and well.
- HHI-5 — Potential site of the old homestead.
- HHI-6 — Historic artefact scatter and mound.
- HHI-7 — Culcairn to Holbrook rail line (non-operational).

Figure 10-5 shows the location of these identified heritage sites/items.