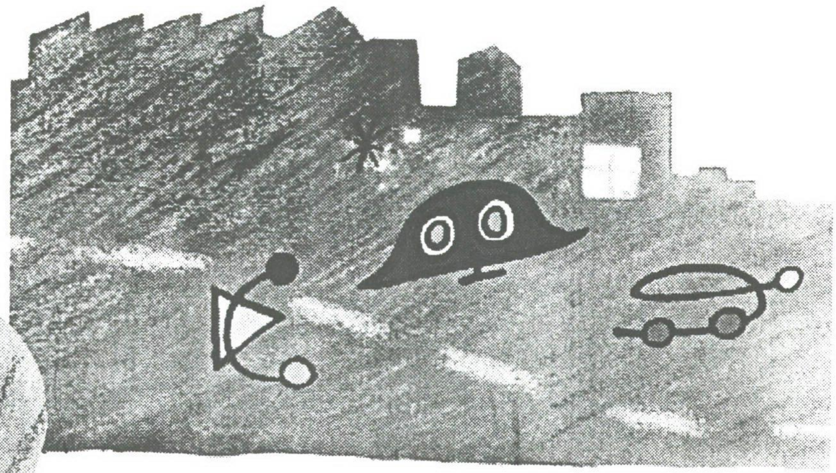

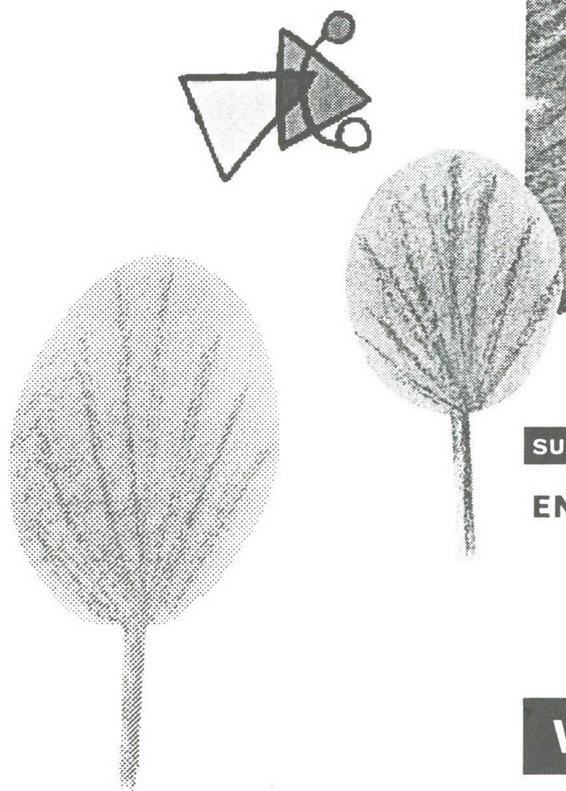

SUPPLEMENT TO **M5 EAST MOTORWAY**

ENVIRONMENTAL IMPACT STATEMENT

WORKING PAPERS

VOLUME 1 OF 3

1996

RTA

Better Roads.Safer Roads.
Saving Lives

SUPPLEMENT TO M5 EAST MOTORWAY

ENVIRONMENTAL IMPACT STATEMENT

WORKING PAPERS

VOLUME 1 OF 3

1996

Note: The proposal assessed in the Supplement to the 1994 M5 East EIS is referred to in these working papers variously as: Alternative H, the Southern Variation, the proposal, the preferred alternative (or option).

Completed by Manidis Roberts Consultants

Level 4

88-90 Foveaux Street

Surry Hills NSW 2010

Tel (02) 9281 5199

Fax (02) 9281 9406

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Specialist Working Papers for the Supplement to the 1994 M5 East Motorway EIS

Volume 1 of 3

BBC Consulting Planners, 1995a. M5 East motorway: variation from Bexley Road to General Holmes Drive: supplementary report on matters relating to zoning. Prepared for Manidis Roberts Consultants on behalf of the Roads and Traffic Authority, Sydney, December, 1995. 1 pg

BBC Consulting Planners, 1995b. M5 East motorway: variation fro Bexley road to General Holmes Drive: land use and social impacts. Prepared for Manidis Roberts Consultants on behalf of the Roads and Traffic Authority, Sydney, December, 1995. 14 pgs

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BRIGGS BRINDLE & CHAMBERS
CONSULTING PLANNERS
PTY LIMITED
ACN 061 868 942

22-36 MOUNTAIN STREET BROADWAY NSW PO BOX 438 BROADWAY NSW 2007
TEL: (02) 211 4099 FAX: (02) 211 2740

PROPOSED M5 MOTORWAY

VARIATION BETWEEN BEXLEY ROAD AND GENERAL HOLMES DRIVE

SUPPLEMENTARY REPORT ON MATTERS RELATING TO ZONING

Prepared for
Manidis Roberts on behalf of
the Roads and Traffic Authority

By
BBC Consulting Planners,
22-36 Mountain Street, N.S.W.
PO Box 438, Broadway, N.S.W. 2007

Phone: (02) 211 4099 Fax: (02) 211 2740

Job No. 95073
M0995015
December, 1995

BBC
CONSULTING PLANNERS

1. INTRODUCTION

A working paper entitled "Proposed M5 Motorway Between Fairford Road and General Holmes Drive - Report on Matters Relating to Zoning" prepared by BBC Consulting Planners in conjunction with Freehill Hollingdale and Page dated June 1994 considered approval and zoning related matters relating to the proposed M5 East Motorway.

This supplementary working paper considers two variations from Bexley Road to General Holmes Drive being the northern and southern variations.

2. PROVISIONS OF RELEVANT PLANNING INSTRUMENTS

The land on which the proposed variations would be located falls within the LGAs of Canterbury and Rockdale.

Land on or under which the variation would be located falls into one or more of the following categories:

- proposed county road reservations under Canterbury and Rockdale Planning Scheme Ordinances;
- the following zones within the LGA of Canterbury under the provisions of the Canterbury Planning Scheme Ordinance:
  - Residential 2(a);
  - Existing Recreation 6(a);
- the following zones within the LGA of Rockdale under the provisions of the Rockdale Planning Scheme Ordinance:
  - Residential 2(a);
  - Special Uses "B" (Railway) 5(b);
  - Existing Recreation 6(a);
  - Residential 2(b1);
  - Residential 2(b2);
  - Residential 2(c1);
  - Residential 2(c2)
  - General Business 3(a);
  - Automotive Business 3(d);
  - Light Industrial 4(b1);
  - Light Industrial (Restricted) 4(b2);
  - Special Uses "A" (Defence Purposes) 5(a);
  - Special Uses "A" (WS&D) 5(a).
- land that is unzoned (roads or between the banks of unzoned waterways);
- land within Sydney (Kingsford Smith) Airport.

Generalised zoning is shown on Figure 26 of the supplementary EIS.

3. FINDINGS

The zoning status of land on which the variations are located falls within categories discussed in the working paper or zones with similar characteristics. Consequently, the findings of the working paper apply to the proposal as varied.

BRIGGS BRINDLE & CHAMBERS
CONSULTING PLANNERS
PTY LIMITED
ACN 061 868 942

22-36 MOUNTAIN STREET BROADWAY NSW PO BOX 438 BROADWAY NSW 2007
TEL: (02) 211 4099 FAX: (02) 211 2740

M5 EAST MOTORWAY -

VARIATION FROM BEXLEY ROAD TO GENERAL HOLMES DRIVE

LAND USE & SOCIAL IMPACTS

Prepared for
Manidis Roberts on behalf of
the Roads and Traffic Authority

By
BBC Consulting Planners,
22-36 Mountain Street, N.S.W.
PO Box 438, Broadway, N.S.W. 2007

Phone: (02) 211 4099 **Fax: (02) 211 2740**

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1. INTRODUCTION

This working paper is a supplement to the **M5 East Motorway Land Use and Social Impacts Working Paper** prepared by BBC Consulting Planners in April 1994. It considers two variations of the proposal east of Bexley Road. The variations involve different motorway alignments and comprise:

- The northern variation being a driven tunnel from Bexley Road to The Illawarra rail line running generally along the northern side of Wolli Creek crossing the creek at Turrella. The proposed motorway would be constructed in cut and cover tunnel from the Illawarra rail line to Princes Highway, driven tunnel from the highway to Marsh Street, Arncliffe. The access ramps to Marsh Street would be constructed in cut and cover tunnel from West Botany Street to Marsh Street. The proposal would be located at or above grade from Marsh Street to its conclusion at General Holmes Drive.
- The southern variation would follow a straighter alignment within a driven tunnel from Bexley Road to the Illawarra rail line. It would be located in cut and cover tunnel from here to the Princes Highway and would then follow an alignment similar to the northern variation through to General Holmes Drive.

Vehicular access arrangements to the M5 East Motorway would be the same for each variation and include:

- access ramps to and from the west at Bexley Road;
- access ramps to and from the west at the Princes Highway;
- access ramps to and from the east and west at March Street (all movements);
- a grade separated interchange with General Holmes Drive with access to and from the north.

As the M5 East Motorway would be substantially underground east of Bexley Road, changes to local vehicular access arrangements under both variations would be kept to a minimum. Allen Street would be closed at the Princes Highway with the intersection of Ann Street and Princes Highway upgraded to provide right turns as an alternative access to the Allen Street rail line underpass. A small access street from Valda Avenue to Marsh Street Arncliffe would also be closed. Arncliffe Road, Ann Street, West Botany Street and Marsh Street may be temporarily affected during construction of cut and cover tunnel sections.

2. LAND USE IMPACTS

2.1 Northern variation

2.1.1 Existing Land Use

From Bexley Road to Marsh Street, the northern variation of the proposed motorway would be located within a driven tunnel which runs generally along the northern side of Wolli Creek and residential and industrial areas of Turrella and Arncliffe. Land use in the vicinity of cut and cover sections includes commercial and industrial uses along Princes Highway and residential uses along Ann, Allen, West Botany and Marsh Streets.

From Marsh Street to General Holmes Drive, land use comprises vacant land and park land including the Eve Street wetland and its natural drainage line to the Cooks River which runs along the southern side of the SWOOS. Limited residential development fronts the western side of Marsh Street and Council's garbage depot is at the end of Eve Street. Kogarah Golf Club is on the northern side of the SWOOS. To the east of the Cooks River the motorway would run along the periphery of Sydney (Kingsford Smith) Airport from Cooks River to General Holmes Drive. The proposal would be located generally within road reserve over most of this area.

2.1.2 Land Use Impacts

The extended length of driven tunnel means that fewer properties would be directly affected compared with the EIS proposal. Consideration has been given to direct and indirect land use impacts of the variations. A **direct impact** is considered to be where a property would need to be totally or partially acquired by the RTA for the construction of the motorway. An **indirect impact** is considered to occur where the driven tunnel section of each variation passes underneath a property. The assessment of the number of properties indirectly affected has been based on the proposed tunnel location and aerial photography interpretation. This is subject to review at the detailed design stage once the size and configuration of the tunnel is known.

2.1.3 Impacts on Residential Uses

Direct Impacts

The following residential properties would be directly affected and would be acquired:

- 25 older style dwelling houses in Ann Street including 9 flats;
- 4 residential properties fronting Eden Street;
- 3 residential properties fronting Princes Highway;
- 13 residential properties on West Botany Street;
- 7 residential properties on Marsh Street.

In addition two residential properties and one vacant lot on Marsh Street would be affected by partial acquisition.

Indirect Impacts

It is estimated that approximately 153 houses and three residential flat buildings would be indirectly affected.

2.1.4 Impacts on Industrial and Commercial Uses

Direct Impacts

Industrial properties directly affected include:

- a large motor vehicle showroom on the Princes Highway between Allen and Ann Streets currently being expanded;
- three other car sales yards on the Princes Highway one on the western side and two on the eastern.

A number of other properties would be affected by partial acquisition including uses fronting the eastern side of the Princes Highway comprising a car sales yard, two office buildings and two service stations and properties on the western side of the highway including an equipment hire establishment.

Further acquisition of vacant land and parkland would be required to allow the widening of Marsh Street in the vicinity of its intersection with the proposed motorway and access ramps. A bus depot on the western side of Marsh Street would be partially affected.

Indirect Impacts

Industrial properties indirectly affected include:

- a number of industrial properties on the northern side of Hirst Street between Loftus Street and Bonar Street;
- a number of properties along Wollongong Road between Bonar Street and the Illawarra rail line.

2.1.5 Impacts on Open Space

Open space likely to be directly affected is limited to:

- Part of the Earlwood Carpark for a proposed exhaust vent. This land is zoned open space although used as a carpark.
- A small piece of land (100 square metres) off Hartill-Law Avenue within the road reservation proposed for an intake vent. This land is used as parkland.
- Eden Street north of Burrows Street is zoned open space although this street functions as a road providing access to properties on Eden Street.
- A small linear park adjacent and to the east of Marsh Street. The southern part of this park would be required fore the proposal. The northern part containing play equipment at the southern end of Valda Avenue would be retained.
- Vacant land immediately to the east of Marsh Street and south of the SWOOS which is part of Riverine Park. Part of this land is zoned open space and part is within a road reservation.
- Kogarah Golf Club would be marginally affected by road widening along Marsh Street within an existing County Road Reserve and where the proposal crosses to the northern side of the SWOOS to avoid the Eve Street wetlands also within the existing road reserve. This may require some adjustment to course layout.
- Part of Riverine Park containing a drainage line from the Eve Street wetland on the southern side of the SWOOS would be marginally affected.

2.1.6 Impacts on Community and Government Facilities

Community and government facilities that would be directly affected by this variation include:

- a small church at the corner of Burrows Street and the Princes Highway; and
- a large Commonwealth property at the corner of Burrows and Arncliffe Streets.

2.1.7 Impacts on Adjacent Land Uses

Uses nearby the proposed motorway in the area east of Arncliffe Street include:

- residential development at North Arncliffe along Allen, Ann and Burrows Streets and to the east of the Princes Highway along Duncan Street, West Botany Street, Valda Avenue and surrounding streets to Marsh Street;
- industrial and commercial uses generally along the Princes Highway;
- recreation facilities including Kogarah Golf Club and Riverine Park.

Residential uses abut the proposed motorway in its sections out of tunnel along both sides of West Botany Street and Marsh Street, and thus would be susceptible to a range of impacts including:

- community severance;
- noise;
- changes in air quality;
- visual impact of any structures;
- changes in local traffic conditions.

The extent of impact will vary depending on specific design details of the proposed motorway. As the proposed motorway access ramps would be below the general ground level within an open or covered excavation, visual and severance impacts would be minimised and greater opportunity provided to control noise emissions.

The amenity of industrial areas would not be affected to any significant extent. Access to remaining properties in Allen Street would be affected by the closure of Allen Street at the Princes Highway. Vehicles using the Allen Street underpass of the rail line would gain access via Ann Street. The intersection of Ann Street and the Princes Highway would be improved to cater for additional flow. Properties on Ann and Allen Streets required for cut and cover tunnel sections would be available for redevelopment following construction.

This would result in additional traffic flows along Ann Street causing some loss of amenity for residential properties in this street.

2.1.8 Impacts at Vent Locations

The proposed variation incorporates the following provision for tunnel ventilation:

- an exhaust vent at the Earlwood carpark as proposed in the EIS;
- an exhaust vent in Henderson Street, Turrella;
- intake and exhaust vents on the Commonwealth property off Arncliffe Street.

In addition intake vents are proposed at Hartill-Law Avenue (near Wolli Creek) and in the railway reserve near Heath Street, Turrella.

Approximately 350 square metres would be required for each exhaust vent and 100 square metres for each separate intake vent. The exhaust vents would be in the order of 15 metres high and 8-10 metres wide. The intake vents would be low rise, approximately 1-1.5 metres high.

Properties directly affected by the proposed intake and exhaust vent locations include:

- part of the existing carpark behind the Earlwood carpark (exhaust vent);
- vacant land off Hartill-Law Avenue (air intake) located within the road reserve;
- part of the rail reserve near Heath Street, Turrella (air intake);
- an industrial property at Henderson Street Turrella (exhaust vent);
- part of the Commonwealth property at Arncliffe Street (intake and exhaust vents).

The air exhaust structures would be designed to ensure no significant adverse impacts on local air quality at ground level, ensuring that the amenity of nearby residential areas will not be significantly affected. The vent locations would not generate any activity other than routine maintenance and noise associated with vent shutters would be controlled by available acoustic measures. The proposed Arncliffe vent is located on existing Commonwealth land approximately 50 metres from nearby residential properties. It is estimated that the air quality in the vicinity of nearby residential properties would not be affected to any significant extent.

2.1.9 Mitigative Measures

The additional length of driven tunnel and cut and cover tunnel limits the extent of land use and other amenity impacts such as visual and noise impacts. Possible mitigative measures to decrease potential adverse land use impacts include:

- careful consideration of the detailed design of the air vents and tunnel portals would reduce the visual impacts of the proposed M5 East Motorway;
- consideration at the detailed design stage of reducing land take and thus the number of residences and businesses directly affected;
- using surplus land above the tunnel for residential, industrial or other appropriate uses;
- rehabilitating any open space disrupted during the construction.

2.2 Southern Variation

2.2.1 Existing Land Use

From Bexley Road to Marsh Street, the southern variation of the proposed motorway would be located within a driven tunnel which runs generally along a straighter alignment under the residential suburbs of Bardwell Park and Arncliffe and the industrial areas of Turrella and North Arncliffe. Land use in the vicinity of cut and cover sections includes commercial and industrial uses along Princes Highway and residential uses along Ann, Allen, West Botany and Marsh Streets.

From Marsh Street to General Holmes Drive, land use comprises vacant land and park land including the Eve Street wetland and its natural drainage line to the Cooks River which runs along the southern side of the SWOOS. Limited residential development fronts the western side of Marsh Street and Council's garbage depot is at the end of Eve Street. Kogarah Golf Club is on the northern side of the SWOOS. To the east of the Cooks River the motorway would run along the periphery of Sydney (Kingsford Smith) Airport from Cooks River to General Holmes Drive. The proposal would be located generally within road reserve over most of this area.

2.2.2 Land Use Impacts

The extended length of driven tunnel means that fewer properties would be directly affected compared with the EIS proposal. Consideration has been given to direct and indirect land use impacts of the variations. A **direct impact** is considered to be where a property would need to be totally or partially acquired by the RTA for the construction of the motorway. An **indirect impact** is considered to occur where the driven tunnel section of each variation passes underneath a property. The assessment of the number of properties indirectly affected has been based on the proposed tunnel location and aerial photography interpretation. This is subject to review at the detailed design stage once the size and configuration of the tunnel is known.

2.2.3 Impacts on Residential Uses

Direct Impacts

The following residential properties would be directly affected and would be acquired:

- 9 older style dwellings in Ann Street;
- 4 residential properties fronting Eden Street;
- 3 residential properties fronting Princes Highway;
- 13 residential properties on West Botany Street;
- 7 residential properties on Marsh Street.

In addition two residential properties and one vacant lot on Marsh Street would be affected by partial acquisition.

Indirect Impacts

It is estimated that approximately 181 houses and three residential flat buildings would be indirectly affected.

2.2.4 Impacts on Industrial and Commercial Uses

Direct Impacts

Industrial properties directly affected include:

- three other car sales yards on the Princes Highway one on the western side and two on the eastern.

A number of other properties would be affected by partial acquisition including uses fronting the eastern side of the Princes Highway comprising a car sales yard, two office buildings and two service stations and properties on the western side of the highway including an equipment hire establishment.

Further acquisition of vacant land and parkland would be required to allow the widening of Marsh Street in the vicinity of its intersection with the proposed motorway and access ramps. Also partially affected would be a bus depot on the western side of Marsh Street.

Indirect Impacts

Properties indirectly affected include a number of commercial properties on Firth Street at the commercial centre adjacent to Arncliffe Station.

2.2.5 Impacts on Open Space

Open space likely to be directly affected is limited to:

- A small parcel of land on the edge of the Bardwell Park Golf Course proposed for an air intake vent.
- Eden Street north of Burrows Street is zoned open space although this street functions as a road providing access to properties on Eden Street.
- A small linear park adjacent to Marsh Street. The southern part of this park would be required fore the proposal. The northern part containing play equipment at the southern end of Valda Avenue would be retained.
- Vacant land immediately to the east of Marsh Street and south of the SWOOS which is part of Riverine Park. Part of this land is zoned open space and part is within a road reservation.
- Kogarah Golf Club would be marginally affected by road widening along Marsh Street within an existing County Road Reserve and where the proposal crosses to the northern side of the SWOOS to avoid the Eve Street wetlands also within the existing road reserve. This may require some adjustment to course layout.
- Part of Riverine Park containing a drainage line from the Eve Street wetland on the southern side of the SWOOS would be marginally affected.

2.2.6 Impacts on Community and Government Facilities

Community and government facilities that would be directly affected by this variation include:

- a small church at the corner of Burrows Street and the Princes Highway; and
- a large Commonwealth property at the corner of Burrows and Arncliffe Streets.

2.2.7 Impacts on Adjacent Land Uses

Uses nearby the proposed motorway in the area east of Arncliffe Street include:

- residential development at North Arncliffe along Allen, Ann and Burrows Streets and to the east of the Princes Highway along Duncan Street, West Botany Street, Valda Avenue and surrounding streets to Marsh Street;
- industrial and commercial uses generally along the Princes Highway;
- recreation facilities including Kogarah Golf Club and Riverine Park.

Residential uses abut the proposed motorway in its sections out of tunnel along both sides of West Botany Street and Marsh Street, and thus would be susceptible to a range of impacts including:

- community severance;
- noise;
- changes in air quality;
- visual impact of any structures;

- changes in local traffic conditions.

The extent of impact will vary depending on specific design details of the proposed motorway. As the proposed motorway access ramps would be below the general ground level within an open or covered excavation, visual and severance impacts would be minimised and greater opportunity provided to control noise emissions.

The amenity of industrial areas would not be affected to any significant extent. Access to remaining properties in Allen Street would be affected by the closure of Allen Street at the Princes Highway. Vehicles using the Allen Street underpass of the rail line would gain access via Ann Street. The intersection of Ann Street and the Princes Highway would be improved to cater for additional flow. Properties on Ann and Allen Streets required for cut and cover tunnel sections would be available for redevelopment following construction.

This would result in additional traffic flows along Ann Street causing some loss of amenity for residential properties in this street.

2.2.8 Impacts at Vent Locations

The proposed variation incorporates the following provision for tunnel ventilation:

- intake and exhaust vents at corner of Hill and Duff Streets, Arncliffe;
- intake and exhaust vents at Bardwell Road near the corner of Royal place and Bardwell Road;
- intake and exhaust vents on the Commonwealth property off Arncliffe Street.

Approximately 350 square metres is required for each exhaust vent and 100 square metres for each separate intake vent. The exhaust vents would be in the order of 15 metres high and 8-10 metres wide. The intake vents would be low rise, approximately 1-1.5 metres high.

Properties directly affected by the proposed intake and exhaust vent locations include:

- three residential properties on the corner of Royal Place and Bardwell Road and part of the golf course land adjoining;
- three residential properties in Hill Street Arncliffe;
- part of the Commonwealth property at Arncliffe Street.

The air exhaust structures would be designed to ensure no significant adverse impacts on local air quality at ground level, ensuring that the amenity of nearby residential areas will not be significantly affected. The vent locations would not generate any activity other than routine maintenance and noise associated with vent shutters would be controlled by available acoustic measures. The proposed vents at Bardwell Road, Bardwell Park and Duff Street, Arncliffe adjoin or are adjacent to residential properties. The proposed vent at Arncliffe Street is located on existing Commonwealth land approximately 50 metres from nearby residential properties. It is considered that the air quality in the vicinity of nearby residential properties would not be affected to any significant extent.

2.3 Mitigative Measures

The additional length of driven tunnel and cut and cover tunnel limits the extent of land use and other amenity impacts such as visual and noise impacts. Possible mitigative measures to decrease potential adverse land use impacts include:

- careful consideration of the detailed design of the air vents and tunnel portals would reduce the visual impacts of the proposed M5 East Motorway;
- consideration at the detailed design stage of reducing land take and thus the number of residences and businesses directly affected;
- using surplus land above the tunnel for residential, industrial or other appropriate uses;
- rehabilitating any open space disrupted during the construction.

3. SOCIAL IMPACTS

3.1 Northern Variation

A description of communities in the vicinity of the proposed variation are discussed in the April 1994 Working Paper. Impacts of the variation are discussed below with reference to the communities of the Turrella/Arncliffe area.

3.1.1 Severance and Instability

Consideration of severance impacts are relevant in areas where the proposal is located outside driven tunnel. This includes only a limited length of the proposal between the Illawarra rail line and Princes Highway and in the vicinity of entry ramps off the Princes Highway and Marsh Street.

Fifty four (54) dwellings at Arncliffe would be directly affected in two main locations:

- near the Princes Highway in Eden and Ann Streets to provide for the cut and cover tunnel section and the Princes Highway access ramps;
- in the vicinity of West Botany and Marsh Streets to provide for the Marsh Street access ramps.

Residential development in the vicinity of Ann, Allen and Eden Street is at the northern end of a small residential community west of the highway. The proposal has the potential to sever a small residential area on Ann and Allen Streets from the main community to the south bound by the rail line, the highway and Wickham Road. This severance is likely to be temporary as redevelopment of the area above the tunnel would enable the provision of replacement housing stock.

The maintenance of existing local access arrangements and the visual unobtrusiveness of the proposed motorway in these locations would act to minimise any community severance impacts. The vehicular connection from Valda Avenue to Marsh Street would be lost with access to Valda Avenue being from West Botany Street. The use of cut and cover construction methods may result in the availability of residential of open space redevelopment sites over the proposed motorway and the ramps once construction is completed.

The potential for severance through the Turrella/Arncliffe area has been reduced by the additional length of tunnel through critical areas and the location of the proposal "below ground" running under existing streets and generally within excavation. These measures act to minimise adverse impacts on community cohesion and stability.

3.1.2 Access Patterns

Vehicular Access

In the Turrella/Arncliffe area, the proposed M5 East Motorway would pass under the highway, West Botany Street and Marsh Street. All existing local roads would be retained with the exception of Allen Street which would be closed to the Princes Highway and the Valda Avenue connection to Marsh Street.

As discussed above, access to the Allen Street underpass currently provided from the Princes Highway via Allen Street would be provided via an upgraded intersection at Ann Street and the Princes Highway. Access to properties on Argyle Street would be provided from Ann Street and from the Princes Highway using the existing access road adjacent to the SWOOS reserve. Local access would be provided to properties on Allen Street via Ann Street.

Pedestrian Access Patterns

Existing pedestrian accessways along the street system would be largely retained including into Allen Street from Princes Highway. Pedestrian access along the Princes Highway, West Botany Street and Marsh Street would be retained. There may be some temporary closures during construction.

East of Marsh Street, the motorway would generally follow the location of the sewer main which is itself a barrier to movement. The motorway would have no significant impact on pedestrian movement patterns in this area. At the intersection of the proposed motorway with General Holmes Drive, the motorway would be on structure above existing foreshore and airport control tower access points and this would have no significant impact on public access in these areas.

3.1.3 Residential Amenity/Character

The issue of residential amenity or change in the character of a residential environment is an indirect social impact arising from the combined effect of many attributes of the physical environment such as noise, air quality, traffic volumes and visual impact. All of these issues are subject to the separate investigations by specialist sub-consultants. The broad social impacts are considered below.

The location of the proposed variation within tunnel or within a covered excavation passing beneath existing streets would do much to minimise impacts on residential amenity relative to a structure at or above grade and would provide the opportunity for more effective acoustic screening and landscape treatment.

3.1.4 Wider Changes to Traffic Patterns

The M5 East creates the opportunity for reduction in traffic growth along a number of roads presently passing through residential communities in the area. This would enable these communities to benefit from improved access along arterial roads performing a more localised access role. In general, these roads have experienced substantial traffic growth over the years not commensurate with their originally perceived role in the traffic hierarchy. Land uses along such roads are often incompatible with their existing traffic volumes, and in some cases, the heavy vehicles using them. Particular examples include Bexley Shopping Centre, residential areas along Forest Road, Stoney Creek Road, West Botany Street, Bestic Street and Marsh Street and various other strip shopping centres, schools, churches and community facilities.

Access to these facilities would be safer and amenity improved significantly over what would be the case without the M5 East. Should the project not proceed, these areas would be subject to increased disruption due to traffic growth and road works required to accommodate that growth.

3.1.5 Property Affectation/Dislocation/Hardship

A number of residential and non-residential properties would need to be totally or partially acquired to enable the construction of the motorway. These are outlined in Section 2.1.

Fewer properties are affected under the proposed northern variation compared with the proposal considered in the EIS, enabling displacement and dislocation to be minimised.

A major road proposed is inevitably associated with dislocation associated with the acquisition of properties required for the construction of a motorway. Uncertainty is also a feature of such proposals, particularly in the often lengthy period leading up to final approval and construction. Such uncertainty is inevitable, partly as a result of open consultation practices adopted today. The RTA has policies and procedures in place relating to land acquisitions to ensure that such impacts of displacement or hardship are minimised. These procedures are outlined in the April 1994 Working Paper.

In addition to the properties directly affected, approximately 153 dwelling houses, three residential flat buildings and a number of industrial and commercial properties could be indirectly affected with the driven tunnel containing the proposed motorway underneath. The construction of the tunnel or the operation of the motorway would have no direct physical impact on these properties. However there may be some concern about impact on property values and resale potential if the tunnel is registered on the title of these properties.

3.1.6 Mitigative Measures

Section 4.5 of the **M5 East Motorway Land Use and Social Impacts Working Paper** dated April 1994 outlines mitigative measures to minimise social impacts that are appropriate to the proposed northern variation.

3.2 Southern Variation

A description of communities in the vicinity of the proposed variation are discussed in the April 1994 Working Paper. Impacts of the variation are discussed below with reference to the communities of the Turrella/Arncliffe area.

3.2.1 Severance and Instability

Consideration of severance impacts are relevant in areas where the proposal is located outside driven tunnel. This includes only a limited length of the proposal between the Illawarra rail line and Princes Highway and in the vicinity of entry ramps off the Princes Highway and Marsh Street.

Thirty-eight (38) dwellings at Arncliffe would be directly affected in two main locations:

- near the Princes Highway in Eden and Ann Streets to provide for the cut and cover tunnel section and the Princes Highway access ramps;
- in the vicinity of West Botany and Marsh Streets to provide for the Marsh Street access ramps.

A further six dwellings would be required for exhaust vents at Bardwell Park and Arncliffe.

Residential development in the vicinity of Ann, Allen and Eden Street is at the northern end of the a small residential community west of the highway. The proposal has the potential to sever a small residential area on Ann and Allen Streets from the main community to the south bound by the rail line, the highway and Wickham Road. This severance is likely to be temporary as redevelopment of the area above the tunnel would enable the provision of replacement housing stock.

The maintenance of existing local access arrangements and the visual unobtrusiveness of the proposed motorway in these locations would act to minimise any community severance impacts. The vehicular connection from Valda Avenue to Marsh Street would be lost with access to Valda Avenue being from West Botany Street. The use of cut and cover construction methods may result in the availability of residential of open space redevelopment sites over the proposed motorway and the ramps once construction is completed.

The potential for severance through the Turrella/Arncliffe area has been reduced by the additional length of tunnel through critical areas and the location of the proposal "below ground" running under existing streets and generally within excavation. These measures act to minimise adverse impacts on community cohesion and stability.

3.2.2 Access Patterns

Vehicular Access

In the Turrella/Arncliffe area, the proposed M5 East Motorway would pass under the highway, West Botany Street and Marsh Street. All existing local roads would be retained with the exception of Allen Street which would be closed to the Princes Highway and the Valda Avenue connection to Marsh Street.

As discussed above, access to the Allen Street underpass currently provided from the Princes Highway via Allen Street would be provided via an upgraded intersection at Ann Street and the Princes Highway. Access to properties on Argyle Street would be provided from Ann Street and from the Princes Highway using the existing access road adjacent to the SWOOS reserve. Local access would be provided to properties on Allen Street via Ann Street.

Pedestrian Access Patterns

Existing pedestrian accessways along the street system would be largely retained including into Allen Street from Princes Highway. Pedestrian access along the Princes Highway, West Botany Street and Marsh Street would be retained. There may be some temporary closures during construction.

East of Marsh Street, the motorway would generally follow the location of the sewer main which is itself a barrier to movement. The motorway would have no significant impact on pedestrian movement patterns in this area. At the intersection of the proposed motorway with General Holmes Drive, the motorway would be on structure above existing foreshore and airport control tower access points and this would have no significant impact on public access in these areas.

3.2.3 Residential Amenity/Character

The issue of residential amenity or change in the character of a residential environment is an indirect social impact arising from the combined effect of many attributes of the physical environment such as noise, air quality, traffic volumes and visual impact. All of these issues are subject to the separate investigations by specialist sub-consultants. The broad social impacts are considered below.

The location of the proposed variation within tunnel or within a covered excavation passing beneath existing streets would do much to minimise impacts on residential amenity relative to a structure at or above grade and would provide the opportunity for more effective acoustic screening and landscape treatment.

3.2.4 Wider Changes to Traffic Patterns

The M5 East creates the opportunity for reduction in traffic growth along a number of roads presently passing through residential communities in the area. This would enable these communities to benefit from improved access along arterial roads performing a more localised access role. In general, these roads have experienced substantial traffic growth over the years not commensurate with their originally perceived role in the traffic hierarchy. Land uses along such roads are often incompatible with their existing traffic volumes, and in some cases, the heavy vehicles using them. Particular examples include Bexley Shopping Centre, residential areas along Forest Road, Stoney Creek Road, West Botany Street, Bestic Street and Marsh Street and various other strip shopping centres, schools, churches and community facilities.

Access to these facilities would be safer and amenity improved significantly over what would be the case without the M5 East. Should the project not proceed, these areas would be subject to increased disruption due to traffic growth and road works required to accommodate that growth.

3.2.5 Property Affectation/Dislocation/Hardship

A number of residential and non-residential properties would need to be totally or partially acquired to enable the construction of the motorway. These are outlined in Section 2.2.

Fewer properties are affected under the proposed southern variation compared with the proposals considered in the EIS or the northern variation, enabling displacement and dislocation to be minimised.

A major road proposed is inevitably associated with dislocation associated with the acquisition of properties required for the construction of a motorway. Uncertainty is also a feature of such proposals, particularly in the often lengthy period leading up to final approval and construction. Such uncertainty is inevitable, partly as a result of open consultation practices adopted today. The RTA has policies and procedures in place relating to land acquisitions to ensure that such impacts of displacement or hardship are minimised. These procedures are outlined in the April 1994 Working Paper.

In addition to the properties directly affected, approximately 181 dwelling houses, three residential flat buildings and a number of industrial and commercial properties could be indirectly affected by being located directly over the driven tunnel. The construction of the tunnel or the operation of the motorway would have no direct physical impact on these properties. However there may be some concern about impact on property values and resale potential if the tunnel is registered on the title of these properties.

3.2.6 Mitigative Measures

Section 4.5 of the **M5 East Motorway Land Use and Social Impacts Working Paper** dated April 1994 outlines mitigative measures to minimise social impacts that are appropriate to the proposed northern variation.

Report

M5 EAST MOTORWAY - TUNNELLING SUPPLEMENTARY REPORT

December 1995

CONNELL WAGNER
Engineers • Managers

Connell Wagner Pty Limited
A.C.N. 003 505 673

SYDNEY
116 Military Road
NEUTRAL BAY NSW 2089
Telephone: (02) 909 5599
Facsimile: (02) 908 2044

Ref: C:\project\m5_eis\m5b26oct.rep

CONTENTS

1.0 INTRODUCTION

This report describes the proposed "straight line tunnel" option for the M5 East motorway. The straight line tunnel option involves a main tunnel consisting of two tubes approximately 4 km long with a western portal at Bexley Road and an eastern portal at Marsh St. The main tunnel provides for two lanes in each direction although the section between Bexley Road and Princes Highway has a 3.5m breakdown lane which is not provided in the short sector between Princes Highway and Marsh St. The straight line tunnel option is called the southern alignment or option 'H'. An alternative alignment (called the northern alignment or option 'G') is also described.

The report describes a preferred method of excavation and also describes an alternative excavation method.

Issues covered in this report relate to the proposed tunnel. They include;

- location
- horizontal alignment
- vertical alignment (longitudinal section)
- internal dimensions
- typical cross sections
- ventilation system (*)
- ventilation tower locations and dimensions (*)
- portal arrangement
- geotechnical conditions

(*) The design of the ventilation system is addressed conceptually in order to describe the ventilation factors which affect the tunnel design. Details of the ventilation system will be addressed in a future detailed design stage or may be mentioned in the context of the other reports, particularly Land Use and Air Quality reports listed below. Other reports relating to the M5 East proposal include;

EIS Supplement	**Manidis Roberts Consultants**
Concept design	RTA - Parramatta
Construction Programme	RTA
Traffic	Wilson/Masson
Hydrology and Flood Protection	Willing & Partners
Urban Design/Visual Impact	Context Landscape Design
Aquatic flora and fauna	UWS Water Research Laboratory
Terrestrial flora and fauna	Mount King Ecological Surveys
Noise Control	Renzo Tonin and Associates
Air Quality	Holmes and Associates
Land Use and Social	Briggs Brindle and Chambers
Archaeology	Haglund and Associates

2.0 BACKGROUND

In 1989 the Connell Group prepared a report - "F5 South Western Freeway - Tunnel Options for Wolli Creek". That report identified a number of alternative options for a tunnel to bypass the Wolli Creek valley between Bexley Road and Turrella.

The concept for a tunnel as an alternative means of linking Bexley North and Turrella is based on the idea that a tunnel would have a less significant impact than a surface built structure through the Wolli Creek Valley.

2.1 1994 Alignment Studies

In 1994, Connell Wagner "M5 East Motorway - Tunnelling - May 1994" reported on aspects of tunnel alignments north of Wolli Creek. Two options were studied:

- a short tunnel option (option 7E) involved a western portal at Bexley Road and an eastern portal at Turrella. The motorway east of Turrella was to be elevated with a flyover at Princes Highway, and

- an extended tunnel option (option 7L) involving the same western portal at Bexley Road and the same alignment, but the eastern portal was to be at the Illawarra rail line with the motorway passing beneath the Princes Highway.

As part of the outcome of the exhibition of the EIS in 1994, the concept was modified to include a "straight line tunnel" option with the intention of minimising tunnel length and minimising property acquisition costs.

2.2 Tunnelling Feasibility

The topography of this area is dominated by the sandstone ridges to the north and south of the steep sided Wolli Creek Valley. The northern ridge extends to Unwin Street in Earlwood, much further east than the southern ridge which extends only to Turrella Railway Station.

A geological overview of the area suggests that the best tunnelling conditions for a driven tunnel, as opposed to a cut and cover tunnel, are attained by locating the tunnel at depth in the sandstone rather than in the soft ground in the floor of the valley. The cover to the tunnel, from the crown of the tunnel to ground surface, should ideally be at least one (1) tunnel diameter and composed of good quality rock although this cover should be considered as an absolute minimum.

Tunnel portals are best located at abrupt changes in ground level so that adequate cover is attained within a short distance of the portal.

Other factors affecting the vertical alignment include desirability of draining the tunnel by gravity, wherever possible, thus excluding the running costs of pumping stations. The tunnel invert also needs to be located above flood levels at the portals to avoid flooding of the tunnel, or be otherwise appropriately protected.

Because of surface development, there is little opportunity for cheaper cut and cover tunnel construction below the sandstone ridges. Cut and cover construction could be carried out in the floor of the Wolli Creek Valley but the merits of this approach would depend on the required grading of the road along the tunnel section.

3.0 TUNNEL ALIGNMENT SELECTION CRITERIA

The general criteria for selection of the tunnel alignment are as follows:

3.1 Horizontal Alignment

- The horizontal alignment should be based on motorway standards;
- The horizontal alignment should allow the tunnel to be located in competent rock;
- The alignment at the portals must be positioned so that the effects of early morning or late afternoon sun are minimised or artificially controllable.
- The horizontal alignment should account for the location of surface ventilation tower(s).

3.2 Long section (Vertical Alignment)

- The vertical alignment should minimise the depth from surface level to tunnel crown, in order to minimise tunnel grades, consistent with the need to tunnel through best quality rock available in the zone;
- The tunnel cover should be kept above a minimum (dictated by geotechnical conditions) such that surface settlements are eliminated and noise generation during construction and in the long term, is not a factor.
- It is desirable that the tunnel generally rise from portal to centre point in order to promote natural drainage.

3.3 Portal Location

- Tunnel portals are best located at abrupt changes in ground level so that adequate cover is attained within a short distance of the portal;
- The portals should be located at a level above the 1 in 100 flood level or be suitably protected;
- Grading of the tunnel should be downhill towards each portal for a short distance where possible, to assist in avoiding inundation.

3.4 Gradient

Gradient limitations within the tunnel should be based on;

- Maximum grade 6% to meet highway standards;
- Minimum grade 1% for tunnel drainage;

3.5 Cross Section

The selection and design of the tunnel cross section is to be based on the following requirements;

- 2 traffic lanes westbound and 2 traffic lanes eastbound;
- a 3.5m breakdown lane between Bexley Road and Princes Highway load/unload ramps;
- no breakdown lane between Princes Highway load/unload ramps and Marsh St;
- walkways for emergency egress and maintenance access;
- space for lighting, ventilation, communication, cabling;
- provision for Fire Services;
- signage;
- up to two lay-by facilities in each direction for vehicle breakdown, located at the end points of ventilation compartments;
- cross connections between parallel tunnel chambers for fire escape.

3.6 Ventilation

The availability of exhaust stack locations is a major factor in the selection of the horizontal alignment. The costs of a longer main vehicle tunnel may be offset by the savings in shorter exhaust tunnels and the reduction in exhaust fan power. Economical exhaust air velocities will mean that the exhaust tunnels may have larger cross sectional areas than each of the main vehicle tubes. There is generally more flexibility in the selection of a tunnel alignment, than in the selection of exhaust stack locations. Exhaust stacks need to be located on high ground with a relatively low rise above surrounding features, or they need to be located in low ground (in a "valley" location) with a higher rise.

The design of the ventilation system is to be based on

- the need to disperse smoke which may obscure vision;
- the use of mechanical ventilation in a fire;
- the use, where possible, of longitudinal ventilation involving the use of jet fans and the piston effect of traffic flow.

  Otherwise, segments of the tunnel will involve

  - longitudinal ventilation with jet fans opposing traffic flow or
  - a semi transverse ventilation system with either exhaust or supply air in ducts, or
  - a fully transverse ventilation system involving ductwork for both supply and exhaust air.

4.0 THE "STRAIGHT LINE" TUNNEL OPTION

In a 1989 Connell Group report a long tunnel option was considered on the north side of Wolli Creek between Bexley Road North and the west end of Unwin Street near Waterworth Park.

In 1994 the design of the M5 tunnel concentrated on the short tunnel option between a western portal (transition) at Bexley Road North and an eastern portal (transition) east of Nanny Goat Hill, but with three alternative alignments between the two portal areas.

In 1995 the most recent deliberations have been based on the "straight line" tunnel option between a western portal (transition) at Bexley Road North and an eastern portal (transition) east of the Illawarra rail line.

4.1 Horizontal Alignment

The southern tunnel alignment (option "H") on which the project straight line design model has been based is as shown on Figure A1. Working from west to east from the Bexley Road portal, the tunnel route remains north of Wolli Creek at a maximum 6% down grade until the crown (roof) of the tunnel is able to pass under Wolli Creek. The tunnel then flattens and takes a straight line to Princes Highway ramps, and subsequently to Marsh St ramps just south of the SWOOS (South West Ocean Outfall Sewer).

An alternative alignment which is to be acceptable in project tenders is shown in Figure A2. This alignment (called the northern alignment or option "G") remains north of Wolli Creek until crossing under Wolli Creek near Turrella. The western half of this tunnel follows the alignment on which the 1994 EIS was based.

The alignment at portals is such that there is no natural protection available from the dazzling effects of the sun. It may be possible to reduce this effect by the erection of shades suspended above the portals.

4.2 Longitudinal Section (Profile)

The longitudinal section for the preferred tunnel alignment is as shown on the enclosed long section. In the west, the tunnel gradient is at a maximum of 6% until the crown (roof) of the tunnel is able to pass under Wolli Creek. The tunnel then flattens to generally 1%, rising to the east, with a low point between Wolli Creek and Bardwell Creek. In the east, the tunnel rises to set up for west facing ramps at Princes Highway and Marsh Street.

The longitudinal section geometry between Arncliffe Park and Marsh St for the southern alignment (or Loftus St and Marsh St for the northern alignment) is a function of;

- the length of entry and exit ramps to Princes Highway.
- the quality and depth of rock below surface.
- the relationship between tunnel width (taking ramp tapers into account) and the quality and depth of rock below surface. Where the Princes Highway ramp tapers meet the main tunnel, an excavated span of up to 16m will be required.
- the relative merits of property acquisition followed by cut and cover tunnelling (or open slot) against the merits of remaining deep enough to continue with bored tunnel.

4.3 Western Portal and Transition to Motorway on Embankment

The concept involves termination of the bored tunnel just east of Bexley Road.

The tunnel emerges at Bexley Road and the transition to standard motorway on embankment passes through a section of open slot. The general arrangement for the transition is shown on Figures B1 and B2 (plan) and Figure C (long section). Between the open slot and tunnel portal, a new bridge will need to be constructed where Bexley Road passes over the M5 motorway, or as an alternative, the bored tunnel portal be located just west of the Bexley Road bridge. The design in this area needs to provide for a possible future limited grade separated intersection between the M5 and Bexley Road. "Limited" refers to the east bound traffic exit from M5 to Bexley Road and the westbound traffic on-ramp from Bexley Road to the M5.

The section of open slot will also include an aquabridge to carry a small Wolli Creek tributary and a 450mm diameter sewer line. Figure C shows an elevation of the tunnel transition. The Wolli Creek aquabridge consists of two 1800mm diameter pipes which replace the existing open drain which is fed from one (1) existing 1800mm diameter pipe. A flood protection wall is also provided on the northern side of the open slot, to prevent inundation of the depressed motorway. This flood protection wall causes water surcharging in large storm events to be channelled to a point where the expressway rises sufficiently to allow culverts connecting the over land flow-path to Wolli Creek to pass underneath the motorway. Details of stormwater drainage issues will be included in the Willing and Partners model of the entire Wolli Creek Catchment area.

Depending on the detailed design in the area of Bexley Road, Figure C shows the short length of cut and cover tunnel that may be required just east of Bexley Road to reach a depth suitable for tunnelling using a Tunnel Boring Machine (TBM) or Road Header.

The intake air grille in this area needs to be located away from vehicle exhaust emissions from Bexley Road and the M5 below. This intake air shaft feeds air into the east bound tunnel and may also feed a short length of the west bound tunnel.

Detailed design would be required in this area in due course, should the EIS determination be favourable. At this stage geotechnical assessment of the western portal area has identified the possible need for acquisition of one property on Wolli Ave adjacent Bexley Road although it is possible for this acquisition to be avoided with some adjustment to the long section, and with the bored tunnel portal on the western side of Bexley Road.

4.4 Eastern Portal and Transition to Elevated Motorway

Figures D1 and D2 show the plan view for the eastern transition from the termination of the bored tunnel to the eastern end of the tunnel at Marsh St for both the southern and the northern alignments. The longsectional view for the southern alignment is illustrated on Figure D1. The longsectional view for the northern alignment is illustrated on Figure E1.

4.4.1 Southern Alignment

For the southern alignment, the concept involves an eastern portal at Marsh St with a cut and cover section between the Illawarra Rail Line and Princes Highway, and with separate cut and cover tunnels for the load and unload ramps on the west face of Princes Highway and the west face of Marsh St. These cut and cover ramp tunnels obviously change to open slots as dictated by vehicle height clearance requirements. Figure D1 shows a plan view of the general arrangement at the eastern end of the tunnel for the southern alignment. It should be noted that the bored tunnel section for the southern alignment would terminate at Firth St.

4.4.2 Northern Alignment

For the northern alignment the arrangement would have an eastern portal at Marsh St with a cut and cover section between the Bonar St/Loftus St area and Princes Highway, and with separate cut and cover tunnels for the load and unload ramps on the west face of Princes Highway and the west face of Marsh St. It should be noted that the bored tunnel section for the northern alignment would terminate in the Loftus/Bonar St area. The longsectional view for this area is illustrated on Figure E1.

4.5 Tunnel Cross Sections

4.5.1 Basic Tunnel Sections

The basic tunnel cross-section, is shown in Figure G. This section is based on

- 2 lanes at 3.5 metres in each direction
- a 3.5m breakdown lane between Bexley Road and Princes Highway
- no breakdown lane between Princes Highway and Marsh St
- provision of an emergency walkway on one side only
- a structure gauge height of 4.6 metres, allowing the passage of double decker buses and trucks
- no provision for a bicycle track
- an allowance outside the structure gauge for lighting and other services
- a ventilation duct, where necessary, above the suspended ceiling
- New Jersey barriers on each side of the tunnel and a single walkway 0.80 metres wide with a duct below for cabling.

The illustrated tunnel section (Figure G) is not based on any speeific tunnel excavation equipment. Excavation to achieve the required cross section may be carried out using one or a combination of

- tunnel boring machines
- roadheaders
- mobile miners
- machine mounted heavy breakers and ripper dozers

The final selection of machinery (eg. Tunnel Boring Machine versus Roadheader) will be based on such factors as

- contractor's preference (which includes machine availability and lead time)
- the number of working faces developed (out of a possible maximum of 12 faces)
- the destination for tunnel spoil, and
- programme requirements.

4.5.2 Alternative Tunnel Sections

An alternative tunnel section involves a "double decker" tunnel which would involve excavation of the upper portion of the tunnel by road header followed by conventional excavation of the remainder of the tunnel using ripper dozers, hydraulic excavators and rock breakers.

The concept of a double decker tunnel is certainly worthy of detailed consideration. At this stage, the side by side double tube option and the double decker options should remain open through the detail design stage and be open to tender until such time as tenderers prices for the two options can be compared and a final selection made. Both methods have advantages and disadvantages particularly in terms of costs, duration and interfaces with other activities on the programme eg. tunnel fitout.

Interested parties should be aware of the general procedure in which the double decker option could be constructed. In particular, the options for transition between side by side motorway lanes and double decker tunnel should be considered.

The attached Figure H shows the double decker tunnel shape and the concept for an underground transition from side-by-side to double decker. Figure I describes the concept for an external transition from side-by-side to double decker.

In summary the underground transition is more involved and more expensive. While the transition external to the tunnel (i.e. one where the motorway on the embankment or elevated motorway is changed to double decker motorway outside of each portal) is simpler and less expensive.

4.6 Tunnel Drainage

All tunnel portals require flood protection barriers satisfying the requirements of a 1:100 year flood level. Willing & Partners is responsible for provision of safe levels for portal design against flooding.

Throughout the length of the tunnel and portal areas, drainage sumps are required at regular intervals for collection and pump out of seepage water.

4.7 Public Utilities and Services

No major service diversions are required over the length of the tunnel for the straight line tunnel.

At the western portal, two 1800mm diameter pipes are designed for 1 in 100 year flows and form an aqueduct over an open slot section of the motorway.

5.0 GEOTECHNICAL INVESTIGATIONS

5.1 Previous Geotechnical Investigations

The original geotechnical assessment done by Peter Burgess (1989) was limited to a review of background geology in the area, and was conducted by a literature search and a field inspection. In late 1993 and early 1994 further geotechnical investigations were carried out. Stages 1 and 2 involved 6 boreholes being drilled at points along the 1994 alignment north of Wolli Creek. The usefulness of information gathered from these boreholes is now limited to the borehole east of the Bexley Road portal and to a limited extent, the borehole drilled in SJ Harrison Memorial Park.

5.1.1 Stage 1 Geotechnical Investigation

Stage 1 Geotechnical investigation was conducted by Golder Associates (December 1993 Report No.93620147). The purpose of the Stage 1 investigation was to provide preliminary data to assist route selection, and to enable a preliminary assessment to be made on the likely subsurface conditions that may be encountered during tunnel construction. The Stage 1 borehole was drilled to a depth of 60.6 metres, just north of Wolli Creek near Hartill-Law Avenue.

The subsurface material encountered was assessed to be moderately weathered, competent, Hawkesbury Sandstone. There were relatively few defects encountered in the borehole. The majority of the defects were thin (20 to 30mm thick) crushed seam and/or bedding shear planes which are sub-horizontal. No steeply inclined joints were encountered in the borehole, although it must be stressed that such joints are not readily identified in vertical boreholes, and this aspect must be further investigated by the drilling of inclined boreholes.

A fractured zone was encountered at a depth of about 18m in the borehole.

5.1.2 Stage 2 Geotechnical Investigation

The Stage 2 investigation was carried out by Pells, Sullivan, Meynink P/L and is documented in report No. PSM43.R1 - February 1994.

Stage 2 involved four boreholes including one borehole near each of the tunnel portal locations, and one borehole in the area approximately one quarter and three quarters of the way along the tunnel alignment north of Wolli Creek.

5.2 Stage 3 and Stage 4 Geotechnical Investigation

Stage 3 and 4 geotechnical investigations were carried out by Pells, Sullivan, Meynink P/L and Coffey Partners International. The boreholes involved in Stages 3 and 4 are described below.

Figures J, K and L show the location of the boreholes.

5.2.1 Stage 3.

Stage 3 involved 2 boreholes that were essential for finalising the horizontal and vertical alignment of the tunnel. Boreholes 7 and 8 (following on from previous M5 investigation numbering) were drilled in the positions shown in Figures J and K.

> Borehole 7 was drilled in Coolabah Reserve, at the mid point along the tunnel. Information from this borehole allows an accurate determination of rock cover beneath Bardwell Creek, which in turn determines the gradient at either end of the tunnel. The final grades have a significant effect on the ventilation concept design.
>
> Borehole 8 was required to determine the extent of open cut excavation, and therefore the extent of property acquisition between West Botany St and Marsh St.

5.2.2 Stage 4

Stage 4 of the investigation involved an additional 3 boreholes (No. 9, 10 and 11.) which were used to provide more detail on the vertical alignment. These boreholes were additional to the absolute minimum covered under Stage 3. They allow a more accurate determination of the extent of property acquisitions.

> Borehole 9 was drilled at Bonar St at the approximate location of the eastern bored tunnel portal under the original concept. This borehole would have been required to determine the extent of cut and cover tunnelling and/or open slot construction, dependent on the future use of the surface.
>
> Later, (after the adoption of a through tunnel to Marsh St) its purpose was simply to establish the depth of tunnel beneath Bonar St.

After several alignment changes in the Princes Highway area, Borehole 10 was drilled on Army property on the corner of Arncliffe St and Burrows St. This borehole was to be used to confirm the depth of rock and the type of tunnel possible between Illawarra Line and Princes Highway.

Borehole 11 was located at the point where the southern tunnel alignment passes under Wolli Creek. This borehole was required to determine

- the minimum vertical cover to the tunnel crown in this location
- the tunnelling feasibility through this area, and
- the possible need for tunnel strengthening and special controls against water ingress.

5.3 Stage 5 (Geophysical Supplement).

Unexpected and inconsistent depths to rock between Princes Highway and Bonar St, as revealed by boreholes, necessitated a series of geophysical surveys. These surveys used seismic velocity measurements to estimate the profile of subsurface rock and to assess the extent of valleys (intrusions) in the rock strata between Princes Highway and Arncliffe Park/Bonar St.

5.4 Results

The results of the Stages 3,4 and 5 of the geotechnical investigations are documented in Pells Sullivan Meyninck Report PSM152.R1 December 1995.

In summary, the southern alignment provides a longer bored tunnel opportunity between Arncliffe Park and Princes Highway. The results of Stage 5 (the geophysical work) show that with reasonable confidence, the southern alignment (option "H") can be followed on the basis of bored tunnel to Illawarra Rail and Open Cut (with optional Cover) from Illawarra Rail to Princes Highway - with the possible exception of having to do an open cut excavation just west of Illawarra Rail in Firth Street where the Arncliffe St "valley" (intrusion) rises sharply to outcropping on the west side of Firth St. The details of this area could be confirmed by a borehole in Firth St.

Dependent on long sectional geometry (depth to crown), and the location of ramp tapers, the bored tunnel may require a concrete filler wall dividing the through lanes, but this should be considered as a small consequence of avoiding more property acquisitions west of Firth St. For a 15m net excavated tunnel span, about 8m of rock is needed, and, even then, significant support work will be required.

6.0 TUNNEL VENTILATION AND SMOKE EXTRACTION

6.1 Background

Ventilation of the M5 road tunnels is required to dilute vehicle emissions to acceptable and safe limits. These limits, known as air quality goals, are set by the NSW Environmental Protection Agency (EPA). Ventilation is also required to control the spread of smoke in case of a tunnel fire.

The main parameters used in ventilation design are

- maximum vehicle emission data
- the maximum allowable concentration of gases or air quality goals
- the minimum visibility permitted, and
- the amount of traffic in the tunnel under the worst traffic conditions.

The cost of a ventilation system is largely dependent on the compartment length between fresh air supply points, and polluted air extraction points. Cost is, however, only one factor to be considered on the positioning of exhaust stacks. The other factors concern the effect of the exhaust stack on the surrounding environment. These factors are discussed in detail in the main EIS document.

There are various alternative ventilation systems which are selected on the basis of viability and cost. A brief description of the options follows:

Longitudinal Ventilation

In this system the whole of the required air volume flow is moved through the tunnel at constant velocity by tunnel roof mounted jet fans. They blow most efficiently in the same direction as traffic although they may be reversed in emergency. A longitudinal system normally allows air supply and exhaust through the portals. The maximum economical length between intake and relief in a longitudinal system to which fixed air quality goals apply is such that the M5 tunnel requires a maximum compartment length of about 1.2km. Figure M illustrates the general arrangement for the M5 tunnel with a longitudinal system with mechanically assisted (fan) reliefs at the end of each compartment.

A standard longitudinal ventilation system based on longitudinal ventilation throughout the length of both tubes of the tunnel would require exhaust air to be expelled through the western portal of the west bound tube and the eastern portal of the east bound tube, as illustrated in Figure M. It is however, feasible (although less efficient) for the longitudinal system in the western compartment of the westbound portal and the eastern compartment of the eastbound tube be based on supply from the portal against the traffic flow, thereby eliminating exhaust from portals.

Whilst a longitudinal system is, in principle, able to handle smoke in the event of a fire, a detailed design may call for separate smoke extraction ducts with grills activated (opened) locally by smoke detectors.

Transverse Ventilation

This is fully ducted system with a fresh air supply duct and a polluted air extraction duct running for the full length of the tunnel. Supply air grilles are spaced regularly through the tunnel usually at road level, and similarly exhaust air grilles connect with the exhaust duct at high level. Banks of ventilation fans are connected to both ends of each ventilation compartment with supply air volume equalling exhaust air volume. The fans are activated and controlled by air quality monitors along the length of the tunnel with flow rates varied by changing fan pitch or fan speed, as the traffic densities and therefore pollution levels increase.

Semi Transverse

This system has either supply air in a duct and exhaust air in traffic or supply air in traffic and exhaust air in duct.

The systems described above may also be combined in such a way that certain tunnel ventilation compartments employ a semi-transverse system, whilst other compartments employ a longitudinal system. Overall, this arrangement is known as a mixed system. A mixed system applicable to the M5 tunnel is illustrated in Figure N. This is the most likely system applicable to the M5 tunnel because the expulsion of exhaust air through a portal in a residential area is not preferred to a system involving expulsion of air through an elevated stack.

Except for a fully longitudinal system without relief, the systems above require both exhaust stack structures, and air intake structures. An exhaust structure can either be a relatively low structure on high ground, or a relatively high structure on low ground in a "valley" location. The height of proposed exhaust stack structures is determined by a plume analysis of the exhaust gases from which ground level concentrations are determined under all meteorological conditions. Air intake structures are generally at ground level, and should be positioned to minimise cost.

The M5 tunnel under examination in the revised EIS could be up to 4.2 kilometres in length. This is too long for a longitudinal system as the required air volume flow would produce excessive air velocities for the proposed tunnel cross section. Air velocities through a tunnel space are limited to a desirable maximum of 7 m/s with velocities up to 10 m/s for peak traffic conditions, and 12 -15 m/s for emergency events such as tunnel fire.

These limits on air velocity mean that the tunnel ventilation system needs to be divided into segments of preferably maximum length 1.2 km. Each of the segments is designed independently based on length and gradient.

6.2 Design Parameters

The tunnel ventilation has been designed in accordance with the proceedings from the 1987 Permanent International Association Road Congress (PIARC). The maximum air volume flow required is calculated using the following design parameters:

- Tunnel segment length and gradient
- Air quality goals
- Vehicle emission data
- Traffic volumes

6.2.1 Air Quality Goals

The major air pollutants that result from vehicle emissions are hydrocarbons, nitrogen oxides (NO_x), and carbon monoxide (CO). The EPA has indicated that for CO the 15-minute goal is 87 parts per million for a road tunnel.

Another factor in the determination of dilution volumes is visibility. A large percentage of trucks in a tunnel can lead to poor visibility caused by diesel smoke, and this can be the governing criterion. The EPA at this stage has not provided visibility related air quality goals.

The EPA at this stage has also not provided air quality goals for NO_x levels within road tunnels, and therefore the ventilation concept design has been based on dilution of Carbon Monoxide only. Should the EPA introduce air quality criteria for other pollutants the concept design for the ventilation system may change.

6.2.2 Vehicle Emissions

Vehicle pollutant emissions are decreasing with time as vehicle emission laws are tightened and more pollution control equipment is introduced as part of the motor vehicle manufacturing process.

The recommended vehicle emission data within the PIARC proceedings is conservative because of the reduction in vehicle pollutant emissions over time, and because Australia adopted vehicle emission regulations before many European countries.

The vehicle emissions adopted in the concept design of the tunnel ventilation system were based on the Metropolitan Air Quality Study Emissions Inventory. This study provides emission rates for hydrocarbons, Nitrous Oxides, and Carbon Monoxide for various road categories.

6.2.3 Traffic Volumes

The ventilation system was designed for various traffic scenarios including the congested state which is 140 vehicles per km per lane. The PIARC design method has speed factors which allow adjustment of pollutant emissions based on vehicle speed.

Vehicles powered by diesel engines such as trucks and buses have greater emission rates for diesel smoke and NO_x. For the worst case we have assumed that 20% of all vehicles are trucks or buses. This has a large effect on dilution volumes required for the visibility criteria and for dilution of nitrous oxides.

Air volume flows were determined for the following traffic conditions:

Traffic Scenario	Traffic Speed	No. Vehicles per lane
1	0 - Congested	140
2	10	100
3	20	60
4	40	40
5	80	20

The worst case for CO is the congested case because of the number vehicles in the tunnel. For greater speeds, vehicle emissions are greater, but there are fewer vehicles per kilometre which means total pollution is less.

For NO_x pollutants the worst case dilution volume occurs for higher traffic speeds than the congested case, even though there are fewer vehicles in the tunnel. This is due to the increased vehicle emission rates that occur at higher speeds. NO_x emissions also increase significantly with uphill grades. As mentioned above, dilution volumes have not been determined for NO_x emissions as the EPA has not specified Air Quality goals for NO_x.

The dilution air volume flows are calculated assuming three lanes of traffic, in order to allow for a possible future expansion which would utilise the proposed break down lane.

6.3 Air Quantities

The ventilation design concept requires supply air volume flows to match exhaust air volume flows. Both the southern and northern alignments require four (4) ventilation compartments and therefore three exhaust stacks and three air intakes.

Three exhaust stack locations identified for the **southern alignment** are

Royal Place, Bardwell Park
Duff St, Arncliffe, and
Burrows St, Arncliffe.

Three exhaust stack locations identified for the **northern alignment** are

Earlwood Shopping Centre Car Park
Turrella Industrial Estate, and
Burrows St, Arncliffe.

The air volume flow required to dilute pollutants to meet the specified air quality goals, at each of the exhaust stack locations, is as specified in the following table.

The exhaust stacks will expel air at a constant velocity of 15 m/s. This is to ensure that pollutants are dispersed to acceptable levels at ground surface. In order to maintain a constant expulsion velocity for variable air volume flows, a system of dampers is required in the exhaust stack. The stack diameters given in the following table are based a constant expulsion velocity of 15 m/s, and also make a 25% allowance for dampers in the air stream.

Stack Location	Air Volume Flow (m^3/s)	Internal Stack Diameter
Southern Alignment		
Royal Place, Arncliffe	849	9.5m
Duff St, Arncliffe	365	6.2m
Burrows St, Arncliffe	361	6.2m
Northern Alignment		
Earlwood Shopping Centre Car Park	863	9.6m
Turrella - Henderson St Industrial Area	462	7.0m
Burrows St - Arncliffe	425	6.7m

The ventilation concept design also requires several air intake structures to service each of the four ventilation compartments. For the segments adjacent to portals supply air will be longitudinal from the portals. This supply has a greater background CO concentration, and this is taken in account when calculating dilution air volume flows.

Air supply vents are also required at the end of each compartment adjacent to the point of exhaust air extraction. Whilst the exhaust air stacks may be located remote from the tunnel in order to avoid residential areas, air supply vents can be located at ground level and environmental (visual) impacts minimised. The supply air vents would therefore be located as close as possible to the tunnel alignment on any appropriate and available land. The air intake volume flow needs to match the exhaust air volume flow, however the intake velocity would be limited to 10 m/s which results in larger intake grille areas. The following table provides air intake volume flows and areas. The table is based on the analysis of the Mixed Option illustrated in Figure N. The grille areas can be any shape, dependant on the final location. The locations provided are at the ventilation compartment interfaces over the tunnel alignment.

Three intake structures for the **southern alignment** are proposed to be located at

Royal Place, Bardwell Park
Duff St, Arncliffe, and
Burrows St, Arncliffe.

Three intake structures for the **northern alignment** are proposed to be located at

Hartill-Law Avenue (just north of Wolli Creek)
Turrella (near the industrial area - south of the East Hills Rail Line), and
Burrows St, Arncliffe.

Air Intake Location	Air Volume Flow (m^3/s)	Vent Area (m^2)
Southern Alignment		
Bexley Road Portal (through tunnel)	294	29
Royal Place, Bardwell Park	567(*)	57
Duff St, Arncliffe	384	38
Burrows St, Arncliffe	267(*)	27
Marsh St Portal (through tunnel)	63	6
Northern Alignment		
West Portal (through tunnel)	286	29
Hartill-Law Ave	594(*)	60
Turrella	521	52
Burrows Street	285(*)	26
East Portal (through tunnel)	64	6

Note (*) - these volumes may be reduced if a ventilation designer decides to supply all or part of the required air through a portal against traffic flow. The reduction in air through the intake would be equivalent to the increase in air through the portal.

6.4 Smoke Extraction

The tunnel ventilation system will also be used for smoke extraction in the event of a tunnel fire. A longitudinal system would require a smoke exhaust duct for the full length of the tunnel. The concept design has not specifically addressed smoke extraction as the design parameters are dependant on what type of vehicles use the tunnel. This is being addressed under a hazardous goods study.

A tunnel fire is an infrequent event, and will be addressed as part of the detailed design with the fan control system including a fire mode. Fire mode may involve the reversal of jet fans to remove the smoke from the compartment affected by fire. Air flow volumes may also be greater, although this is accommodated by air flow velocities temporarily greater than the desirable maximum for normal operating conditions.

6.5 Summary

The design of the ventilation system will ensure that air quality within the tunnels conforms to the air quality goals set by the NSW EPA.

The ventilation concept has been designed for the worst case traffic conditions, which is congested traffic in both directions. This is the most conservative approach, and the final ventilation system may designed under less onerous conditions. Traffic lights could be installed at the tunnel entry portal, or traffic could be held at the pay station when traffic in the tunnel becomes stationary due to congestion. The lights would be activated by a proximity switch buried in the road way, which senses if a vehicle is stationary for more than one minute.

The ventilation system will also provide for smoke extraction in the case of a tunnel fire. Within the longitudinally ventilated segments of the tunnel a smoke extraction duct is provided with smoke detector activated grilles.

Air quality will be constantly monitored through regularly spaced detectors, which will activate the ventilation control system.

Air is supplied to the tunnel through both portals, and also from several air intake vents. Within the tunnel tubes, where air travel between the intake and the exhaust tunnel is in the same direction as traffic flow, longitudinal ventilation utilising jet fans will be used. Where air flow from intake points to exhaust tunnels opposes traffic flow fully or semi-transverse ventilation with ducts, is likely to be used.

There are three locations for air exhaust stacks proposed. The exact location of the exhaust tower and the height above the surface are covered in other project consultants reports.

In this report Connell Wagner has provided a concept for a tunnel ventilation system and calculated potential air volume flows to assist in the environmental assessment of tunnel exhaust stacks. This tunnel ventilation work is based on experience in tunnel design and advice from industry sources. We have not determined fan sizes or spacing. Connell Wagner does not specialise in ventilation design and the detailed design for the tunnel ventilation system will require a specialist.

7.0 CONSTRUCTION IMPACTS

7.1 Method

Road tunnel excavation would normally be carried out by "drill and blast" methods or by machine excavation. "Drill and blast" excavation is unlikely to be permitted in a residential area although it would be quite safe and efficient in terms of excavation productivity.

The choices for machine excavation include one or a combination of

- tunnel boring machines
- roadheaders
- mobile miners
- machine mounted heavy breakers and ripper dozers.

The final selection of machinery (eg. Tunnel Boring Machine versus Roadheader) will be based on such factors as

- contractor's preference (which includes machine availability and lead time)
- the number of working faces developed
- the destination for tunnel spoil, and
- programme requirements
- the possible adoption of a double decker tunnel section.

The exhaust tunnels connecting the main vehicle tunnel to the exhaust shaft(s) would be excavated using a roadheader for initial headings and machine mounted heavy breakers and ripper dozers for bulk excavation. Space for ventilation plant and enlargements for vehicle lay-bys would also be excavated using a roadheader.

7.2 Surface Development

Most of the surface development in the study area is residential with some light commercial and retail establishments in various shopping areas and a more industrial area east of Turrella Railway Station on the south side of Wolli Creek.

Effects on surface developments during construction may include;

- the establishment of work sites
- noise and vibration from rock drilling and rock excavation at portals
- noise associated with the removal of spoil from the tunnel
- noise from ventilation equipment during tunnel construction.

Noise and noise attenuation is covered in more detail in the working paper "Noise Control - Renzo Tonin and Associates".

7.3 Work Sites

The main construction areas associated with the tunnelling works are as follows;

- In the east, a construction area in close proximity to the Marsh St portal will be very limited in terms of space availability. It is more likely that a construction area be established in the Turrella area, with the Princes Highway unload ramp being used for access to the tunnel.
- West of Bexley Road - for construction of the eastern portal and for main tunnelling activities.
- A worksite is also necessary for construction of the exhaust stacks.

7.4 Programme

The programming of a major urban tunnelling contract is governed by

- restraints on access.
- the number of working faces
- environmental limitations associated with noise, vibrations and hours of work set by the EPA.

For excavation by TBM it is likely that the use of one machine only will prove to be the most economic. The programme is therefore governed by the rate of tunnel advance and the necessity to excavate the complete length of one tube from one portal, followed by the adjacent tube.

Although procurement of a TBM is likely to take 12 months, its rate of tunnel advance is fast and may be up to 100 metres per week. Based on working 3 shifts per day (i.e. 24 hours per day) for five days per week and one shift on Saturdays, the dual tunnel will be excavated in approximately one year with other fit out activities elongating the tunnel construction period by another year (maximum). Other tasks related to the tunnel construction (including contingencies) are such that a maximum construction period of 3.5 years has been included in the master EIS.

7.5 Disposal of Spoil

All of the material to be excavated is Hawkesbury Sandstone. Initial heading excavation by machine produces a material which is basically sand. The material is useable in road construction as filling below grade or the building of embankments. Some of the spoil would be required for use in backfilling the tunnel invert if a TBM has been used for initial heading excavation. Bulk excavation (i.e. excavation by heavy breaker and ripper dozer after initial heading work) will produce a more useful construction material in terms of particle size distribution.

The quantities involved (up to 1,000,000 m^3) may be somewhat greater than will be required for motorway embankments and some of the spoil would then need to be removed from the worksite by truck to disposal sites. The actual sites can only be decided by the contractor based upon commercial considerations and demand for fill at the particular time. Because of the long period of excavation, it is likely that a number of fill sites will be used.

Stockpiles of spoil from the tunnel may need to be established at the worksites for disposal by truck.

8.0 CONSTRUCTION COSTS

The estimated construction cost for the M5 tunnel is summarised in Figure P for the southern alignment and Figure Q for the northern alignment. This estimate includes;

- civil construction (including eastern and western portals), tunnel finishes, road pavement, New Jersey barriers, walkway, ceilings, electrical and mechanical equipment, communications, ventilation station structures and electrical and mechanical equipment; and

- a contingency of 15%.

The inclusions for Design and Supervision and property acquisition costs are indicative only. They will require refinement during the detailed design phase. In terms of property acquisitions, at this stage geotechnical assessment of the western portal area has identified the need for possible acquisition of one property on Wolli Ave adjacent Bexley Road.

Detailed design of that portal should be carried out at the appropriate time in consultation with the affected property owners to ensure that those owners are aware of the short term (construction phase) and long term effects of the tunnel proposal.

In the east the northern alignment would require property acquisitions from the Loftus/ Bonar Street area through to Marsh Street, except for a short bored tunnel section between Princes Highway and West Botany Street. For the southern alignment acquisition requirements would be similar except that there is unlikely to be any property acquisition requirement west of the Illawarra Rail Line.

The cost estimates exclude RTA contract administration and other overheads.

9.0 TUNNEL OPERATION

9.1 Operating Costs

The estimated annual operating and maintenance costs directly attributable to the tunnel are tabulated below. It should be noted that these costs have been separated out from other motorway operating costs in the sense that they are only the costs which would not be incurred if the tunnel were to be deleted from the project (and replaced by an alternative. eg. elevated motorway)

Item	COST FOR TUNNEL COMPONENT
Electricity consumption	$1.7m
Toll collection	Nil
Operational Monitoring (Labour)	$0.5m
Staff (3 breakdown crews + 2 managerial staff plus overheads)	$0.75m
** Maintenance items (incl maintenance labour)	$1.0m
TOTAL OPERATING COSTS	$3.9m

The M5 East is expected to be a privately built and operated tollway. The maintenance and operational activities will therefore be part of the owning and operating costs of the motorway operating company.

9.2 Restrictions (Hazardous Goods)

Transport of hazardous goods in the area and possibly on the M5 Motorway has been reported on separately by Risk specialists.

In tonnage terms, petroleum products account for the majority of all hazardous goods transported by road, with the consequent risk of fire if a tanker ruptures. Fires in tunnels are extremely rare with major fires even rarer, with none having occurred in the United Kingdom where road tunnels are common. All these U.K. fires to date have been of a minor nature and confined to a single vehicle with little or no damage to the tunnel.

The consequences of a major fire or explosion could however, be more serious for a road user in a tunnel than in the open air, not least because the confined circumstances will limit access for emergency services and the evacuation of a tunnel user may be more difficult.

The means exist for designers and tunnel operators to control smoke and heat arising from a fire and so assist rescue and restrict damage. Close control and supervision is required to ensure detection and intervention to limit the development of a fire. An essential part of the development of a M5 East tunnel would therefore be a set of operating procedures and emergency systems such as those already in operation at the Sydney Harbour Tunnel Control Centre.

Nevertheless it is an International recommendation (PIARC 1979) that alternative routes should be used for hazardous goods where practicable. Only if alternative routes are of high risk, or there will be a high impact or significant effect of an incident involving hazardous goods, should they be allowed to use a tunnel, and then only under close supervision.

9.3 Radio

The tunnel fitout requires a facility for continued radio reception for tunnel users, and radio override.

9.4 Sprinkler/Flooding System

The tunnel requires a fire protection sprinkler/flooding system designed by a specialist. Current thinking is that excessive sprinkler water application in a fire affected area of a tunnel may be adverse in the sense that it cools smoke excessively and reduces the tendency for smoke to rise to the extraction facility.

9.5 Signage

Emergency message signage is to be provided to keep tunnel users informed of abnormal occurrences.

9.6 Control Centre

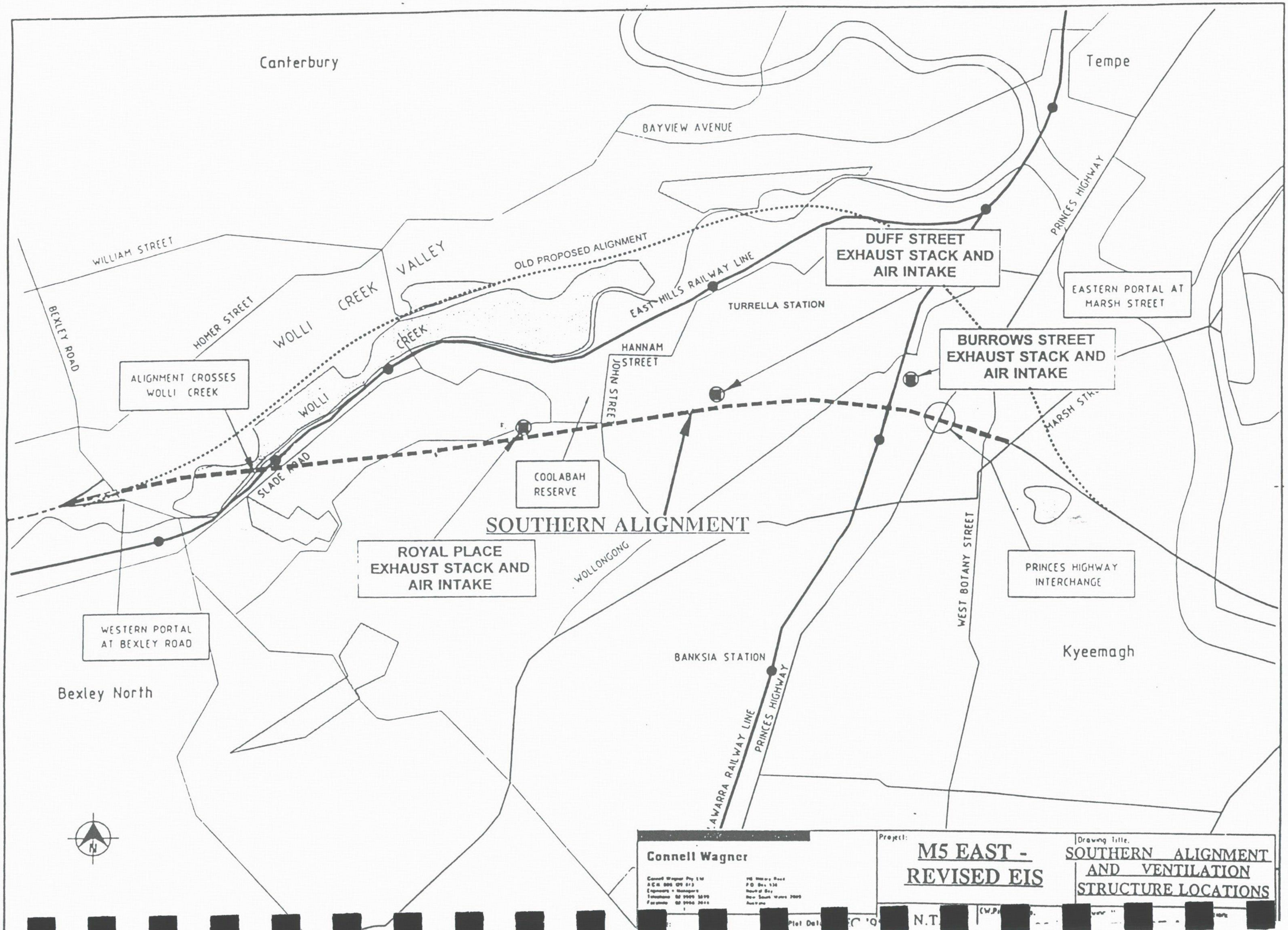
A control centre housing CCTV and tunnel environment and equipment monitoring facilities will be required, possibly being located in the area of the toll plaza or in the Burrows St ventilation facility, where a car park may also be constructed. The control centre would provide a direct link to all emergency services.

9.7 Emergency Service Exercise

An exercise of all emergency services needs to take place prior to the commissioning of the tunnel.

Illustrations and Tables

Figures A - Q


Canterbury
Tempe
BAYVIEW AVENUE
PRINCES HIGHWAY
WILLIAM STREET
OLD PROPOSED ALIGNMENT
WOLLI CREEK VALLEY
EAST HILLS RAILWAY LINE
DUFF STREET EXHAUST STACK AND AIR INTAKE
EASTERN PORTAL AT MARSH STREET
BEXLEY ROAD
HOMER STREET
WOLLI CREEK
TURRELLA STATION
BURROWS STREET EXHAUST STACK AND AIR INTAKE
HANNAM STREET
JOHN STREET
ALIGNMENT CROSSES WOLLI CREEK
WOLLI
MARSH STREET
SLADE ROAD
COOLABAH RESERVE
SOUTHERN ALIGNMENT
ROYAL PLACE EXHAUST STACK AND AIR INTAKE
WOLLONGONG
WEST BOTANY STREET
PRINCES HIGHWAY INTERCHANGE
WESTERN PORTAL AT BEXLEY ROAD
BANKSIA STATION
Kyeemagh
Bexley North
PRINCES HIGHWAY
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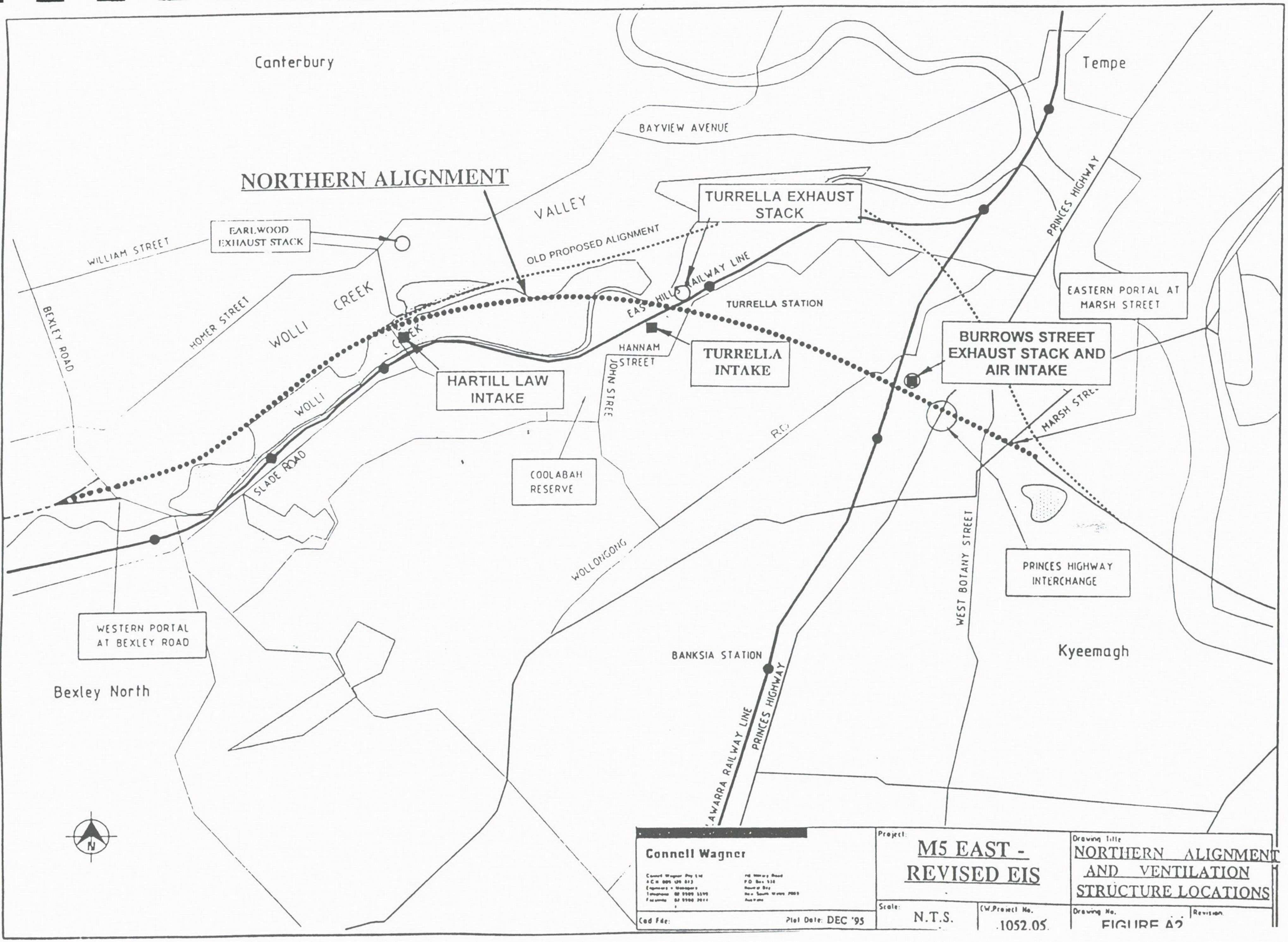
Connell Wagner
Project:
M5 EAST - REVISED EIS
Drawing Title:
SOUTHERN ALIGNMENT AND VENTILATION STRUCTURE LOCATIONS



Canterbury
Tempe
BAYVIEW AVENUE
NORTHERN ALIGNMENT
VALLEY
TURRELLA EXHAUST STACK
PRINCES HIGHWAY
EARLWOOD EXHAUST STACK
WILLIAM STREET
OLD PROPOSED ALIGNMENT
EAST HILLS RAILWAY LINE
TURRELLA STATION
EASTERN PORTAL AT MARSH STREET
BEXLEY ROAD
HOMER STREET
WOLLI CREEK
HANNAM STREET
TURRELLA INTAKE
BURROWS STREET EXHAUST STACK AND AIR INTAKE
HARTILL LAW INTAKE
JOHN STREET
MARSH STREET
RD
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COOLABAH RESERVE
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Kyeemagh
Bexley North
ILLAWARRA RAILWAY LINE
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Connell Wagner
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M5 EAST - REVISED EIS
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NORTHERN ALIGNMENT AND VENTILATION STRUCTURE LOCATIONS
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Plot Date: DEC '95
Scale:
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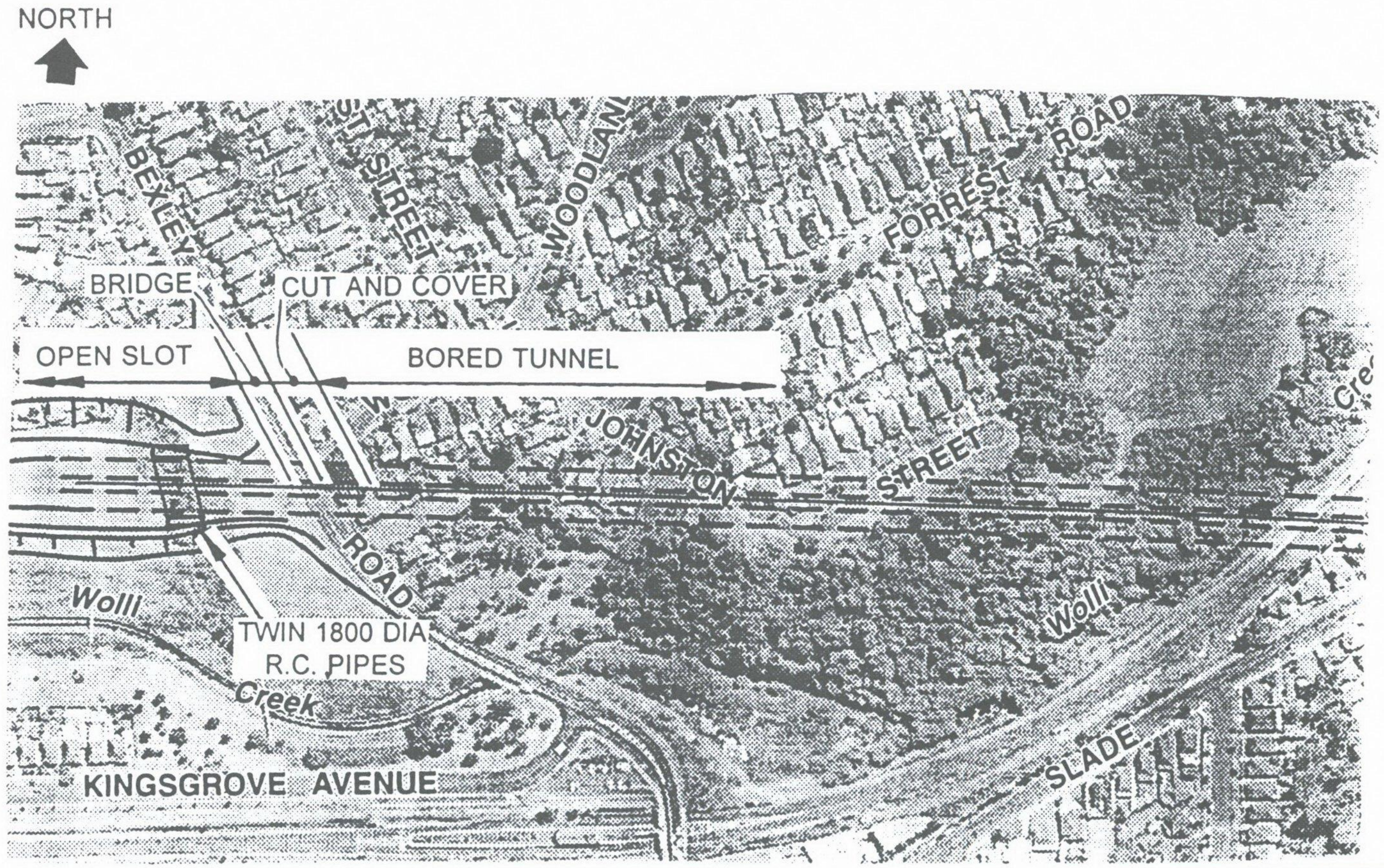
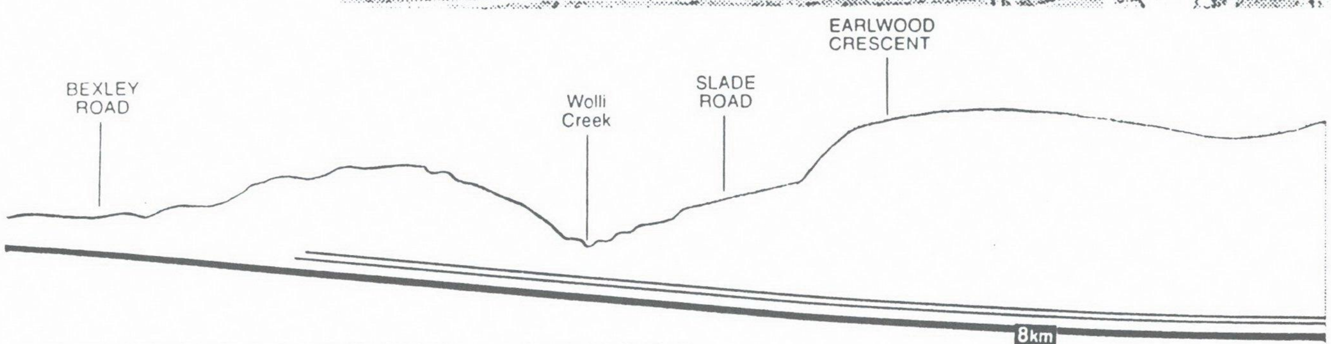
CW Project No.
1052.05
Drawing No.
FIGURE A2
Revision





SCHEMATIC LONGSECTION ONLY - NOT TO SCALE

FIGURE B1 - SOUTHERN ALIGNMENT TRANSITION FROM BORED TUNNEL TO FREEWAY: WESTERN PORTAL PLAN

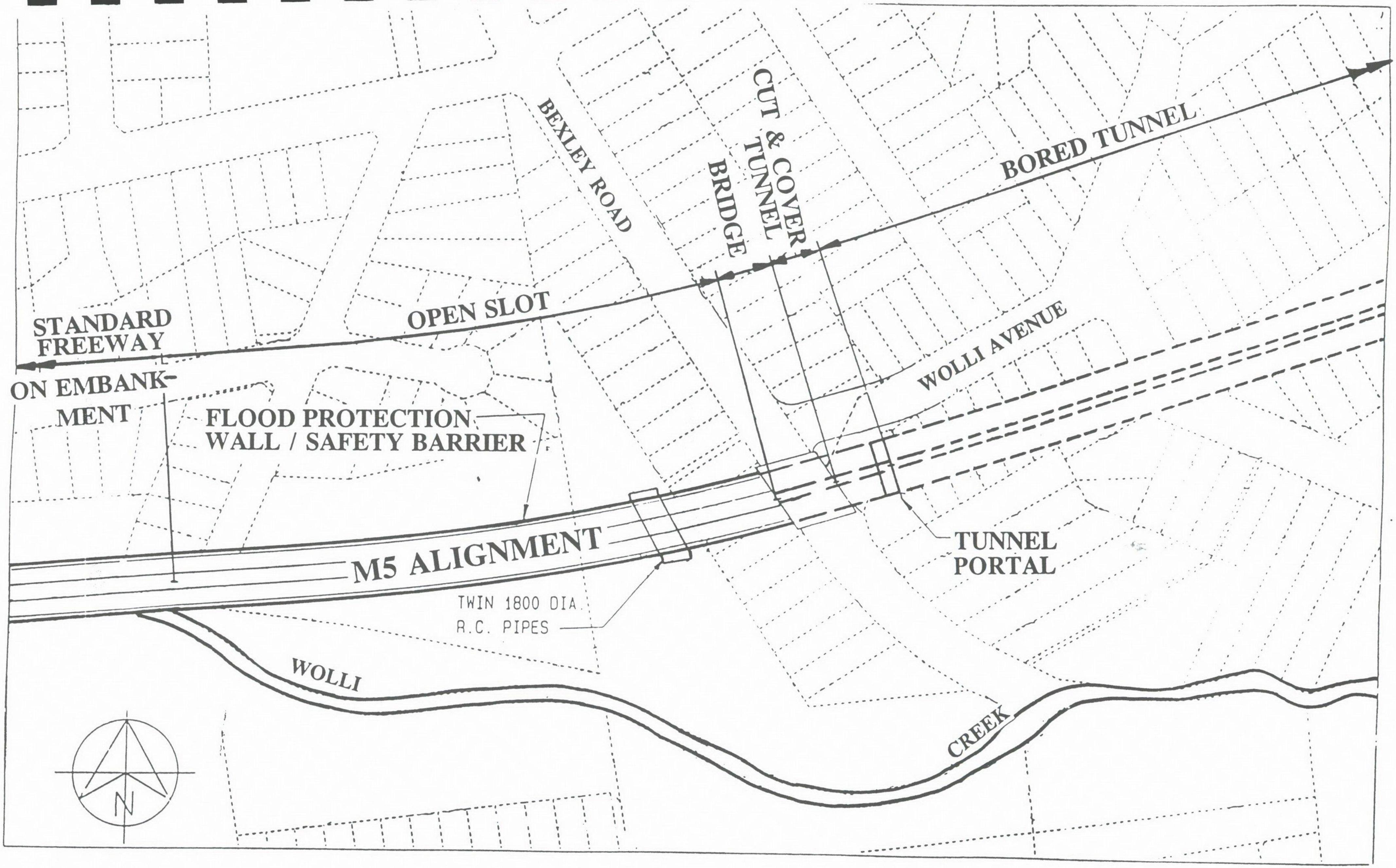
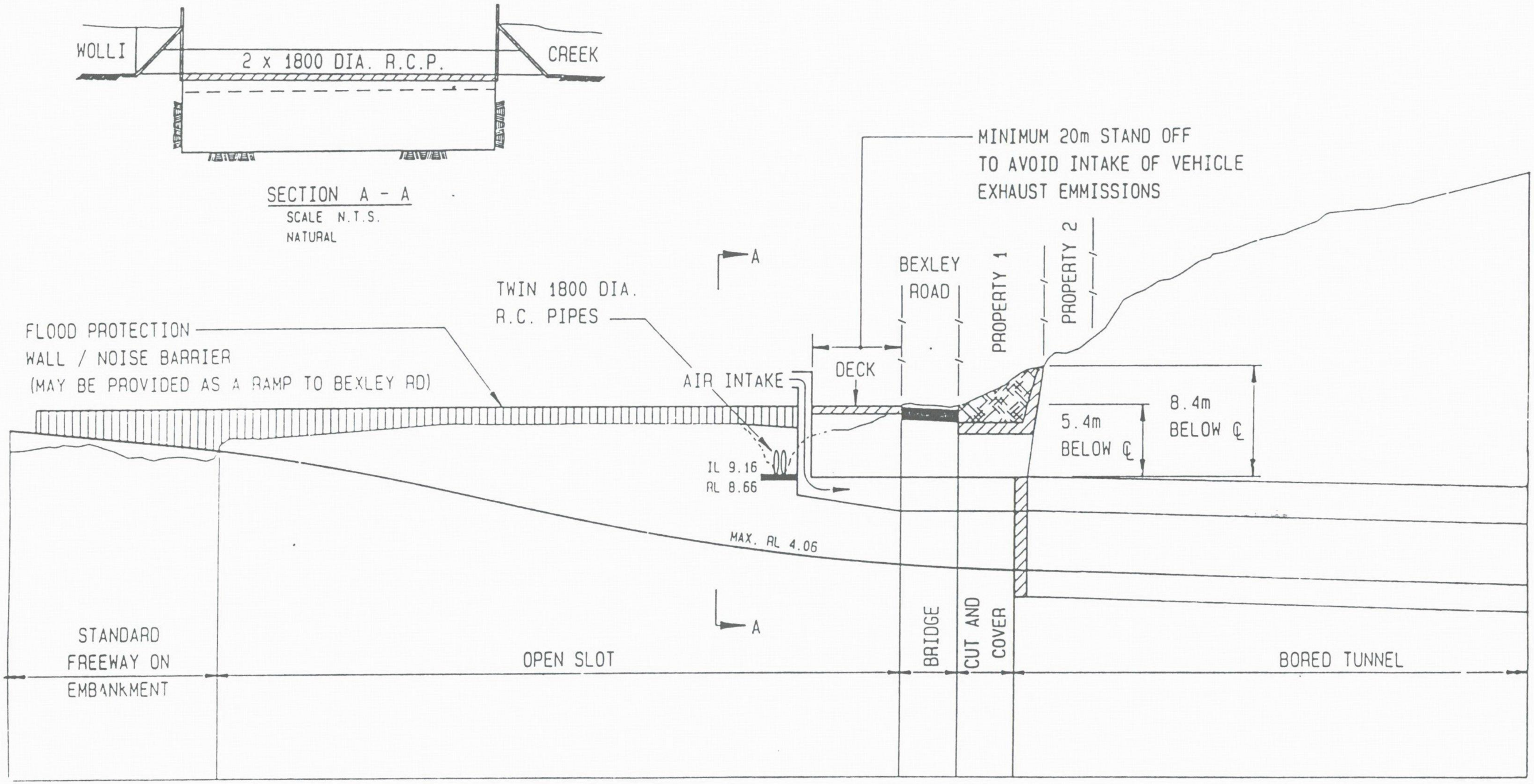


FIGURE B2 - NORTHERN ALIGNMENT TRANSITION FROM BORED TUNNEL TO FREEWAY: WESTERN PORTAL PLAN



M5 EAST MOTORWAY
TRANSITION FROM BORED TUNNEL
TO FREEWAY - WESTERN PORTAL
LONGITUDINAL SECTION
(NORTHERN *AND* SOUTHERN ALIGNMENTS)
N.T.S.

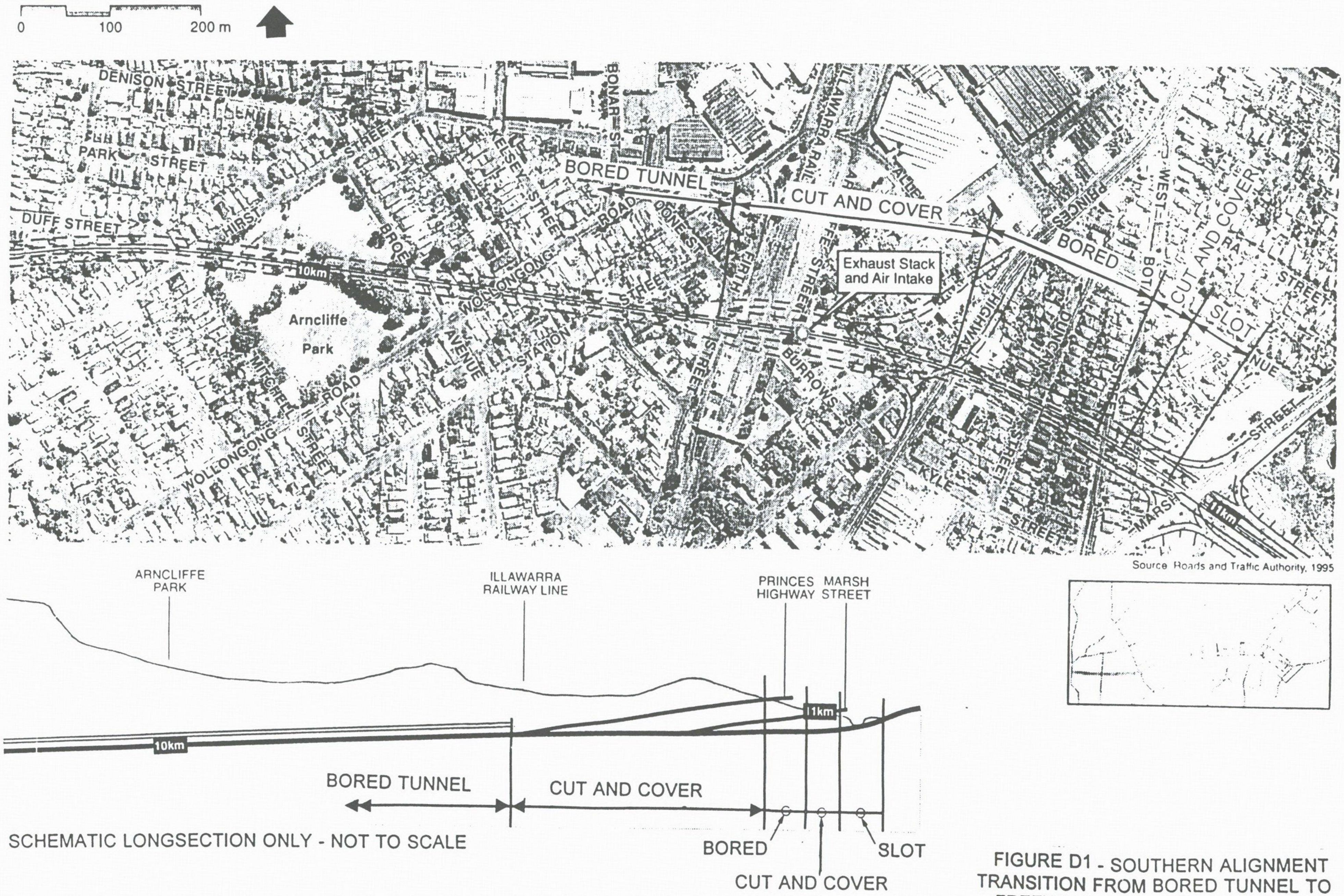
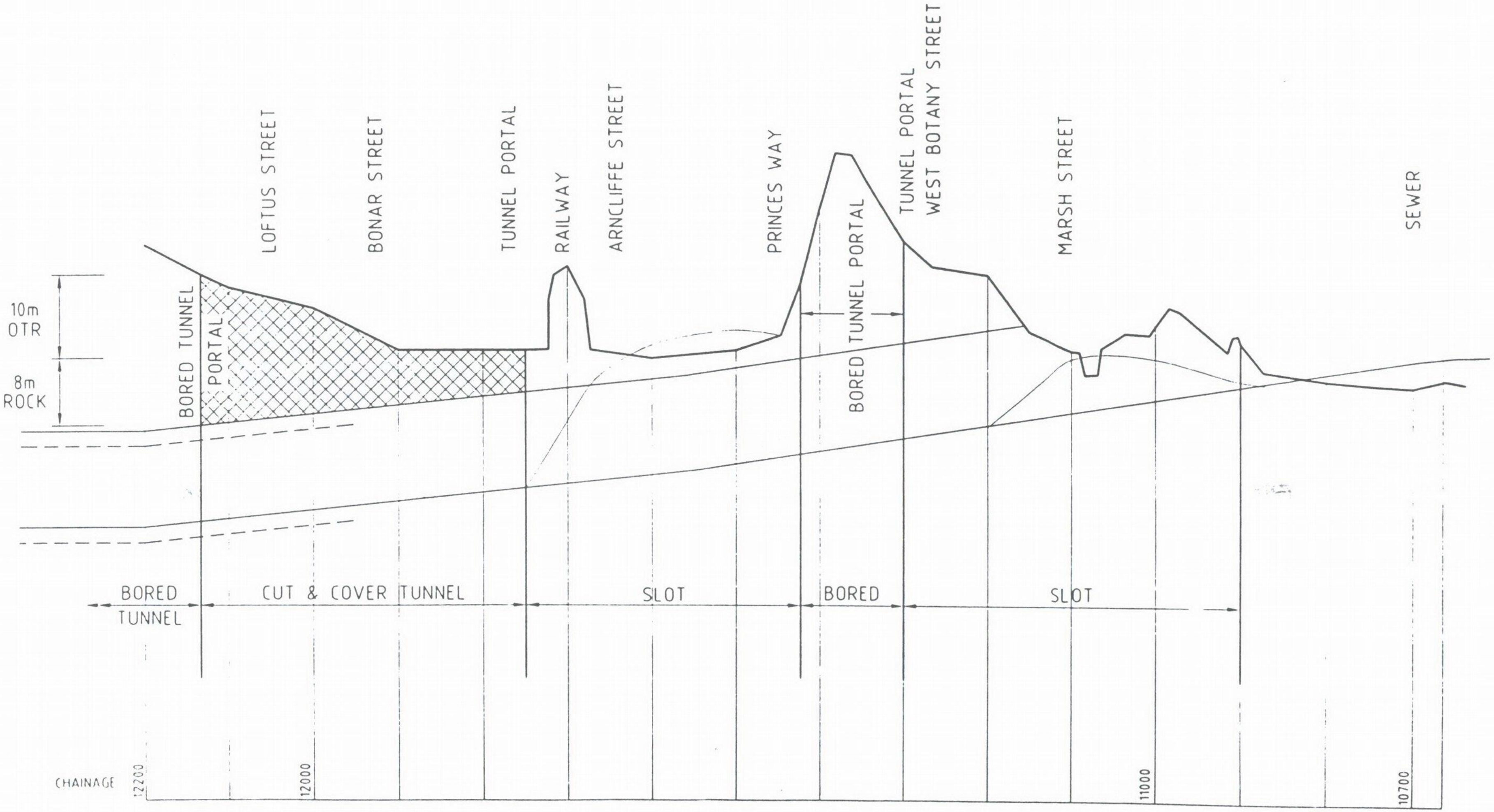


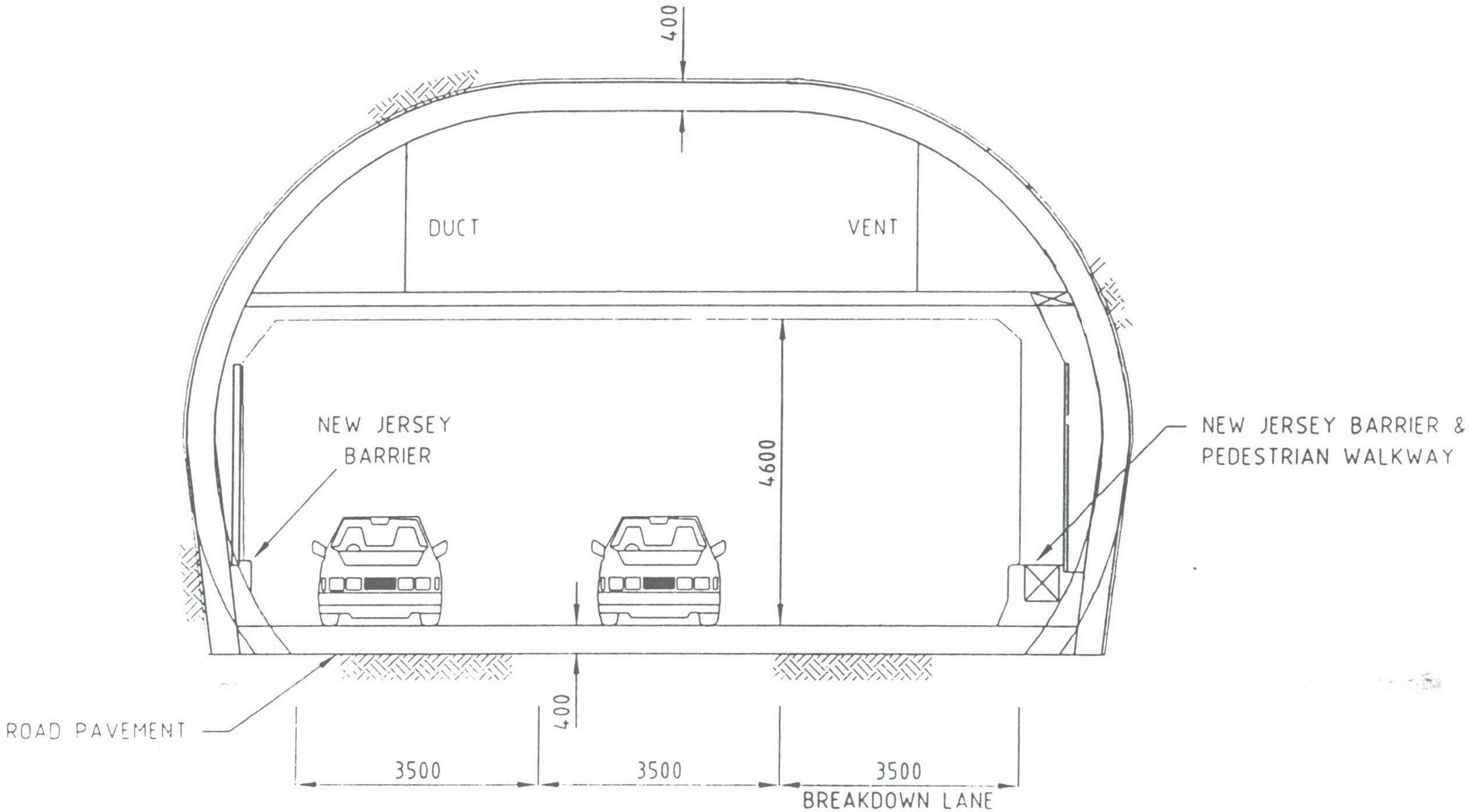
FIGURE D1 - SOUTHERN ALIGNMENT TRANSITION FROM BORED TUNNEL TO FREEWAY: EASTERN PORTAL PLAN

FIGURE D2 - NORTHERN ALIGNMENT TRANSITION FROM BORED TUNNEL TO FREEWAY EASTERN PORTAL PLAN



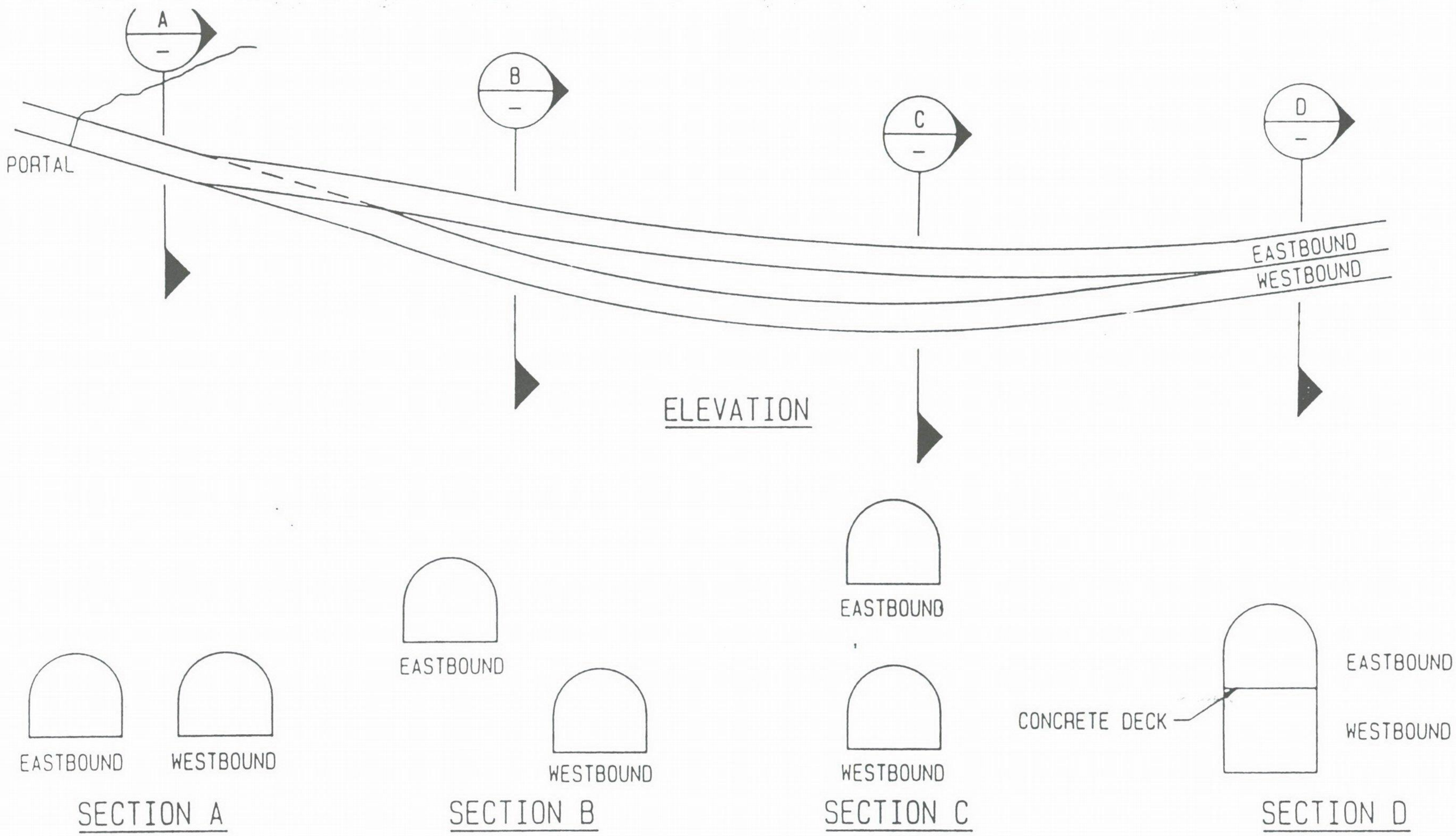
M5 EAST MOTORWAY
TRANSITION FROM BORED TUNNEL
TO FREEWAY - EASTERN PORTAL
LONGITUDINAL SECTION
(NORTHERN ALIGNMENT)
N.T.S.

FIGURE E1



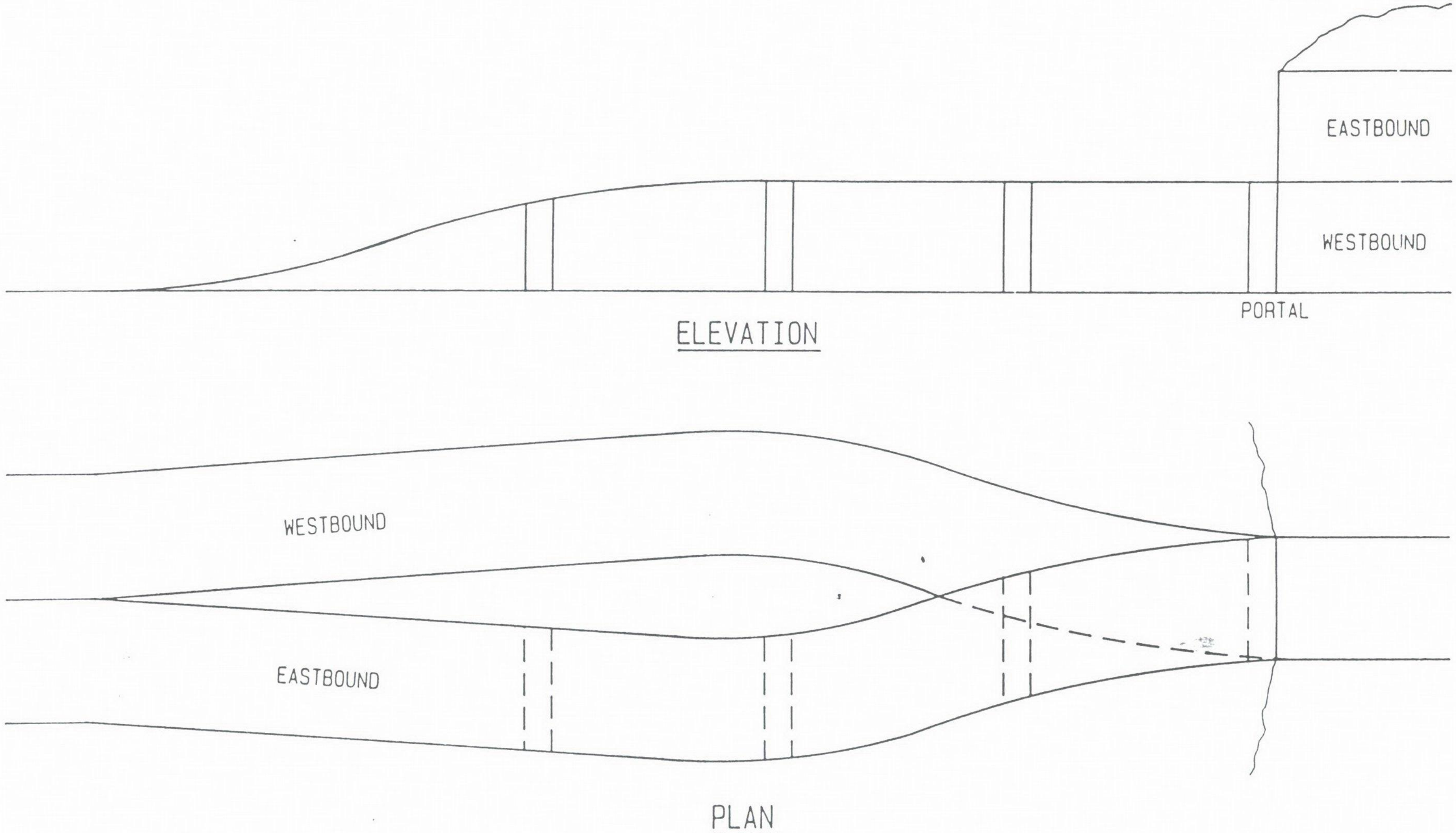
M5 EAST MOTORWAY
TYPICAL SECTION
TWO LANE TUNNEL & BREAKDOWN LANE

FIGURE G



M5 MOTORWAY
ALTERNATIVE TUNNEL SECTION
UNDERGROUND TRANSITION

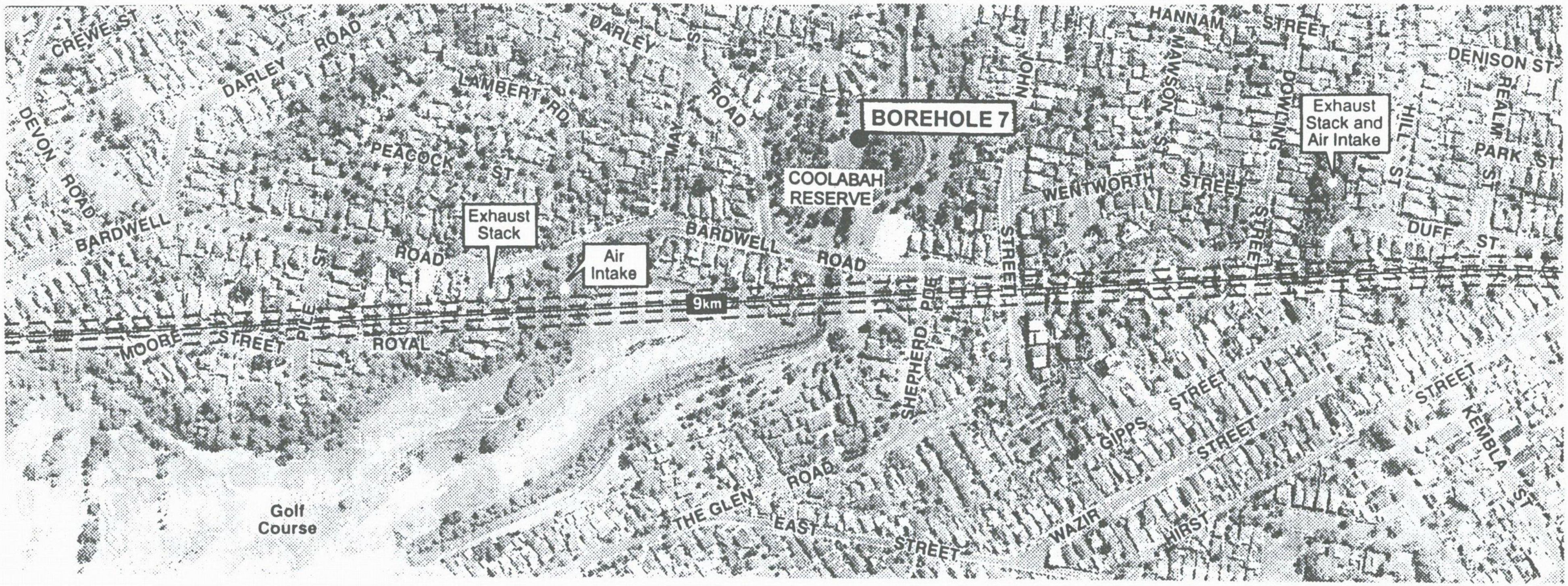
FIGURE H



M5 MOTORWAY
ATERNATIVE TUNNEL SECTION
EXTERNAL TRANSITION

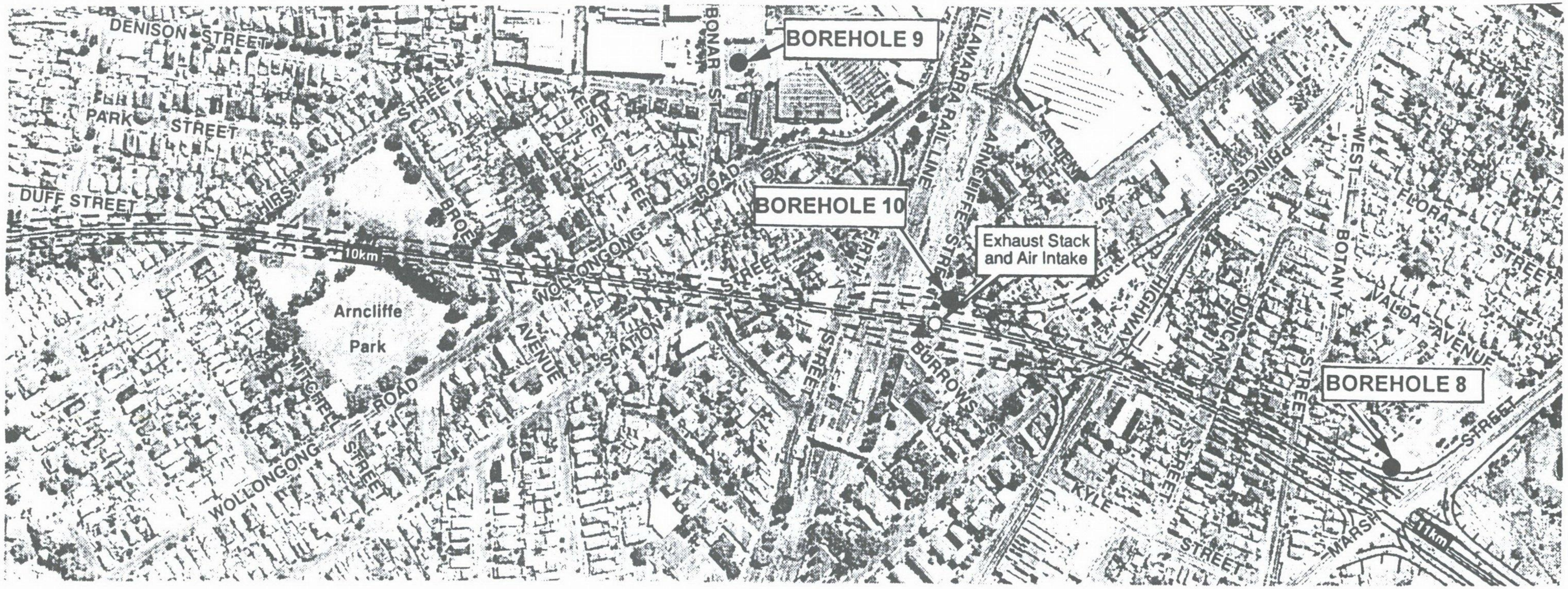
FIGURE I

A4



Drawn	Signed	Date	**Connell Wagner**	Project: M5 EAST MOTORWAY	Drawing Title: STAGES 3 & 4 GEOTECHNICAL INVESTIGATIONS LOCATION OF BOREHOLE 7
Designed	Signed	Date	Connell Wagner Pty Ltd A C N 005 139 873 Engineers + Managers Telephone 02-9909 5599 Facsimile 02-9908 2044		
Verified	Signed	Date	116 Military Road P O Box 538 Neutral Bay New South Wales 2089 Australia		
Approved	Signed	Date	Cad File: Plot Date:	Scale: N.T.S. / CW.Project No. 1052.05	Drawing No. FIGURE J / Revision:

A4



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Verified	Signed	Date
Approved	Signed	Date

Connell Wagner

Connell Wagner Pty Ltd
A.C.N. 005 139 873
Engineers • Managers
Telephone 02-9909 5599
Facsimile 02-9908 2044

116 Military Road
P.O. Box 538
Neutral Bay
New South Wales 2089
Australia

Project: M5 EAST MOTORWAY

Drawing Title: STAGES 3 & 4 GEOTECHNICAL INVESTIGATIONS LOCATION OF BOREHOLES 8, 9 & 10

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Drawing No. FIGURE K

Revision:

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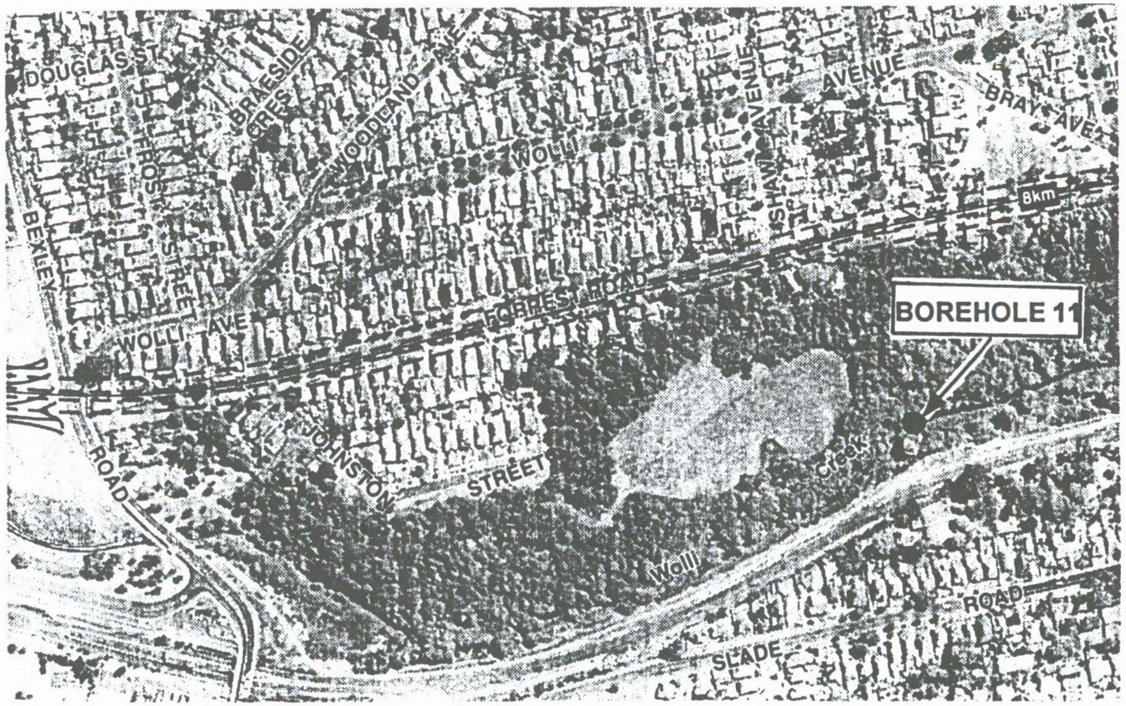

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Verified	Signed	Date	
Approved	Signed	Date	

Connell Wagner

Connell Wagner Pty Ltd
ACN 005 139 873
Engineers • Managers
Telephone 02-9909 5599
Facsimile 02-9908 2044

116 Military Road
PO Box 538
Neutral Bay
New South Wales 2089
Australia

Cad File: Plot Date:

Project: M5 EAST MOTORWAY

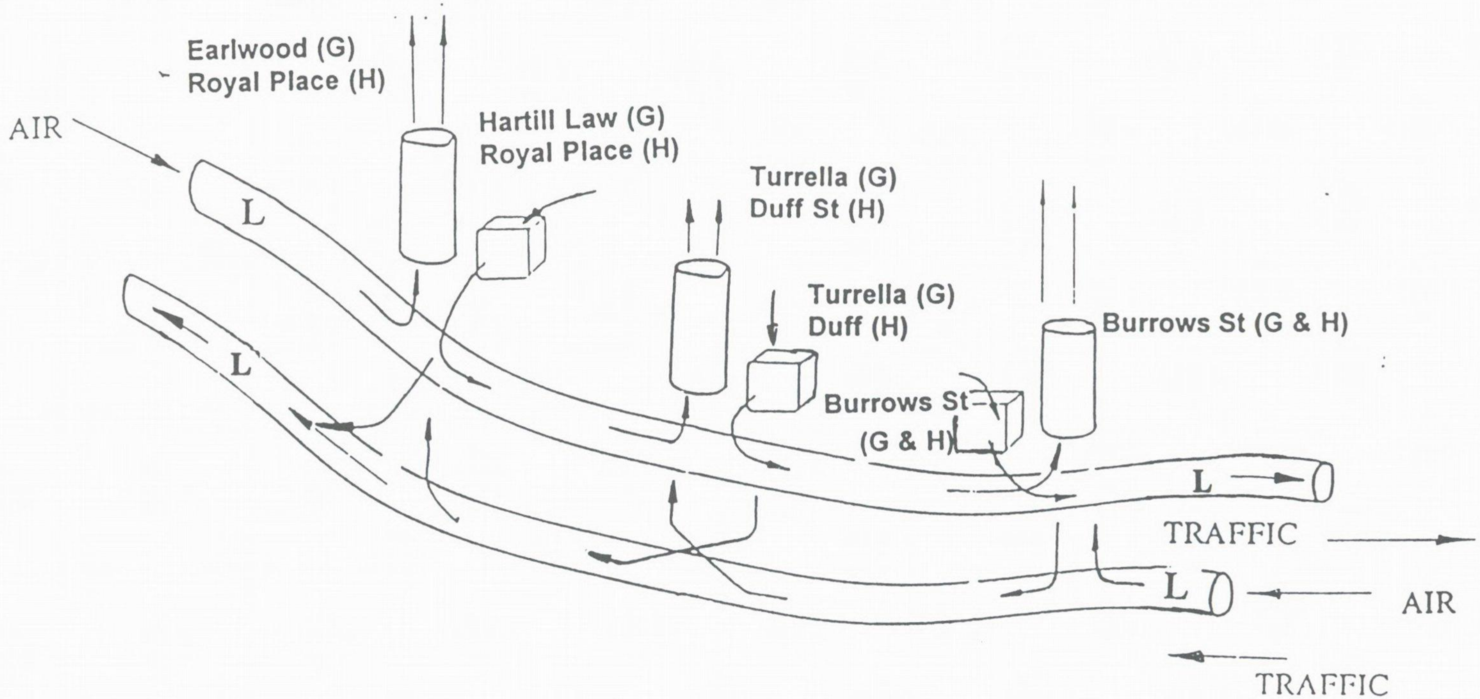
Drawing Title: STAGES 3 & 4 GEOTECHNICAL INVESTIGATIONS LOCATION OF BOREHOLE 11

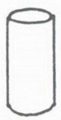
Scale: N.T.S.

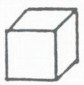
CW.Project No. 1052.05

Drawing No. FIGURE L

Revision:




EXHAUST STACK


AIR INTAKE

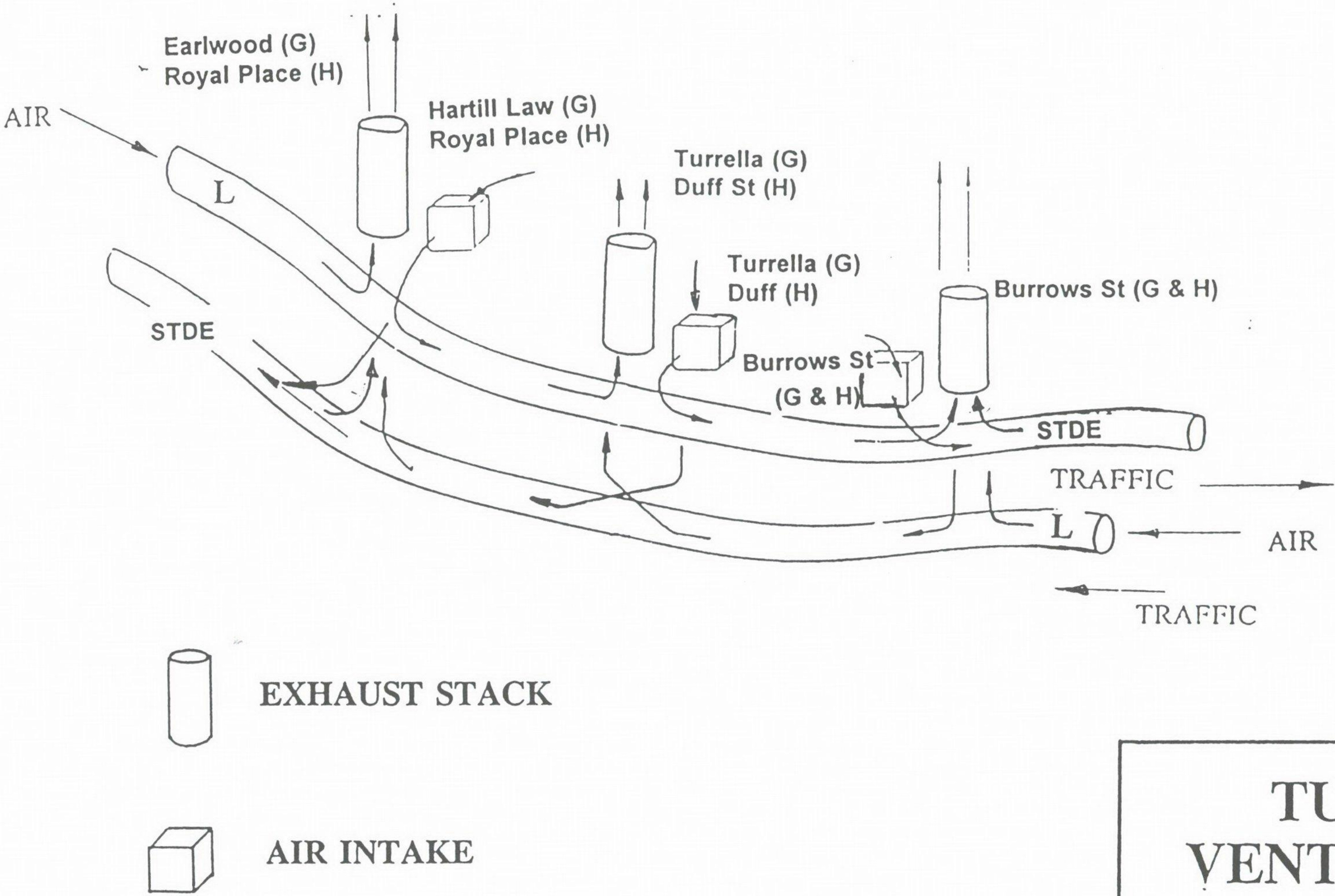
(G) = Option G - Northern Alignment
(H) = Option H - Southern Alignment

L = LONGITUDINAL
D = DUCTED
STDE = SUPPLY IN TRAFFIC - DUCTED EXHAUST
DSLE = DUCTED SUPPLY - LONGITUDINAL EXHAUST

TUNNEL VENTILATION SYSTEM

LONGITUDINAL VENTILATION OPTION

Figure M



(G) = Option G - Northern Alignment
(H) = Option H - Southern Alignment

L = LONGITUDINAL
D = DUCTED
STDE = SUPPLY IN TRAFFIC - DUCTED EXHAUST
DSLE = DUCTED SUPPLY - LONGITUDINAL EXHAUST

TUNNEL VENTILATION SYSTEM

MIXED VENTILATION OPTION

Figure N

M5southcost.WK1

M5 MOTORWAY - COST ESTIMATES -

21-Dec-95

1995 Tunnel Option 'H' - Southern Option

		Sector Costs ($'million)
FAIRFORD ROAD SECTOR		94.0
Fairford Rd - Bexley Rd General Construction	38.3	
Bridges Fairford-Bexley Rd	13.5	
Interchanges Fairford - Bexley Rd	14.0	
Noise Barriers Fairford - Bexley Rd	4.7	
Toll Plaza	6.5	
Flood Mitigation Fairford - Bexley Rd	2.0	
Utility adjustments Fairford - Bexley Rd	15.0	
MAIN TUNNEL (3865m - 3 lane tube/2 lane tube and cut and cover section)		309.6
Excavation	83.4	
Concrete	61.2	
Roadworks	8.4	
Tunnel Lining - Architectural	11.9	
Ventilation Structures	2.7	
Ventilation & Services systems	142.0	
PRINCES HWY RAMPS		22.2
MARSH ST RAMPS		11.2
MARSH ST - GEN HOLMES DRV SECTOR		52.9
Elevated Fwy	32.4	
Marsh/M5 Interchange (E of Marsh)	0.7	
Cooks River Bridge	6.8	
SWOOS Bridge	3.6	
Embankment to Gen Holmes Drive	3.4	
Retaining Wall	1.1	
Seawall	0.9	
Traffic signals		
Noise Barriers	1.0	
Provision for Cyclists	1.0	
Utility Adjustments	2.0	
DESIGN & SUPERVISION		30
ACQUISITIONS		60.0
TOTAL		**580.0**

FIGURE P

M5northcost.WK1

M5 MOTORWAY - COST ESTIMATES -

21-Dec-95

1995 Tunnel Option 'H' - Northern Option

		Sector Costs ($'million)
FAIRFORD ROAD SECTOR		94.0
Fairford Rd - Bexley Rd General Construction	38.3	
Bridges Fairford-Bexley Rd	13.5	
Interchanges Fairford - Bexley Rd	14.0	
Noise Barriers Fairford - Bexley Rd	4.7	
Toll Plaza	6.5	
Flood Mitigation Fairford - Bexley Rd	2.0	
Utility adjustments Fairford - Bexley Rd	15.0	
MAIN TUNNEL (3865m - 3 lane tube/2 lane tube and cut and cover section)		330.3
Excavation	85.3	
Concrete	78.6	
Roadworks	8.5	
Tunnel Lining - Architectural	12.3	
Ventilation Structures	5.9	
Ventilation & Services systems	139.7	
PRINCES HWY RAMPS		22.2
MARSH ST RAMPS		11.2
MARSH ST - GEN HOLMES DRV SECTOR		52.9
Elevated Fwy	32.4	
Marsh/M5 Interchange (E of Marsh)	0.7	
Cooks River Bridge	6.8	
SWOOS Bridge	3.6	
Embankment to Gen Holmes Drive	3.4	
Retaining Wall	1.1	
Seawall	0.9	
Traffic signals		
Noise Barriers	1.0	
Provision for Cyclists	1.0	
Utility Adjustments	2.0	
DESIGN & SUPERVISION		30
ACQUISITIONS		60.0
TOTAL		**600.7**

FIGURE Q

Connell Wagner

Roads and Traffic Authority - Sydney Region

M5 East Motorway - Soils and Groundwater Study

Report

April 1995

Connell Wagner

Connell Wagner Pty Ltd
A.C.N. 005 139 873
Engineers • Managers
Telephone 02-909 5599
Facsimile 02-908 2044

116 Military Road
P.O. Box 538
Neutral Bay
New South Wales 2089
Australia

Offices
Adelaide, Auckland, Bangkok, Brisbane, Cairns, Christchurch, Darwin, Gold Coast, Hong Kong, Indonesia, Mackay, Melbourne, Newcastle, Perth, Singapore, Sydney, United Kingdom, Wellington

1052.04
WLP/jp

7 April 1995

Regional Development Manager
Roads and Traffic Authority - Sydney Region
83 Flushcombe Road
BLACKTOWN NSW 2148

Attention: Mr J Brewer

Dear Sir

Re: M5 East Motorway - Soils and Groundwater Study

Please find attached a report and accompanying summary on the investigation of soils and groundwater for the proposed M5 East Motorway, in accordance with your letter dated 31 January 1995 (your ref: JDB:rtr).

This project was carried out in association with Pells Sullivan Meynink Pty Ltd and CM Jewell and Associates Pty Ltd.

Thank you for the opportunity to carry out this work for the RTA.

Yours faithfully

Richard Weber
Associate

EXECUTIVE SUMMARY

Introduction

This Executive Summary is to accompany and complement the report on an investigation into soils and groundwater for the proposed M5 East Motorway for the NSW Roads and Traffic Authority.

The work carried out has included field work, laboratory analyses and review of information available from other studies. Investigations were carried out on hydrogeological conditions and potential impacts of tunnelling; potential impacts on groundwater by toxic spills and the need for a spill remedial action plan, in response to the EIS submission from the Department of Water Resources (DWR). Investigations on soil erodibility, acid sulphate soil potential and management were carried out in response to the submission from the Department of Conservation and Land Management (CaLM).

Data on soil erodibility were required for use in the preparation of soil and water management plans and design of erosion and sediment control works. These are presented in Table 6.1 of the report, together with other relevant information. Erodibility (K) of 0.02 is considered low, 0.03 moderate, 0.04 high and 0.05 very high. The Soil Loss Class given in Table 6.1 of the report is in accordance with the NSW Department of Housing manual on Soil and Water Management for Urban Development. While erosion and sediment control would be an important design criteria for the whole project, particular attention would be required for Class 2 soils. The Emerson Class given refers to the dispersibility of the soil. Erosion from such soils creates runoff with high turbidity which will not readily settle out without addition of flocculants in the sediment pond.

Conclusions reached from the study include the following:

- **Western Section**

The western section from King Georges Road to the western tunnel portal will be constructed above the surface involving duplication of the existing two lanes. As major earthworks required were previously carried out in conjunction with the construction of the adjacent existing lanes of the M5, there will only be surface disturbance during construction of this section. Thus there will be no interference with hydrogeology or potential for acid sulphate generation, other than adjacent to the crossing of Salt Pan Creek. However, potential impacts remain with respect to future spills of toxic materials and erosion and sediment control.

Deeper aquifers are associated with the Ashfield Shale formation which are known to be generally saline and therefore not generally suitable for use. The overlying material derived from the shales is of low permeability and would limit infiltration of any spillages. However, shallower perched water tables may be expected to be associated with surface fill materials and to flow to Wolli Creek. Thus a spill remedial action plan for protection of aquifers would not be required for this section. However, safeguards may be required for the protection of Wolli Creek from spills through the surface drainage system or shallow fill material. This may include retention of construction stage sediment basins (the scope of work for the study was limited to protection of aquifers from spillages).

The source of the fill materials is unknown. Thus its properties may be variable and the absence of contaminated material and potentially acid sulphate soils has not been confirmed.

Soils in this section have the highest erodibilities (K in Table 6.1) of the project. However dispersibility is generally relatively low so properly designed sediment basins should be capable of adequately treating runoff without the use of flocculants, in conjunction with other management practices.

Table 7.1 indicates that soils adjacent to Salt Pan Creek have a high potential for generation of acid runoff and accompanying aluminium toxicity in receiving waters. Works in this area will need to be carefully managed with respect to disturbance and drainage of these soils and management of extracted material.

- **Driven Tunnel Section**

The driven tunnel section passes through Hawkesbury Sandstone. This material has a very low permeability on average but is also highly variable and complex. There also appears to be quite an open connection to the Wolli Creek alluvium.

Thus the tunnel is expected to generally encounter very low inflows with possible localised areas of high flows. Total seepage is estimated to be in the range of 2 to 10 l/s which would be expected to have a localised effect on the groundwater regime within the sandstone, but no effect on Wolli Creek.

The groundwater in Hawkesbury Sandstone is generally of a quality that would be acceptable for discharge during operation of the tunnel, although discolouration due to high iron concentration is commonly associated with groundwater from sandstone. However, during construction, water being pumped from the tunnel would be expected to be high in suspended sediment and turbidity, and contain small quantities of contaminants such as grease and oil associated with the drilling work.

There would generally be low risk to aquifers from spills of toxic materials, as infiltration would be limited by the generally very low hydraulic conductivity, with the exception of localised zones of higher permeability. Thus a spill remedial action plan for protection of aquifers would not be required. However, safeguards for the protection of surface water may be required as discussed for the western section. Although there are no known direct uses of the groundwater here, it is anticipated that the DWR and Environment Protection Authority (EPA) would require that design and management of the project not unnecessarily compromise its future use.

Potential acid sulphate generation is not associated with Hawkesbury Sandstone as this does not contain the sulphide minerals required. Erosion is not a concern in an underground tunnel although erosion and sediment controls will be required for the portal area, stockpiles of excavated material, and water removed from the tunnel during construction.

- **Cut and Cover Tunnel**

The cut-and-cover section of tunnel will pass through a sand aquifer. The design will therefore need to incorporate measures to minimise inflows into the excavation (which would otherwise require disposal as sediment laden and potentially acidic water) and prevent any spills of contaminants, during construction or operation, entering the groundwater. Although there is no known direct use of the groundwater here, it is anticipated that the DWR and EPA would require that design and management of the project not unnecessarily compromise its future use. In addition, groundwater contamination here would ultimately flow to Wolli Creek. The drainage system in the tunnel should be designed to be capable of storing spills of any probable magnitude to allow collection and clean up.

Laboratory testing of soil taken from boreholes here (Turrella) indicate the potential for acid sulphate generation when soils are exposed to the atmosphere. Therefore, water in the excavation and excavated material will need to be monitored and managed appropriately. This includes temporary stockpiles and ultimate disposal/re-use of the material. Although the construction area will mainly drain into an excavation, erosion and sediment control will be required for the associated surface works. Surface drainage should be diverted around the excavation. Water collected in the excavation and at the surface may require treatment to reduce turbidity (by use of gypsum or other flocculant) prior to discharge, as indicated by the high dispersibility (Emerson Class 1) of one of the soil samples from this location.

- **Eastern Portal to General Holmes Drive**

The section which is to be in an open cutting is in similar conditions to the adjacent cut and cover section and the same comments apply. The rest of this section is constructed above ground.

East of Marsh Street, there is a high risk of contamination of groundwater by any spills of toxic materials as this area is underlain by the Botany Sands Aquifer at a shallow depth. Although the aquifer is polluted in places, it is still used for irrigation. A recommended scope for a spill remedial action plan is provided in the report.

The sandy soils in this area have a low potential for erosion as indicated by the low erodibility (K) and dispersibility and low slopes (Table 6.1). Nevertheless, erosion and sediment controls measures will be required, primarily by way of good site management practices.

Acid sulphate potential is variable in this area as shown by the results in Table 7.1 of the report, for samples taken at Marsh Street, the Golf Course and the Airport.

An acid sulphate soil management plan would be required.

Connell Wagner Pty Ltd

M5 EAST EXTENSION
HYDROGEOLOGICAL AND ENVIRONMENTAL STUDY FOR EIS

Report PSM124.R1 MARCH 1995

CONTENTS

1. INTRODUCTION

This report presents the results of hydrogeological and environmental studies carried out for supplementary EIS studies for the M5 East Extension by Pells Sullivan Meynink Pty Ltd (PSM) in conjunction with C M Jewell and Associates Pty Ltd. The work was commissioned by Connell Wagner Pty Ltd in their facsimile dated 2 February 1995.

The scope of work for the study comprised:

- review/assess hydrogeological conditions along the motorway route
- assess the impact of tunnelling or deep excavation on the local groundwater system
- assess the impact on the groundwater system of a major spillage of toxic material
- assess the need for a remedial action plan for spillage events
- assess the erodability of topsoil to provide the information required for design of erosion and sediment control measures and
- assess whether acid sulphate (pyritic) soils are present along the route of the motorway, and if present, map their distribution and advise on their management during and after construction.

2. SCOPE OF FIELD WORK

Field work comprised mainly sampling to depths of up to 2m in 23 hand auger holes. The locations of the holes are shown on Figure 1. In addition two deep boreholes were drilled in the cut-and-cover section of the tunnel on either side of Wolli Creek. Logs of these holes are given in Appendix A.

Samples were taken from the hand auger for chemical and erosion potential testing. Appropriate cleaning of the auger was performed between each sampling operation to avoid contamination of the samples.

Samples from the two deep boreholes were taken using a Standard Penetration Test split spoon sampler or 50mm diameter thin wall sampling tubes.

Samples were forwarded to Sydney Analytical Laboratories and the Laboratory of Jeffrey and Katauskas using a Chain of Custody system.

3. HYDROGEOLOGICAL CONDITIONS

3.1 General

The proposed route of the M5 East Extension may be divided into four sections, namely;

- from King Georges Road intersection at Ch 3.5 km to western portal of the driven tunnel at Ch 7 km,
- driven tunnel in Hawkesbury Sandstone from the western portal at Ch 7 km to Ch 10 km,
- a length of cut-and-cover tunnel from Ch 10 km to the eastern portal at Ch 10.2 km and
- from the eastern portal at Ch 10.2 km to the intersection with General Holmes Drive at Ch 13.5 km.

This part of the report deals with the hydrogeological conditions along each section of the motorway route.

3.2 King Georges Road to Western Portal

Most of this section of the route is underlain by Ashfield Shale beneath a variable cover of residual soils and artificial fill.

This section of the road will be a surface construction, and the primary interest in this area is thus the risk of transport of spilled material in groundwater.

The Ashfield Shale has low primary hydraulic conductivity, but, locally, has significant transmissivity developed within fractures and crush zones. Extensive packer testing (50 separate sections) in the Homebush Bay area showed a strongly bi-modal distribution. Shale sections without significant fracturing typically show Lugeon values of less than 1 (equivalent to a hydraulic conductivity value of $< 1 \times 10^{-5}$ cm/s). Fractured sections typically show Lugeon values in the range 30 - 60 (3×10^{-4} - 6×10^{-4} cm/s) with Lugeon values as high as 180 recorded.

Where present, residual shale soils generally have a lower hydraulic conductivity than the parent material and may provide an effective barrier between shale groundwaters and the surface or superficial fill materials.

Groundwater in the Ashfield Shale is generally saline - typical salinities are greater than 14,000 mg/L consequently very little beneficial use is made of these groundwaters.

Fill deposits present along this section of the route are expected to be highly variable. Local perched water tables and nuisance seepage may be encountered. There is likely to be hydraulic continuity between groundwater in the fill and the un-canalised sections of Wolli Creek.

It is possible that waste materials may be present in the fill.

The eastern part of this section (east of Bonalbo St) is underlain by Hawkesbury Sandstone. Hydrogeological conditions in the area are likely to be similar to the Driven Tunnel section, discussed in Section 3.3.

3.3 Driven Tunnel

Hydrogeological conditions along the driven tunnel have been assessed on the basis of 6 boreholes drilled in January 1994 together with data available on the Hawkesbury Sandstone from other investigations in the Sydney area.

Figure 2 shows the locations of the boreholes. Water level measurements were made in the open holes about 2 weeks after drilling. The results of the measurements are given in Table 1.

TABLE 1
WATER LEVELS

Borehole No.	Collar RL (m)	Groundwater RL (m)	Approximate Tunnel Invert
2	3.5	-0.3	-21
3	42.5	7.9	-34
4	32.8	15.6	-23
5	30.0	12.0	-14
6	45.0	-0.9	-34

The data in Table 1 indicate a complex groundwater system. The water level in BH2 which was drilled near the eastern driven tunnel portal is reasonably consistent with a water level controlled by Wolli Creek. The higher water levels in Boreholes 4 and 5 suggest either a perched water table within the sandstones controlled by low permeability siltstone horizons or isolated fractures, or else a relatively high seepage gradient from the high ground in the north down towards Wolli Creek.

As can be seen from Figure 2 Boreholes 3 and 6 were drilled close together. This was because complete water loss occurred in BH3 at RL - 18.8m and the core barrel then became irretrievably jammed. BH6 was drilled to continue below this depth. Water loss also occurred at about the same RL and the hole was grouted prior to coring. It appears that the water loss occurred along an open sub-horizontal bedding feature. Such features have been recorded elsewhere in the Hawkesbury Sandstone at similar and slightly greater depths. Examples are the Mill Creek Valley (Lucas Heights Landfill), and Woronora Valley south of Sydney, and a number of locations in the Mardi and Peats Ridge areas north of Sydney. It is believed that the ancient valley of Wolli Creek is incised into the sandstone down to about RL -20m and it could be that the open bedding feature is associated with stress concentration/relief effects.

The water levels in Boreholes 3 and 6 suggest quite open connection to the Wolli Creek alluvium.

No in situ permeability test have been conducted in the sandstone along the tunnel route at this time. Such testing is proposed for the detailed design investigations. Permeability data is available from several other tunnelling projects in Sydney as summarised in Table 2.

TABLE 2.

Permeability Date From Boreholes in Hawkesbury Sandstone (Ocean Outfall Tunnels and Sydney Harbour Tunnel)

Lugeon Value	Cumulative length of Borehole Tested
0.01 or less	194
0.5	24
1	6
25 or greater	12

The geometric mean of the data summarised in Table 2 is a Lugeon value of 0.02. This equates to a permeability value of about 2×10^{-7} cm/s which is a very low value. However, the fact that Lugeon values of 25 or greater are occasionally encountered is consistent with observations in some shafts and declines through the Hawkesbury in the Appin/Tahmoor area where quite high localised flows were encountered. It is also consistent with the zone of total water loss in Boreholes 3 and 6 as discussed above.

3.4 Cut-and-cover Tunnel

The cut-and-cover tunnel will extend from the eastern driven tunnel portal east of Nanny Goat Hill, beneath Wolli Creek to a portal on the eastern side of Wolli Creek. The EIS states that construction of this portion of the route would be as follows:

> *The first stage would commence with the construction of temporary fences, soil erosion and sediment control measures and the installation of a dewatering system to keep the excavation dry. Thereafter, excavation for the cutting and construction of retaining walls and creek levees (in the area to remain as an open cutting) and the first section of the cut-and-cover tunnel would be undertaken.*
>
> *Stage Two of the eastern portal works would require diversion of Wolli Creek to a temporary channel excavated to the west of the existing creek alignment. The temporary channel would be lined with rock, sprayed concrete or other suitable material to prevent erosion. Construction of the tunnel would proceed in a similar manner to Stage One. The final work in Stage Two would be restoration of Wolli Creek to its former course. The restored creek would be constructed, lined and landscaped to conform to its present state.*

A temporary bridge over Wolli creek would be required for Stage Three, initially to provide access for preparatory works and excavation of the upper portion. Work would proceed in a similar manner to the earlier stages, with the additional requirement to construct an air intake structure. The temporary bridge would again be required in the closing stages of the work to transport backfill material and to provide access for restoration and landscaping.

The two boreholes drilled in this area (PSM1 and PSM2 in Appendix A) show that the profile on the western side of Wolli Creek comprises:

- about 7m of silty sand, overlying
- about 1m of sand overlying
- about 2.5m of clay which in turn overlies sandstone bedrock at 12m.

and on the eastern side comprises:

- about 6m of silty sand, overlying
- about 2.5m of sand, overlying
- about 2.5m of silty sand which overlies clay and sandy clay to at least 20m.

Groundwater levels in both boreholes were are a depth of about 2m which corresponds to the water level in Wolli Creek.

A sample of groundwater was obtained from Borehole PSM1 after first purging the borehole using a Watera inertial pump. Results of analysis of this sample are given in Table 3.

Table 3 Results of Analysis	
pH	5.5
Conductivity	520 μS/cm
Sodium	110 mg/L
Potassium	6.3
Calcium	4.8
Magnesium	8.2
Chloride	170
Bicarbonate	38
Sulphate	31
Nitrate	0.1
Dissolved iron	0.15

The results indicate a low salinity sodium-chloride groundwater. The salinity, ionic balance and relatively low (acidic) pH are typical of sand and sandstone groundwaters in this area, the low pH reflects the lack of neutralising capacity in the aquifer for carbonic and humic acids derived from the soil zone. The chloride/sulphate molar ratio of about 14:1 does not indicate the presence of sulphate derived from pyrite oxidation.

The only horizon of significant permeability is the sand layer noted in both boreholes at about 8m. It is postulated that this comprises a continuous unconfined aquifer. However, while the sand is medium to coarse grained it does contain some silt and therefore probably has a permeability in the range 10^{-3} to 10^{-2} cm/sec. Based on the vertical alignment given in the EIS the cut-and-cover excavation will extend below the sand aquifer horizon. It is anticipated that a continuous cutoff using sheet piles or a slurry trench wall will be required to prevent significant inflows from this sand layer into the excavation.

3.5 Eastern Portal to General Holmes Drive

From the Cut-and-Cover portal on the eastern side of Wolli Creek there will be a short length of open cut (about 250m) before the route takes off on a viaduct as far as Marsh Street. The short length of open cut will be in the same hydrogeological profile as set out in the Section 3.4. The hydrogeological profile beneath the viaduct is not of relevance because apart from temporary excavations for footings or piles there will be no interference with the groundwater regime.

Beyond Marsh Street the route traverses part of the Botany sand aquifer.

This area lies on the western edge of the Botany Sands Aquifer. The sands here are of alluvial origin, and have a generally lower hydraulic conductivity than the aeolean sands further east. Values derived from pumping tests lie in the range 1.4×10^{-2} to 2.0×10^{-2} cm/s, and a value recently derived by model calibration (Merrick 1994) for this part of the aquifer was 1.6×10^{-2} cm/s. Thickness ranges form 1-15m and the stratigraphy comprises minor discontinuous peat beds interbedded with fine-medium sands. Shallow groundwater discharges into the Cooks River, while deeper regional flow is to the south to Botany Bay.

Although of low salinity and formerly of good potable quality, the Botany Sands Aquifer has become increasingly polluted, leading to abandonment of many production boreholes. The remaining 28 industrial abstractions are concentrated in the eastern part of the aquifer, and the only abstractions in the area of concern are for irrigation.

Samples taken from areas adjacent to the proposed motorway route indicate sands and silty sands and gravelly sands extending from the surface to a depth of at least 3m. As the water table generally lies at a depth of less than 2m this indicates a high vulnerability to surface-derived pollution.

4. IMPACT OF TUNNELLING ON GROUNDWATER SYSTEM

In accordance with the permeability data discussed above and previous experience with tunnels in the Hawkesbury Sandstone it is expected that very low inflows will be encountered along the tunnel over most of its length. However, the total water loss encountered in boreholes 3 and 6 indicates that some zones of high inflow may be encountered. If such flows are greater than about 4 1/s and are sustained, then grouting may be necessary to limit long term seepage.

It is estimated that total sustained seepage into the driven tunnel will be in the range 2 to 10 l/s. This will have a localised effect on the groundwater regime within the sandstone. However, it will have no effect on the surface and groundwater regime within Wolli Creek.

Water quality in the Hawkesbury Sandstone is typically good and it is unlikely that seepage water into the tunnel would have to be treated prior to discharge into the stormwater system.

5 SPILLAGE OF TOXIC MATERIAL

5.1 Impact on the Groundwater System

5.1.1 King Georges Road to Bonalbo Street

Given the absence of beneficial use of groundwater in this area, the high salinity of the Ashfield Shale groundwaters and the generally low hydraulic conductivity of the Shale and overlying residual soils, there would be no risk to groundwater resources resulting from spills of toxic chemicals in this area.

The main risk identified relates to seepage of spilled material to Wolli Creek via superficial fill deposits. This risk is essentially of the same order as that associated with direct surface spillage to the creek, except that there would be some attenuation of peak contaminant loadings, and longer duration inflow.

5.1.2 Bonalbo Street to Eastern Portal, including Tunnel Section

Whilst the Hawkesbury Sandstone groundwater if of better quality than that in the Ashfield Shale, there is still no beneficial use in this area. Given the low intergranular hydraulic conductivity of the sandstone, it is anticipated that there would be little direct infiltration of spillages, and a high proportion of any spill (either on the surface or in the tunnel sections) would enter the surface drainage system. The risk to groundwater resources from spillage in these areas is therefore also assessed as low.

5.1.3 Cut-and-Cover Tunnel

The cut-and-cover tunnel will be excavated through alluvial sands of relatively high hydraulic conductivity. It is likely that there is hydraulic continuity between these alluvial deposits and Wolli Creek. However, construction of the tunnel should isolate spillages from the groundwater regime.

Although the groundwater in the alluvial deposits is of good quality, there is no known beneficial use. Thus the primary environmental risk associated with spillage in this tunnel section is of transport of contaminants via the seepage discharge system possibly to Wolli Creek.

5.1.4 Eastern Portal to General Holmes Drive

This section of the route crosses the Botany Sands Aquifer. As indicated in Section 3.5, this aquifer is very vulnerable to surface derived pollution. Some beneficial use is made of groundwater from this aquifer, and there is flow of groundwater to the Cooks River and Botany Bay.

There is a high risk that a major spillage of toxic materials or hydrocarbon fuels on this section of the motorway would result in groundwater contamination. Impact would be limited by the nature of the beneficial use (irrigation only), and the availability of alternative sources of water.

5.2 Remedial Action Plan

This RAP is restricted to the Cut-and-Cover and Eastern Sections only.

5.2.1 Cut-and-Cover Section

The primary requirement is for a tunnel drainage system which segregates spillages in the tunnel form the underlying alluvium, and provides sufficient volume of retention storage to contain any likely spillage volume prior to discharge to surface drainage. A drainage system of this type will in any case be needed to restrict groundwater inflow to the tunnel, as the tunnel invert will below the water table in the alluvial sands.

5.2.2 Botany Sands

A Remedial Action Plan to address spillage onto the Botany Sands must include:

- measures for assessment of the migration and fate of spillage and washdown water
- procedures for rapidly assessing the hazard associated with any particular spillage

i.e. - toxicity/hazard potential of spilled material
- volume spilled

- a decision mechanism to assess the need for remedial action and implement such action

- a contingency strategy for rapid implementation of contamination recovery.

An appropriate decision tree is shown in Figure 3.

A groundwater flow model for this part of the Botany Sands was developed to assist with planning of the Third Runway Works (Merrick 1994). This could be developed for use in remediation planning.

Given the characteristics of the superficial sands and the shallow water table in this area, either trench drains or spear points could be used for contaminant recovery. Both would be likely to produce a substantial volume for contaminated groundwater; contingency arrangements for treatment and/or disposal of this groundwater should be specified.

6. EROSION HAZARD

An assessment of erosion hazard for soils in the King Georges road to Bexley Road sector has been made and is detailed in Table 6.1. Laboratory test results are presented in detail in Appendices C and D, and Soils Maps in Appendix E.

The site is generally in Soil Loss Class 1, indicating a computed soil loss of less than 300 tonnes/ha; Some steeper slopes may be in Class 2 indicating a computed loss of 300-900 tonne/ha without conservation techniques.

The Emerson class provides a further input factor to soil erodibility. Highly dispersive (Class 1) and moderately dispersive (Class 2) soils are substantially more erodible. This should be considered where soil loss classification are borderline.

Where soils are dispersive, gypsum flocculation of retention basins is likely to be required.

Appropriate erosion and sediment controls must be specified in the soil and water management plan for these areas.

TABLE 6.1
SOIL EROSION HAZARD*

Sector	Geology	Soil Landscape	Samples PSM	USCS Class	K	Slope	Soil Loss Class	Emerson Class
King Georges Rd Kirrang St	Ashfield	Blacktown	5	CL	0.038	5-8%	1-2	2
			6	ML	0.05			5
			7	CH	0.03			5
Kirrang St - Armitree St	Ashfield Shale	Birrong Extensive areas of fill	8	CL	0.047	<1	1	6
			9	CL	0.047			5
			10	CL	0.06			5
Armitree St - Bonalbo St	Ashfield Shale	Mainly fill	11	CH	N/A	1%	1	6
			12	CH	N/A			2
			13	CH	N/A			5
			14	CH	N/A	3-5%	1	5
			15	CH	N/A			5
			16	CH	N/A			5
Bonalbo St - Bexley Rd	Hawkesbury Sandstone	Gymea	17	SM	0.022	5-10%	1-2	3
			18	SC	0.034			5
			19	SM	0.022			3
Turrella	Alluvium/ Hawkesbury Sandstone	Birrong	1	SM	0.02	1%	1	4
			1	SC	0.031			1
			2	SM	0.02			5
			2	SM	0.02			5
Marsh St - General Holmes Drive	Botany Sands	Warriewood Warriewood/ Fill	22	SM	0.015	<1%	1	8
			23	SP	0.018			6
			24	SM	0.015			6
			25	SP	0.018			4

*Based on a 2 year ARI 6 hour storm of 12.6mm and an R value of 3500

7. POTENTIAL ACIDIC (ACID SULPHATE) SOILS

On the basis of topography, elevation and likely depositional history, it was assessed that acid-sulphate soils might be present in three areas along the proposed motorway route. These are:

(a) the crossing of Salt-pan Creek

(b) the deeper sediments of Wolli Creek which will be excavated during construction of the cut-and-cover tunnel west of Turrella

(c) the estuarine sediments to be crossed by the embankment section between Marsh Street and the Cooks River.

To further assess these areas, soil samples were obtained from:

- hand auger holes on each bank of Salt-pan Creek (2)

- two boreholes north-west of Turrella Station (5)
- three hand-auger holes east of Marsh Street (3)
- three hand-auger holes north of General Holmes Drive (3)

and submitted for laboratory analysis for pH, conductivity, total actual acidity and total potential acidity. Results are given in Table 7.1.

TABLE 7.1
Results of Laboratory Testing for Potential Acid-Sulphate Soils

Borehole	Location	Depth (m)	Soil Type	pH (units)	EC μS/cm	TAA M/Kg	TPA M/Kg
PSM3	Salt pan Creek	0.9	grey-brown, soft wet silty CLAY	6.3	1280	<0.01	0.50
PSM4	Salt-pan Creek	0.9	dark grey, soft, wet CLAY with some silt	6.6	2140	<0.01	0.65
PSM1	Turrella	6.2	dark grey, very soft clayey SAND	4.9	205	<0.01	0.34
PSM1	Turrella	9.85	grey sandy CLAY	6.2	200	<0.01	0.19
PSM2	Turrella	4.0	dark grey, soft clayey SAND	4.6	180	<0.01	0.34
PSM2	Turrella	10.25	dark grey, soft, wet clayey SAND	6.0	350	<0.01	0.18
PSM2	Turrella	12.05	light grey, soft wet CLAY with some sand	6.8	290	<0.01	0.01
PSM20	Marsh Street	0.8	grey moist SAND with some CLAY	6.8	1310	<0.01	0.12
PSM21	Marsh Street	0.7	brown moist SAND, some clay	6.3	87	<0.01	<0.01
PSM22	Golf Course	1.3-2.0	SAND (black)	5.3	260	<0.01	0.07
PSM23	Sydney Airport	1.3-2.0	fine SAND	6.4	360	<0.01	<0.01
PSM24	Sydney Airport	1.3-2-0	SILTY sand	6.3	30	<0.01	<0.01

From Table 7.1 it can be seen that, as is usual in this area, all the soils have acid pH but low total actual acidity. Potential acidities are however generally high.

pH is measured electrochemically on a 1:5 suspension of soil in water and is defined as the negative logarithm of the molar hydrogen ion activity. As the ionic product of water = $[H+][OH] = 10^{-14}$, pH values below 7 indicate a preponderance of hydrogen ions and are considered acidic. Thus a pH value of 4.6 (eg, PSM2) indicates acidic conditions and a hydrogen ion activity of 2.51×10^{-5} moles/litre in the suspension or 1.25×10^{-4} moles/kg in the soil.

Both the RTA (White & Melville 1993) and EPA (Naylor 1993) recommend the use of the relationship (Total Potential Acidity - total Actual Acidity) as a measure of the acid generation capacity of sulphidic soils.

Total actual acidity (TAA) is measured by titration of a known mass of soil against a standard sodium hydroxide solution. It is a gross measure of the mass of acid present, and may be used to calculate the mass of base required for neutralisation. A TAA of 0.01 (the limit of measurement) implies a hydrogen ion concentration of 1 x 10^{-2} moles/kg in the soil.

Total potential acidity (TPA) is measured by first oxidising all reduced sulphur species (principally sulphides) in the soil with hydrogen peroxide, then titrating of a known mass of soil against the standard sodium hydroxide solution. It is a gross measure of the total mass of acid which might be generated over time if the soil were allowed to oxidise naturally, and may be used to calculate the mass of base ultimately required for neutralisation. A TPA of 0.12 moles/kg implies a hydrogen ion concentration of 1.2 x 10^{-1} moles/kg in the soil. 1 mole of reduced sulphur will generate 2 moles of H^+ (Dent & Bowman 1993); the molar weight of sulphur is 32g, thus a TPA of 0.12 moles/kg is equivalent to a reduced sulphur concentration of 1.92 g/kg or approximately 0.2%.

Naylor indicates that levels of pyrite sulphur greater than 0.2% in clayey sediments, and greater than 0.05% in sandy sediments may cause a significant acid sulphate hazard. Thus, as a guide, clayey soils in which TPA (total potential acidity) minus TAA (total actual acidity) is greater than 0.12 moles/kg, and sandy soils in which TPA minus TAA is greater than 0.03 moles/kg may cause environmental problems due to pyrite oxidation, acid generation in excess of available neutralising capacity, and aluminium solubilisation.

The implications of the results given in Table 7.1 is that, in accordance with current EPA draft guidelines, it will be necessary to prepare an acid sulphate soil management plan for these areas.

This would include:

- provision for further sampling and analysis of soils during the early stages of construction
- plans for management of soil stockpiles and for treatment and discharge of acidic leachate
- a focussed monitoring program for water quality in both surface and groundwater
- contingency procedures to be implemented in case of failure of the proposed management plan.

For and on behalf of
PELLS SULLIVAN MEYNINK PTY LTD
C M JEWELL AND ASSOCIATES PTY LTD

P. Pells

P.J.N. PELLS

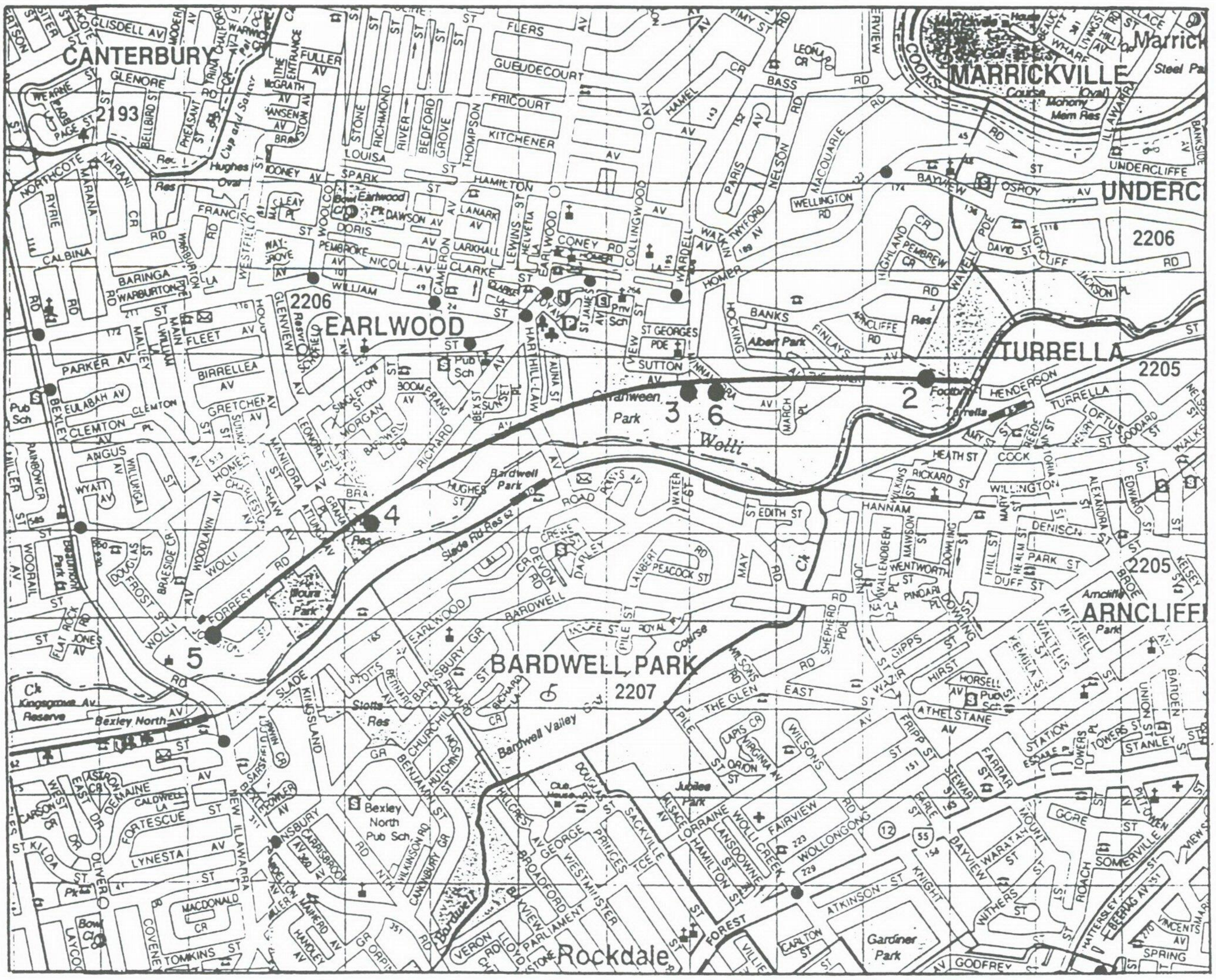
REFERENCES

Dent D.L. and G.M. Bowman 1993. *Definition and Quantitative Assessment of the Acid Sulphate Hazard for Planning and Environmental Management.* 1st Aust. Conf. Acid sulphate Soils, Coolangatta.

Merrick 1993. *A Groundwater Flow Model of the Botany Basin.* Water Down Under conference, Adelaide.

Naylor 1993. *Draft Environmental Guidelines for the Assessment and Management of Coastal Land Developments in Areas of Acid Sulphate soils.* NSW EPA.

White & Melville 1993. *Treatment and Containment of Potential Acid sulphate Soils.* CSIRO Centre for Environmental Mechanics - Report to the Roads and Traffic Authority.

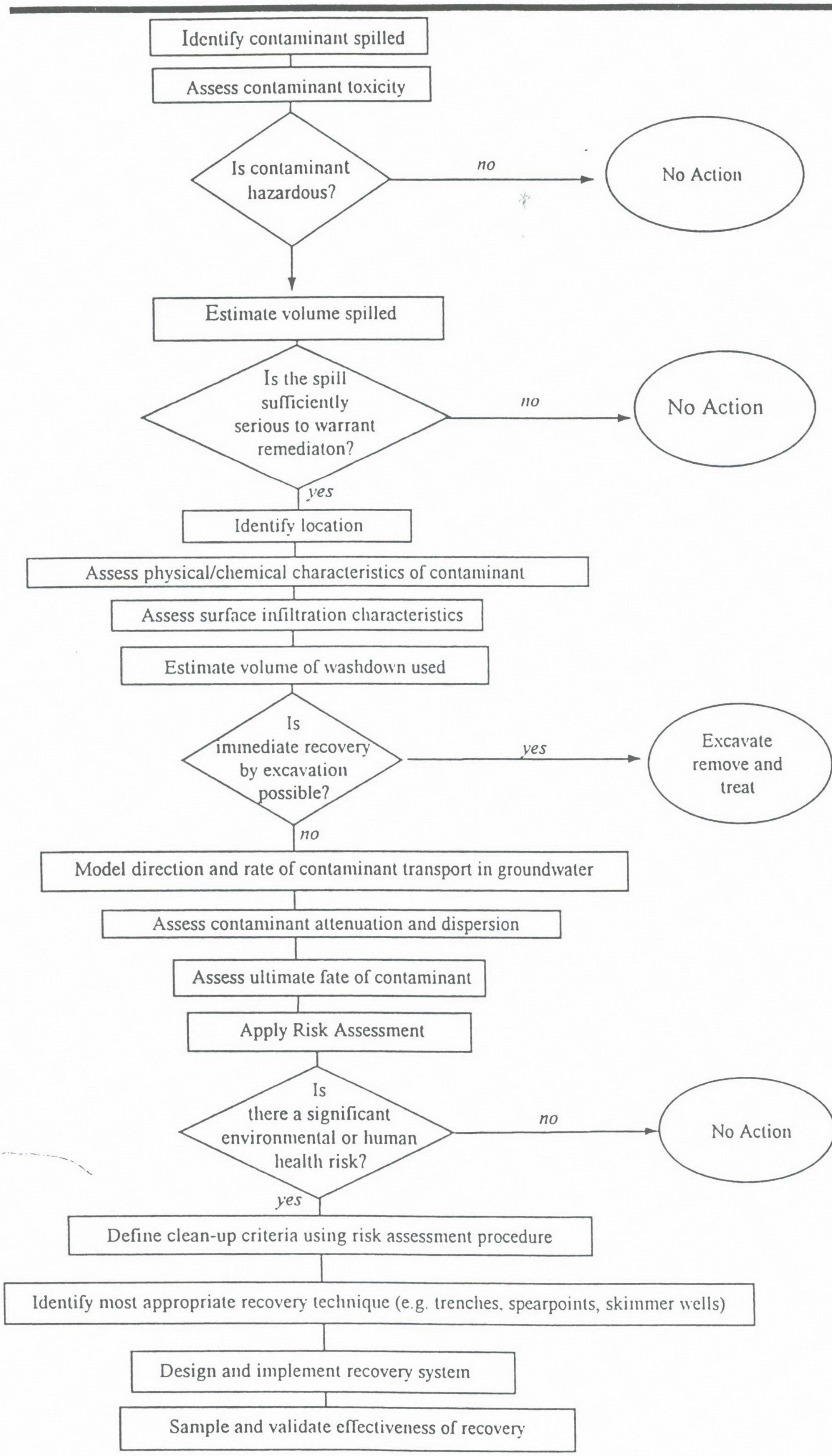


CONNELL WAGNER
M5 EAST EXTENSION

LOCATION PLAN OF CORED BOREHOLES
IN THE TUNNEL SECTION

Pells Sullivan Meynink Pty Ltd | PSM 124 | Figure 2

Figure 3
Contaminant Spill Remedial Action Decision Tree



APPENDIX A

Borehole Logs

SM **Pells Sullivan Meynink Pty Ltd**

Engineering Consultants
Rock-Soil-Water

A C N 061447621

Borehole Log

Hole No: PSM 1
Sheet 1 of 1
Logged by: TRJ

no: PSM 124	borehole location:
t: Connel Wagner Pty	slope/bearing:
ect: M5 Motorway Extension	surface R.L.:
ng subcontractor: Herrick & Dal Santo	datum:
hole complete: 14/2/95	core diameter:
information: Truck Mounted Rig	

Testing	Water	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering (E, H, M, S, F)	Estimated strength (EL, VL, L, M, H, VH, EH)	Point Load Is (50) MPa	RQD (%) (20, 40, 60, 80, 100)	Defect Description/Comment
			0		FILL:Dark brown silty sand, some ash content					
A	14/2 ▽		1, 2, 3, 4, 5, 6, 7		Silty SAND:sand fine to medium grained; dark brown/black; some clay and medium gravel. Medium plasticity at top, becoming non-plastic with depth					
B										
C										dark grey water return
			8		SAND: fine to medium/coarse grained. Some silt					light grey water return
D			9, 10		Silty CLAY: high plasticity; dark grey/orange brown; trace of fine/ medium grained sand.					dark grey/brown water return
E										
			11		Sandy SILT; numerous wood fragments					grey water return
			12		SANDSTONE (?)					orange/brown water return with sandstone fragments
					borehole terminated at 12.9m					

Pells Sullivan Meynink Pty Ltd

Engineering Consultants
Rock-Soil-Water

A.C.N. 061447621

Borehole Log

Hole No: PSM 2
Sheet 1 of 2
Logged by: TRJ

no: PSM 124
nt: Connel Wagner Pty
ject: M5 Motorway Extension
ing subcontractor: Herrick & Dal Santo
e hole complete: 15/2/95
information: Truck Mounted Rig

borehole location:
slope/bearing:
surface R.L.:
datum:
core diameter:

Testing	Water	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering (E H M S F)	Estimated strength (EL VL L M H VH EH)	Point Load Is (50) MPa	RQD (%) (20 40 60 80 100)	Defect Description/Comment
			0–0.6		TOPSOIL; dark brown/black, soft, moist silty sand					
F	15/2 ▽ (~2.0 m)		0.6–6.1		Silty SAND; sand fine to medium grained, dark grey, wet, some clay and fine gravel. Slight/moderate plasticity					
G										
H			6.1–8.5		SAND; light grey, fine to medium/coarse grained. Some silt					
I			8.5–11.0		Silty SAND; as above (?)					dark grey water return
J										
			11.0–12.5		Sandy SILT; numerous wood fragments					light grey water return; numerous wood fragments
K			12.5–		Silty CLAY; grey, some fine/medium sand. Highly plastic					

SM

Pells Sullivan Meynink Pty Ltd

Engineering Consultants
Rock-Soil-Water

A.C.N. 081447821

Borehole Log

Hole No: PSM 2
Sheet 2 of 2
Logged by: TRJ

no: PSM 124
nt: Connel Wagner Pty
ject: M5 Motorway Extension
ing subcontractor: Herrick & Dal Santo
e hole complete: 15/2/95
information: Truck Mounted Rig

borehole location:
slope/bearing:
surface R.L.:
datum:
core diameter:

Testing	Water	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering (E H M S F)	Estimated strength (EL VL L M H VH EH)	Point Load Is (50) MPa	RQD (%) (20 40 60 80 100)	Defect Description/Comment
			14.2		Sandy CLAY; some sand horizons					orange to brown water return; fine to medium sand in return at various intervals
			15.2							
			16.2							
			17.2							
			18.2							
			19.2							
			20.2		borehole terminated at 20.15m					
			21.2							
			22.2							
			23.2							
			24.2							
			25.2							

APPENDIX B

Table of Sample Locations

LOCATIONS

Sample Identification	Borehole (PSM)	Depth (m)	Type
A	1	1.6	SPT
B	1	4	SPT
C	1	6.2	SPT
D	1	8.5	SPT
E	1	9.85	Tube
F	2	1.5	SPT
G	2	4	SPT
H	2	6	SPT
I	2	8	SPT
J	2	10.25	SPT
K	2	12.05	SPT
L	3	0.9	hand auger
M	4	0.9	hand auger
N	5	0.3	hand auger
O	6	0.5	hand auger
P	7	0.7	hand auger
Q	8	0.7	hand auger
R	9	0.5	hand auger
S	10	0.4	hand auger
T	11	0.6	hand auger
U	12	0.6	hand auger
V	13	0.6	hand auger
U	14	0.7	hand auger
W	15	0.5	hand auger
X	16	0.6	hand auger
Y	17	0.5	hand auger
Z	18	0.5	hand auger
AA	19	0.4	hand auger
AB	20	0.8	hand auger
AC	21	0.7	hand auger
AI	22	0.8-1.3	hand auger
AJ	22	1.3-2.0	hand auger
AD	23	0.5-1.3	hand auger
AE	23	1.3-2.0	hand auger
AF	24	0.3-1.0	hand auger
AG	24	1.3-2.0	hand auger
AH	25	0.3-0.8	hand auger

APPENDIX C

Soil Classification and Results of Erosion Crumb Tests

Ref No : L271EJ
Table A: Page 1 of 4
Report No: 1

TABLE A
SUMMARY OF EMERSON CLASS NUMBER TEST RESULTS
(YOUR JOB NUMBER: PSM124)

SAMPLE	Air dried soil crumbs in water	Remoulded soil samples in water	Contact with hydrochloric acid	1:5 Soil/water suspension	Emerson class number
SA A	Slaking No dispersion	No dispersion	Reaction	NA	4
SA AA	Slaking No dispersion	Dispersion	NA	NA	3
SA B	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5
SA D	Slaking Strong dispersion	NA	NA	NA	1
SA F	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5
SA H	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5

TABLE A

SUMMARY OF EMERSON CLASS NUMBER TEST RESULTS

(YOUR JOB NUMBER: PSM124)

SAMPLE	Air dried soil crumbs in water	Remoulded soil samples in water	Contact with hydrochloric acid	1:5 Soil/water suspension	Emerson class number
SA I	*	No dispersion	No reaction	Flocculation	6
SA N	Slaking Slight dispersion	NA	NA	NA	2
SA O	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5
SA P	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5
SA Q	Slaking No dispersion	No dispersion	No reaction	Flocculation	6
SA R	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5

Jeffery and Katauskas Pty Ltd
39 BUFFALO ROAD GLADESVILLE NSW 2111
LAB No 1327

Ngu Toh Ming 1/3/95
Authorised Signature

TABLE A
SUMMARY OF EMERSON CLASS NUMBER TEST RESULTS
(YOUR JOB NUMBER: PSM124)

SAMPLE	Air dried soil crumbs in water	Remoulded soil samples in water	Contact with hydrochloric acid	1:5 Soil/water suspension	Emerson class number
SA S	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5
SA T	Slaking No dispersion	No dispersion	No reaction	Flocculation	6
SA U	Slaking Slight dispersion	NA	NA	NA	2
SA V	Slaking No dispersion	Dispersion	No reaction	Remained dispersed	5
SA W	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5
SA X	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5

Jeffery and Katauskas Pty Ltd
39 BUFFALO ROAD GLADESVILLE NSW 2111

Ngu Toh Ming 1/3/95
Authorised Signature

TABLE A
SUMMARY OF EMERSON CLASS NUMBER TEST RESULTS
(YOUR JOB NUMBER: PSM124)

SAMPLE	Air dried soil crumbs in water	Remoulded soil samples in water	Contact with hydrochloric acid	1:5 Soil/water suspension	Emerson class number
SA Y	Slaking No dispersion	Dispersion	NA	NA	3
SA Z	Slaking No dispersion	No dispersion	No reaction	Remained dispersed	5

NOTES:
- The lowest Emerson Class Number refers to the highest dispersion potential (Range: Class 1 to Class 8).
- The determination of the Emerson Class Number of a soil was completed in accordance with AS1289 C8.1 1980.
- All contact water was distilled water; water temperature was 20°C.
- Water contact time was greater than 5 minutes for all test stages.
- NA: Not applicable.
- *: No soil crumbs between 2-4mm.
- Materials sampled by others & provided on 20.2.95.

Jeffery and Katauskas Pty Ltd
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Ngu Toh Ming 1/3/95
Authorised Signature

C

Ref No : L271BJ
Table A: Page 1 of 1
Report No:2

TABLE A

SUMMARY OF EMERSON CLASS NUMBER TEST RESULTS

(YOUR JOB NUMBER: PSM124)

SAMPLE	DEPTH (m)	Air dried soil crumbs in water	Remoulded soil samples in water	Contact with hydrochloric acid	1:5 Soil/water suspension	Emerson class number
AI PSM 22	0.80 - 1.30	No slaking, no swelling	NA	NA	NA	8
AD PSM 23	0.50 - 1.30	Slaking No dispersion	*	No reaction	Flocculation	6
AF PSM 24	0.30 - 1.00	Slaking No dispersion	*	No reaction	Flocculation	6
AH PSM 25	0.30 - 0.80	Slaking No dispersion	*	Slight reaction	NA	4

NOTES:
- The lowest Emerson Class Number refers to the highest dispersion potential (Range: Class 1 to Class 8).
- The determination of the Emerson Class Number of a soil was completed in accordance with AS1289 C8.1 1980.
- All contact water was distilled water; water temperature was 22°C.
- Water contact time was greater than 5 minutes for all test stages.
- Refer to the Table B for soil descriptions.
- NA: Not applicable.
- *: Remoulded soil sample was unobtainable due to a lack of plastic fines.
- Materials sampled by others and provided on 22.3.95.

Ngu Foh Ming 28.3.95
Authorised Signature

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LAB No. 1327

TABLE B
SUMMARY OF UNIFIED SOIL CLASSIFICATION
(YOUR JOB NUMBER: PSM124)

SA A:	SILTY SAND: Fine to medium grained; black; some medium gravel particles; some high plasticity clay.
SA AA:	SILTY SAND: Fine to medium grained; grey-brown; trace of fine gravel particles.
SA B:	SILTY SAND: Fine to medium grained; dark grey; trace of medium gravel particles.
SA D:	SILTY CLAY: High plasticity; dark grey mottled orange-brown; trace of fine to medium grained sand. M.C. > P.L.
SA F:	SILTY SAND: Fine to medium grained; dark grey; trace of fine gravel particles.
SA H:	SILTY SAND: Fine to medium grained; dark grey; trace of coarse sand.
SA I:	SILTY SAND: Medium to coarse grained; pale grey; trace of fine gravel particles.
SA N:	SILTY GRAVELLY CLAY: Medium to high plasticity; pale grey mottled orange, brown, dark grey; fine to medium gravel particles; trace of root fibres & rootlets; some medium to coarse sand. M.C.> P.L.
SA O:	SANDY SILT: Low plasticity; pale brown; fine sand; trace of coarse sand & fine gravel particles. M.C.< P.L.
SA P:	SILTY CLAY: High plasticity; red-brown mottled orange, grey; trace of fine to medium gravel particles; some medium to coarse sand. M.C.> P.L.
SA Q:	SILTY CLAY: High plasticity; red-brown mottled dark grey, white; trace of coarse sand & fine gravel particles; some fine to medium sand. M.C.> P.L.

TABLE B
SUMMARY OF UNIFIED SOIL CLASSIFICATION
(YOUR JOB NUMBER: PSM124)

SA R:	SILTY CLAY: Medium plasticity; pale grey mottled red, orange, dark grey, yellow; trace of fine sand. M.C.> P.L.
SA S:	SANDY SILT: Low plasticity; grey-brown; fine to medium sand; trace of coarse sand, rootlets & root fibres. M.C.< P.L.
SA T:	SILTY CLAY: High plasticity; brown mottled orange; trace of coarse sand; some fine to medium sand. M.C.> P.L.
SA U:	SILTY CLAY: High plasticity; brown mottled orange, red; some fine to medium sand. M.C.< P.L.
SA V:	SILTY CLAY: High plasticity; brown mottled grey, orange; trace of fine to medium sand. M.C.> P.L.
SA W:	SILTY CLAY: High plasticity; brown mottled red, orange; some medium to coarse sand. M.C.≥ P.L
SA X:	SANDY SILT: Low plasticity; orange-brown; fine to medium grained sand; traces of coarse sand & fine gravel particles. M.C.< P.L.
SA Y:	SILTY SAND: Fine to medium grained; grey-brown; trace of fine gravel particles.
SA Z:	SANDY SILTY CLAY: Medium plasticity; orange-brown mottled pale grey; fine to medium grained sand; traces of coarse sand & fine gravel particles. M.C.≥ P.L.

TABLE B
SUMMARY OF UNIFIED SOIL CLASSIFICATION
(YOUR JOB NUMBER: PSM124)

Borehole	Depth (m)	Unified Classification Description
BH PSM22 SA NO: AI	0.8-1.3	SILTY SAND: Fine to medium grained; dark grey;trace of root fibres.
BH PSM23 SA NO: AD	0.5-1.3	SAND: Fine to medium grained; grey; some silt & slag.
BH PSM24 SA NO: AF	0.3-1.0	SILTY SAND: Fine to medium grained; grey-brown; some fine to medium gravel particles; trace of medium plasticity clay.
BH PSM25 SA NO: AH	0.3-0.8	GRAVELLY SAND: Fine to medium grained; orange brown; some silt; traces of medium plasticity clay & root fibres.

APPENDIX D

Results of Laboratory Tests

(pH, TAA, TPA, conductivity)

APPENDIX D

SYDNEY ANALYTICAL LABORATORIES

Sample No(s)	1:5 pH	μs/Cm Conductivity	Mole/kg TAA	Mole/kg TPA
SPT-C	4.9	205	<0.01	0.34
VT-E	6.2	200	<0.01	0.19
SPT-G	4.6	180	<0.01	0.34
SPT-J	6.0	350	<0.01	0.18
SPT-K	6.8	290	<0.01	0.01
L	6.3	1280	<0.01	0.50
M	6.6	2140	<0.01	0.65
AB	6.8	1310	<0.01	0.12
AC	6.3	87	<0.01	<0.01
AE	6.3	30	<0.01	<0.01
AG	6.4	360	<0.01	<0.01
AJ	5.3	260	0.07	<0.01

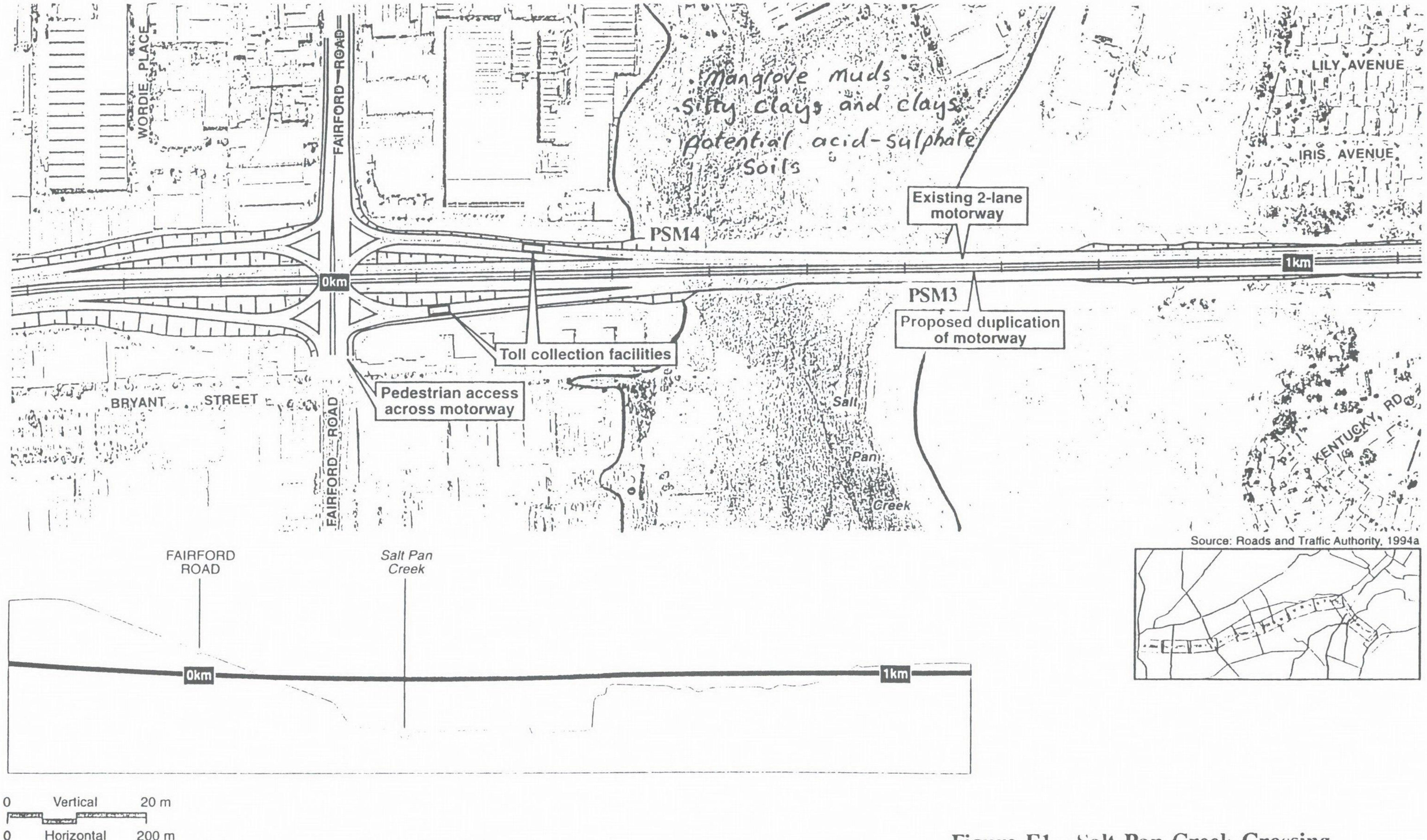


Figure E1 - Salt-Pan Creek Crossing

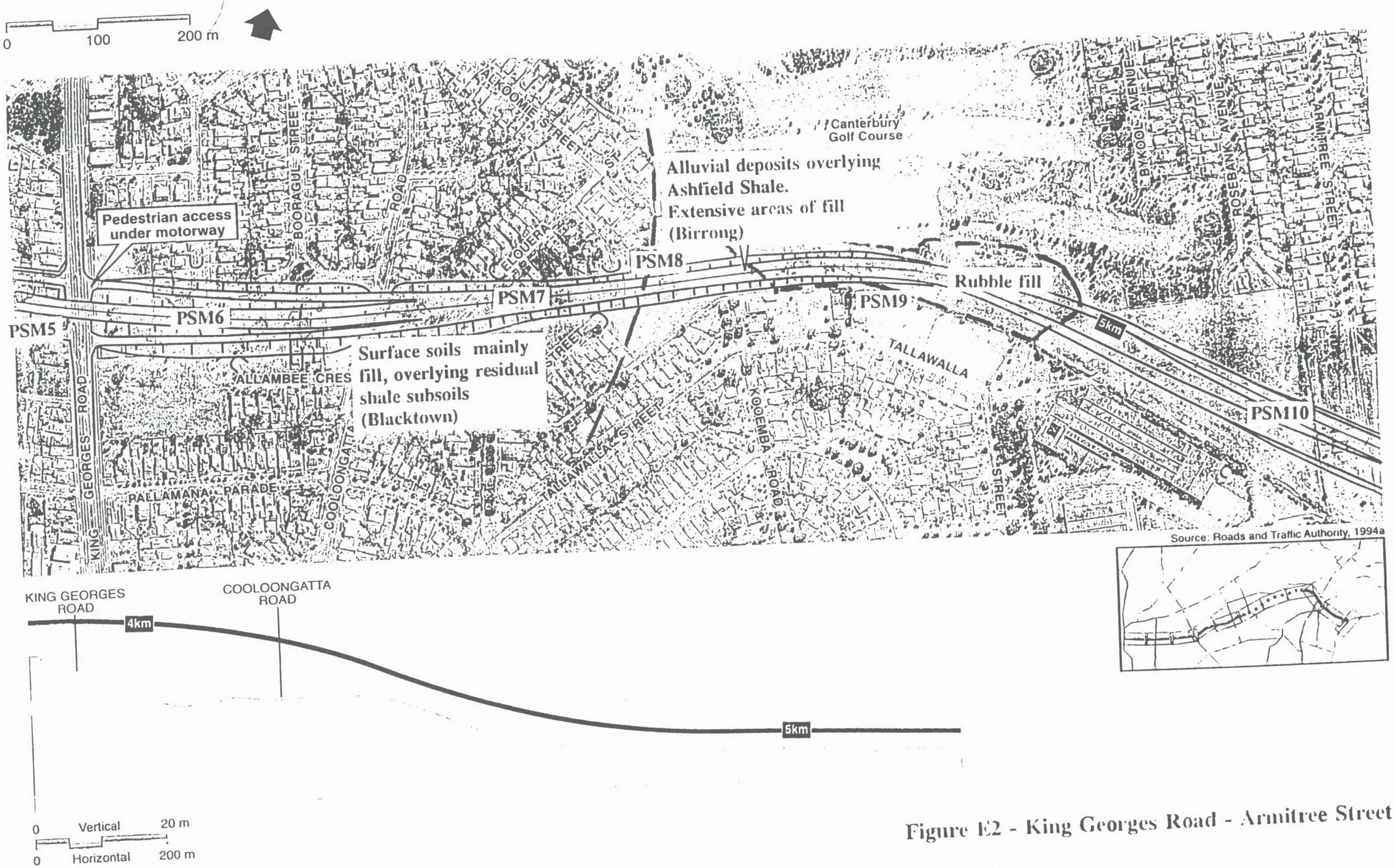


Figure E2 - King Georges Road - Armitree Street

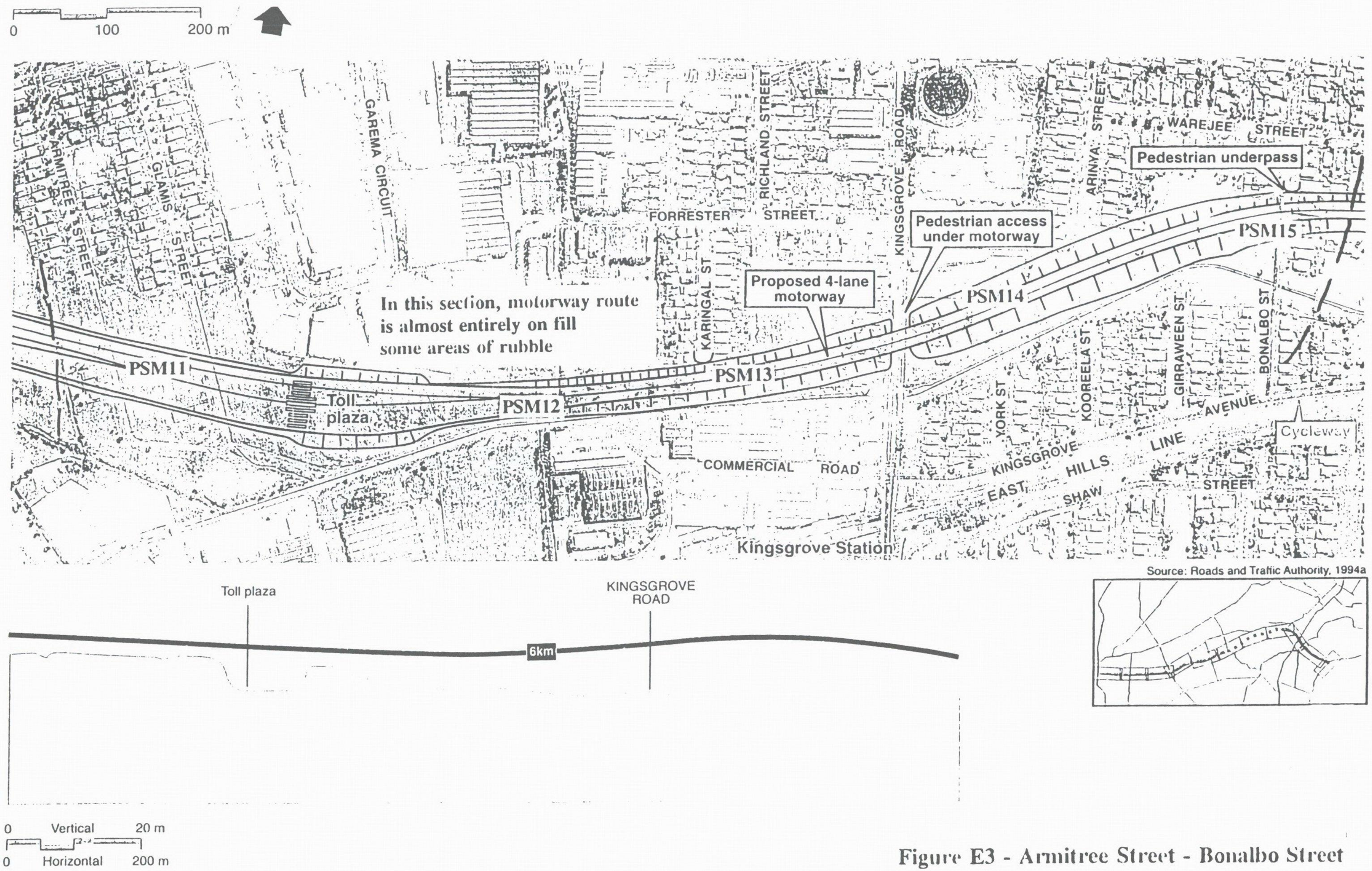


Figure E3 - Armitree Street - Bonalbo Street

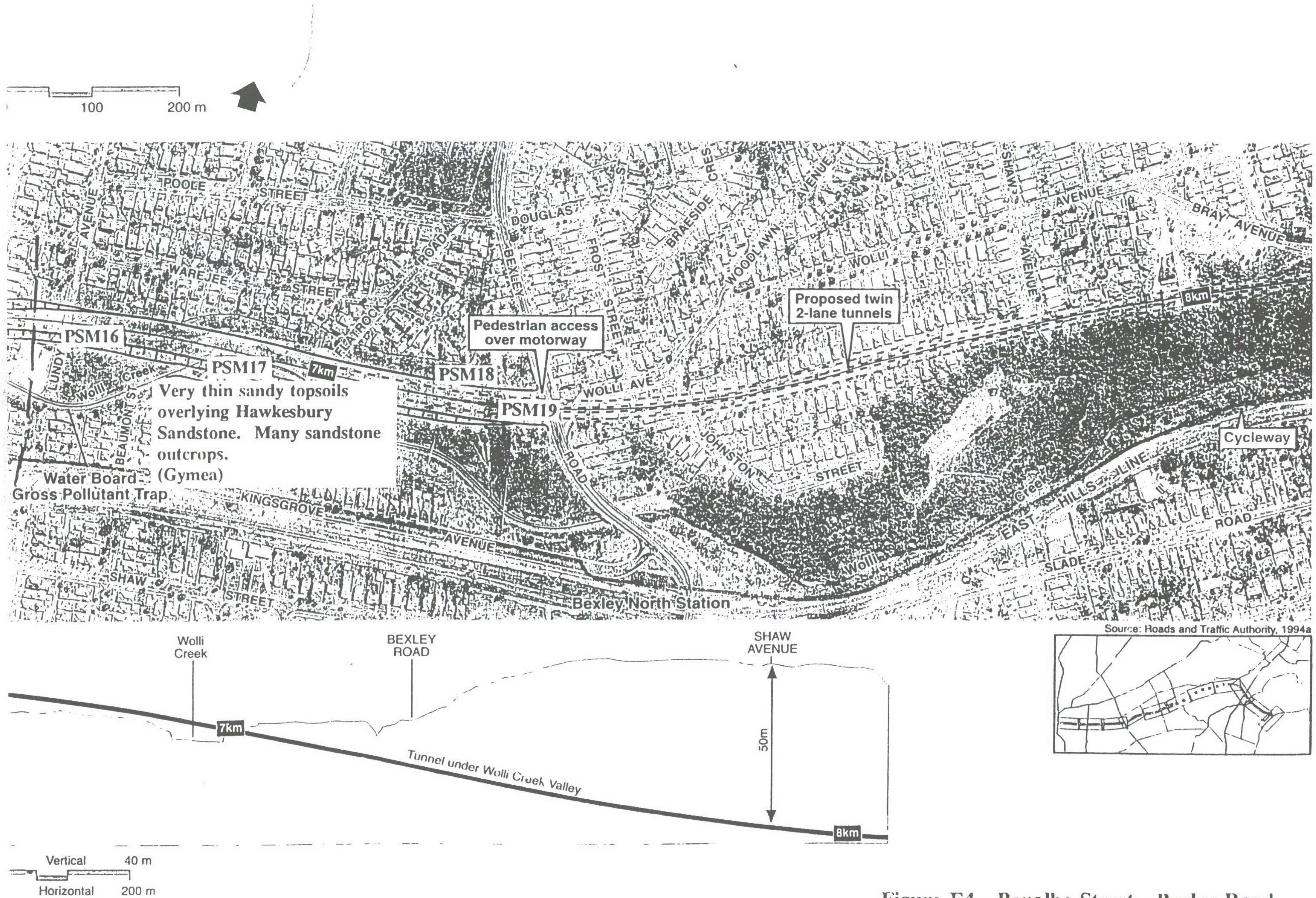
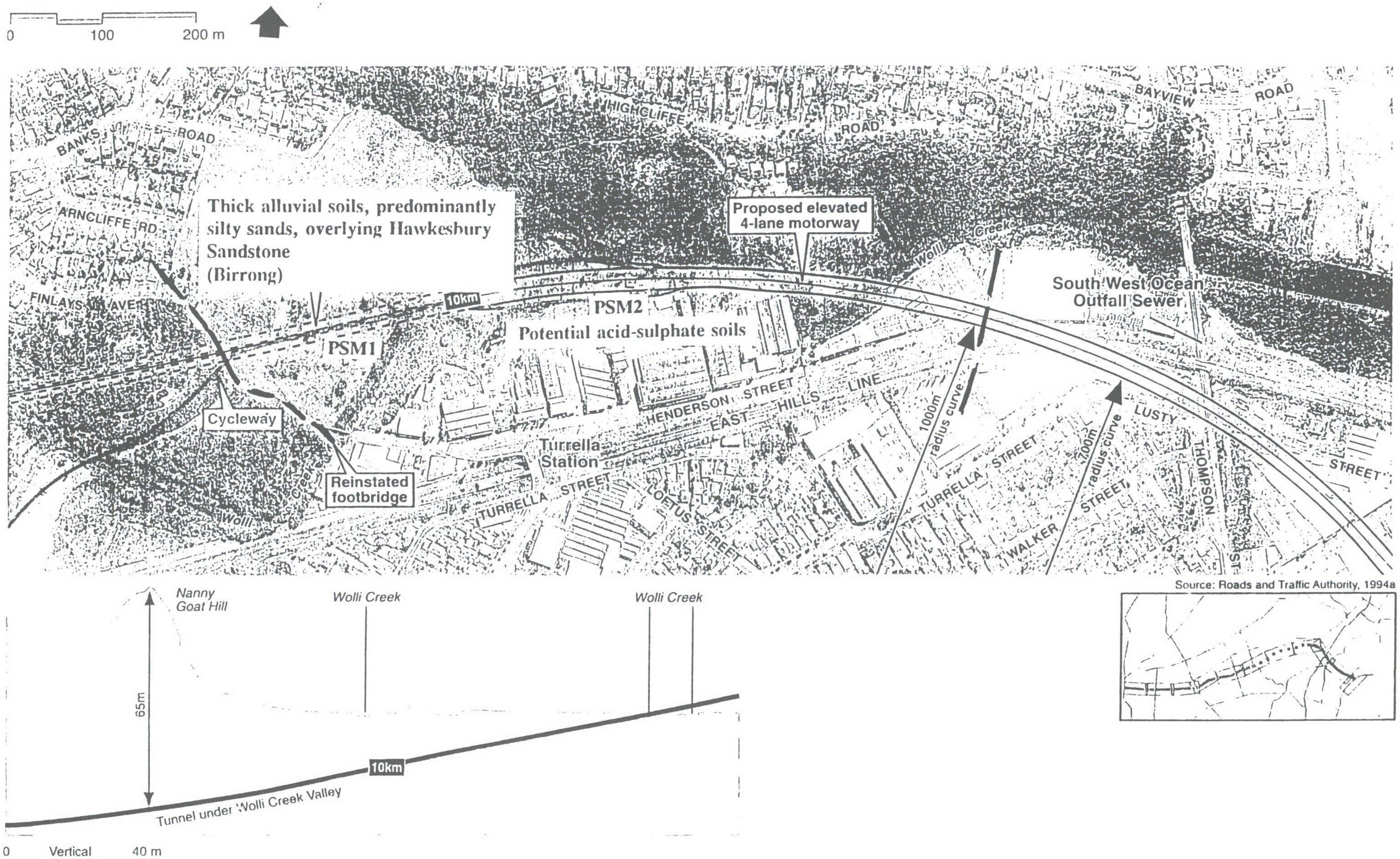


Figure E4 - Bonalbo Street - Bexley Road



0
100
200 m
BANKS ROAD
ARNCLIFFE RD
FINLAYS AVE
HIGHCLIFFE ROAD
BAYVIEW ROAD
Thick alluvial soils, predominantly silty sands, overlying Hawkesbury Sandstone (Birrong)
Proposed elevated 4-lane motorway
Wolli Creek
South West Ocean Outfall Sewer
10km
PSM2
Potential acid-sulphate soils
PSM1
Cycleway
Reinstated footbridge
Turrella Station
HENDERSON STREET
EAST HILLS LINE
TURRELLA STREET
LOFTUS STREET
1000m radius curve
700m radius curve
LUSTY STREET
THOMPSON ST
WALKER STREET
Wolli Creek
Source: Roads and Traffic Authority, 1994a
Nanny Goat Hill
Wolli Creek
Wolli Creek
65m
10km
Tunnel under Wolli Creek Valley
0 Vertical 40 m

gur 5 - rella

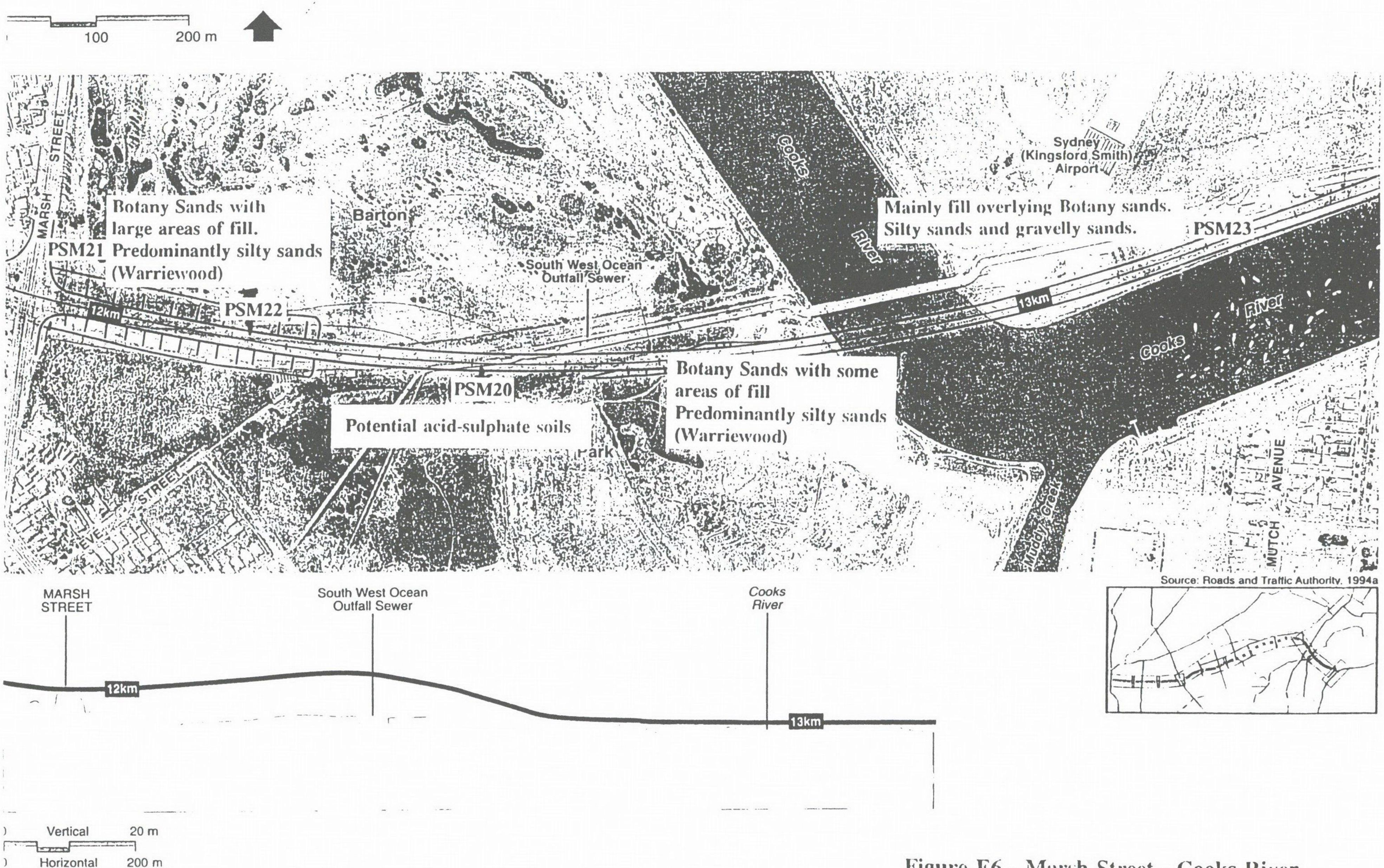
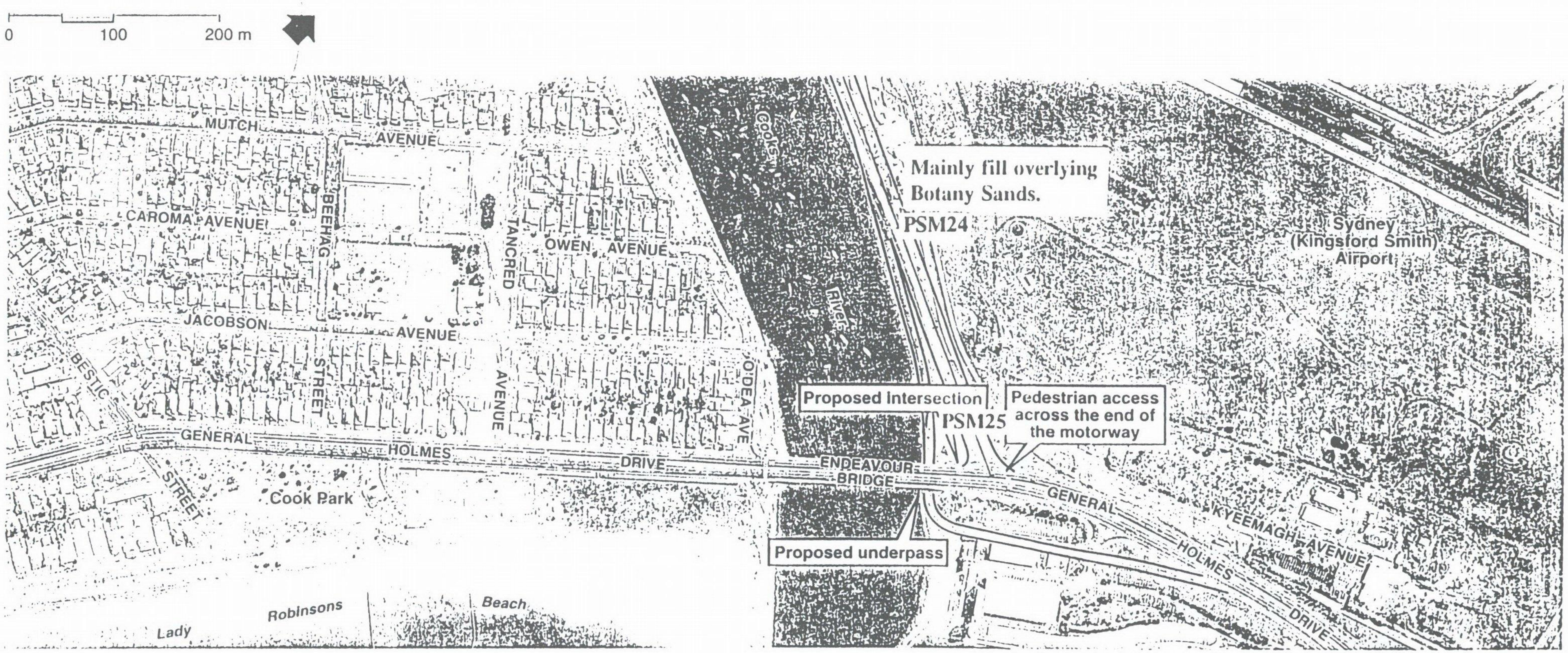
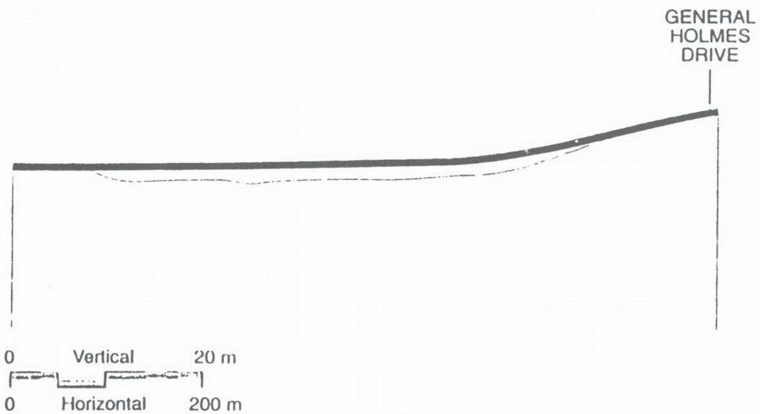


Figure E6 - Marsh Street - Cooks River





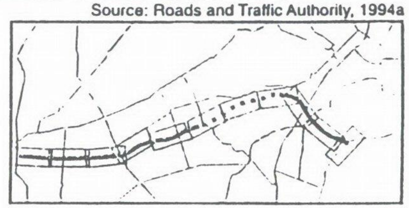


Figure E7 - Cooks River - General Holmes Drive

Roads and Traffic
Authority
Sydney Region

Our Reference: JB/Vea
Mr J Brewer
Telephone: 831 0158

RTA

83 Flushcombe Road
Blacktown
New South Wales 2148
Telephone (02) 831 0911
Facsimile (02) 831 0926
PO Box 558
Blacktown NSW 2148
DX 8120

Mr Richard Weber
Connell Wagner
P O Box 538
NEUTRAL BAY NSW 2089

M5 East EIS.

Dear Mr Weber

I refer to our discussion of 16 January 1995 concerning some additional work required in relation to the M5 East EIS.

Two areas in particular have been raised:

1. The Department of Conservation and Land Management has requested that a soils assessment survey be undertaken which considers the differing soil erodibilities as well as testing for and management of any acid sulphate soils which may be encountered along the corridor.

2. The Department of Water Resources has requested that the Authority address a number of groundwater issues:

   - The impact that a major spillage of toxic material would have on the aquifer system.
   - The need for a remedial action plan to address spillage problems.
   - The effects tunnelling or deep excavation will have on local g[illegible]ater system.
   - The provision of a brief hydr[illegible]ological summary of the aquifer system surrounding the project site.

The letters are annexed for your information..

The Authority wishes to gather data on the matters raised at a level commensurate with the concept design work carried out to date

Would you please forward an outline of work and proposed fee breakdown to address these matters, as on extension of your previous work, by Friday 27 January 1995.

Thank you for your assistance.

Yours sincerely

J D Brewer
Regional Development Manager

17·1·95

(151)

20 AUG 1994
REGIONAL DEVELOPMENT BRANCH

20 SEP 1994
REGIONAL DEVELOPMENT BRANCH

New South Wales Government

Water Resources

The Project Manager, RTA
M5 East Motorway EIS
83 Flushcombe Road
BLACKTOWN NSW 2148
Attention: Mr John Brewer

Telex: 121188
Facsimile: (02) 895 7281
Telephone: (02) 895 6211
Ext: 7441
Contact Name: John Ross
Our Reference: 0075901
[AKW9732#]

16.9.94

Dear Sir/Madam,

EIS - M5 East Motorway

Thank you for inviting the Department of Water Resources (DWR) to comment on the above EIS. The Department has reviewed the relevant documentation and makes the following comments.

General Aquatic and Riparian Environmental Considerations

The EIS is detailed and well structured. The coloured aerial photographs, artist's impressions and diagrams are useful aids in interpreting information presented. Main issues concerning the Department of Water Resources (DWR) are addressed in Parts E, F, G and H.

Possible Permits/Licensing Requirements

The EIS outlines the need for construction type works in or near rivers and creeks in the study site which may require permits or licensing. Some of these are:

(a) reclamation, narrow strip of Cooks River (tidal) up to 6m (p161);

(b) diversion of Wolli creek (non-tidal) to a temporary channel excavated to the west of the existing creek alignment (p190); and

(c) construction of temporary drainage facilities (p192).

More information should should be given on these activities to allow for a more thorough assessment of impacts to the water environment. Further information on (b) and (c) may be obtained from the Regional River Officer, Mr Glen Adamson on (02) 895 7758.

Erosion Controls

A number of activities and measures are outlined in the EIS to mitigate soil erosion, runoff and impacts on water quality. Soil erosion and sediment control measures (division drains, catch drains, sediment traps, hydro-mulching, filter fences, etc.) will be implemented before other works start and will remain during the construction phase (p187 and 335). Also topsoil will be stockpiled in an appropriate location and seeded, and smaller vegetative material will be mulched (p187). The EIS states that no disposal of effluent will be permitted onsite (p336). The Department supports these measures to minimise impact on water quality. It is noted that the EIS anticipates that the extended tunnel option will produce a better net result for water quality (p462).

Wetlands

Estuarine - freshwater wetlands exist within the study area and will be affected to varying degrees by the proposal (pp387-414). Areas to be affected include wetland and riparian vegetation along Wolli Creek, above and below Turrella Weir, and Salt Pan Creek. Turrella Weir (Henderson St) separates the estuarine lower Wolli Creek from the upper freshwater reaches. The DWR would prefer that there be no destruction or adverse impacts to wetland areas or riparian vegetation, but accepts that the proponent has attempted to reduce impacts to acceptable levels by adopting the most appropriate mitigative measures.

Monitoring and Auditing

The Department supports the undertaking of monitoring and auditing as outlined in the EIS (pp481-484), and the preparation of the environmental Management Plan before the works begin (p184).

Hydrogeological Considerations

The M5 Motorway Extension will be built over the Triassic Wianamatta Group shales and siltstones in the west, and Triassic Hawkesbury Sandstone, and Quaternary Alluvium to the east.

Generally, aquifers associated with the Wianamatta Group are regarded as a low potential groundwater resource. However aquifers associated with the Hawkesbury Sandstone and Quaternary Alluvium (Botany sands aquifer) provide an excellent groundwater resource. This is reflected in the distribution of registered groundwater users in the vicinity of the Motorway at its eastern end, where the majority of users obtain water from the Botany sands aquifer.

The Department of Water Resources, as the State's water manager, ensures that the interests of the environment and registered groundwater users are maintained. In this respect, the EIS covering the M5 Motorway Extension has failed to address a number of pertinent groundwater issues. These are:

- the impact that a major spillage of toxic material would have on the aquifer system;
- the need for a remedial action plan to address spillage problems; and
- the effects tunnelling or deep excavation will have on the local groundwater system.

The lining of the sediment traps have not been described in detail. The sediment traps will need to be lined with an impermeable material (ie. Clays, etc) to minimise the risk of heavy metals and liquid pollutants infiltrating into the groundwater system.

Although the EIS has established an elaborate review of surface water issues the proposal should also address groundwater impacts especially in view of the significance of the resource. A brief hydrogeological summary of the aquifer systems surrounding the project site should be provided in the EIS.

Water Quality Matters

In assessing the water quality aspects of the EIS the Department has reached similar conclusions to those of the authors. The 2 main potential water quality impacts of this development are (a) during construction and (b) during operation.

Mitigative measures are proposed to minimise impacts on water quality in local streams during construction (including diversion drains to reduce water flow from external areas onto the site) and the treatment of water leaving the construction site to reduce its sediment load. These are essential during construction, as are measures to reduce pollution from construction plant (eg fuel and oil spills). Effluent from the amenities installed for use during construction is also to be removed.

Operational pollution (post-construction) will result mainly from traffic usage during wet weather owing to runoff from the increased areas of impervious pavement. Methods of dealing with this polluted runoff, including gross pollution traps, sedimentation basins, porous drains, are covered in the EIS, and it will be essential to ensure that adequate numbers and sizes of these are specified in the final design of the motorway.

I trust the above information/comment will be helpful in the furtherance of these important project.

Yours sincerely,

John A. Ross
for J.F. Clarke, Regional Director
Sydney-South Coast

1. → R. Benedet

2. → G. Davis

4.27

NRR.

CALM
SOIL CONSERVATION SERVICE

Level 3
Macquarie Tower
10 Valentine Avenue
Parramatta NSW 2150
PO Box 1416
Parramatta NSW 2124

Phone (02) 895 7503
Fax (02) 895 7501

Office of Economic Development
Premier's Department
Level 28, State Office Block
Phillip Street
Sydney NSW 2000

Our Ref: M243:G40915
Your Ref: 93/0657
Contact: Mr Owen Graham

Attention: Mr GLEN DAVIS

Dear Sir,

M5 EAST MOTORWAY - EIS - REVIEW

I refer to your request for a review of the subject document with regard to issues of relevance to the Soil Conservation Service.

From review of the EIS (Manidis Roberts Consultants) document and the Water Pollution Control Plan 1994B (Willing and Partners) document, there appears to have been confusion in terminology between commentary in these two documents and practices implied and stated in "industry standard" documentation. This particularly relates to entrapment of eroded sediment by sediment trapping devices or structures. Sound site management practices generally ensure that sediment traps are desilted when they reach approximately 60% of total capacity with eroded sediment. This practice maintains their efficiency. The above documents state that "60% entrapment rate is considered acceptable and is in accordance with general practice ....." (Willing & Partners, Section 7.6). Clearly the latter is not correct and appears to be the basis for the abovementioned confusion in terminology.

In addition, the Service recommends that the matters listed below are undertaken prior to any commencement of works.

1) SOILS ASSESSMENT

This is to determine the relative erodibilities of soils, both topsoil and subsoil. In doing so, erosion control (and water quality control) structures can be planned with adequate capacity and correct procedures for routine management. This soils assessment should also test for the presence of acid sulphate soils and describe measures to maintain their integrity or deal with such soils if they become exposed to the atmosphere.

(2) PLANNING

Soil conservation measures should be addressed in an Erosion and Sediment Control Plan(s) for motorway corridor. Clearly control measures are dynamic and depend on the stage of development. Whilst it is acknowledged that many such control measures are discussed in the two documents described above, these should be integrated in an appropriate plan which also acknowledges the fundamental (but not mentioned) principles of progressive revegetation thereby minimising the area of soil exposed to erosion processes and hence a reduced erosion hazard. These matters are fully discussed in the Services "Urban Erosion and Sediment Control" (1992) handbook.

(3) SCS INVOLVEMENT

Effective erosion and sediment control during development is rarely achieved unless adequate monitoring and active liaison is undertaken at all stages of development (planning, construction and maintenance). To this end, the Service will seek involvement in these three phases with the nominated tenderers to help achieve such effective erosion control. Past involvement with the F3 in the early 1990's demonstrates this matter.

Summary

After consideration of the EIS and associated documents, the Service recommends that the above mentioned matters are addressed in the "Clause 64" (or equivalent) document which will be produced subsequent to the EIS. The principal items for listing being:

- that the suggestions that "60% entrapment rate for eroded sediment is acceptable" is amended to state that sediment trapping structures should be regularly maintained and de-silted when they have accumulated 60% of available capacity,

- that erosion and sediment control measures in the planning, construction and maintenance phases of the project are addressed in accordance with the principles and practices described in the Soil Conservation Service's "Urban Erosion and Sediment Control" (1992) handbook,

- that a soils assessment (survey) is undertaken which considers the differing soil erodibilities as well as testing for and management of any acid sulphate soils which may be encountered along the corridor, and

- that the Soil Conservation Service be actively involved in the planning, construction and maintenance phases of the project to offer advice so as to achieve minimisation of erosion and sedimentation.

It should be noted that the Crown Lands Service of this Department (Blacktown Office) will respond separately to this correspondence.

Please do not hesitate to contact the undersigned at the Parramatta Soil Conservation Service Office if you require further information on this matter.

Yours faithfully,

O.P. Graham

O.P. Graham
District Soil Conservationist
PARRAMATTA

27th September, 1994

AN ASSESSMENT OF M5 EAST MOTORWAY CONSTRUCTION AND OPERATIONAL ACTIVITIES ON FISH AND DECAPODS IN WETLAND HABITATS

February 3, 1995

Report Prepared for:

Roads and Traffic Authority
83 Flushcombe Road
Blacktown
NSW 2148

Report Prepared by:

The Ecology Lab Pty Ltd
14/28-34 Roseberry Street
Balgowlah, NSW 2093

AN ASSESSMENT OF M5 EAST MOTORWAY CONSTRUCTION AND OPERATIONAL ACTIVITIES ON FISH AND DECAPODS IN WETLAND HABITATS

Prepared by Sean Connell and Marcus Lincoln Smith

February 3, 1995

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SUMMARY

The Ecology Lab Pty Ltd was commissioned by the Roads and Traffic Authority (RTA) to describe fish and macroinvertebrates within a number of wetland habitats (sections of Salt Pan Creek, Wolli Creek, Cooks River and Barton Park wetlands) as part of an assessment of the potential impacts of construction and operational activities of the M5 Motorway on aquatic ecology in these areas.

With the exception of the Barton Park wetlands, sampling indicated that the creek and river locations provided habitat for a significant number of fish. Salt Pan Creek and Wolli Creek supported habitats, mainly mangrove, thought to be nursery habitats for a number of commercially important fish and prawns. Sampling revealed that large numbers of juvenile fish of economic importance were indeed using this habitat, as well as many adult conspecifics and prawns. None of the fish sampled were considered to be rare, endangered or unique to these locations. We consider, therefore, that although these habitats do not support a unique fauna, **they do support a significant fauna in terms of abundance and commercial value.**

Our investigations indicated that a number of environmental concerns addressed in the M5 East Motorway EIS (Manidis and Roberts, 1994) are unlikely to be of concern for the ecology of fish and decapods. It is unlikely that the operation of the M5 Motorway will affect these biota negatively. Instead, **their habitat may be improved if water quality increases**, as predicted in the EIS. The small scale loss of vegetation is likely to have a negligible effect on these biota. Concerns for fish and macroinvertebrate ecology, however, are associated with the construction phase at Wolli Creek. **Negative impacts may be associated with the diversion of Wolli Creek and possible increases in run-off of pollutants and sediment.**

The diversion of Wolli Creek may block the migratory route of commercially important mullet and prawns. This effect would be negligible if up and downstream sections are isolated for as shorter time period as practically possible (maximum of a few days). Of greatest concern, however, is that mitigative measures associated with water quality would only prevent 60% of sediment export from the Wolli Creek construction site (Willings and Partners, 1994). Unfortunately, without information on the likely amounts of sediment and associated pollutants that may be discharged into Wolli Creek during construction, it is difficult to assess the severity and likelihood of impacts associated with water quality. **It is recommended, therefore, that a monitoring program is implemented** to assess whether construction activities at Wolli Creek have an adverse (or even beneficial) impact on fish and particularly decapods.

1.0 INTRODUCTION

1.1 Background and Aims to the Study

The proposed extension of the South-Western M5 motorway has been identified as one of Sydney's essential corridors for motor-vehicle traffic (Manidis Roberts, 1994). Currently, road and rail systems are close to capacity, resulting in serious problems for the movement of people and freight (Roads and Traffic Authority, 1992). Of particular concern is the movement of freight between Port Botany, Kingsford-Smith Airport and the growing south-western industrial areas (Manidis Roberts, 1994). The intended M5 corridor would facilitate the movement of freight between these terminals and industrial areas more efficiently.

The eastward extension of the South-Western motorway covers significant areas of natural habitat remaining in the Sydney metropolitan area. Large proportions of this habitat include tidal creeks and mangrove wetlands. These wetlands and their potential response to the construction and operation of the motorway have been described in detail in Specialist Working Papers to the Environmental Impact Statement (Manidis and Roberts, 1994). Important issues relating to aquatic ecology were:

(1) The duplication of a two lane bridge at Salt Pan Creek;
(2) The construction and operation of a tunnel and bridge at Wolli Creek;
(3) The construction and operation of motorway adjacent to wetlands at Barton Park;.
(4) The construction of a bridge over the Cooks River.

Following release of the EIS, New South Wales State Fisheries identified the need for an ecological study of fish and aquatic macroinvertebrates within these habitats. The Ecology Lab Pty Limited was commissioned by the Roads and Traffic Authority to address the concerns of NSW Fisheries. This included an assessment of the effects of the proposed motorway and description of measures that the Roads and Traffic Authority could take to minimise any adverse effects on fish and aquatic invertebrates.

Of particular concern was the current distribution of aquatic fauna and how it may be affected by the loss of habitat. To address these issues, The Ecology Lab sampled fish and macroinvertebrates (decapods) within the creeks and wetlands considered by NSW Fisheries to require assessment. The aims of the study may be summarised as follows:

(1) Description of fish, decapods and their habitats in Salt Pan Creek, Wolli Creek, Cooks River and the wetlands of Barton Park.

(2) Determine whether any fish and decapods were rare and endangered fauna in terms of Section 4a EP and A Act.

(3) Assessment of significance and prediction of impacts from construction and operation of the motorway.

(4) Recommendations for mitigation of any significant impacts.

1.2 Review of Existing Information

1.2.1 Fish Habitats

The relationship between aquatic fauna and their habitat is of central importance to their distribution and abundance. Estuarine habitats have been defined as a semi-enclosed body of water which occurs where freshwater meets and mixes with water from the sea (Burchmore *et al.*, 1993). New South Wales wetlands are often characterised by mangrove forests, saltmarshes and soft sand or mud substrata. Although many of these habitats have disappeared or have been modified under urban and industrial development, a significant proportion remain and may be of significant commercial importance to fisheries in New South Wales. The wetlands of Salt Pan and Wolli Creeks contain extensive estuarine habitats, while the Barton Park Wetlands contain remnants of what were once part of an extensive area of estuarine wetlands near the mouth of the Cooks River (Manidis and Roberts, 1994).

Estuarine wetland habitats are thought to be extremely important nursery grounds for fish and prawns of commercial importance, probably because they provide appropriate food and shelter for the juvenile stage of life. Botany Bay has been traditionally a major source of estuarine fish for the Sydney markets. Furthermore, a significant number of valuable fish species commonly harvested from coastal areas and the continental shelf, use or are thought to be dependent on estuaries. "Estuarine-dependent species" have been defined as those species whose populations mainly inhabit an estuarine environment during at least one phase of its life-history (Pollard, 1976). Pollard estimated that approximately 70 percent by value and 66 percent by weight of New South Wales commercial fisheries production from 1962 to 1972 was estuarine dependent.

1.2.2 Mangroves

Mangroves provide an important nursery habitat for many fish, including some of economic value. The associations fish have with mangrove habitats can be divided into three categories: fish that (1) utilise this habitat throughout their life-cycle, (2) visit mangroves intermittently as adults or (3) occur seasonally as eggs, larvae or juveniles (Hutchings and Saenger, 1987). The proportion of fish within each category varies geographically (Hutchings and Saenger, 1987).

Associations between tropical and sub-tropical mangroves have been documented in several studies (Stephenson and Dredge, 1976; Beumer, 1978; Blaber, 1980; Quinn, 1980; Hutchings and Saenger, 1987), yet little is known about fish and mangrove associations in temperate regions, particularly Sydney. In the Sydney region, the most comprehensive study of fish associations with mangroves was done by Bell *et al.* (1984), who sampled a mangrove creek bimonthly over two years. This study reported 46 species of fish belonging to 24 families. Six species dominated the assemblage: *Ambassis jacksoniensis, Girella tricuspidata, Pseudomugil signifer, Liza argentea, Torquigener hamiltoni* and *Gerres subfasciatus*. Fourteen species, including four of the above, were of commercial importance. These fish accounted for 38% of all individuals. Peaks in overall abundance of fish were caused primarily through recruitment of juveniles. Unfortunately, this important study was restricted to one mangrove creek and to be applied more generally, this type of work should be repeated in other creeks.

An important result of this study, however, is that it confirms that mangroves in the Sydney region may be nursery areas of critical importance. Bell and his co-workers suggested that the exclusive use of this habitat by small juveniles would indicate that mangroves are important nursery areas for fish caught in adjacent estuarine and inshore habitats. Consequently, mangrove creeks of Sydney may provide important recruitment sites that offer suitable shelter and food for new recruits.

1.2.3 Saltmarshes

Saltmarshes are characterised by herbaceous plants which occur in the intertidal zone, but are not subject to regular tidal inundation (Burchmore *et al.*, 1987). Aquatic habitats within saltmarshes may be divided into two categories: (1) ponds formed from depressions within saltmarshes and (2) channels which flood only during extreme high tides (Morton *et al.*, 1988). There is limited information on the value of Australian saltmarsh habitat to fish. The available information suggests that some saltmarshes in eastern Australia support relatively few species of fish. The importance of saltmarshes as a nursery habitat for species of economic importance, however, is equivocal.

We are not aware of any studies investigating associations between fish and saltmarsh habitat in the Sydney region. In Queensland, however, Morton *et al.*, (1987), reported the monthly abundances of fish associated with an inlet that drains a saltmarsh. A total of 19 species was recorded from the inlet, of which 11 were of economic importance. The numerically dominant species, most of which were juveniles, were: *Torquigener pleurosticus, Acanthopagrus australis, Ambassis marianus, Liza argentea, Torquigener hamiltoni* and *Velamugil georgii*.

Morton *et al.*, (1988) sampled ponds within the same saltmarsh and found far fewer species than in the adjacent channel. Few species of economic value were present, and it was concluded that the saltmarsh ponds surveyed were not significant nursery area for fish of economic value.

1.2.4 *Muddy, Unvegetated Substratum*

The substrata of creeks and open areas of wetland are often muddy. This is particularly true for Salt Pan and Wolli Creeks, Cooks River and the open areas of the Barton Park wetlands. In the Sydney region, two descriptive studies of fish and macrobenthos on muddy substrata of a similar habitat type to Salt Pan and Wolli Creeks, were done in Botany Bay (SPCC, 1981) and Sanbrook Inlet, Hawkesbury River (The Ecology Lab, 1989). In both studies sampling was done using two methods: (1) gill netting which collected relatively large fish and crabs, (2) beam trawling which collected small, bottom-dwelling fish and decapods.

Sampling of shallow mud habitat in Woolooware Bay and the Cooks River found 38 species of fish, half of which were of economic value (SPCC, 1981). Adults of commercial species were considered transients that foraged in this and other shallow habitats of Botany Bay. The fish caught included: *Platycephalus fuscus, Liza argentea, Gerres subfasciatus, Pomatomus saltatrix, Myxus elongatus, Acanthopagrus australis, Herklotsichthys castelnaui, Sillago maculata, Mugil cephalus, Girella tricuspidata* and *Argyosomus hololepidotus*. The fish collected that were of no economic value were mostly gobies: *Favonigobius exquisites, Favonigobius tamarensis, Favonigobius lateralis, Redigobius macrostoma* and *Gobiopterus semivestita*.

Sampling of a shallow mud bank at the western end of Sanbrook Inlet revealed a similar fish fauna to the above study (The Ecology Lab 1989). The main species of commercial value were: *Sillago maculata, Sillago cilata, Acanthopagrus australis, Pomatomus saltatrix, Liza argentea, Myxus elongatus, Gerres subfasciatus* and several species of flathead (*Platycephalus* spp.). As in Botany Bay, most of the fish of no commercial value were gobies, the most abundant being *Favonigobius exquisites, Favonigobius tamarensis, Arenigobius bifrenatus, Pseudogobius olorum, Redigobius macrostoma* and *Gobiopterus semivestita*.

Both studies sampled large numbers of crustaceans, many of which were of economic value. The most abundant species collected included two species of crab, *Portunus pelagicus* and *Scylla serrata* and three species of prawns, *Penaeus plebejus, Metapenaeus macleayi* and *Metapenaeus bennettae*. At Sanbrook Inlet, non-commercial species of snapping-shrimp (*Alpheus* spp.) and sergestid shrimp (*Acetes sibogae*) were common (The Ecology Lab, 1989).

1.2.5 Fish from Salt Pan Creek, Wolli Creek and Cooks River

We are not aware of any studies done on fish and macroinvertebrate fauna in Salt Pan and Wolli Creeks. Two major studies have described fish and/or decapods inhabiting similar habitats of this region. These were Bell *et al.*, (1984), who sampled a mangrove creek in Sydney and NSW Fisheries who sampled the Cooks River and Woolooware Bay (SPCC, 1989). Both these studies have been described in detail above. 1981

1.2.6 Fishing

A conversation with NSW State Fisheries advised that Salt Pan and Wolli Creeks were used for both commercial and recreational fish activities. At Salt Pan Creek all fish and (i.e. mud crabs: *Scylla serrata)* may be collected by haul-line and net, however, given the shallow water depth of this creek, this waterway is infrequently used by commercial fishermen. Recreational fishermen, however, are known to collect fish and after dusk, mud crabs. At Wolli Creek, both fish and crabs may be collected commercially and recreationally, however, all fishermen are restricted to using haul-lines that restrict catches to fish. Wolli creek is more popular with recreational than commercial fishermen.

During the course of our studies, we noted that recreational angling was popular within the parts of Salt Pan and Wolli Creek we sampled. At Salt Pan Creek four anglers were noted over four days. Three fished from the shore and the fourth fished from a motorised 2.3 m dingy. Evidence of bait collecting was observed on the mud banks adjacent to some anglers. At Wolli Creek two fishermen were observed line fishing approximately 30 m downstream of Turrella Weir. Conversations with the fishermen indicated that they often fished these creeks, from which they mainly caught bream and mullet.

Brighton Le Sands Amateur Fishing Club is located near the Cooks River and downstream of Wolli Creek. A conversation with the Vice President of this fishing club, revealed that members of his club fished in Botany Bay rather than in these creeks.

1.2.7 Conclusions

Wetland habitats, particularly mangroves, are likely to be important habitats for fish and decapods of the Sydney region. Reviews and major studies within Australia have emphasised the importance of estuarine habitats for a number of species, including fish and prawns of commercial importance. At various localities along the proposed M5 East Motorway, there are significant estuarine habitats that include mangrove-lined creeks, saltmarshes and open wetlands. Consequently, a thorough assessment of the effects of the motorway should include fish, decapods and their habitats.

Although this review of existing information emphasises the importance of estuarine habitats to fish and decapods, it also highlights the lack of information available on associations these biota have with wetland habitats within the Sydney region. Prior to this study, no information existed on the species, distribution and abundance of fish and decapods that inhabit Salt Pan and Wolli Creeks. It is important that these assemblages are described and their patterns of abundance quantified so that informed decisions can be made.

2.0 SAMPLING METHODOLOGY

2.1. Survey Methods

Fish habitats were described by reference to (1) habitats maps of West *et al.* (1985), (2) the M5 Motorway EIS (Manidis and Roberts, 1994) and (3) by field inspections.

Fish and decapods were sampled using three methods: gill netting, beach seining and beam trawling. Each method has various advantages and disadvantages. The gill netting technique is best for catching large and mobile fish such as mullet and bream, but it cannot sample small fish and decapods that are caught easily with a seine net or beam trawl. Seine netting catches both benthic and pelagic assemblages, while beam trawling catches benthic assemblages. Seine netting is usually limited to creek banks with a gentle slope, free from obstructions. Consequently, beam trawling is often used where seine netting is not practical, such as creeks with steep banks and/or with obstructions. Given that the potentail for seining at Salt Pan and Wolli Creeks was variable, this study used a combination of seine netting and beam trawling to sample small biota.

2.1.1 Gill Netting

Estimates of the distribution and abundance of large fish (>100 mm fork length: see below) were made using gill nets. These were rectangular panels of net which form a wall. Fish swam into the net and became entangled by their gills or spines. The nets used in this study measured 2 m deep x 60 m long and were made from 65 mm and 100 mm monofilament mesh .

Each net was deployed for two hours at most sites. Given tidal limitations at Salt Pan Creek, nets were only deployed for one hour at the two sites upstream of the South Western Motorway bridge. Upon retrieval, all species of fish were identified, counted and their fork length measured (Length Caudal Fork or LCF: i.e., from the tip of the head to the fork of the tail fin).

2.1.2 *Seine Netting*

The distribution and abundance of small fish (<100 mm LCF) and decapods (>2 mm diameter) were estimated using seine nets. Seine nets are rectangular panels of net which were hauled across the top of the creek bottom and trapped relatively small and slower moving species. The net used in this study was made from 2 mm plastic mesh and measured 1 m deep x 10 m long.

The net was deployed to form a semicircle whose opening faced the river-bank. Once deployed, the net was hauled onto the river-bank trapping fish and decapods in the net. All fish and decapods collected by the seine net were preserved in dilute formalin (10%) and taken to the laboratory where they were counted and identified to the lowest practicable taxonomic level. The LCF of fish of economic value was measured.

2.1.3 *Beam Trawling*

The distribution and abundance of small bottom-dwelling fish (<100 mm LCF) and decapods (>2 mm diameter) were also estimated by beam trawling. A beam trawl is a cone-shaped net that is towed along the creek bottom by boat. The dimensions of the net used were: 1 m wide at the net opening (base of cone) and 1.5 m long (from opening to apex), with 2 mm mesh.

The net was towed at a speed of about one knot for one minute. After one minute, the net was hauled from the bottom and washed. Washing removed sediment, leaving fish, crustaceans and often a large amount of mangrove detritus. The contents of each trawl were preserved in dilute formalin (10%), taken to the laboratory, counted and identified to the lowest practicable taxonomic level. The LCF of fish of economic value was measured.

2.2 Sampling Places and Times

2.2.1 *Salt Pan Creek*

Fish and decapods were sampled from the South Western Motorway (SWM) bridge to Davies Reserve, opposite Clarendon Road (Figure 1). All three sampling techniques described above were used at the same locations and sites within this 4 to 5 km length of creek. Locations were haphazardly separated by 100's of meters. Within each location, two sites separated by 10's of meters were sampled using three replicate hauls of each technique. Due to lack of suitable habitat, seine netting was not done at Sites 1 and 2. Sampling was done during daylight hours in late November and early December, 1994.

2.2.2 *Wolli Creek (Tidal Portion)*

Fish and decapods were sampled from Turrella Weir to approximately 200 m downstream of the South West Ocean Sydney Outfall Sewer. All three sampling techniques were used within this 2 to 3 km stretch of creek. Three locations separated by 100's of meters were chosen for sampling. Within these locations, two sites separated by 10's of meters were selected (Figure 2). Three replicate gill nets were deployed within each site. Due to lack of suitable seining and beam trawling habitat, these techniques could not be employed at all sites. Three replicate beam trawls were employed only at sites 2, 4, 5 and 6. Seine netting was not replicated (qualitative sampling) due to lack of suitable seining sites and one haul was done at each of Sites 2, 3, 5 and 6. Sampling was done during daylight hours of late November and early December, 1994.

2.2.3 *Wolli Creek (Freshwater Portion), Cooks River and Barton Park Wetlands*

Fish and decapods were sampled qualitatively using a dip net, seine net or beam trawl in the freshwater portion of Wolli Creek, in the Cooks River and in the Barton Park Wetlands. Within the freshwater portion of Wolli Creek, dip netting and three seine hauls were done (Figure 2). At Cooks River, three beam trawls and two seine hauls were done (Figure 2). At Barton Park dip netting and three seines were done at each of the three wetlands: Marsh Street, Eve Street and Muddy Creek (Figure 3).

2.3 Statistical Methods

2.3.1 Multivariate Analyses

To detect patterns of similarity in the communities sampled, a suite of multivariate techniques included in a computer program, PRIMER (Plymouth Routines In Multivariate Ecological Research), were used. Similarities were ranked among every pair of samples to form a triangular matrix of association. The relative distances between paired samples are proportional to relative similarity in species composition (Clarke, 1993). The matrix was calculated by the Bray-Curtis similarity measure (Bray and Curtis, 1957). Prior to construction of the matrix, the data were transformed using the fourth root transformation to reduce similarity by very abundant species and therefore increase the contribution of rarer species to the community structure.

Bray-Curtis dissimilarities/similarities among samples were used to construct a two-dimensional MDS (multi-dimensional scaling) plot. This scatter plot identifies each replicate sample with an alphabetical letter, and locates it in two dimensional space on the basis of ranked similarity with other samples. Such plots display the relationship between replicates in fewer dimensions (in this case, two), than the original data matrix. This technique of reducing high-dimensional data to fewer dimensions is subject to constraints inherent in the data matrix. The measure of how well the data have been reduced to two dimensions is indicated by a stress value (Kruskal and Wish, 1978), where values between 0 and 0.1 provide accurate information, values between 0.1 and 0.2 are adequate, but values above 0.2 should be interpreted with caution (Clarke, 1993), as this may not provide an adequate representation of the relationship among categories (i.e. sites compared). Since the plots are determined on arbitrary ordinations, reflections, locations and scales (Clarke, 1993), the axes of the plot were not labelled.

The significance of any apparent groupings identified in the MDS plot was determined using the ANOSIM (Analysis of Similarities) permutation test (Clarke and Green, 1988). The analytical design was based on one factor, location. A two factor design including sites could not be calculated, because there were insufficient sites per location to provide an adequate number of permutations to determine significant pairwise comparisons. Similarity analyses (SIMPER) were used to determine the relative contribution that a particular species or taxa made to the dissimilarity among locations (Clarke, 1993).

2.3.2 *Univariate Analysis*

A univariate technique, analysis of variance (ANOVA), was used to examine differences between sites for animals sampled quantitatively (see Winer, 1971; Underwood, 1981 for further details). In this study, ANOVA compared mean abundance and variance among locations and between sites within each location. The analytical design used a two-factor ANOVA, in which sites were nested within locations and both factors were treated as random.

Prior to analysis, data were tested for homogeneity of variance by Cochran's test and transformed where necessary (Underwood, 1981). If these transformations failed to remove heteroscedasticity, raw data were analysed, but critical probabilities were reduced from 0.05 to 0.01 to guard against the increased likelihood of Type I error (Underwood, 1981).

Where the test for differences between sites within locations was non-significant ($p>0.05$) the test for locations was made more powerful by post-hoc pooling (Winer, 1971). When ANOVA was significant, Student Newman Keuls (SNK) tests were used to identify differences amongst which means (Winer, 1971; Underwood, 1981).

3.0 RESULTS

3.1 Salt Pan Creek

Description of Habitats

In general, large, healthy mangroves (principally *Avicennia marina* with some *Aegiceras corniculatum*) formed thick stands on the banks of Salt Pan Creek. The mangrove flats and creek bottom were composed mainly of mud. In some shallow areas, however, seagrass mats (*Zostera*, possibly *Z. capricornia*) up to 2 m^2 were observed. Sampling sites were restricted to the main channel, which in this area ranged from approximately 4 to 200 m wide at low tide. The depth of the main channel varied greatly (from approximately 0.3 m to greater than 3 m at low tide). At high tide the banks of the channel were submerged so that fish were able to swim over the mangrove-lined mudflats.

Within the immediate vicinity of the existing M5 bridge, natural mangroves stands were smaller and less dense. Furthermore, this area has been extensively planted with young mangroves. The mudflats immediately below the bridge showed signs of bioturbation. That is, the sediment was disrupted in the form of discrete and clearly recognised burrows and trails. This would indicate that organisms (probably crabs) inhabit this area.

Description of Fish and Decapods

At Salt Pan Creek a number of species were collected by beam trawls, seine and gill nets. A total of 22 fish were collected from the gill nets, representing two species from two families: these were 21 sea mullet (*Mugil cephalus*), one dusky flathead (*Platycephalus fuscus*), (Table 1). These species are common in NSW estuaries and are of economic value. Two mud crabs (*Scylla serrata*) were also caught. The seine net caught a total of 15,557 fish representing 23 species. Approximately 75% of these fish consisted of 5 species of goby, of which the glass goby (*Gobiopterus semivestita)* accounted for 58% of the total catch (Table 2). Beam trawling caught 291 fish representing 9 species from 4 families. All except nine individuals from these trawls were gobies (Table 3). The most numerous goby was *Redigobius macrostoma*, which accounted for 55% of all individuals. Seine netting caught the same species as beam trawls plus a number of others. Species caught by both these methods were common to NSW estuaries and therefore none were considered rare or endangered to the Sydney or NSW regions.

Penaeid prawns were caught using both the seine and beam trawl. Using the seine net, 483 penaeid prawns were caught, while the beam trawl caught 90. Of those prawns that were whole and could be identified from the seine samples, approximately 76% were from the genus *Metapenaeus* (probably *M. macleayi* and/or *M. bennettae*) and 23% represented the genus *Penaeus* (probably *P. plebejus*). Identifiable prawns from the beam trawls comprised 58% *Metapenaeus* and 42% *Penaeus*. These species are of commercial value.

3.1.1 Analysis of Assemblages

Seine Netting

A two-dimensional plot derived from an MDS ordination indicated differences in the assemblages of fish and prawns caught by seine net (Figure 4). Samples from Locations 1 and 3 were more similar to each other than samples from Location 2. Samples collected from the middle location "b" grouped separately from "a" and "c" (Figure 4), suggesting that Location 2 was distinct from Locations 1 and 3. The stress value of 0.15 indicated that this visual assessment was reasonable. Moreover, Analysis of Similarity (ANOSIM) confirmed this grouping (Table 4) .

Analyses by SIMPER identified those taxa that contributed greatly to the dissimilarity between groups (Table 5). Generally, the greatest contributors were species that were more abundant in one group and not abundant in the other. Hence, *Ambassis jacksoniensis* and *Gobiopterus semivestitus* mostly contributed to group differences (11.56 and 10.31% respectively), where at Location 2 the former species was less abundant and the latter species was more abundant than at Locations 1 and 3. Of the commercially important species, penaeid prawns and sea mullet did not contribute greatly to the differences (5.01 and 4.9% respectively), whereas flat-tail mullet (*Liza argentea*) was an important discriminator (8.52%) (Table 5).

Beam Trawling

Assemblages collected by beam trawling differed among locations. Location 1 differed from Locations 3 and 4 (ANOSIM, Table 6). The outlying points "a" on the MDS plot represent samples from Location 1 that generally contained either no species or small numbers of particular species (Figure 5). Three to four taxa were primarily responsible (approximately 80%) for differences between groups: *Pseudogobius olorum, Redigobius macrostoma, Favonigobius exquisites* and penaeid prawns (Table 7).

3.1.2 *Analysis of Populations*

Gill Netting

The number of fish species and total number of fish did not differ among locations or between sites within the locations sampled at Salt Pan Creek (Figure 6a, Table 8). The number of sea mullet (numerically dominant species within samples), however was detected to differ between sites within Location 3 (Table 8). Crabs and *P. fuscus* were not tested for spatial differences because their numbers were too small (Table 1).

Seine Netting

The mean number of fish species did not differ among locations but differed between sites within locations (Figure 7a, Table 9). The number of species of Gobiidae, however, did not differ at either spatial scale (Figure 7b, Table 9). Comparisons of total numbers of all fish and all of gobies numbers among locations and sites also did not reveal any spatial differences (Figure 7c,d, Table 9).

The abundances of 5 species of fish were tested for spatial differences (Figure 8, Table 9). Only *Ambassis jacksoniensis* differed among locations: it was more abundant at Location 3 than Locations 1 and 2 (Figure 8b, Table 9). No species differed between sites. The abundance of penaeid prawns differed between sites but not among locations (Figure 8f, Table 9). The abundances of other taxa were too small to be tested statistically (Table 2).

Beam Trawling

Of 291 fish caught beam trawling, all but 9 individuals were gobies. Although the mean number of species did not differ at either spatial scale (Figure 9a, Table 10), the mean number of goby species differed among locations (Table 10). The total number of all fish and gobies differed between sites, but not among locations (Figure 9b, Table 10). Only the goby *P.olorum* was caught in sufficient numbers for analysis (Table 3). Although ANOVA detected location differences after post-hoc pooling, an SNK test could not unambiguously identify which locations differed (Table 10, Figure 9c). The abundance of penaeid prawns showed no significant differences at either spatial scale (Figure 9d, Table 10).

Length Frequency Distributions of Fish of Economic Value

Most of the fish sampled were either large juveniles (caught seine netting or/and beam trawling) or adults (caught gill netting). This finding, however, should be interpreted cautiously because although casual observations indicated large numbers of sea mullet (approximately 100 to 200 mm LCF) were present in Salt Pan Creek, the gill nets failed to catch any of these fish.

The size frequency distributions of sea mullet caught gill and seine netting indicate that both juvenile and adults of this species utilise Salt Pan Creek (Tables 11 and 12). Most fish caught gill netting were 200 to 350 mm (LCF) long. Within this range, mid-sized fish (250-300) occurred in the greatest proportion (Figure 10). Fish of lengths up to about 300 mm are aged about 2-3 years, while fish longer than 300 mm are generally older than 3 years (SPCC, 1981). Sea mullet of these sizes undergo annual migrations out of estuaries, the 2+ fish (sexually immature) usually migrate in summer and the 3+ fish (sexually mature) migrate in autumn (SPCC, 1981). Most sea mullet caught beach seining were between 20 to 60 mm (LCF) long. Within this size range, sea mullet are known as juveniles and use creeks and rivers as nursery grounds. Generally, these juveniles will spend up to 2-3 years within these habitats before they undergo annual migrations.

With the exception of mullet only one other species was caught gill netting: dusky flathead. The one individual caught was 434 mm TL. No juveniles of this species were caught seine netting or beam trawling. There were, however, large numbers of juveniles of other species caught using the latter techniques (Table 11). All these species use estuaries as juveniles.

3.2 Wolli Creek (Tidal portion)

Description of Habitats

Below Turrella weir, habitats associated with Wolli Creek consisted of 1.5 hectares of saltmarsh, 2.5 hectares of mangroves (mainly *Avicennia marina* and some *Aegiceras corniculatum*) and a few clumps of common reed (*Phragmites australis*) (Adcock and Osborne, 1994). Habitat maps of West *et al.* (1985) indicated an absence of mangroves. Adcock and Osborne may provide an explanation for this. They suggested that a previous study (Brown, 1987 [cited in Adcock and Osborne, 1994]) demonstrated through aerial photography techniques, that the current stands are recent in origin. Furthermore, they suggest that the presence of mangrove seedlings would indicate that the extension of the stand was continuing.

The mangrove habitat was thickest and most extensive near the downstream sampling sites 4, 5 and 6. The mangrove flats and creek bottom were mainly composed of mud. The water depth at low tide ranged between 0.4 m (near Turrella weir and under the South Western Sewage Outfall) to over 3.5 m (Site 2). The width of the creek at low tide ranged from 4 m with upstream sites to approximately 80 m with downstream sites.

Description of Fish and Decapods

Gill netting caught 57 fish, representing six species from six families. The most abundant species was sea mullet (*Mugil cephalus*) which accounted for 60% of the fish caught (Table 13). Three mud crabs (*Scylla serrata*) were also caught in the gill nets. All species caught using this method were common to NSW estuaries and of economic value.

Beam trawling yielded 309 fish, of which 307 were gobies and two were the perchlet *A. jacksoniensis* (Table 14). Seine netting caught 3,547 fish representing 13 species from seven families (Table 15). All these species are common to NSW estuaries and are of no commercial value. Twenty-nine penaeid prawns were caught in beam trawls. Of those that could be identified, most (65%) represented the genus *Metapenaeus* (probably *M. macleayi* and *M. bennettae*). The remainder were identified as *Penaeus* species (probably *P. plebejus*). These decapods are common to estuaries of NSW and form the basis of an important demersal fishery. None of the species caught beam trawling were rare or endangered.

Of 3,547 fish caught seine netting, approximately 75% one species of goby *(P. olorum)*(Table 15). The remaining 25% consisted of 15 species from 11 families. Seven of these were of commercial value. Of 32 penaeid prawns caught, 30 represented the genus *Metapenaeus* (probably *M. macleayi* and *M. bennettae*) and two were *Penaeus* species (probably *P. plebejus*). Again, these decapods are common to estuaries of NSW and form the basis of an important demersal fishery. None of the species caught seine netting were considered rare or endangered.

3.2.1 *Analysis of Assemblages*

A one-way ANOSIM failed to detect differences among sites sampled by beam trawling (ANOSIM, R= 994, P> 0.10). This indicated that the assemblages did not differ among the sites sampled. There were too few fish were caught in the gill nets and too few seine nets hauled to warrant analysis of these samples for community patterns (Table 13 and 15).

3.2.2 *Analysis of Populations*

Gill Netting

The number of fish species, total number of fish and number of sea mullet (numerically abundant species) did not differ among locations or between sites within the locations sampled at Wolli Creek (Figure 11, Table 16). Crabs and other fish were not tested for spatial differences because their numbers were too small.

Seine Netting

Given that seine netting was restricted by the lack of suitable habitat at Wolli Creek, this information has been presented in a qualitative format (Table 15). The abundance of each species appeared to be variable, with no along-stream gradients apparent.

Beam Trawling

The mean number of species of fish and species of goby did not differ among the four sites sampled by beam trawl (Table 17, Figure 12a,b). While spatial differences were not detected for the mean number of fish (Figure 12b, Table 17), analysis without the two *A. jacksoniensis* caused ANOVA to detect site differences for the mean number of gobies. Both *A. jacksoniensis* occurred at different sites. Variation among sites was also detected for *P. olorum* (Figure 12, Table 17). No spatial differences were detected for penaeid prawns (Figure 12, Table 17).

Wolli Creek (Freshwater portion)

Above Turrella weir, the plant assemblage is characterised by a notable absence of estuarine plants (e.g. mangroves) and presence of freshwater plants (e.g Tall spikerush (*Eleocharis sphacelata*)). A dense tree cover grew along the near-vertical banks. For a distance of approximately 100 m above the weir, water depth varied from one metre to over two meters and creek width varied between approximately 4 to 8 m.

Within the freshwater portion of Wolli Creek three seine hauls yielded three species of fish from three families (Table 18). Mosquitofish (*Gambusia affinis*) was most abundant (92%), followed by the striped gudgeon (*Gobiomorphus australis*, 7%) and the common jollytail (*Galaxias maculatus*, 1%). Dip netting caught approximately the same species with the addition of a juvenile sea mullet, *Mugil cephalus* (43 mm LCF) (Table 18). Five carid shrimps and two long-necked tortoises (*Chelodina longicollis*) were also caught. All these species are common to estuarine habitats with NSW, but only sea mullet is of commercial value.

Length Frequency Distributions of Fish of Economic Value

Similar to Salt Pan Creek, most fish sampled in Wolli Creek were either large juveniles or adults. The size of fish caught in gill nets are likely to be biased towards the large size classes of fish, as explained for Salt Pan Creek.

Five species of adult fish were caught gill netting and four of these were caught as juveniles in seine nets: *Acanthopagrus australis, Gerres subfasciatus, Mugil cephalus* and *Liza argentea* (Table 19). The one species caught as an adult but not as a juvenile was *Platycephalus fuscus*. Furthermore, one species was caught as a juvenile but not as an adult: *Rhabdosargus sarba*. These results indicate that Wolli Creek not only provided habitat for a range of juveniles of commercial value, but also for a large proportion of adult species.

Sea mullet caught gill netting were between 250 and 400 mm (LCF) long, with most occurring in the mid-range (300-350 mm LCF), (Figure 13). No species of commercial value were caught beam trawling. No frequency distribution is presented for those species caught seine netting because samples sizes were too small (n< 14).

Cooks River

The Cooks River is a 21 km long tidal river which connects to Botany Bay. This river has been canalised with retaining walls. Hence, the banks are generally devoid of any substantial vegetation. The river bottom is mainly mud. The river was approximately 100 m wide at the sites sampled.

Downstream of the confluence of Wolli Creek and Cooks River, two seine hauls caught nine species of fish from six families. Five of these were of commercial importance, but the catch was numerically dominated by *A. jacksoniensis*, a species of no commercial importance (Table 18). The main species of commercial interest were juveniles of *A. australis* (LCF= 28 mm) and *Engraulis australis* (mean LCF= 24 mm) and adults of the species *Pomatomus saltatrix* (LCF= 159 mm), *G. subfasciatus* (LCF= 142 mm). Only three penaeid prawns were caught of which two were *Metapenaeus*. All species within these samples were common to estuarine habitats within the Sydney region.

Three beam trawls within the Cooks River yielded five species of fish, all from the family Gobiidae (Table 18). None of these species are of commercial value or considered to be rare or endangered. One blue swimmer crab (*Portunus pelagicus*) and one penaeid prawn (*Metapenaeus*) were caught. Both are common estuarine decapods and utilised in commercial harvesting.

3.3 Barton Park Wetlands

The Barton Park wetlands are three of a series of wetlands (Fig. 3) which have survived industrial development (Adcock and Osborne, 1994). The main physical feature these three wetlands share is that they were all dependant on a small body of relatively still water (pond) which connects to a drainage channel. These channels ultimately connect with the Cooks River. In general, the drainage channels were strongly tidal and supported a number of wetland species, including mangroves. Vegetation associated with the ponds did not contain mangroves and varied greatly in terms of type and cover.

Of the three wetland areas sampled, only the Marsh Street wetland contained fish. Dip netting revealed that mosquito fish, *Gambusia affinis*, inhabited the drainage channel to this wetland. It is possible that more intense sampling could have revealed other species within these habitats. This is because some species may occur at some times of the year and not others. This may be particularly true with regard to the episodic nature of juvenile recruitment. Our sampling, however, coincided with the season of greatest recruitment, hence the lack of fish and decapods may be representative of other times not sampled.

4.0 DISCUSSION

4.1 FISH AND DECAPODS AND THEIR HABITATS

The present study is the only study which has documented the species of fish and decapods and their patterns of abundance within Salt Pan and Wolli Creeks. The assemblage of decapods (particularly penaeid prawns) and fish compare favourably with other studies done in similar habitats in the Sydney region. Species found to be common in the present study were also prevalent in the work reported in SPCC (1981) and Bell *et al.*, 1984 and unpublished work held by The Ecology Lab.

The freshwater portion of Wolli Creek contained a number of fish species commonly associated with freshwater habitats. These species are abundant and widely distributed throughout many freshwater habitats in the Sydney region. The presence of sea mullet within the samples indicated that Turrella weir may be periodically over-topped by the tidal portion of Wolli Creek. Sea mullet spend various proportions of their life-cycle in marine as well as freshwater habitats.

Investigations of Barton Park wetlands indicated that assemblages of fish and decapods in these areas were depauperate. Only one species of fish was collected: an exotic fish, *Gambusia affinis*. More intensive sampling may have detected more species. Despite this, we consider that the water bodies sampled were inadequately flushed which would severely limit the value of these habitats for fish and decapods. Inadequate flushing may give limited access to fish and decapods, limit food availability and water quality. Furthermore, the possible presence of pollutants in the water and in the mud substratum may also limit the value of these habitats for such fauna.

With the exception of the Barton Park wetlands, sampling indicated that the creek and river locations sampled provided habitat for a significant number of fish. Salt Pan Creek and Wolli Creek support habitats, mainly mangrove, thought to be critical nursery habitats for a number of commercially important fish and prawns. Sampling not only revealed that large numbers of juvenile fish of economic importance were indeed using this habitat, but so too were many adult conspecifics. Although these habitats per se. are not used intensively by commercial fishermen, it is likely that these fish contribute to the NSW catch after they mature and leave the nursery area. None of the fish sampled were considered to be rare or endangered and thus unique to these locations. In conclusion, therefore, we consider that although these habitats do not support a unique fauna, they do support a significant fauna in terms of abundance and commercial value. Discussion of management issues will primarily deal with Salt Pan and Wolli Creeks which are nursery habitats for a range of biota, including many of commercial value. Discussion of Barton Park Wetlands and Cooks River will be discussed where appropriate.

4.2 MANAGEMENT ISSUES

4.2.1 *Construction*

4.2.1.1 Removal of riparian zones due to land clearing

At Salt Pan Creek, mangroves would be cleared to duplicate the existing two lane bridge. Such loss is expected to be insignificant compared to the overall mangrove population (Adcock and Osborne, 1994). Given that the abundances of fish and decapods immediately up and downstream were not particularly unique or abundant, it is likely that the loss of this small section of habitat will have a negligible effect on abundance of aquatic fauna at Salt Pan Creek.

At Wolli Creek, riparian vegetation below Turrella weir would to be disturbed by the emergence of the tunnel (eastern portal). Construction of the eastern portal may reclaim a small portion of Wolli Creek and pass over a section of saltmarsh unique to the area. In broad terms, the loss of riparian vegetation at these locations is likely to have a negligible effect on fish and macroinvertebrate abundance within Wolli Creek. Sampling did not reveal these locations to be uniquely associated with a particular assemblage or population of species. Moreover, the abundant species were largely representative of other locations within the creek and literature suggests that saltmarsh habitat is unlikely to support a unique assemblage of fish.

At Barton Park Wetlands there is a possibility that numbers of wetland plants will be reduced through clearing at Marsh Street and Muddy Creek wetlands. With regard to our sampling of these wetlands, the loss of wetland habitat within these locations is likely to have a negligible effect on fish and decapods. Qualitative sampling revealed only one species of fish in Eve Street Wetland: *Gambusia affinis* (mosquitofish). This species is an exotic species of no commercial importance and is one of the most widespread freshwater fishes in the world. The Barton Park wetlands do not appear to be a significant habitat for fish and decapods. Hence, a reduction in plant numbers is likely to have an insignificant impact on these biota. These conclusions apply for other potential impacts (i.e. increases in pollution and sedimentation) and therefore the Barton

Park Wetlands are not discussed further.

4.2.1.2 Pollutants

With the utilisation of mitigation measures, the change in water quality at Salt Pan Creek and Cooks River during the construction phase has been predicted to be immeasurably small (Willing and Partners, 1994b). Hence, it is unlikely that the discharge of pollutants associated with the construction phase will affect fish and macroinvertebrate diversity or abundance at these locations.

As a result of tunnel spoils, particularly at Wolli Creek, increased run-off of heavy metals (such as lead and zinc) oils, grease and fuel from construction site is likely. Willing and Partners (1994b), indicate that if certain mitigative measures are followed, a net reduction in the export of pollutants to Wolli Creek would occur during the operation phase of the motorway. The RTA's proposal to increase water quality by implementation of stricter controls on the release of discharge into the creeks may help improve this habitat for fish during the operational phase. There is, however, no information on the likely increase or decrease in these pollutants during the construction phase.

It is not possible to recommend a single set of pollutant concentrations that would prevent the deleterious effects of pollution on fish and decapods. It is, however, strongly recommended by ANZECC (1992) that site-specific studies be undertaken to determine appropriate concentrations of each particular system. Hence, we recommend that an appropriate criterion of pollutant concentrations is agreed to and not exceeded during construction at Wolli Creek. ANZECC (1992), in part, establish a set of physico-chemical water quality guidelines that may assist in developing a criterion of upper-limit concentrations of pollutants for Wolli Creek.

4.2.1.3 Sediments

With the utilisation of mitigation measures, the change in water quality at Salt Pan Creek and Cooks River during the construction phase has been predicted to be immeasurably small (Willing and Partners, 1994b). Hence, it is unlikely that the discharge of sediments associated with the construction phase will influence fish and macroinvertebrate abundance in either a positive or negative sense.

As a result of tunnel construction from Wolli Creek, it is estimated that 60, 000 cubic meters of soil and rock will be removed (Manidis and Roberts, 1994). Consequently, sedimentation of Wolli Creek may increase due to erosion of earthworks at the adjacent construction site. Willing and

Partners (1994b) indicate that if certain mitigative measures are followed, a net reduction in suspended solids (48%) should occur during the operation phase of the motorway. There is no information, however, on levels of suspended solids likely during the construction phase. Hence, although the EIS states that mitigative measures would be used during construction and would prevent 60% of sediment export from the site (p 336), it is reasonable that our assessment of impacts should err on the side of a potential increase in suspended solids during the construction phase.

The run-off of sediments is likely to be associated with periods of rainfall. This may be especially apparent with heavy rainfall (3 to 15 millimetres), which Willing and Partners (1994a) estimate occur approximately 20 times per year in the Sydney region. During these times, sudden bursts of suspended solids in Wolli Creek are likely to increase turbidity and siltation. An increase in turbidity and siltation may affect aquatic fauna though decreased growth, spawning success, hatching rate, larval mortality, destruction of spawning bed, pathological effects on gill epithelia, behavioural avoidance of turbid conditions and changes in species composition (e.g. Moore, 1977).

Turbidity

Without predictions of the concerntrations of suspended solids likely to be associated with rainfall, it is difficult to assess the severity and likelihood of impacts associated with increases in turbidity. We know that fish kills have been caused by suspended solids in concentrations found in natural systems during flooding, dredging and spoil disposal (Moore, 1977). Sublethal levels of suspended solids effect fish in the same way as those deprived of sufficient oxygen, namely: damage to gill epithelia and drain on metabolic resources (e.g. increased carbohydrate utilisation). In general, those fish most susceptible to effects of suspended solids have been found to be: (1) juveniles rather than adults of the same species, and (2) the more pelagic rather than the bottom-dwelling (e.g. gobies) species (Moore, 1977).

Most decapods (e.g. prawns and crabs) feed by filtering the surrounding water. They select the organic fraction of their food by eliminating over-large and non-organic particles. An increase in organic particles may force filter-feeders to do more work for the nourishment returned and reductions in growth may result (Moore, 1977). In very high concentrations of suspended particles, it is possible for their feeding as well as breathing apparatus to become clogged (Moore, 1977).

Sedimentation

An estimate of maximal average siltation expected on the bottom of Wolli creek was not presented in the EIS. Under severe conditions, direct effects of sedimentation on benthos may alter the benthic habitat. Although most invertebrate fauna may be able to burrow through newly deposited sediment, the death of those that cannot, may cause a reduction in food availability for benthic-feeders (e.g. bream). Studies report that impacts will be most acute where the sediment is different to the original substratum. Where sediment is similar, macroinvertebrates may survive sedimentation of up to several centimetres (Engler *et al*, 1991; Olsgard and Hasle, 1993).

4.2.1.4 Secondary Effects

Adcock and Osborne's (1994) specialist's report on impacts to aquatic plants indicated that an increase in suspended particles may only reduce the photosynthetic capacity of submerged plants in Wolli Creek. Given this limited impact on vegetative habitat, it is unlikely that fish and/or decapods would be affected as a secondary result of a reduction in plant distribution and abundance.

In conclusion, without an indication of the likely increase or decrease in suspended solids and siltation within Wolli Creek, it is not possible to assess to severity or the likelihood of the impact sedimentation may have on fish and decapods. Hence, it is recommended that a monitoring program is implemented in order to assess whether construction activities have an adverse (or even beneficial) impact on fish, and, particularly decapods.

4.2.1.5 Temporary Diversion of Wolli Creek

Construction of the east portal at Wolli Creek would require diversion of Wolli Creek through a temporary channel excavated to the west of the existing creek. To avoid erosion and thus avoid increases in turbidity and sedimentation, the channel would be lined with rock or sprayed concrete. After construction is complete the diversion would be restored to its existing state and Wolli Creek returned to its normal course (Manidis and Roberts, 1994).

Of concern is the amount of time the creek upstream of the dams will be separated from the downstream portion. The detrimental effect of diversion will be minimised if up and downstream sections are isolated for as short a time as possible. Ideally, the diversion needs to be completed before damming commences. Hence, water could be diverted before or within a few days of dam operation. From spring through autumn, species of commercial value migrate between creeks/rivers and marine habitats. For example, sea mullet spawn in the open sea in autumn and their small juveniles make their way into estuarine habitats such as Wolli Creek some months latter. Furthermore, prawns such as mature *Metapenaeus macleayi* move from estuaries to the sea during spring and summer for the purposes of mating and spawning.

In this context, if the up and downstream sections are not isolated for more than a few days, diversion of the creek could take place at any time of the year. The diversion should be of similar width and depth as the existing section that is to be dammed. This should facilitate the movement of fish and prawns. If these mitigative measures are used, it is considered unlikely that the diversion will have adverse effects on prawn and mullet migrations.

The loss of fish and decapods caused by the drainage of water in the original creek between the temporary dams (Manidis and Roberts, 1994: stage 2) and back-fill of the temporary drainage channel (Manidis and Roberts, stage 3) is likely to be insignificant in context of the broader Wolli Creek. This is because species composition and abundance was not particularly unique or high in the proposed damming area and the scale of damming in relation to the remainder of tidal portion of the creek is small. Moreover, the proportion of the creek that would be dammed represents less than approximately 5% of over all tidal portion.

4.2.2 Operation phase

Impacts on fish and decapods associated with the operation of the motorway are likely to be negligible. If the stormwater drainage and water quality measures outlined in the EIS are implemented (Manidis and Roberts, 1994: pages 182 and 333-334) the change in water quality at Salt Pan Creek is expected to be immeasurably small, and, at Wolli Creek and Cooks River it is expected to improve (Manidis and Roberts, 1994). If water quality improves at Wolli Creek, this is likely to improve this habitat for fish and decapods, particularly for the diseased sea mullet observed.

4.3 ENVIRONMENTAL PLANING AND ASSESSMENT ACT

In this section we address issues in accordance with the seven issues listed in Schedule 2, Section 4A of Amendment of Environmental Planning and Assessment Act 1979 No. 203. This is intended to indicate whether there is likely to be a significant effect on the environment of inhabiting fauna. Hence, in this section we specifically take into account:

(a) the extent of modification or removal of habitat, in relation to the same habitat type in the locality:

The modification or removal of habitat in the Barton Park Wetlands and Cooks River is likely to be negligible in both the construction and operational phases. The removal or modification of habitat in Salt Pan and Wolli Creeks during the operational phase is likely to be negligible. The possible removal of riparian zones due to construction activities at Salt Pan and Wolli Creek are expected to be insignificant compared to the overall mangrove population. Temporary modification of Wolli Creek would occur through the temporary creation of a diversion. This diversion represents a small proportion of the overall tidal proportion of the creek (less than approximately 5%). Hence, the extent of modification is very small.

(b) the sensitivity of the species of fauna to removal or modification of this habitat:

It is not possible to assess the sensitivity of each species of fish and decapod to the removal or modification of habitat. It is possible, however, to asses the effect of habitat removal or modification on the distribution and abundance of the assemblage of species studied. We consider that the small scale removal of riparian zones and diversion of Wolli Creek are unlikely to have a significant impact on fish and decapod patterns of abundance at the scale of Salt Pan and Wolli Creek.

(c) the time required to regenerate critical habitat, namely, the whole or any part of the habitat that is essential for the survival of that species of fauna:

We cannot predict the time with which it would take for (i) the mangroves to regenerate or (ii) the dammed section of Wolli River to regenerate to a condition suitable for species to inhabit. It is unlikely, however, that the removal or modification of habitats, will threaten the survival of a species within Salt Pan or Wolli Creeks.

(d) the effect on the ability of the fauna population to recover, including interactions between the subject land and adjacent habitat that may influence the population beyond the area proposed for development or activities:

The effect of construction activities is unlikely to effect the ability of fish and decapods to recover because of the scale of these modifications of the habitat. These fauna are highly mobile and can recolonise these localities quickly. Furthermore, abundances of juveniles can increase rapidly with episodic recruitment because marine fish and invertebrates produce many thousands of eggs per individual. These eggs are generally dispersed into the open water column where they drift with currents for various amounts of time before returning to these habitats as juveniles. This characteristic allows many marine fauna to recolonise locations which may be some meters to many thousand kilometres from egg release.

(e) any proposal to ameliorate the impact:

The loss of fish and decapods caused by diversion may be ameliorated by ensuring the up and downstream sections of the dams are isolated for a short a time as possible (maximum of a few days). Furthermore, large and commercially valuable fish may be herded out of the area intended to be drained of water or backfilled. This may be done by simply driving a small boat along the direction of the creek the fish need to be herded. This procedure would be effective, given that large fish are often easily frightened away from areas of excess noise and disturbance.

(f) whether the land is currently being assessed for wilderness by the Director of National Parks and Wildlife under the Wilderness Act 1987:

It is unlikely that these areas would be assessed for wilderness given that areas along the creek banks are often highly developed and far from a pristine state.

(g) any adverse effect on the survival of that species of protected fauna or of population of the fauna.

It is unlikely that any one of the species sampled or their populations within the sampling locations would be adversely affected. Again, given the way fish and decapods replenish their populations, it is unlikely that the survival of any one species or creek/river population would be adversely effected.

4.4 CONCLUSION

The estuarine habitats of Salt Pan and Wolli Creeks are worthy of preservation because they support a relatively abundant and diverse assemblage of fish and decapods, many of which were of commercial importance. On the basis of predictions made in the EIS and in our studies, we consider that operational activities at all locations and loss of vegetative habitat during construction at Salt Pan and Wolli Creek are likely to have a negligible effect on these biota. The effects of concern are likely to occur during the construction phase and centre around Wolli Creek. These include the diversion of Wolli Creek and possible increases in levels of run-off of pollutants and sediment.

Impacts associated with the diversion of Wolli Creek are likely to be negligible if the up and downstream sections are isolated for as short a time period as practically possible (maximum of a few days). The EIS predicts that, when fully implemented, the mitigative measures proposed should prevent 60% of sediment export from the Wolli Creek construction site. What is of concern is the export of the remaining 40%. Without information on the likely amounts of sediment and associated pollutants that may be discharged into Wolli Creek during the construction phase, it is difficult to assess the severity and likelihood of impacts associated with water quality. It is recommended, therefore, that a monitoring program be implemented to assess whether construction activities have an adverse (or even beneficial) impact on fish and particularly decapods.

GLOSSARY

Decapod.	A classification or name given to a group of animals which include shrimps, lobsters, crayfish and crabs.
Conspecifics.	Individuals of the same species.
Heteroscedasticity.	A term given to data whose numbers differ greatly.

ACKNOWLEDGMENTS

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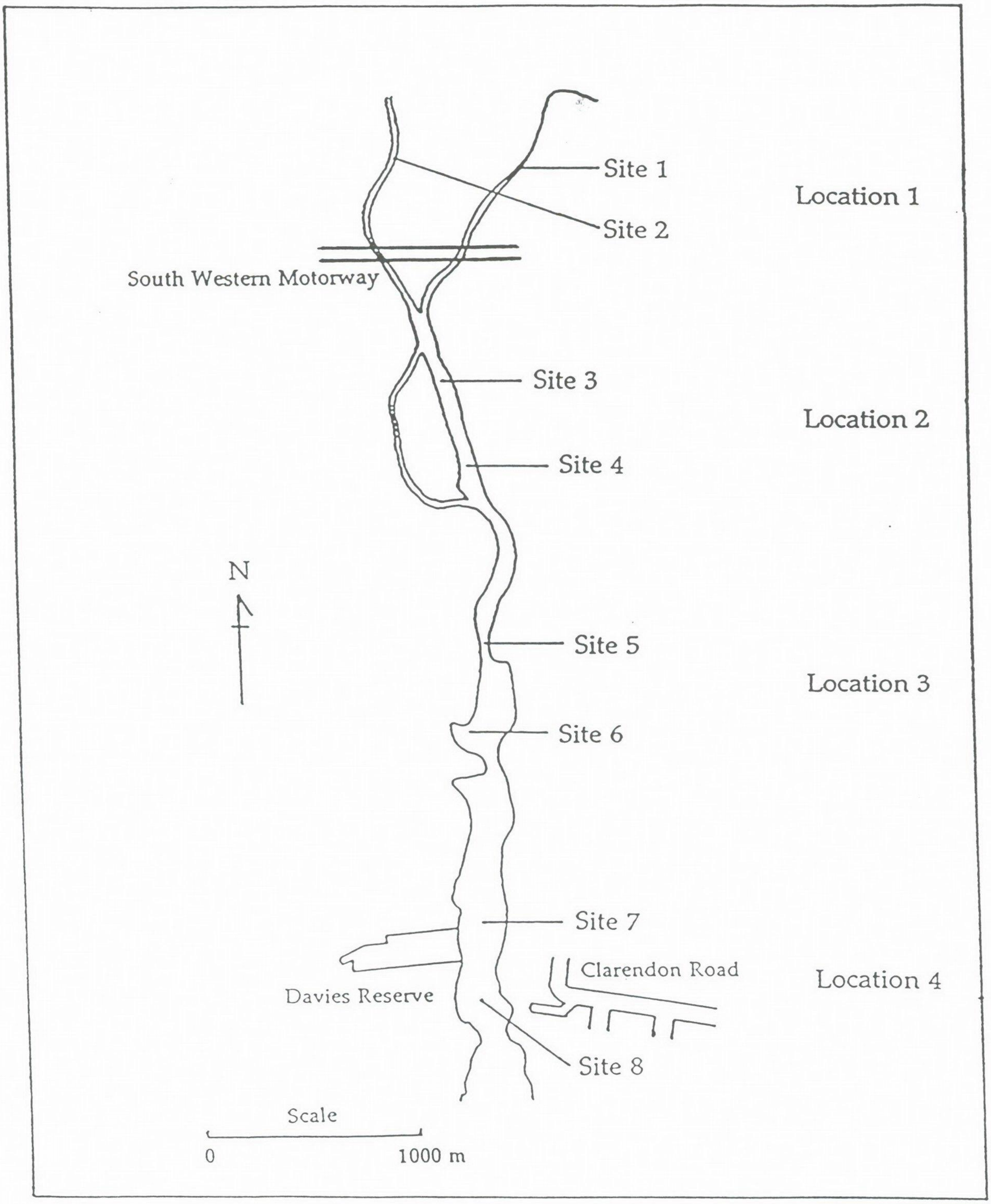


Figure 1. Map of Salt Pan Creek showing the locations and sites used for sampling.

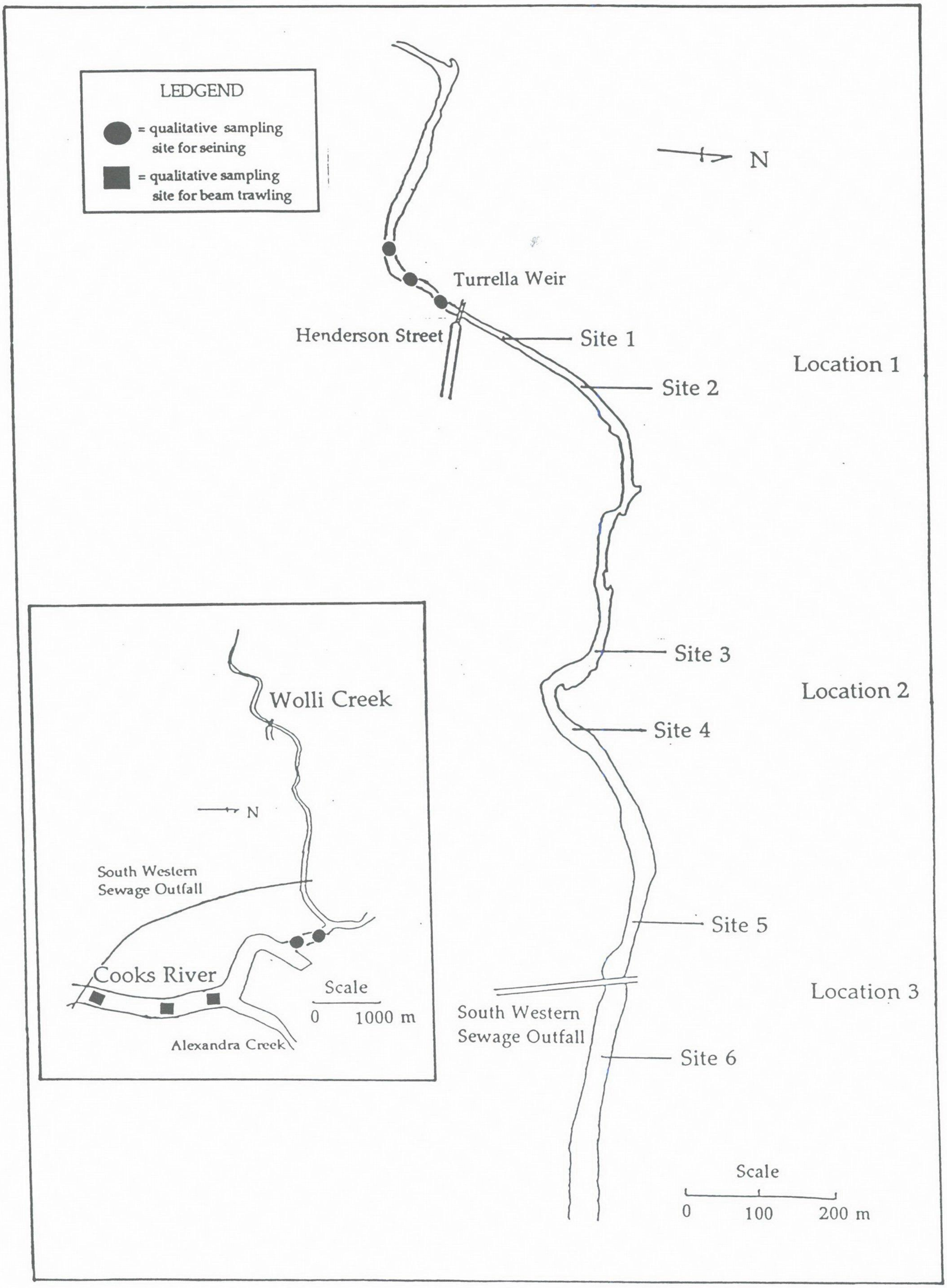


Figure 2. Map of Wolli Creek showing locations and sites used for sampling. The freshwater portion of Wolli Creek is situated above and the tidal portion below Turrella weir. Insert shows Wolli Creek and its conjunction with Cooks River. Sites used for qualitative sampling at Cooks River and the freshwater portion of Wolli Creek are shown (see legend).

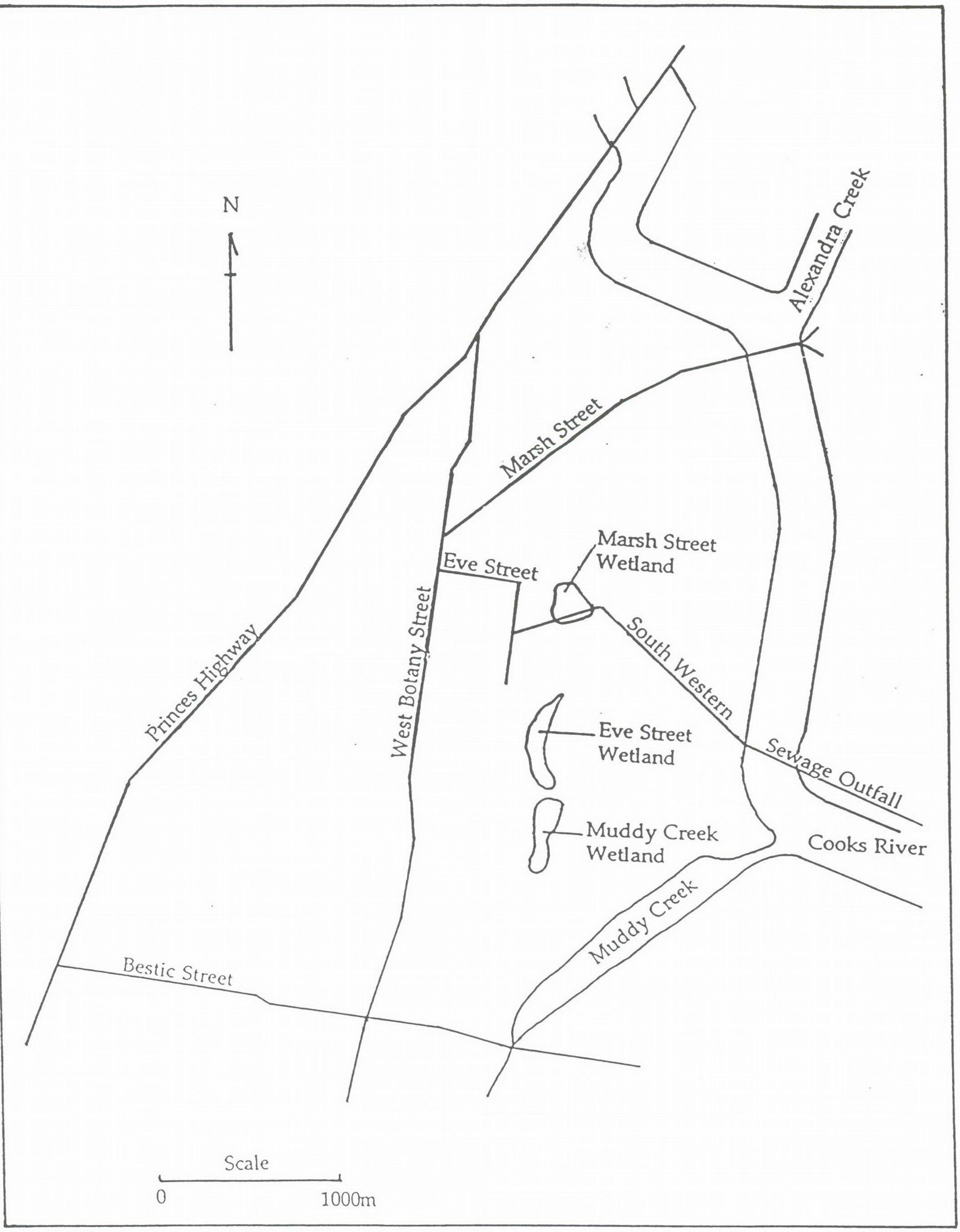


Figure 3. Map of wetlands within Barton Park.

Figure 4. Two dimensional MDS configuration showing a change in assembalge structure among locations. a= Location 1, b= Location 2, c= Location 3.

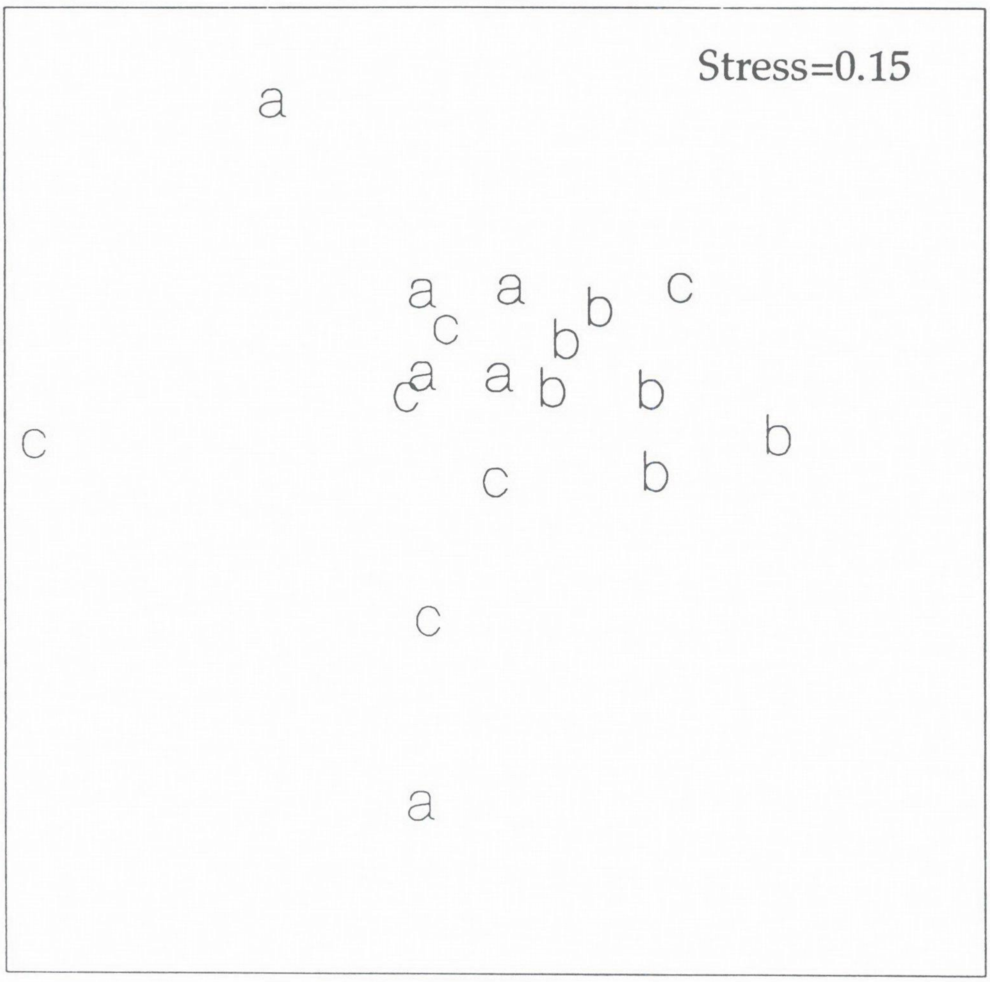


Figure 5. Two dimensional MDS configuration showing a change in assemblage structure among locations. a= Location 1, b= Location 3, c= Location 4.

Figure 6. Mean number of fish (per gill net+ S.E.) vs. locations within Salt Pan Creek. Location number increases with increasing distance downstream. Location 1 represents the furthermost upstream locality. Each location is represented by 2 sites.

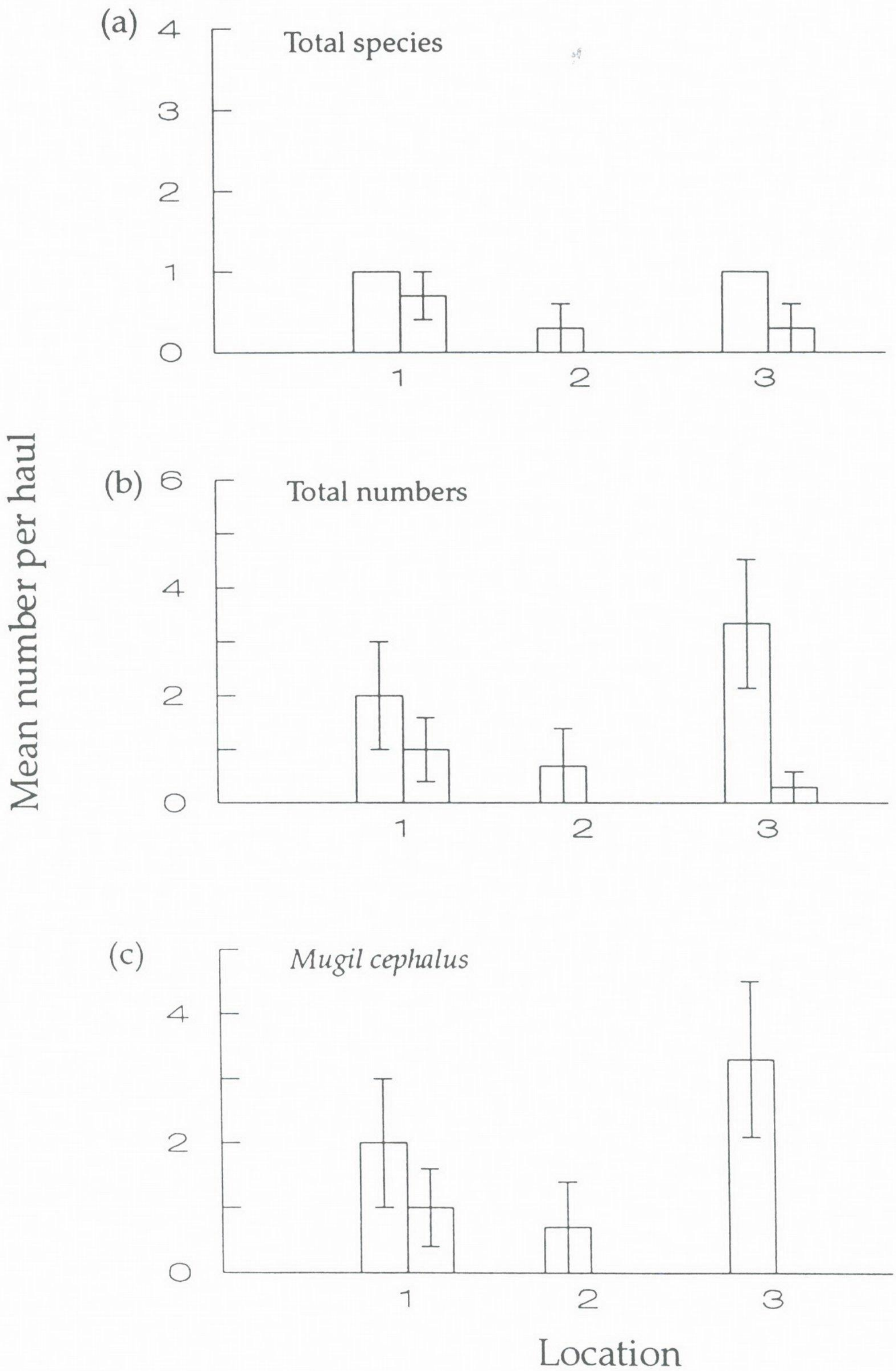


Figure 7. Mean number (per seine net $\pm$ S.E.) vs. locations within Salt Pan Creek. Location number increases with distance downstream. Location 1 represents the furthermost upstream loacility. Each location is represented by 2 sites.

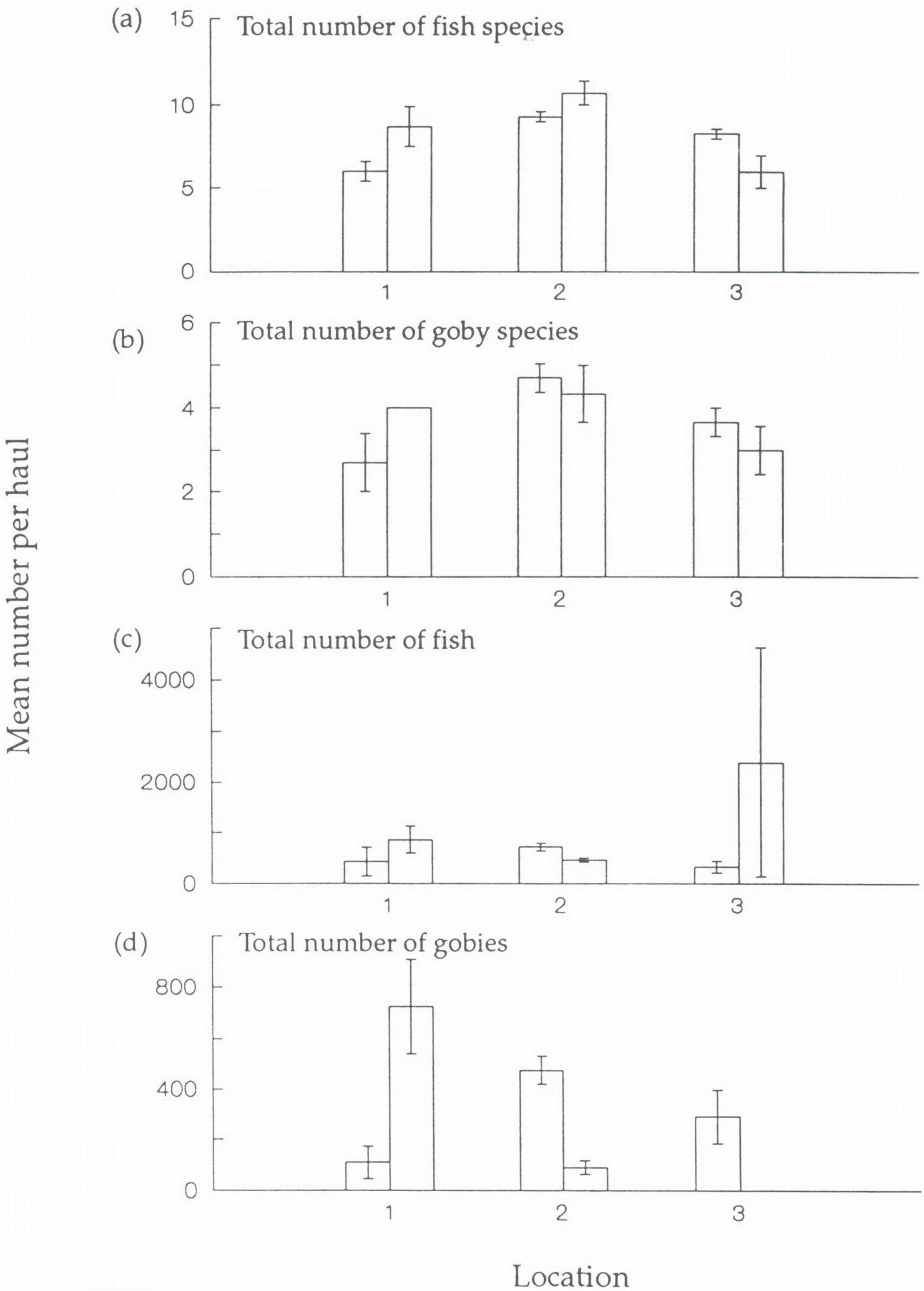


Figure 8. Mean number (per seine net ± S.E.) vs. locations within Salt Pan Creek. Location number increases with distance downstream. Location 1 represents the furthermost upstream loacility. Each location is represented by 2 sites.

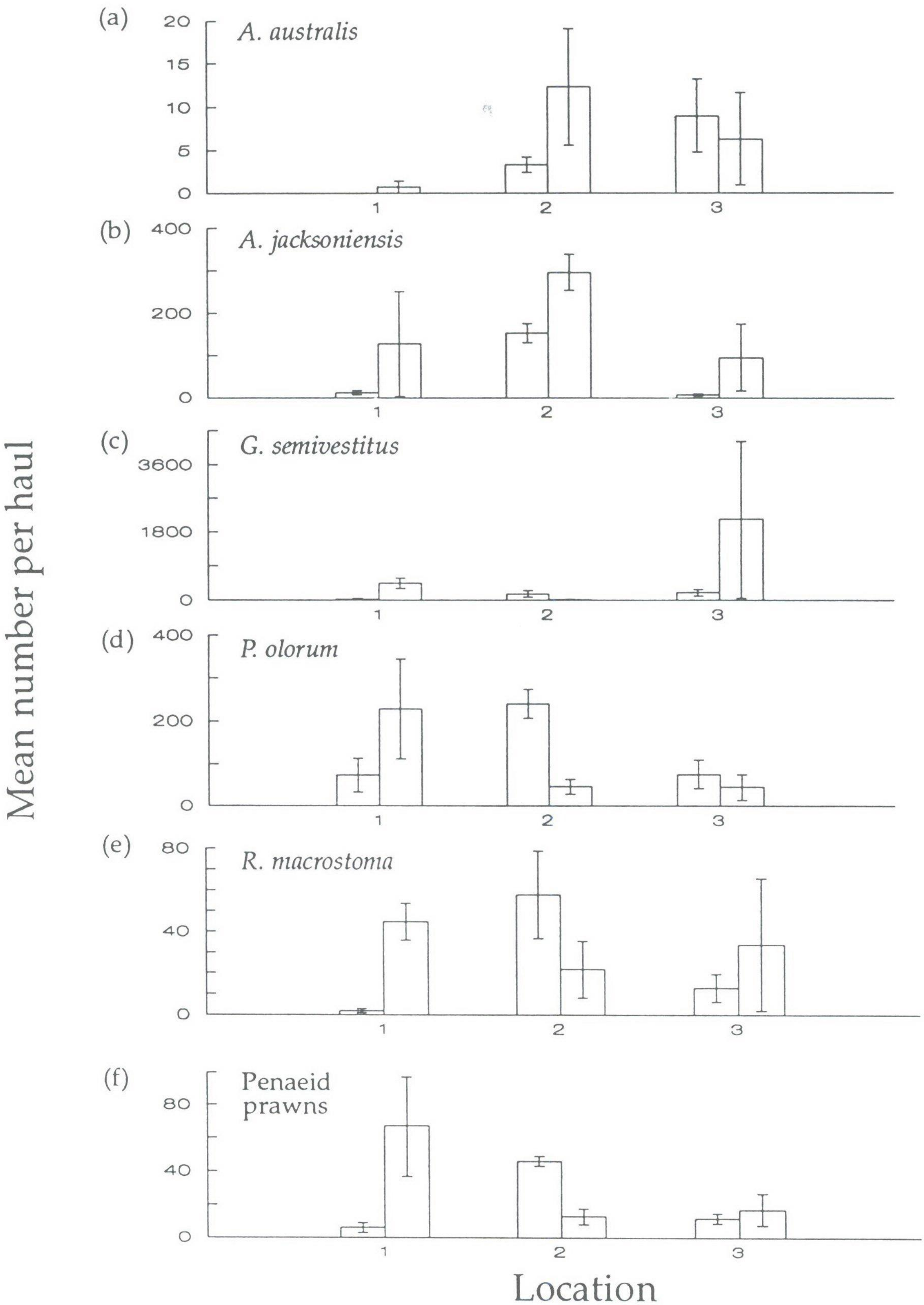


Figure 9. Mean number (per beam trawl ± S.E.) vs. locations within Salt Pan Creek. Location number increases with distance downstream. Location 1 represents the furthermost upstream loacility. Each location is represented by 2 sites.

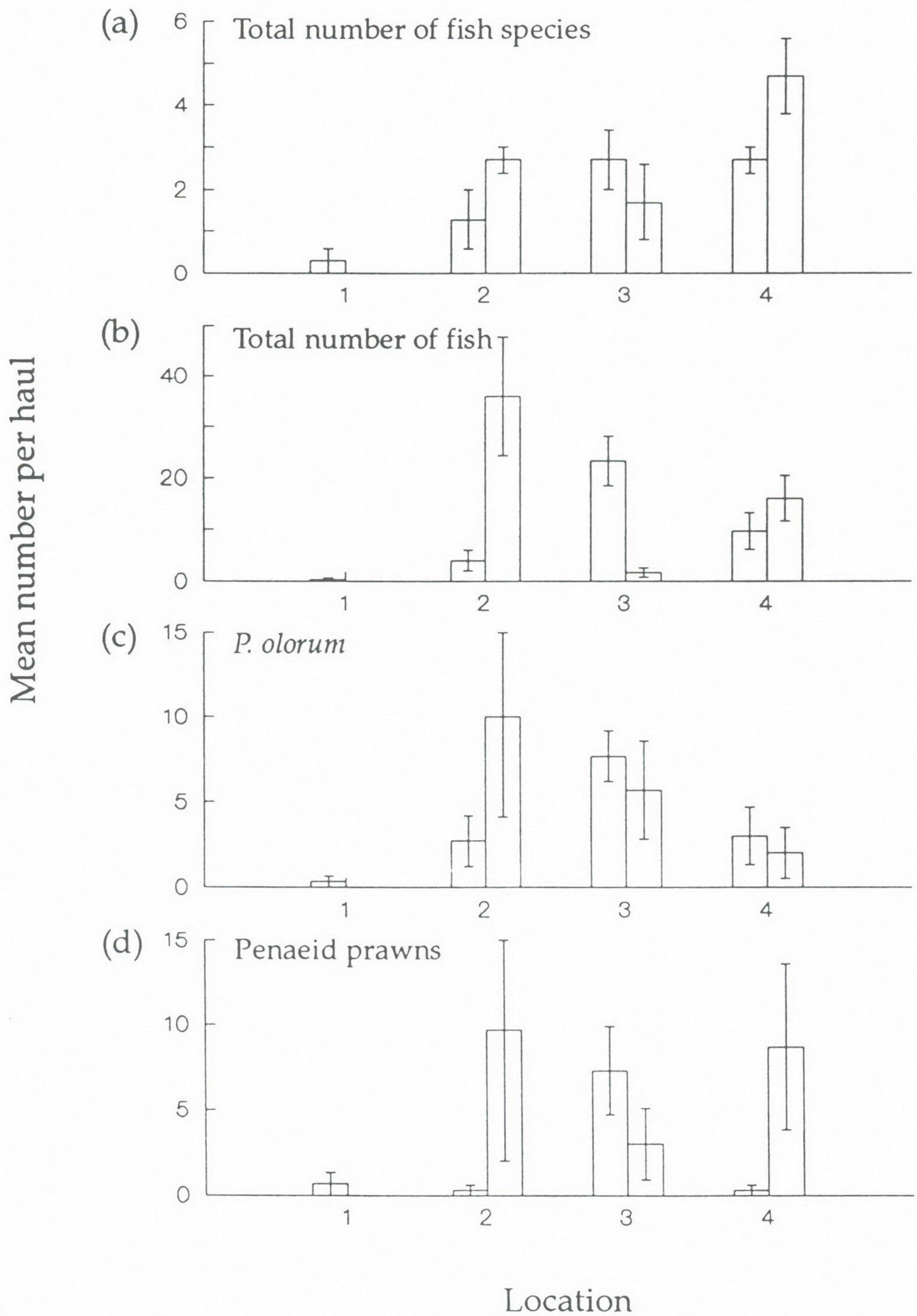


Figure 10. Size frequency of *Mugil cephalus* (LCF) at Salt Pan Creek.

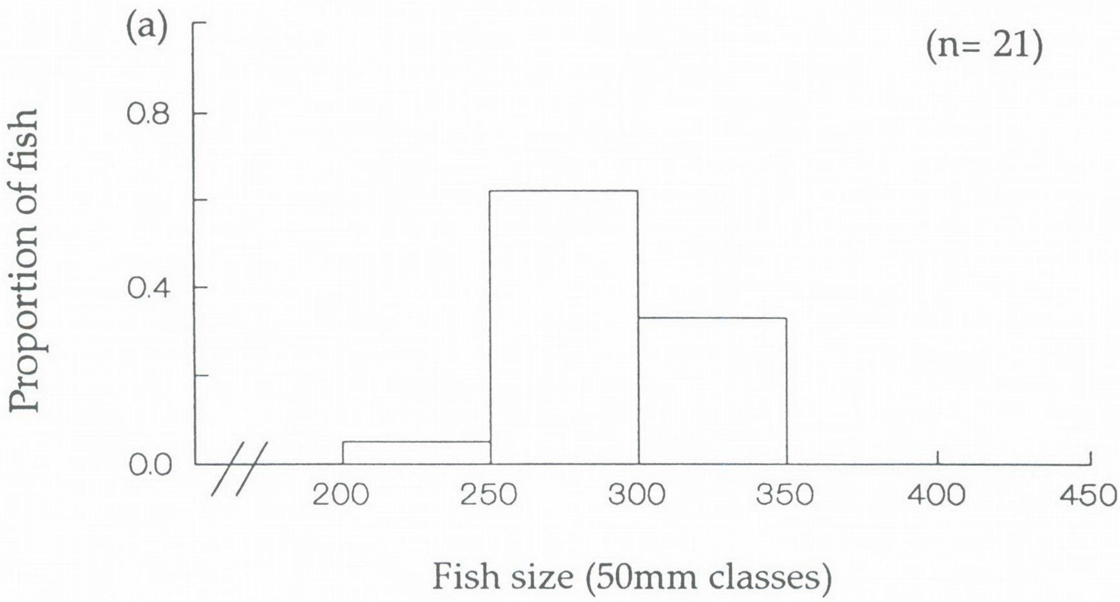


Figure 11. Mean number of fish (per gill net+ S.E.) vs. locations within Wolli Creek. Location number increases with increasing distance downstream. Location 1 represents the furthermost upstream locality. Each location is represented by 2 sites.

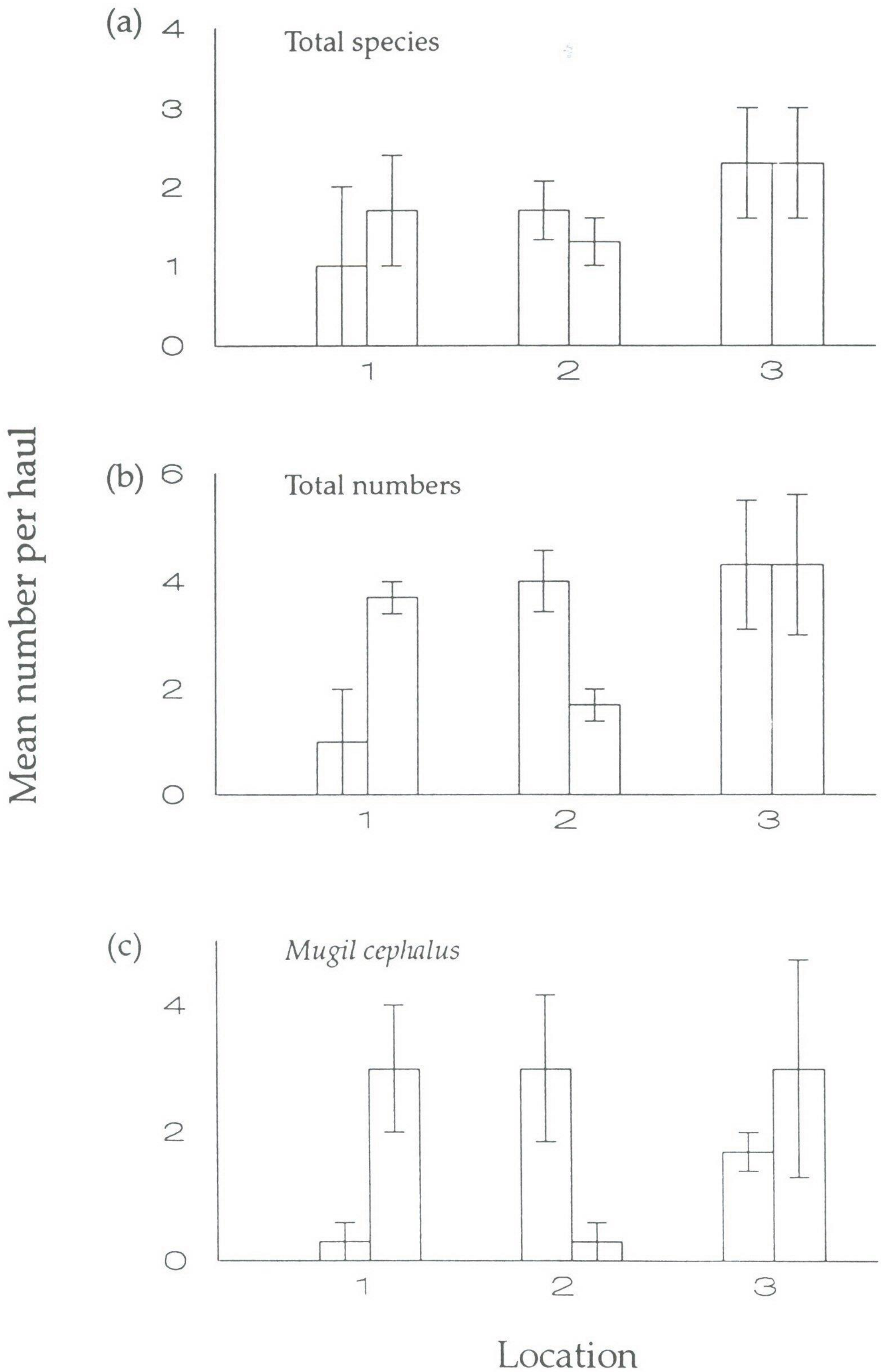


Figure 12. Mean number (per beam trawl ± S.E.) vs. locations within Wolli Creek. Site number increases with distance downstream. Site 2 represents the furthermost upstream loacility.

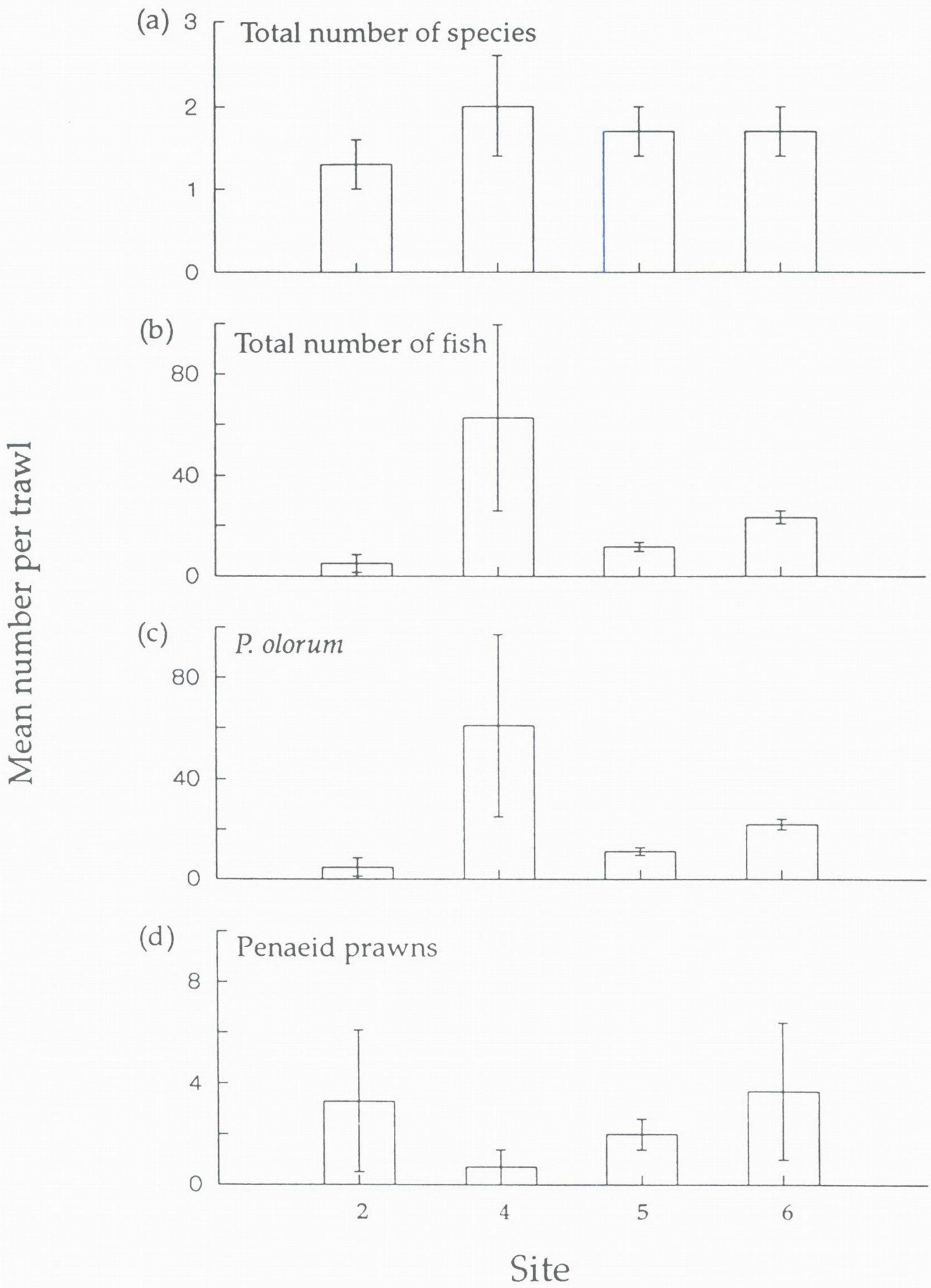


Figure 13. Size frequency of *Mugil cephalus* (LCF) at Wolli Creek.

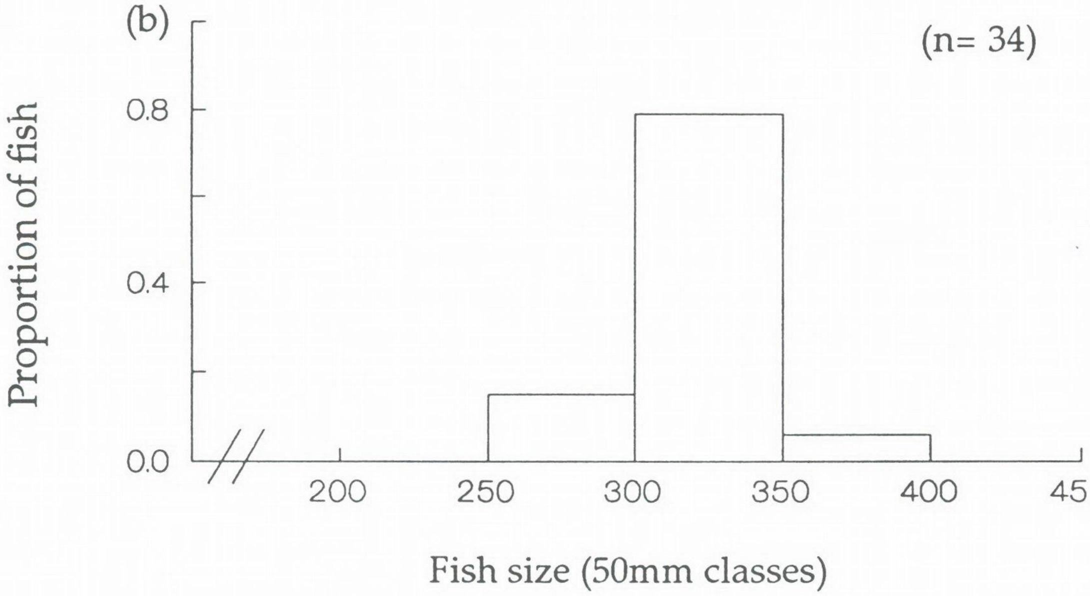


Table 1. Mean and standard error (SE) of fish and crabs caught gill netting at Salt Pan Creek (n=3). Species of recreational/commercial importance indicated by *.

FAMILY	SPECIES	COMMON NAME	Location	1		2		3		4	
			Site	1	2	3	4	5	6	7	8
Platycephalidae	*Platycephalus fuscus*	* Dusky flathead	Mean	0	0	0	0	0	0	0.3	0
			SE	0	0	0	0	0	0	0.3	0
Mugilidae	*Mugil cephalus*	* Sea mullet	Mean	0	0	2	1	0.7	0	3.3	0.3
			SE	0	0	1	0.6	0.7	0	1.2	0.3
Portunidae	*Scylla serrata*	* Mud crab	Mean	0	0	0.3	0	0	0	0.3	0
			SE	0	0	0.3	0	0	0	0.3	0

Table 2. Mean and standard error (SE) of fish and prawns caught in seine net at Salt Pan Creek (n=3). Species of recreational/commercial importance indicated by *.

FAMILY	SPECIES	COMMON NAME	Location	2		3		4	
			Site	3	4	5	6	7	8
Clupeidae	*Hyperlophus sp.*	Sprat	Mean	0	0	0	31	2	0
			SE	0	0	0	15.5	2	0
Engraulidae	*Engraulis australis*	* Australian anchovy	Mean	0.7	0	0	0	0	1
			SE	0.7	0	0	0	0	1
Scorpaenidae	*Centropogon australis*	Fortesque	Mean	0	0.3	0	0	0	0
			SE	0	0.3	0	0	0	0
Scorpaenidae	*Notesthes robusta*	Bullrout	Mean	0	0.7	0	0	0	0
			SE	0	0.3	0	0	0	0
Chandidae	*Ambassis jacksoniensis*	Perchlet	Mean	11.3	127.3	152	296.3	6	94
			SE	5.4	124.3	23.1	42.2	2.5	79
Pomatomidae	*Pomatomus saltatrix*	* Tailor	Mean	0.3	0	0	0	0	0
			SE	0.3	0	0	0	0	0
Sparidae	*Acanthopagrus australis*	* Yellow-fin bream	Mean	0	0.7	3.3	12.3	9	6.3
			SE	0	0.7	0.9	6.7	4.2	5.4
Sparidae	*Rhabdosargus sarba*	* Tarwhine	Mean	2.3	0	0.3	0.7	0	0
			SE	1.5	0	0.3	0.7	0	0
Gerreidae	*Gerres subfasciatus*	* Silver biddy	Mean	0	0	0.3	3.7	1	29.3
			SE	0	0	0.3	0.9	1	29.3
Monodactylidae	*Monodactylus argenteus*	Silver batfish	Mean	0	0.3	0	0	0	0
			SE	0	0.3	0	0	0	0
Girellidae	*Girella tricuspidata*	* Luderick	Mean	0	1	0	0	0	0
			SE	0	1	0	0	0	0
Mugilidae	*Mugil cephalus*	* Sea mullet	Mean	5.7	1	1	6.7	0	0
			SE	5.7	1	0.6	4.4	0	0
Mugilidae	*Liza argentea*	* Flat-tail mullet	Mean	0.3	2.3	35	20.7	0	30.3
			SE	0.3	2.3	31.1	10.3	0	30.3
Gobiidae	*Arenigobius bifrenatus*	Bridled Goby	Mean	0	0	0	0	0	0.3
			SE	0	0	0	0	0	0.3
Gobiidae	*Pseudogobius olorum*	Swan River goby	Mean	72.7	227.7	240	45.3	74.7	43.7
			SE	39.8	116.7	34.2	17.4	34.3	31
Gobiidae	*Favonigobius exquisitus*	Exquisite goby	Mean	0.3	2	3	4.7	3.3	3.3
			SE	0.3	0.6	1.5	2.3	2.4	3.3
Gobiidae	*Gobiopterus semivestitus*	Glass goby	Mean	35	449.3	172.3	17.7	200.3	2140
			SE	25.2	137.8	82.1	11.1	82	2080.2
Gobiidae	*Favonigobius tamarensis*	Tamar River goby	Mean	0	0	3	1.7	0	0
			SE	0	0	2.1	0.9	0	0
Gobiidae	*Redigobius macrostoma*	Largemouth goby	Mean	2	44.7	57.7	21.7	12.7	33.7
			SE	1	8.9	21.1	13.7	6.7	31.7
Gobiidae		Unid. gobies	Mean	0	0.3	0	0	0	0
			SE	0	0.3	0	0	0	0
Eleotrididae	*Philypnodon grandiceps*	Flathead gudgeon	Mean	0.3	0	0	0	0	0
			SE	0.3	0	0	0	0	0
Poeciliidae	*Gambusia affinis*	Mosquito fish	Mean	0	0	0	0	0.7	0
			SE	0	0	0	0	0.7	0
Pseudomugilidae	*Pseudomugil signifer*	Southern blue-eye	Mean	296.7	3.7	53	0	14.3	0
			SE	296.7	2.3	50.5	0	13.8	0
Tetraodontidae	*Tetractinos hamiltoni*	Common toadfish	Mean	0	0	0	3	1.7	2.7
			SE	0	0	0	3	0.9	2.2
Penaeidae	*Metapenaeus sp.*	* prawn	Mean	4.7	44.7	32	12.7	6.7	15.7
			SE	2.6	15.9	12.2	4.7	1.9	10
Penaeidae	*Penaeus*	* prawn	Mean	0.7	18.7	11.7	0	4.7	0.3
			SE	0.3	11.6	11.7	0	4.7	0.3
Caridae	*Cardina sp.*	Carid shrimp	Mean	0	0	0	0	0	81
			SE	0	0	0	0	0	41

Table 3. Mean and standard error (SE) of fish and prawns caught beam trawling (n=3). Species of recreational/commercial importance indicated by *.

FAMILY	SPECIES		COMMON NAME	Location	1		2		3		4	
				Site	1	2	3	4	5	6	7	8
Scorpaenidae	*Centropogon australis*	*	Fortesque	Mean	0	0	0	0	0	0	0	0.3
				SE	0	0	0	0	0	0	0	0.3
Girellidae	*Girella tricuspidata*	*	Luderick	Mean	0	0	0	0	0.3	0	0	0
				SE	0	0	0	0	0.3	0	0	0
Gobiidae	*Arenigobius bifrenatus*		Bridled Goby	Mean	0	0	0	0	0	0	0	0.3
				SE	0	0	0	0	0	0	0	0.3
Gobiidae	*Pseudogobius olorum*		Swan River goby	Mean	0.3	0	2.7	10	7.7	5.7	3	2
				SE	0.3	0	1.5	5.8	1.5	2.9	1.7	1.5
Gobiidae	*Redigobius macrostoma*		Largemouth goby	Mean	0	0	1	24	1.3	1	5.3	7.3
				SE	0	0	1	8.3	0.9	1	1.7	2.7
Gobiidae	*Gobiopterus semivestita*		Glass goby	Mean	0	0	0	0	0	0.3	0	2.7
				SE	0	0	0	0	0	0.3	0	2.2
Gobiidae	*Favonigobius tamarensis*		Tamar River goby	Mean	0	0	0	0	0	0	0.3	0.7
				SE	0	0	0	0	0	0	0.3	0.7
Gobiidae	*Favonigobius exquisites*		Exquisite goby	Mean	0	0	0.3	1	0	0	1	2.3
				SE	0	0	0.3	1	0	0	0.6	0.3
Penaeidae	*Metapeneaus sp.*	*		Mean	0	0	0.3	9.3	4.3	0	0	3
				SE	0	0	0.3	7.8	2.4	0	0	3
Penaeidae	*Penaeus*	*		Mean	0	0	0	0.3	2.7	3.0	0.3	5.7
				SE	0	0	0	0.3	1.5	2.1	0.3	5.7

Table 4. Results of ANOSIM test of differences among assemblages caught seine netting in Salt pan Creek. Pairwise comparisons between locatins are shown. Significance levels are adjusted (Bonferroni: Rices, 1989) to allow for multiple comparisons.

Locations compared	% Significance Level
1 and 2	0.6*
1 and 3	29.9
2 and 3	0.2*

Table 5. Comparison of average species abundance between groups identified by ANOSIM. These species were caught seine netting in Salt Pan Creek. Percent contribution is the contribution of each species to the average Bray-Curtis dissimilarity between the two groups, also expressed as cummulative percentage ("Cum. percent"). Species are listed in order of decreasing importance.

Species	Location 2 Ave. abund.	Locations 1 & 3 Ave. abund.	Percent contribution	Cum. Percent
Ambassis jacksoniensis	224	59.7	11.56	11.56
Gobiopterus semivestitas	95.0	706.2	10.31	21.87
Lisa argentea	27.8	8.3	8.52	30.39
Pseudomugil signifer	26.5	78.7	7.29	37.68
Hyperlophus sp.	15.5	0.5	5.88	43.55
Redigobius macrostoma	39.7	23.3	5.86	49.41
Pseudogobius olorum	142.7	104.7	5.8	55.21
Acanthopagrus australis	7.8	0.4	5.51	60.72
Gerres subfasciatus	2.0	7.6	5.25	65.96
Mugil cephalus	3.8	1.7	5.01	70.98
Penaeid prawns	29.3	25.6	4.9	75.88

Table 6. Results of ANOSIM test of differences among assemblages caught beam trawling in Salt pan Creek. Pairwise comparisons between locatins are shown. Significance levels are adjusted (Bonferroni: Rices, 1989) to allow for multiple comparisons.

Locations compared	% Significance Level
1 and 2	10.4
1 and 3	0.6*
1 and 4	0.2*
2 and 3	68.4
2 and 4	24.7
3 and 4	2.4

Table 7. Comparison of average species abundance between groups identified by ANOSIM. These species were caught beam trawling in Salt Pan Creek. Percent contribution is the contribution of each species to the average Bray-Curtis dissimilarity between the two groups, also expressed as cummulative percentage ("Cum. percent"). Species are listed in order of decreasing importance.

Species	Location 4 Ave. abund.	Location 1 Ave. abund.	Percent contribution	Cum. Percent
Redigobius macrostoma	6.3	28.5	30.5	30.5
Favonigobius exquisitus	1.7	18.3	19.6	50.06
Pseudogobius olorum	2.5	16.9	18	68.09
Penaeid prawns	4.5	12.6	13.4	81.53
Favonigobius tamarensis	0.5	6.1	6.6	88.08
Gobiopterus semivestitas	1.3	4.9	5.2	93.32
Crab	0	2.9	3.1	96.43

Species	Location 3 Ave. abund.	Location 1 Ave. abund.	Percent contribution	Cum. Percent
Penaeid prawns	4.4	27.4	30.8	30.8
Pseudogobius olorum	3.8	25.4	28.6	59.4
Redigobius macrostoma	9.6	21.6	24.3	83.7
Acanthopagrus australis	0.8	5.8	6.6	90.3
Crab	0	3.4	3.9	94.2
Gobiopterus semivestitas	0.4	3	3.4	97.6

Table 8. Summary of ANOVA's describing species number, total abundance and abundance of Mugil cephalus at Salt Pan Creek. Post-hoc pooling was not possible for any of these factors

	Species richness (all fish) C= 0.333				Total number (all fish) C= 0.433				*Mugil cephalus* C=0.448			
Source	d.f.	MS	F	P	d.f.	MS	F	P	d.f.	MS	F	P
Location	2	0.72	2.17	>0.25	2	3.72	0.71	>0.25	2	3.2	0.5	>0.25
Site (Location)	3	0.33	2.00	>0.10	3	5.22	3.13	>0.05	3	6.3	3.9	<0.05
Residual	12	0.167			12	1.67			12	1.6		
Transformation	None				None				None			

Table 9. Summary of ANOVA's describing abundances of biota caught seine netting among locations and sites at Salt Pan Creek. Where "Site(loc)" was non-significant at P>0.25, this factor was pooled with the residual to provide a more powerful test of "Location". Post-hoc pooling did not detect location effects. Pooling was done only for variates with homogeneous data.

		Species richness (all fish) C= 0.419, NS			Species richness (Gobiidae) C= 0.308, NS			Total number of fish C=0.966, SIG			Total number of Gobies C=0.966, SIG		
Source	d.f.	MS	F	P	MS	F	P	MS	F	P	MS	F	P
Location	2	15.7	2.12	>0.25	2.72	2.33	>0.1	10888326	0.48	>0.25	1667499	0.78	>0.25
Site (Location)	3	7.17	4.16	<0.05	1.17	1.62	>0.1	2246456	0.86	>0.25	2125060	0.91	>0.25
Residual	12	1.72			0.72			2614441			2329897		
Transformation	None				None			None			None		

		Acanthopagrus australis C= 0.489, NS			*Ambassis jacksoniensis* C= 0.466, NS			*Gobiopterus semivestitas* C=0.469, NS			*Pseudogobius olorum* C=0.315, NS		
Source	d.f.	MS	F	P	MS	F	P	MS	F	P	MS	F	P
Location	2	100.1	2.49	>0.10	16.6	13.9	<0.5	4.47	1.46	>0.25	2.19	0.85	>0.25
Site (Location)	3	44.3	0.95	>0.25	1.2	0.43	>0.25	9.75	2.78	<0.10	2.58	2.13	<0.25
Residual	12	46.3			2.8			3.51			1.21		
Transformation	None				None			Log E(x+1)			Log E(x+1)		

		Redigobius macrostoma C= 0.569, NS			Penaeid Prawns C= 0.865, NS		
Source	d.f.	MS	F	P	MS	F	P
Location	2	539	0.3	>0.25	1.11	0.28	>0.25
Site (Location)	3	1778	2.02	>0.10	4.03	3.72	<0.05
Residual	12	881			1.08		
Transformation	None				Log E(x+1)		

Table 10. Summary of ANOVA's describing abundances of biota caught beam trawling among locations and sites at Salt Pan Creek. Where "Site(loc)" was non-significant at P>0.25, this factor was pooled with the residual to provide a more powerful test of "Location". Although post-hoc pooling detected location effects for P. olorum, an SNK test could not unambiguously identify which locations differed. Pooling was done only for variates with homogeneous data.

	Species richness (all fish) C= 0.280, NS				Species richness (Gobiidae) C= 0.333, NS			Total number of fish C=0.433, NS			Total number of Gobies C=0.373, NS		
Source	d.f.	MS	F	P	MS	F	P	MS	F	P	MS	F	P
Location	2	12.33	2.12	>0.05	9.04	9.43	<0.05	8.04	2.96	>0.10	7.86	2.91	>0.15
Site (Location)	3	2.58	4.16	>0.05	0.95	1.92	>0.1	2.71	1.12	<0.05	2.7	4.54	<0.05
Residual	16	1.04			0.5			0.61			0.59		
Transformation	None				None			None			None		
					SNK test: 1=2=3=4								

	Pseudogobius olorum C= 0.277, NS				Penaeid prawns C= 0.373, NS		
Source	d.f.	MS	F	P	MS	F	P
Location	2	3.35	6.32	>0.05	1.86	0.87	>0.25
Site (Location)	3	0.53	0.69	>0.25	2.13	2.73	>0.05
Residual	16	0.77			0.78		
Transformation	Log E(x+1)				None		
	SNK test: 1=2=3=4						

Table 11 Mean fork length shown for each species of commercial value caught (a) seine netting and (b) beam trawling at Salt Pan Creek.

(a) Seine netting

SPECIES	COMMON NAME	Mean Length	(n)
Engraulis australis	Australian anchovy	24	5
Pomatomus saltatrix	Tailor	33	1
Acanthopagrus australis	Yellow-fin bream	31	95
Rhabdosargus sarba	Tarwhine	27	10
Gerres subfasciatus	Silver belly	61	103
Girella tricuspidata	Blackfish	38	3
Mugil cephalus	Sea mullet	36	43
Liza argentea	Flat-tail mullet	37	266

(b) Beam trawling

SPECIES	COMMON NAME	Mean Length	(n)
Acanthopagrus australis	Yellow-fin bream	18	6
Girella tricuspidata	Blackfish	34	1

Table 12. Mean fork length shown for each species caught in gill nets at Salt Pan Creek.

SPECIES	COMMON NAME	Mean Length	(n)
Platycephalus fuscus	Dusky flathead	434	1
Mugil cephalus	Sea mullet	285	21
Scylla serrata	Mud crab	90	2

Table 13. Mean fork length shown and number is shown for each species caught in gill nets at Wolli Creek.

SPECIES	COMMON NAME	Mean Length	(n)
Platycephalus fuscus	Dusky flathead	488	2
Acanthopagrus australis	Yellow fin bream	177	9
Gerres subfasciatus	Silver belly	129	5
Girella tricuspidata	Blackfish	241	3
Mugil cephalus	Sea mullet	316	34
Liza argentea	Flat-tail mullet	295	4
Scylla serrata	Mud crab	104	3

Table 14 . Mean and standard error (SE) of fish and prawns caught in the beam trawl at Wolli Creek (n=3). Species of recreational/commercial importance indicated by *.

FAMILY	SPECIES	COMMON NAME	Location				
			Site	1	2	3	4
Chanididae	*Ambassis jacksoniensis*	Perchlet	Mean	0	0	0.3	0
			SE	0	0	0.3	0
Gobiidae	*Pseudogobius olorum*	Swan River goby	Mean	4.7	61.3	11	22
			SE	3.7	36.4	1.5	2.1
Gobiidae	*Favonigobius exquisites*	Exquisite goby	Mean	0	0.3	0	1.3
			SE	0	0.3	0	0.7
Gobiidae	*Gobiopterus semivestitus*	Glass goby	Mean	0.3	0	0	0
			SE	0.3	0	0	0
Gobiidae	*Favonigobius tamarensis*	Tamar River goby	Mean	0	0.3	0.3	0
			SE	0	0.3	0.3	0
Gobiidae	*Redigobius macrostoma*	Largemouth goby	Mean	0	0.7	0	0
			SE	0	0.7	0	0
Penaeidae	Metapeneaus sp.	* prawn	Mean	1.3	0.3	1.3	1.3
			SE	0.9	0.3	0.33	0.7
Penaeidae	Penaeus	* prawn	Mean	0	0	0	2.3
			SE	0	0	0	2.3
Caridae	*Cardina sp.*	Carid shrimp	Mean	2	0	0	0
			SE	2	0	0	0

Table 15 . Number of fish and invertebrates caught beach seining at Wolli Creek. Species of recreational/commercial importance indicated by *.

FAMILY	SPECIES	COMMON NAME Site	2	3	4	5	6
Clueidae	*Hyperlophus vittatus*	* Sandy sprat	0	0	0	0	1
Engraulidae	*Engraulis australis*	* Australian anchovy	0	0	0	0	0
Chanididae	*Ambassis jacksoniensis*	Port Jackson glassfish	1	87	11	11	35
Pomatomidae	*Pomatomus saltatrix*	* Tailor	0	0	0	0	0
Sparidae	*Acanthopagrus australis*	* Bream	0	1	3	0	0
Gerreidae	*Gerres subfasciatus*	* Silver biddy	0	0	0	1	0
Percichthyidae	*Girella tricuspidata*	Blackfish	0	0	0	0	0
Mugilidae	*Mugil cephalus*	* Sea mullet	0	0	83	3	0
Mugilidae	*Liza argentea*	* Flat-tail mullet	0	1	0	1	0
Eleotrididae	*Gobiomorphus australis*	Stripedgudgeon	2	3	6	1	0
Gobiidae	*Pseudogobius olorum*	Swan River goby	22	360	1413	183	679
Gobiidae	*Redigobius macrostoma*	Largemouth goby	0	1	0	0	3
Gobiidae	*Favonigobius tamarensis*	Tamar River goby	0	1	6	12	5
Gobiidae	*Favonigobius exquisites*	Exquisite goby	0	0	12	15	40
Gobiidae	*Gerres semivestita*	Glass goby	30	18	13	78	145
Pseudomugilidae	*Pseudomugil signifer*	Southern blue eye	0	4	3	13	0
Penaeidae	*Metapeneaus sp.*	*	2	1	25	4	0
Penaeidae	*Penaeus sp.*	*	0	0	1	1	0
Caridae	*Cardina sp.*	Carid shrimp	197	0	0	0	0
		Unidentified prawns	0	0	0	9	0

Table 16. Summary of ANOVA's describing species number, total abundance and abundance of Mugil cephalus at Wolli Creek. Although post-hoc pooling was possible for "Species richness", no differences were detected.

	Species richness (all fish)				Total number (all fish)				*Mugil cephalus*			
	C= 0.333				C= 0.433				C=0.448			
Source	d.f.	MS	F	P	d.f.	MS	F	P	d.f.	MS	F	P
Location	2	1.72	6.2	>0.25	2	6.50	1.04	>0.25	2	0.89	0.11	>0.25
Site (Location)	3	0.27	0.22	>0.25	3	6.27	2.63	>0.05	3	8.00	2.82	>0.05
Residual	12	1.27			12	2.39			12	2.83		
Transformation	None				None				None			

Table 17. Summary of ANOVA's describing abundances of biota caught beam trawling among sites at Wolli Creek.

	Species richness (all fish) C= 0.500, NS				Species richness (Gobiidae) C= 0.500 NS			Total number of fish C=0.626, NS			Total number of Gobies C=0.541, NS		
Source	d.f.	MS	F	P	MS	F	P	MS	F	P	MS	F	P
Site	3	0.22	0.44	>0.25	0.31	1.92	>0.25	5.51	3.04	>0.05	2.97	5.26	<0.01
Residual	8	0.50			0.50			1.81			0.56		
Transformation	None				None			Log E(x+1)			Log E(x+1)		
											SNK test: 1=2=3=4		

	Pseudogobius olorum C= 0.494, NS				Penaeid prawns C= 0.509, NS		
Source	d.f.	MS	F	P	MS	F	P
Site	3	9.72	3.24	<0.05	5.64	0.47	>0.25
Residual	8	4.88			12		
Transformation	Log E(x+1)				None		
	SNK test: 1=2=3=4						

Table 18. Vertebrates and invertebrates caught (a) beach seining and (b) dip netting in the freshwater portion of Wolli Creek (above Turrella weir).

	FAMILY	SPECIES	COMMON NAME Site	1	2	3
(a)	Poeciliidae	*Gambusia affinis*	Mosquitofish	163	1	3
	Eleotridae	*Gobiomorphus australis*	Striped gudgeon	11	1	0
	Galaxiidae	*Galaxias maculatus*	Common jollytail	2	0	0
	Caridae	*Cardina sp.*	Carid shrimp	5	0	0
	Chelidae	*Chelodina longicollis*	Long-necked tortoise	0	0	2
(b)	Poeciliidae	*Mugil cephalus*	Sea mullet	1	0	0
	Eleotrididae	*Gambusia affinis*	Mosquitofish	4	3	1
	Eleotridae	*Gobiomorphus australis*	Striped gudgeon	1	0	0

Table 19. Mean fork length shown for each species of commercial value caught seine netting at Wolli Creek.

SPECIES	COMMON NAME	Mean Length	(n)
Acanthopagrus australis	Yellow-fin bream	30	4
Rhabdosargus sarba	Tarwhine	28	5
Gerres subfasciatus	Silver belly	123	2
Mugil cephalus	Sea mullet	36	13
Liza argentea	Flat-tail mullet	28	2

CURRENT OPTIONS FOR THE M5 EAST MOTORWAY-
PADSTOW TO BOTANY/MASCOT:
THE ABORIGINAL POTENTIAL

M5 East Supplement

Prepared by Haglund and Associates for
the Roads and Traffic Authority,
October 1995.

CURRENT OPTIONS FOR THE M5 EAST MOTORWAY -

PADSTOW TO BOTANY/MASCOT:

THE ABORIGINAL HERITAGE POTENTIAL

M5 East Supplement

Summary

The two route variations discussed here are seen as likely to have little or no impact on Aboriginal heritage aspects. Of the two, the southern variant appears least likely to have any impact. However, mitigating measures are recommended to ensure that this will be the case.

Assessment

1. Scope of Project

The background to this study and relevant environmental data have been presented in previous reports (Haglund 1989, 1994 and several draft reports to Manidis Roberts Consultants). The comments below relate to potential impacts on Aboriginal heritage aspects by two alternative routes for the M5 tunnel, one largely north and one largely south of Wolli Creek (Fig.1), referred to below as the northern and southern routes.

For this review the main areas of concern were:

> The potential effects of tunnel construction and use, and of associated works such as vents and air intakes.
>
> The proposed southeastward route linking up with General Holmes Drive, in areas close to the Eve Street Wetlands.

Much of the information obtained for previous reports is applicable also to these routes. Some proposed locations for air vents for the tunnel part were visited to assess the condition and character of the surface, others were assessed on the basis of their underlying geology and/or their location in heavily used and developed areas (Fig.2). Systematic and more detailed inspection for evidence of Aboriginal presence may be needed in some of these, if the relevant route is selected and when precise locations have been determined. Such inspection may require clearing of vegetation cover and involvement by Aboriginal representatives.

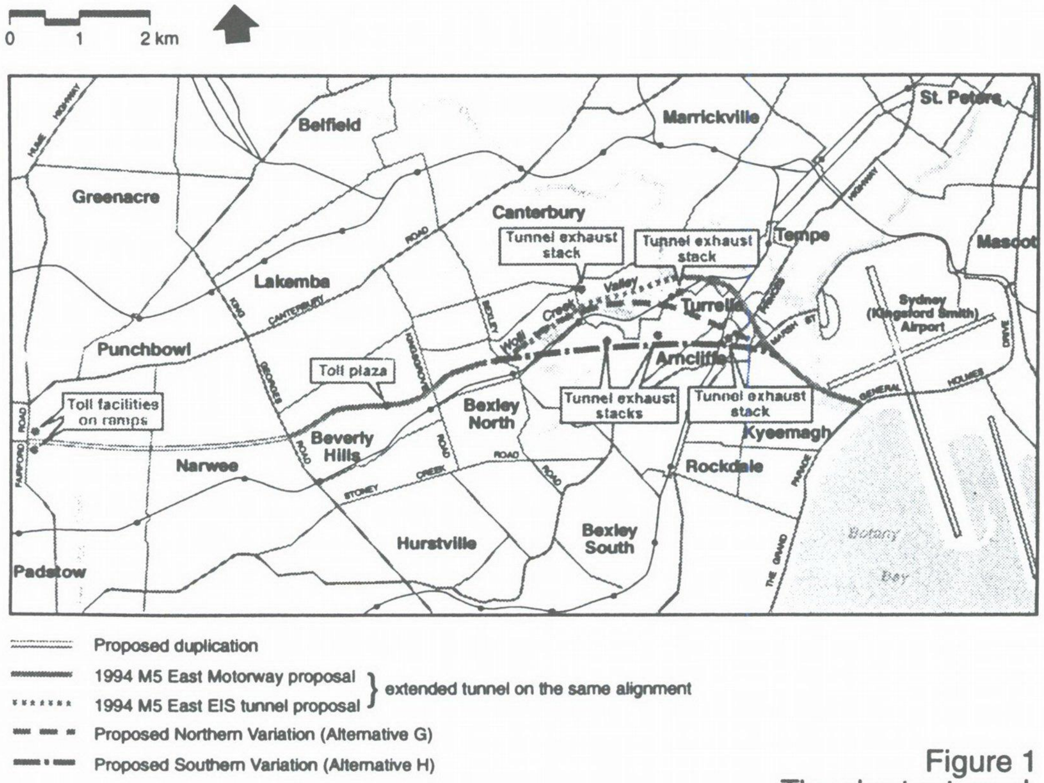
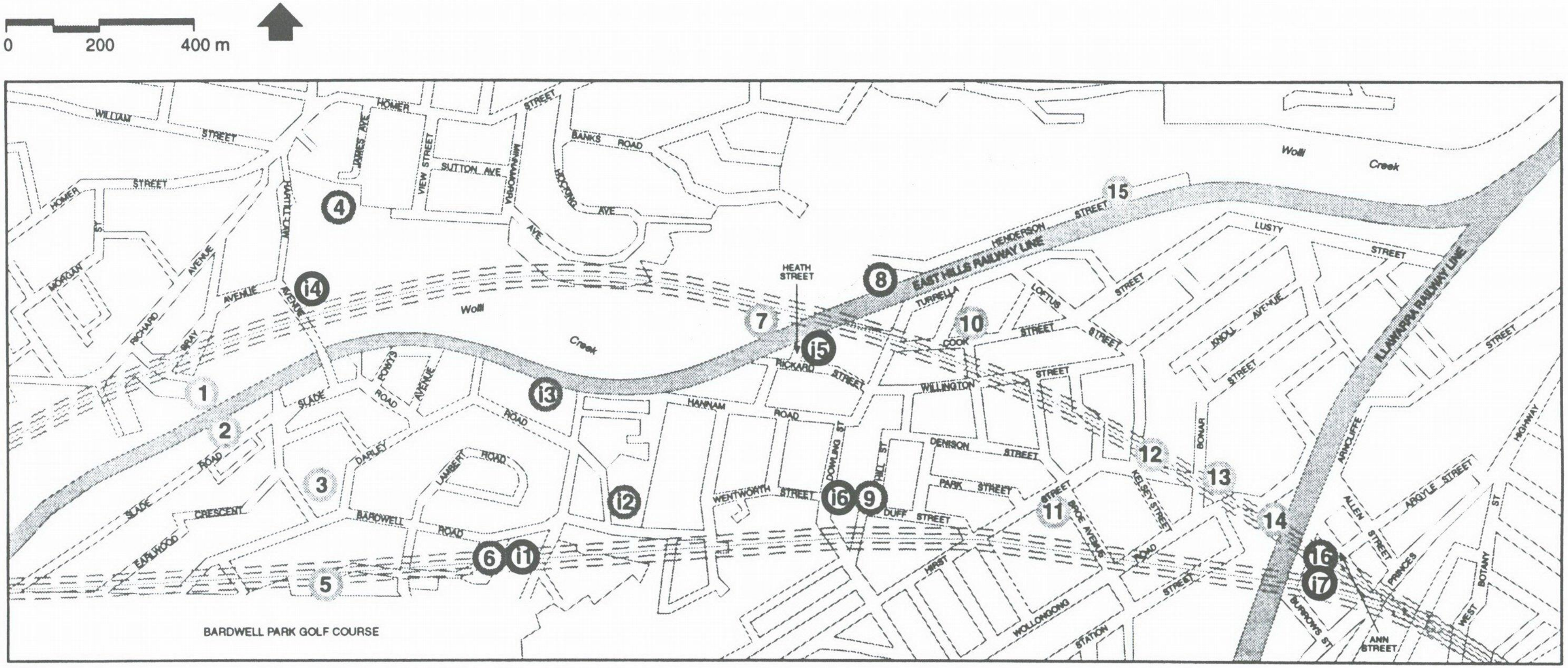


Figure 1
The shorter tunnel,
the extended tunnel and
the Variations

The brief provided by Manidis Roberts Consultants noted that it forms an extension of the main study and the need for a comparative evaluation of potential impacts of the two routes.

Detailed mapping on orthophoto maps at 1: 4,000, had been provided for the main study. For the present variations the proposed air intake and vent sites were located in relation to nearby streets. Information on subsurface deposits was taken from Burgess 1989, and information about the eastern part, the approach to Cooks River near Eve Street Wetlands and Barton Park, was provided in drawings and two supplementary reports (Osborne 1995, Connell Wagner 1995).



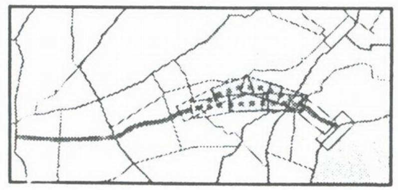
Exhaust stack locations considered

1 Bardwell Park RSL car park (20-25m high, 10m diameter)
2 Slade Road Reserve, Bardwell Park (20-25m high, 10m diameter)
3 Shepherd Park, Bardwell Park (15m high, 10m diameter)
4 Earlwood Car Park (15m high, 10m diameter)
5 Moore Street at Golf Course (20-25m high, 10m diameter)
6 Royal Place at Golf Course (15m high, 10m diameter)
7 Heath Street, Turrella (25m high, 9m diameter)
8 Henderson Street, Turrella (25m high, 9m diameter)
9 Duff Street, Arncliffe (15m high, 9m diameter)
10 Cook and Reede Streets, Turrella (20-25m high, 9m diameter)
11 Arncliffe Park, Arncliffe (20-25m high, 9m diameter)
12 Loftus/Kelsey/Hirst Streets, Turrella (20-25m high, 9m diameter)
13 Wollongong Road/ Bonar Street, Turrella (20-25m high, 9m diameter)
14 Firth Street/Illawarra Rail Line, Turrella (20-25m high, 9m diameter)
15 Henderson Street Mail Exchange, Turrella (25m high, 9m diameter)
16 Arncliffe Army Reserve depot (15m high, 9m diameter)

Air intake locations considered

i1 Royal Place at Golf Course
i2 Coolabah Reserve
i3 Ron Gosling Reserve
i4 Hartill-Law Avenue
i5 Heath Street, Turrella
i6 Duff Street, Arncliffe
i7 Arncliffe Army Reserve depot

10m x 8m, 3m high (nominal)



Exhaust stacks
Preferred exhaust stacks
Air intakes
Preferred air intakes

Figure 2
Vent stack and air intake locations

2. Results

2.1 Northern route:

Tunnel: From Bexley Road to Marsh Street, Arncliffe.

Judging from the information provided and discussed in previous reports, the construction and use of the proposed tunnel is unlikely to have any impact on Aboriginal heritage aspects. Although it runs below or near some areas with cliff faces and the potential to contain Aboriginal sites, e.g. Illoura, Girrawheen Parks (Haglund 1989) proposed construction methods aim to ensure that neither rock shelters nor houses are affected by vibration. The tunnel also runs below, and eastern exit is well clear of alluvial sediments along Wolli Creek which have been identified as having some potential to retain prehistoric material..

Air intake and exhaust vent locations.

Air intakes are planned for three locations: Girrawheen Park close to Hartill-Law Avenue; near Arncliffe Street east of the Illawarra railway line and on the south side of East Hills Railway easement between Heath and Amy Streets. Of these only the last is at all likely to cut through alluvial deposits. These are likely to be recent and disturbed, and are unlikely to retain Aboriginal archaeological material (cf. section 3 below). Depending on the precise location selected for the intake in Girrawheen Park, the surface may need inspection at the time of clearing.

Vent stacks are also planned for three locations: in car park (on solid rock) southwest of St.James Avenue, Earlwood; near Arncliffe Street east of the Illawarra Railway (with the air intake), and between Turella Station and Henderson Street. Again, only the third location is likely to cut through alluvium, which is probably recent and may be covered with fill and/or disturbed to some depth. Here some monitoring and sampling of the underlying alluvium removed for the vent is recommended.

2.2 Southern route:

Tunnel: From Bexley Road to Marsh Street, Arncliffe.

The tunnel crosses Wolli Creek well below the creek and below areas of possible high level alluvium, to run well below the rock surface. It is unlikely to have any impact on Aboriginal sites.

Air intake and exhaust vent locations.

Air intakes combined exhaust vents nearby, are planned for three locations: Bardwell Valley Golf Course just below Bardwell Road and Royal Place, on low ground below rock faces; near the intersection of Gipps and Duff Streets, Turella, and at Arncliffe Street, Arncliffe, i.e. all in heavily used areas.

Of these the first pair, in Bardwell Park golf course, is located on high alluvium which could contain lenses of Aboriginal archaeological material. Depending on the precise location of the vents, the surface may need detailed inspection, possible in connection with surface clearing. Some monitoring and sampling of the underlying alluvium removed for the vent is also recommended.

2.3 Eastern end of both routes.

Eve Street Wetlands - Barton Park.

The general area has been much disturbed but the Eve Street Wetlands may be a relic of a pre-European landscape; they were left undeveloped because they were unsuitable for filtering or crop-growing (Callaghan 1990). Such a landscape could retain evidence of past Aboriginal land use. This will be relevant only if, and to the extent that the cut and cover part of the tunnel and any support construction, drainage works etc. relating to the proposed route might cut into such surfaces.

3. Discussion and assessment

Reference has been made to (probable) high alluvium, which would have been deposited during a period of somewhat higher sea level (Burgess 1989). Tunnelling for one set of vent plus air intake would therefore cut through sediments that could contain archaeological deposits such as shell middens. As the vents are of small diameter, the probability appears low, but sampling or monitoring of the deposit in the vent/air intake area may be appropriate.

Two locations involve tunnelling through recent alluvium, probably also a layer of recent fill or extreme surface disturbance. On such alluvium Aboriginal sites would have been on or close to the present surface and therefore much exposed to disturbance or destruction by floods and/or development.

Conclusion:

On the basis of information available in relation to the routes considered here, we may conclude that:

- The construction of air vents and air intakes in the proposed locations and use of access routes to these are unlikely to cause damage to potential Aboriginal sites.

- Tunnel construction would not involve blasting that could cause cracking or collapse of cliff faces with rock shelters.

- Road construction in/near the Eve Street Wetlands is unlikely to have adverse impact on Aboriginal heritage aspects.

These route variations therefore appear unlikely to adversely affect the Aboriginal heritage of the area (known and unknown).

The southern route seems even less likely than the northern to interfere with Aboriginal heritage aspects.

Potential impacts of the present proposal appear limited to possible disturbance of patches of sub-surface archaeological deposits if present just where some air intake, vent, road cutting or support cuts through the sediments. The probability of such an event appears extremely low.

Should the locations of air intake/exhaust vents be moved to near rock faces, there might be some impact on deposits in minor rock shelters, if present. This also seems unlikely.

4. Need for further investigation and/or mitigating measures

However, the following precautionary measures should be considered:

If vents are to be constructed close to or on the cliff faces adjoining Bardwell Park Golf Course, there may be a need for clearing and inspection of the adjoining cliff face.

If archaeological deposits are present in areas of alluvium that would be directly affected by the motorway construction, they are likely to occur at such depths that they would not be easily reached by test excavation. Nor would there be any surface indication of their presence. However, thhe presence of such deposits may be investigated through monitoring of the relevant portions of the excavation for construction. Large scale, systematic archaeological excavation would not be feasible except below fairly shallow fill, and is unlikely to be warranted, but sizeable samples of e.g. shell bed should be retrieved for analysis, if noted.

5. Recommendations

The recommendations in the main report stand with regard to any portions of route retained by the present proposal.

If, however, if either of these routes is selected, the additional measures outlined in section 4 above are recommended.

The RTA should therefore engage, or require the contractor to engage, an archaeologist to be present during earthworks at possible sensitive areas, such as at the Eve Street Wetlands and the site of the air intake and exhaust vent sites noted above as possibly archaeologically sensitive.

Note that the Metropolitan Local Aboriginal Land Council will be consulated in relation to the reports on the various options considered as part of the Aboriginal heritage assessment, and may when a decision has been made, request participation, monitoring etc. during construction works in certain areas.

A copy of this report should be forwarded to:

the Sites Officer
the Metropolitan Local Aboriginal Land Council,
P.O.Box 1103
Redfern NSW

Four copies of this report should be forwarded to:

the Sydney Zone Team
Head Office, NPWS of NSW
P.O. Box 1967
Hurstville NSW 2220

6. Maps and plans used for this report

Kogarah U0937-12 to 14, 21 to 22 and 51 to 52 Orthophotomap 1:2000 Series

Kogarah U0937-52 Orthophotomap 1:2000 Series

Leichhardt U0945-94 Orthophotomap 1:2000 Series

Peakhurst U0037-33 Orthophotomap 1:2000 Series

7. References

Burgess, P. 1989 F5 South Western Freeway. Report on tunnel options for Wolli Creek. Also Appendix: Tempe to Bexley North. Proposed tunnel option. Background geology. Prepared on behalf of Connell Group, Consulting Engineers.

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AIR QUALITY ASSESSMENT

A VARIATION TO THE PROPOSED M5 EAST MOTORWAY

26 November, 1996

Prepared
for
Manidis Roberts Consultants

by

Holmes Air Sciences

2B 14 Glen Street
Eastwood NSW 2122
Phone (02) 9874-8644
Fax (02) 9874-8904

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1.0 INTRODUCTION

This report has been prepared by Holmes Air Sciences for Manidis Roberts Pty Ltd who are acting for the Roads and Traffic Authority of NSW (RTA). Its purpose is to assess the air quality impacts of a Variation to the proposed M5 East Motorway.

The assessment forms part of a supplementary report to the original Environmental Impact Statement (EIS) (**Manidis Roberts, 1994**) which was displayed between 11 July, 1994 and 10 October, 1994. In response to public reaction to the EIS, the RTA is considering an extension to the proposed tunnel as well as changes to the surface road configuration. In addition, the road east of King Georges Road will not be tolled. This is predicted to result in increased traffic on the motorway over that considered in the 1994 EIS.

Background to the proposal, monitoring data and discussion of the general impacts of roadways have been discussed in detail in the 1994 EIS. This information is not reproduced in full detail in this supplementary document, however for ease of reading some aspects of these issues have been summarised.

2.0 PROPOSAL

Following display of the 1994 EIS, public concern was expressed about the proposed alignment of the route. Particular concern was expressed about the viaduct originally proposed for Turrella as well as effects on residential properties in North Arncliffe. It was suggested that the tunnel be extended through North Arncliffe to reduce impacts. However when the extension to the tunnel was examined it became apparent that a realignment of the tunnel may be a more viable option than simply extending the original proposed alignment of the tunnel. This is shown in **Figure 1**. Due to the increased length of the tunnel it would be necessary to have three exhaust vents rather than the one proposed in the original EIS. In addition the toll east of King Georges Road would be removed

The surface road would consist of duplication of the existing 2 lanes from Fairford Road to King Georges Road. A new 4 lane motorway would be constructed along the full length from King Georges Road to General Holmes Drive. The road would be a surface road from King Georges Road to Bexley Road, then a twin 2-lane tunnel to Marsh Street, and a surface road to General Holmes Drive.

There would be two east facing ramps at Fairford Road to complement the existing two west facing ramps, a full diamond interchange at King Georges Road, west facing ramps at Bexley Road, a full diamond at Marsh Street, and north facing connection onto General Holmes Drive by split centre loading to provide smooth flow for trucks to and from Foreshore Road. From the M5 East there would be an eastbound to northbound exit ramp at Princes Highway, and from Princes Highway a south to west/north to west connection to the M4 East.

Between Fairford Road and King Georges Road, the work would be part of the Interlink M4, and would have a mini toll plaza on each of the two east facing ramps to be provided at Fairford Road.

East of King Georges Road, the road would not be tolled. The toll plaza site would be retained to provide a site clear of the carriageway for use by Police/EPA/RTA Vehicle Inspectors for roadside enforcement, as was canvassed generally in the 1994 EIS.

The surface road would consist of two 3.5 m lanes in each direction separated by a concrete barrier, with the total width between the eastbound and westbound lanes being 1.6 m. A 3.5 m clearway/breakdown lane would replace the 2.5 m shoulder/cycleway proposed in the 1994 EIS. The traffic would not in effect be any closer to the residences than for the 1994 EIS, but this extra metre would make a difference to kerbside concentrations and concentrations at varying distances from the kerb since the kerb itself would been displaced from its proposed position in the EIS.

The tunnel would carry two 3.5 m lanes. Two options are being considered. These are:

- Two 3.5 m lanes, total width between kerbs of 7.0 m
- 2.5 m breakdown lane, two 3.5 m lanes, 1.0 m shoulder, total 10.5 m.

Other details are in accordance with the 1994 EIS.

In considering the possible locations for tunnel vents, various constraints were taken into account. Firstly the location relative to the entrance and exit from the tunnel were considered in relation to ventilation requirements. Points that were a quarter of the way along the tunnel were considered to be the optimum location, however other constraints, such as the ability to find a suitable location for the vent were obviously taken into account.

A total of seven possible sites were considered and the locations of these are shown in **Figure 2**. Factors such as local terrain, the presence of sensitive receptors and distance from the tunnel (and therefore the requirements for additional tunnelling) were all taken into account.

The area has some complex terrain and this is shown in **Figure 3**. Terrain would interact with stack emissions in a way which cannot be determined without dispersion modelling. To this end, all the possible vent locations were modelled taking into account various stack heights.

Three preferred locations were determined, namely:

- Royal Place
- Duff Street
- Arncliffe Street

These will be considered in detail in this report.

3.0 AIR QUALITY GOALS

This section discusses the ambient air quality goals which relate to motor vehicle emissions. Their health impacts are discussed in detail in the EIS and will not be reproduced in this report.

The New South Wales Environment Protection Authority (NSW EPA) notes air quality goals for nitrogen dioxide, carbon monoxide, particulate matter, lead and sulphur dioxide determined by the World Health Organisation (WHO), the United States Environment Protection Agency (US EPA) and the National Health and Medical Research Council of Australia (NHMRC). Air quality goals for hydrocarbons have been used previously, but these have been discarded because they are not specific for reactive species which are the important elements in the formation of photochemical smog.

Table 1 lists the EPA's air quality goals for New South Wales. Not all of these are major emissions from motor vehicles.

TABLE 1 - NSW AIR QUALITY GOALS

Pollutant	Standard[1]	Agency
Total suspended particulate matter (TSP)	90 $\mu g/m^3$ (annual mean)	NHMRC
Particulate matter < 10 μm (PM_{10})	50 $\mu g/m^3$ (annual mean) 150 $\mu g/m^3$ (24-hour maximum)	US EPA US EPA
Lead	1.5 $\mu g/m^3$ (90-day average)	NHMRC
Carbon monoxide	87 ppm or 108 mg/m^3 (15-minute maximum) 25 ppm or 31 mg/m^3 (1-hour maximum) 9 ppm or 11 mg/m^3 (8-hour maximum)	WHO WHO NHMRC
Nitrogen dioxide	0.16 ppm or 328 $\mu g/m^3$ (1-hour maximum) 0.05 ppm or 103 $\mu g/m^3$ (annual mean)	NHMRC US EPA
Ozone	0.10 ppm or 214 $\mu g/m^3$ (1-hour maximum) 0.08 ppm or 170 $\mu g/m^3$ (4-hour maximum)	NHMRC NHMRC
Sulphur dioxide	25 pphm or 700 $\mu g/m^3$ (10-minute maximum) 20 pphm or 570 $\mu g/m^3$ (1-hour maximum) 2 pphm or 60 $\mu g/m^3$ (annual mean)	NHMRC NHMRC NHMRC
Suspended matter	40 $\mu g/m^3$ (annual mean)	WHO

4.0 METEOROLOGY

4.1 Wind data for Mascot

The closest meteorological monitoring station with long term data which can be considered as reasonably representative of the development site is the Bureau of Meteorology Station at Sydney Airport. The data available comprise three-hourly measurements of wind speed and wind direction.

Figure 4 presents the seasonal and annual wind rose diagrams for Mascot. On an annual basis, the most common winds are from the S, SSE, NW and W. There are marked seasonal variations. The most common winds in spring and summer are from the SSE and S, however in summer there is also a high frequency of winds from the NE. In autumn the southerly winds still predominate but there are also winds from the NW. In winter, winds from the NW and W predominate and there is a much lower frequency of southerly winds.

5.0 ESTIMATE OF EMISSIONS

Emission estimates for traffic on the motorway were determined in the EIS, however since then a comprehensive emissions inventory which relates vehicle emissions to different travel conditions in NSW has been prepared for the Metropolitan Air Quality Study (MAQS) (**Carnovale 1995**). These have been used in the current report, along with modifications which take into account grade within the tunnel. Details of the emission estimates both for the surface road and the tunnel, are presented in **Appendices A** and **B**.

In addition an assessment of the regional impacts of the M5 East Motorway has been undertaken. This comprises an estimate of the total vehicle emissions into the Sydney airshed, with and without the M5 East Motorway built.

5.1 Emissions from surface road

This section provides a brief description of the methods used to calculate the major emissions from vehicles, namely nitrogen oxides, carbon monoxide, hydrocarbons, particulate matter and lead. This information is required as input to the dispersion models used to predict ground-level concentrations of the various pollutants. Emission rates during peak hour for the proposed motorway are estimated from the total traffic volume and the emission rate per vehicle. Details of assumptions relating to the percentages of heavy vehicles, petrol and diesel fuelled, are presented in **Appendix A**. The estimated peak hour traffic flows for each section in 2001 and 2011 are summarised in **Table 2**.

TABLE 2 - ESTIMATED PEAK HOUR TRAFFIC FOR 2001 AND 2011

Roadway Section	2001		2011	
	Eastbound	Westbound	Eastbound	Westbound
Fairford Rd to Penshurst Rd	4482	2597	5177	3227
Penshurst Rd to King Georges Rd	3757	2242	4350	2830
King Georges Rd to Bexley Rd	4797	2468	5131	2812
Tunnel	3745	1750	3988	2080
Marsh St to General Holmes Drive	2700	1285	3263	1524

An estimate of these emissions has been made by **Pengilley (1989)** and US EPA emission factors (**US EPA, 1985**). These data were used in the previous study, however a comprehensive emissions inventory which relates vehicle emissions to different travel conditions in NSW has now been prepared for the Metropolitan Air Quality Study (**Carnovale 1995**). These emission rates have been combined with traffic flow data to determine air quality impacts in 2001 and 2011. **Appendix A** provides a detailed description of the calculation of vehicle emissions which are summarised in **Table 3**.

TABLE 3 - ESTIMATED PEAK HOUR TRAFFIC EMISSIONS - (KG/KM/HOUR)						
Roadway Section		Carbon Monoxide	Nitrogen Oxides	Hydrocarbons	Particulate Matter	Lead
2001						
Fairford Road to	Eastbound	49.23	15.17	4.72	0.72	0.005
Penshurst Road	Westbound	31.06	13.43	3.50	0.79	0.008
Penshurst Road to	Eastbound	41.87	13.83	4.14	0.09	0.011
King Georges Road	Westbound	27.26	12.42	3.16	0.74	0.007
King Georges Road	Eastbound	66.79	16.70	6.99	1.66	0.014
to Bexley Road	Westbound	30.65	14.85	3.67	0.91	0.007
Marsh Street to	Eastbound	31.12	11.82	3.28	0.65	0.008
General Holmes Dr	Westbound	17.31	10.21	2.32	0.65	0.004
2011						
Fairford Road to	Eastbound	49.03	14.88	4.63	1.47	N/A
Penshurst Road	Westbound	32.40	15.82	3.77	0.95	N/A
Penshurst Road to	Eastbound	39.14	15.09	3.96	0.80	N/A
King Georges Road	Westbound	29.05	14.75	3.46	0.90	N/A
King Georges Road	Eastbound	50.11	17.07	4.99	1.78	N/A
to Bexley Road	Westbound	30.32	16.65	3.79	1.05	N/A
Marsh Street to	Eastbound	31.54	14.32	3.51	0.83	N/A
General Holmes Dr	Westbound	18.64	12.06	2.60	0.81	N/A

5.1.1 Carbon monoxide

The way in which vehicle emissions vary with speed is fundamental to the understanding of the analysis presented in this report. The relationship between speed and carbon monoxide emission is shown in **Figure 5** where the estimated CO emission rates in the years 1988 and 2000 are presented for light duty petrol vehicles (hot start). It is assumed that approximately 30% and 96% of cars are fitted with catalytic converters in 1988 and 2000 respectively. At present about 65% of the fleet are fitted with catalytic converters and so the year 2000 assumption of 96% may be an overestimate. For cars without catalytic converters, there is a marked decrease of emissions with speed. Fitting cars with catalytic converters reduces the overall emissions and again the same pattern of decreasing emission rate with speed is observed.

The emissions of CO from vehicles were determined for previous studies from these relationships (**Nigel Holmes & Associates, 1992, 1994**). The emissions inventory prepared for MAQS takes a different approach. Although similar principles apply in terms of the relationship between speed and emissions, the roads are divided into different categories and emissions from the mix of traffic on that type of road is determined. These categories are described as follows:

Freeway/Highway — Major roads with relatively high average speeds (say in excess of 40 km/h), low congestion levels (say

	less than 5% idle time) and low proportion of heavy duty vehicles.
Arterial	Major roads with moderate average speeds (say 20-40 km/h), moderate congestion levels (say 20% idle time) and low proportion of heavy duty vehicles (say less than 7% of total fleet vehicle kilometres travelled (VKT)).
Commercial-Arterial	Major roads with moderate average speeds and congestion levels and moderate proportions of heavy duty vehicles (say greater than 7% of total fleet VKT).
Commercial-Highway	Major roads with relatively high average speeds, low congestion levels and moderate proportions of heavy duty vehicles.
Residential/Minor	Secondary roads with moderate average speeds, negligible levels of congestion and a very low proportion of heavy duty vehicles (say one half the arterial road level).

All sections of the proposed motorway except from Fairford Road to Penshurst Road (2011) and from King Georges Road to Bexley Road (2011) have been classified as freeway. These sections have been classified as congested for eastbound traffic, due to the large volume of traffic predicted to be using the road, and freeway for westbound. Emission rates for different vehicle categories have also been determined. Details of these are presented in **Appendix A**.

5.1.2 Oxides of Nitrogen

Oxides of nitrogen emissions show a different trend with speed from carbon monoxide and this is illustrated in **Figure 6**. As in the case of carbon monoxide, catalytic converters reduce the overall NO_x emission rate, however the trend with increasing speed is reversed, that is NO_x increases with increasing speed, although the effect is more gradual.

As for carbon monoxide, while the same trend remains, these emission factors have been replaced by those determined for MAQS (see **Appendix A**).

5.1.3 Hydrocarbons

Hydrocarbon emissions vary with speed in a similar way to carbon monoxide and have been determined for MAQS in the same way (see **Appendix A**).

5.1.4 Particulate Matter

Particulate matter emission rates for the different road categories are presented in **Appendix A**. These comprise exhaust emissions as well as emissions from tyre and brake wear.

5.1.5 Lead

Lead emissions are decreasing with time as a higher proportion of the fleet use unleaded petrol. In 2001 it has been assumed that only 15% of light vehicles will use leaded petrol. By 2011 it has been assumed that all cars will be fitted with catalytic converters and thus use unleaded petrol. Lead impacts have therefore only been modelled in 2001. Emissions for different vehicle types (excluding heavy duty diesel vehicles which do not emit lead) are listed in the tables presented in **Appendix A**.

5.2 Emissions from tunnel vents

Concentrations of carbon monoxide in the tunnel will be controlled by the use of ventilation. The WHO 15-minute goal of 87 ppm (108 $\mu g/m^3$) has been determined by the EPA as the appropriate goal for tunnel air. All other emissions will therefore follow in a pro rata manner using the emission rates relevant to the traffic mix in the tunnel and presented in **Appendix B**. Assumptions about the volumetric flow rate of tunnel air were provided by Connell Wagner. It was assumed conservatively that the carbon monoxide emission rate was at the maximum concentration allowable and with the maximum airflow rate from the stack. These conditions were assumed to occur for 24-hours per day.

Of the seven possible stack locations considered, three were selected as the most suitable on the basis of local land usage and engineering constraints. Ideally the stacks should be located on high ground. This results in the emissions being better dispersed by the stronger winds experienced at greater elevation compared to the relatively calm conditions which would prevail in the valley. Locating the stack in the valley means that it must be substantially taller than if it were located on the ridge. Therefore locations on ridges rather than in the deeper section of the Wolli Creek Valley were considered preferable. The final stack locations are indicated by open squares in **Figure 2**. The locations are at Royal Place, Duff Street and Arncliffe Rail. The emission conditions for each stack are presented in **Table 4**.

TABLE 4 - VENT OPTIONS - EMISSIONS CONDITIONS

	Royal Place	Duff Street	Arncliffe Rail
Stack height (m)	15	15	15
Stack diameter at tip (m)	9.2	9.0	7.0
Temperature (K)	298.0	298.0	298.0
Exit velocity (m/s)	15.0	16.0	15.0
Mass emission rate (g/s) 2001			
CO	85.2	113.0	47.3
NO_x	67.2	89.2	37.3
Hydrocarbons	8.4	11.1	4.7
PM_{10}	1.8	2.4	1.0
Lead	0.030	0.040	0.018
Mass emission rates (g/s) 2011			
CO	85.2	113.0	47.3
NO_x	77.6	102.9	43.1
Hydrocarbons	10.2	13.5	5.7
PM_{10}	2.2	2.9	1.2
Lead	0.003	0.004	0.002

5.3 Regional emissions

The MAQS emission rates for road categories outlined in **Section 5.1.1** provide a basis for determining airshed impacts of the proposed motorway. Total annual vehicle kilometres travelled (VKT) have been determined for the Sydney road network with and without the M5 East constructed in 2001, the nominal year of opening. Total emissions into the airshed have been determined from VKT and emission rates per vehicle expressed as g/km. The emissions considered were CO ,NO_x , HC, PM_{10} and carbon dioxide (CO_2).

It should be noted that the roadway categories provided by the traffic modelling undertaken by Masson & Wilson using the NETANAL model are somewhat different from those described above, however some assumptions have been made which give an approximate fit to the MAQS categories. In addition, the total VKT generated by the NETANAL model is lower than that generated for MAQS. This is because the network model was developed to look at peak demands, and as such gives good estimates of traffic volumes for major roads and links over the peak hour periods. It does not take account of all the short trips made outside these hours. The data were therefore scaled up to fit the ABS projection used in MAQS of a total of 26.2 MVKT in 1992 to a subsequent total of 30.1 MVKT in 2001 assuming a growth rate of 2% per annum.

No attempt was made to estimate airshed emissions in 2011 although near-road impacts assessment were carried out for this year. The basis for this decision was that as more vehicles equipped with catalytic converters enter the fleet, the use of VKT as a measure of total regional emissions becomes less useful (although it is currently the most commonly used method). For cars fitted with catalytic converters, the major emissions occur as the catalyst warms up. During the driving conditions experienced on motorways, overall emissions are generally low. Number of trips and trip length are therefore key information in determining overall emissions for catalyst equipped cars. While a local "worst-case" assessment can still be carried out for catalyst-equipped vehicles assumed to be a hot-start condition, estimates of total emission based on VKT information alone have some limitations.

6.0 APPROACH TO ASSESSMENT

Surface Road

The Caline4 dispersion model has been used to estimate the concentration of oxides of nitrogen, carbon monoxide, hydrocarbons, particulate matter and lead, that are likely to be produced in the vicinity of the motorway.

This model is an upgrade of Caline3 the most recent US EPA approved model, and is a steady state Gaussian model which can determine concentrations at receptor locations downwind of "at grade", "fill", "bridges" and "cut section" highways located in relatively uncomplicated terrain. The model is applicable for any wind direction, highway orientation and receptor location.

It is neither feasible nor necessary within the scope of this report to assess air quality at every sensitive receptor along each section of road, taking account of terrain, road grade and distance of receptor from the road, although it is technically possible to do so. This very detailed approach is warranted for model validation which has already been carried out in Sydney for Caline4 (**Williams and Others, 1994**) for the RTA.

The approach in this report has been to identify worst case conditions which comprise 1-hour peak hour traffic flow combined with the poorest dispersion conditions, equivalent to atmospheric inversions with very light winds. The traffic flow has been assumed to be constant (at peak levels) along sections of the route, and although this is clearly a simplification, it is a reasonable approximation to what could happen in practice.

The position of the receptor with respect to the road is also a factor when determining "worst-case" conditions along a roadway. Distances of 0 m, 10 m, 30 m and 50 m have been used here. Traffic numbers in each lane were calculated, and the kerb at the side of the road which carried the most traffic in each lane represented 0 m.

Tunnel vent stacks
The Gaussian dispersion model AUSPLUME has been used to determine ground level concentrations of emissions from the tunnel vent stacks. AUSPLUME is a widely used regulatory model (**VEPA, 1986**) and is considered to be appropriate for use in this case. Modelling runs were undertaken using the parameters listed in **Table 4**. Outputs from these model runs showing the assumed emission conditions are presented in **Appendix C**

Regional impacts
As discussed in **Section 5.3**, regional impacts have been assessed by comparing total emissions into the Sydney airshed with and without the M5 East constructed. MAQS emission rates have been used for the different road categories in the Sydney network and details of the calculations are presented in **Appendix D.**

7.0 ASSESSMENT OF IMPACTS

This section assesses the air quality impacts of the proposal by comparing the predicted ground-level concentrations of roadway emissions with air quality goals or other air quality criteria where specified goals are not available.

7.1 Surface Road

Table 5 presents the maximum predicted 1-hour average increase in ground-level concentrations of carbon monoxide, hydrocarbons, nitrogen oxides, nitrogen dioxide, particulate matter and lead, at 0 m, 10 m, 30 m and 50 m from the existing roadway edge. Predictions for 0 m and 10 m represent those concentrations which could potentially affect cyclists at or near the roadway edge. Predictions at 30 m and 50 m relate to those in nearby residences. Assuming a wind speed of 1.0 m/s and that F-class stability conditions occur, the model has been set to determine the worst-case wind angle. The exact relationship will vary with roadway configuration, but typically, concentrations at 10 m from the roadway edge are approximately 50% of concentrations at the kerbside, and around 25% at 50 m. This will not be the case for NO_2 however since some NO will be oxidised over time.

Carbon Monoxide

It can be seen from **Table 5** that the highest predicted 1-hour carbon monoxide concentration 10 m from the road in 2001 is 6.6 mg/m^3 between King Georges Road and Bexley Road. This is well below the EPA's 1-hour goal of 31 mg/m^3 and levels at 30 m residences are even lower. Levels at kerbside are also below the 1-hour goal.

Despite higher traffic volumes, levels are predicted to be lower in 2011 at 10 m from the motorway, with a maximum 1-hour concentration estimated to be 5.3 mg/m^3 (17% of the goal) between King Georges Road and Bexley Road. This is because a higher proportion of the fleet will be equipped with catalytic converters in 2011 than in 2001 and as a result, the fleet will have a lower average emission rate of carbon monoxide. The highest kerbside concentration is predicted to be 10.9 mg/m^3 along the same section, which is also below the goal.

TABLE 5 - PREDICTED INCREASE IN 1-HOUR AVERAGE GROUND-LEVEL CONCENTRATIONS OF VEHICLE EMISSIONS AT VARIOUS DISTANCES FROM THE ROADWAY EDGE - 2001 AND 2011

Roadway Section	Distance from the edge (m)	Carbon Monoxide (mg/m^3)	Nitrogen Oxides (µg/m^3)	Nitrogen Dioxide* (µg/m^3)	Hydrocarbons (mg/m^3)	Particulate Matter (µg/m^3)	Lead (µg/m^3)
2001							
Fairford Rd to Penshurst Rd	0	11.3	4133	413	1.14	200	2.9
	10	5.6	2153	431	0.58	107	1.4
	30	3.7	1415	283	0.38	71	0.9
	50	2.9	1144	229	0.30	58	0.7
Penshurst Rd to King Georges Rd	0	9.8	3825	383	1.01	380	2.5
	10	5.0	2005	401	0.53	192	1.3
	30	3.3	1328	266	0.35	125	0.8
	50	2.6	1070	214	0.28	100	0.7
King Georges Rd to Bexley Rd	0	13.9	4416	442	1.50	358	3.0
	10	6.6	2288	458	0.72	174	1.4
	30	4.2	1501	300	0.47	113	0.9
	50	3.4	1205	241	0.37	90	0.7
March St to General Holmes Dr	0	7.6	3493	349	0.85	190	1.8
	10	3.9	1894	379	0.45	105	0.9
	30	2.6	1255	251	0.30	70	0.6
	50	2.0	1099	202	0.24	56	0.5
2011							
Fairford Rd to Penshurst Rd	0	10.7	4022	402	1.07	317	
	10	5.2	2091	418	0.54	154	
	30	3.4	1378	276	0.35	100	
	50	2.7	1107	221	0.28	79	
Penshurst Rd to King Georges Rd	0	9.2	4121	412	0.98	213	
	10	4.6	2153	431	0.51	114	
	30	3.0	1415	283	0.33	76	
	50	2.4	1144	229	0.26	61	
King Georges Rd to Bexley Rd	0	10.9	4563	456	1.15	382	
	10	5.3	2362	472	0.58	185	
	30	3.4	1550	310	0.38	120	
	50	2.7	1242	248	0.30	96	
March St to General Holmes Dr	0	7.5	4047	405	0.89	231	
	10	3.9	2153	431	0.47	125	
	30	2.5	1427	285	0.31	84	
	50	2.0	1144	229	0.24	67	

** Assumed to be 20% by weight of total nitrogen oxides (except at kerbside where NO_2 is assumed to be 10% by weight of total nitrogen oxides).*

Nitrogen Dioxide
Estimating nitrogen dioxide concentrations is more complicated than estimating carbon monoxide concentrations. As discussed previously nitrogen oxides are initially emitted as a mixture of nitric oxide and other oxides of nitrogen, which are rapidly oxidised to nitrogen dioxide. At the point of emission the mixture is generally about 5% nitrogen dioxide by mass. At 10 m from the road the nitrogen oxides would be unlikely to contain more than 20% (by mass) nitrogen dioxide. It is estimated (**WHO, 1987**) that 50% conversion of nitric oxide would take place in less than one minute at a nitric oxide concentration of 188 $\mu g/m^3$ (0.1 ppm) in the presence of ozone at a concentration of 200 $\mu g/m^3$ (0.1 ppm), which is a mid to high ozone concentration for Sydney.

For a very light 1.0 m/s wind the exhaust emission from a vehicle would have travelled 60 m in this time under the specified conditions. In practice high concentrations of nitrogen oxides are associated with low ratios of nitrogen dioxide and vice versa. The rapid dilution due to dispersion more than counteracts the increase of proportion of nitrogen oxides in the form of nitrogen dioxide with time.

It is considered that 20% is a conservative estimate for the ratio (by mass) of nitrogen dioxide to nitrogen oxides (as discussed in the preceding report). With this assumption the maximum 1-hour nitrogen dioxide concentration at 10 m from the roadway is predicted to be 458 $\mu g/m^3$ in 2001 and 472 $\mu g/m^3$ in 2011, between King Georges Road and Bexley Road. These are both above the air quality goal for nitrogen dioxide. It should be noted that these predictions do not take into account fully, the benefits of three-way catalytic converters which are fitted to all new passenger vehicles in Australia and which substantially reduce NO_x emissions. Nor do they take account of controls on diesel vehicles.

Predicted levels at 30 m and 50 m from the kerb are predicted to remain below the 1-hour goal of 328 $\mu g/m^3$, but they do come close to the goal with a predictions of 300 $\mu g/m^3$ in 2001 and 310 $\mu g/m^3$ in 2011, between King Georges Road and Bexley Road.

Particulate Matter and Lead
The predicted levels of PM_{10} are for 1-hour averaging periods, while the air quality goal refers to a 24-hour period. Comparing these is therefore a conservative approach (that is an over-prediction) as the maximum predicted 1-hour average will always be higher than the predicted 24-hour average.

The highest predicted increase in PM_{10} at 10 m from the road in 2001 is 192 $\mu g/m^3$, and 185 $\mu g/m^3$ in 2011. These levels are both above the EPA 24-hour goal of 150 $\mu g/m^3$, but it should be emphasised that these are 1-hour predictions which would not persist over a 24-hour period.. Concentrations at 30 m and 50 m from the kerb are all predicted to be below the 24-hour PM_{10} goal for both 2001 and 2011. Concentrations over a year would be substantially less and concentrations at sites further removed from the road would again be reduced. Similarly the NHMRC 90 $\mu g/m^3$ (annual average) TSP goal is unlikely to be exceeded.

Lead impacts have also been assessed for 2001. It should be noted that the lead goal applies to a 90-day average, and the predicted level is for a "worst-case" 1-hour period. Predictions would therefore be greater than the 90-day average. The maximum predicted lead level for the motorway in 2001 is 3.0 $\mu g/m^3$ at the kerb, 1.4 $\mu g/m^3$ 10 m from the kerb, 0.9 $\mu g/m^3$ at 30 m and 0.7 at 50 m. Kerbside values are above the 90-day average of 1.5 $\mu g/m^3$, but this is a short term prediction and is therefore likely to remain below long term goals since "worst-case" conditions are very unlikely to prevail for any significant period of time. Residences further than 10 m from the kerb are predicted to experience lead levels below the 90-day air quality goal.

Hydrocarbons

Hydrocarbon concentrations are no longer specified in the EPA's air quality goals. This is largely due to the fact that a simple hydrocarbon concentration goal is now recognised as not being useful for the purposes of assessing health impacts or identifying the need for air quality management requirements. More detailed information on specific hydrocarbons is required. As previously noted, hydrocarbons, in particular those associated with motor vehicles, are a common contaminant of urban atmospheres and have been for many years. Emission controls on Australian cars and equivalents since 1978 have resulted in a considerable reduction in both evaporative and exhaust emissions of hydrocarbons.

One of the components of hydrocarbons that has become a concern in the community is benzene, which is a known carcinogen (**WHO 1987**). Data from **Nelson and Quigley, 1982**) shows an analysis of the hydrocarbon content of fuel and exhaust. It can be seen that benzene is a component of petrol comprising approximately 2.6%. It can also be seen that the percentage benzene (by mass) in vehicle exhausts was approximately 5% (note these data relate to leaded petrol, but there has not been any substantial change in the benzene content with the introduction of unleaded petrol).

The Victorian EPA 3-minute design ground-level concentration for benzene is 0.10 mg/m^3 (0.033 ppm), but this goal explicitly excludes petrol and liquid mixtures containing 1% or less of benzene.

From **Table 5** the predicted maximum 1-hour increase in total hydrocarbons is of the order of 0.72 mg/m^3 at 10 m from the existing roadway. Assuming a 5% benzene composition in the exhaust the benzene concentration at 10 m from the roadway edge would be approximately 0.036 mg/m^3 or 36 $\mu g/m^3$ (1-hour average), under unfavourable dispersion and with peak traffic flows. This is only 36% of the Victorian EPA design 3-minute goal, which as noted before specifically excludes petrol, but is above the proposed UK goal of 16 $\mu g/m^3$ (the UK goal however is an annual average). Concentrations of total hydrocarbons are of course substantially lower at the locations of residences 30 m from the road, 0.47 mg/m^3 (24 $\mu g/m^3$ benzene), and 50 m from the road, 0.37 mg/m^3 (19 $\mu g/m^3$). It is nevertheless recognised that there may be no safe limit for benzene, but the risks to a particular individual over a lifetime is small, and on a population and individual basis could be offset by lower risks through safer roads, although to an undetermined extent.

The current understanding of long-term health risks is that they are a function of average lifetime exposure levels. For example WHO estimated that the risk of developing leukemia with a lifetime exposure to ambient concentrations of 1 $\mu g/m^3$ of benzene is 4×10^{-6}. This is referred to as a unit risk estimate.

Levels of benzene can range from 3 $\mu g/m^3$ in a rural environment to up to 160 $\mu g/m^3$ in an urban environment (higher close to service stations and storage tanks) with typical levels of about 20 $\mu g/m^3$ in residential areas. Most people would be exposed to much higher levels on occasions, for example when filling their car with petrol or in a smoke-filled indoor environment. The daily intake from ambient air in an urban environment is estimated to range from 30 to 300 μg/m^3 and smoking one pack of cigarettes per day can add approximately 600 μg to this intake.

7.2 Tunnel

The results of the dispersion modelling, using worst-case conditions for tunnel vent stack emissions are shown in **Figures 7** to **9**. Output from the modelling run which includes the assumed parameters is attached in **Appendix B**. These figures show the maximum predicted 1-hour average increase in carbon monoxide concentrations in the vicinity of the stack. **Tables 6** to **8** summarise the predicted ground level concentrations of emissions from the proposed stacks in the years 2001 to 2011.

In general, when the terrain around the stack is reasonably flat, the highest ground-level concentrations close to the stack occur to the southeast and northeast under strong wind conditions (approximately 13 m/s) where the plume is brought to the ground close to the stack. The predicted maximum values are well below the respective air quality standards. Under these reasonably good dispersion conditions, that is strong winds and neutral atmospheric stability, background concentrations of carbon monoxide and other roadway emissions would be very low. Local terrain can also influence the pattern of dispersion from the vent exhaust stacks. Maximum one hour levels are predicted to occur on high ground under stable atmospheric conditions when dispersion is poor.

One further point to consider is the ambient concentration of benzene likely to arise from the tunnel emissions. Benzene typically comprises approximately 5% exhaust hydrocarbon emissions (**Nelson & Quigley, 1982**). For all the stacks considered, the highest predicted 3 minute average for hydrocarbons is 0.17mg/m^3, which corresponds to approximately 8.5 μg/m^3 of benzene. The proposed long-term United Kingdom goal for benzene is 16 μg/m^3 which is higher than the predicted short-term average. Long-term averages are always lower than short-term peaks and the long-term goal is therefore unlikely to be exceeded due to tunnel emissions.

It is therefore concluded that with the designed stack heights, all ambient air quality goals relating to the tunnel emissions will be met.

TABLE 6 - PREDICTED GROUND-LEVEL# CONCENTRATIONS DUE TO EMISSIONS FROM PROPOSED ARNCLIFFE STREET ARMY RESERVE DEPOT EXHAUST STACK, 2001## AND 2011

Pollutants	Carbon monoxide (mg/m^3)	Nitrogen oxides (A) ($\mu g/m^3$)	Nitrogen dioxide ($\mu g/m^3$)	Hydro-carbons (B) (mg/m^3)	PM_{10} ($\mu g/m^3$)	Lead ($\mu g/m^3$)
Maximum predicted ground level concentrations						
2001	**1 hour**	**1 hour**	**1 hour**	**3 mins**	**24 hour**	**90 day**
Increase	0.38	297	60	0.07	3.3	0.004
'Background'	6.9+		63++		54+	1.1**
Total	**7.3**		**123**		**57.3**	**1.104**
2001	**8 hour**				**Annual**	
Increase	0.32				0.12	
'Background'	4.5+				22*	
Total	**4.8**				**22.1**	
2011	**1 hour**	**1 hour**	**1 hour**	**3 mins**	**24 hour**	**90 day**
Increase	0.38	343	69	0.08	4.0	-
'Background'	6.9+		63++		54+	1.1**
Total	**7.3**		**132**		**58.0**	**1.1**
2011	**8 hour**				**Annual**	
Increase	0.32				0.14	
'Background'	4.5+				22*	
Total	**4.8**				**22.1**	
Air quality standard noted by Environment Protection Authority						
	31 (1 hour) 11 (8 hour)		328 (1 hour)		150 (24 hour) 50 (annual)	1.5 (90 day)

\# *Ground level concentrations: in all cases the increase due to the M5 East Motorway has been estimated; where possible the background levels have been added to provided total predicted concentrations.*

\## *2001 is the nominal opening date for the M5 East Motorway.*

'Background' is tile maximum measured ground level concentration. The following sources for this background data are:

\+ *Maximum measured along the route in this study (Envirosciences 1994).*

* * *Measured by the Environment Protection Authority in 1992 at Earlwood (Environment) Protection Authority 1992). Note lead not modelled in 2011.*

\+ \+ *Measured in a monitoring study for the Casula Link (Stephenson 1992).*

(A) *Nitrogen oxide levels are only predicted so as to estimate Nitrogen Dioxide levels.*

(B) *Hydrocarbon levels are only predicted so as to estimate benzene levels and effects on photochemical smog.*

mg/m^3 = milligrams per cubic metre

$\mu g/m^3$ = micrograms per cubic metre

TABLE 7 - PREDICTED GROUND-LEVEL# CONCENTRATIONS DUE TO EMISSIONS FROM PROPOSED ROYAL PLACE EXHAUST STACK, 2001## AND 2011

Pollutants	Carbon monoxide (mg/m^3)	Nitrogen oxides (A) ($\mu g/m^3$)	Nitrogen dioxide ($\mu g/m^3$)	Hydro-carbons (B) (mg/m^3)	PM_{10} ($\mu g/m^3$)	Lead ($\mu g/m^3$)
Maximum predicted ground level concentrations						
2001	1 hour	1 hour	1 hour	3 mins	24 hour	90 day
Increase	0.88	693	138	0.14	4.5	0.005
'Background'	6.9+		63++		54+	1.1**
Total	**7.8**		**201**		**58.5**	**1.105**
2001	8 hour				Annual	
Increase	0.31				0.20	
'Background'	4.5+				22*	
Total	**4.8**				**22.2**	
2011	1 hour	1 hour	1 hour	3 mins	24 hour	90 day
Increase	0.88	800	160	0.17	5.1	-
'Background'	6.9+		63++		54+	1.1**
Total	**7.8**		**223**		**59.1**	**1.1**
2011	8 hour				Annual	
Increase	0.31				0.23	
'Background'	4.5+				22*	
Total	**4.8**				**22.2**	
Air quality standard noted by Environment Protection Authority						
	31 (1 hour) 11 (8 hour)		328 (1 hour)		150 (24 hour) 50 (annual)	1.5 (90 day)

\# *Ground level concentrations: in all cases the increase due to the M5 East Motorway has been estimated; where possible the background levels have been added to provided total predicted concentrations.*

\#\# *2001 is the nominal opening date for the M5 East Motorway.*

'Background' is tile maximum measured ground level concentration. The following sources for this background data are:

\+ *Maximum measured along the route in this study (Envirosciences 1994).*

** *Measured by the Environment Protection Authority in 1992 at Earlwood (Environment) Protection Authority 1992). Note lead not modelled in 2011.*

\+ \+ *Measured in a monitoring study for the Casula Link (Stephenson 1992).*

(A) *Nitrogen oxide levels are only predicted so as to estimate Nitrogen Dioxide levels.*

(B) *Hydrocarbon levels are only predicted so as to estimate benzene levels and effects on photochemical smog.*

mg/m^3 = milligrams per cubic metre
$\mu g/m^3$ = micrograms per cubic metre

TABLE 8 - PREDICTED GROUND-LEVEL# CONCENTRATIONS DUE TO EMISSIONS FROM PROPOSED DUFF STREET EXHAUST STACK, 2001## AND 2011						
Pollutants	Carbon monoxide (mg/m^3)	Nitrogen oxides (A) ($\mu g/m^3$)	Nitrogen dioxide ($\mu g/m^3$)	Hydro-carbons (B) (mg/m^3)	PM_{10} ($\mu g/m^3$)	Lead ($\mu g/m^3$)
Maximum predicted ground level concentrations						
2001	**1 hour**	1 hour	**1 hour**	**3 mins**	**24 hour**	90 day
Increase	1.08	850	170	0.12	3.1	0.004
'Background'	6.9+		63++		54+	1.1**
Total	**8.0**		**233**		**57.1**	**1.104**
2001	**8 hour**				**Annual**	
Increase	0.40				0.16	
'Background'	4.5+				22*	
Total	**4.9**				**22.2**	
2011	**1 hour**	**1 hour**	**1 hour**	**3 mins**	**24 hour**	**90 day**
Increase	0.98	980	196	0.14	3.7	-
'Background'	6.9+		63++		54+	1.1**
Total	**8.0**		**259**		**57.7**	**1.1**
2011	**8 hour**				**Annual**	
Increase	0.40				0.20	
'Background'	4.5+				22*	
Total	**4.9**				**22.2**	
Air quality standard noted by Environment Protection Authority						
	31 (1 hour) 11 (8 hour)		328 (1 hour)		150 (24 hour) 50 (annual)	1.5 (90 day)

#	*Ground level concentrations: in all cases the increase due to the M5 East Motorway has been estimated; where possible the background levels have been added to provided total predicted concentrations.*
##	*2001 is the nominal opening date for the M5 East Motorway.*
	'Background' is tile maximum measured ground level concentration. The following sources for this background data are:
+	*Maximum measured along the route in this study (Envirosciences 1994).*
* *	*Measured by the Environment Protection Authority in 1992 at Earlwood (Environment) Protection Authority 1992). Note lead not modelled in 2011*
+ +	*Measured in a monitoring study for the Casula Link (Stephenson 1992).*
(A)	*Nitrogen oxide levels are only predicted so as to estimate Nitrogen Dioxide levels.*
(B)	*Hydrocarbon levels are only predicted so as to estimate benzene levels and effects on photochemical smog.*

mg/m^3 = milligrams per cubic metre
$\mu g/m^3$ = micrograms per cubic metre

7.3 Regional Assessment

Estimates of emissions in 2001 from vehicles using the Sydney road network with and without the M5 East Motorway constructed are presented in **Table 9**. In most instances there is a small reduction in emissions with the M5 East built. This is due in part to the reduced VKT with the Motorway built and also due to somewhat lower emission rates for freeway travel mode for most pollutants. The exception is nitrogen oxides which are emitted at a higher rate per vehicle under freeway travel conditions compared to arterial travel mode. However the percentage increase for the case with the M5 East built is small, in fact less than 0.5%.

TABLE 9 TOTAL MOTOR VEHICLE EMISSIONS FROM THE SYDNEY NETWORK IN 2001 WITH AND WITHOUT THE M5 EAST (TONNES X 1000)

Emission	Carbon Monoxide	Nitrogen Oxides	Hydrocarbons	Particulate Matter	Carbon dioxide
With M5 East	586.49	78.16	73.69	5.59	11421.22
Without M5 East	594.30	77.79	74.78	5.72	11493.65

8.0 CONCLUSIONS

The results of the air quality assessment conclude that:

1. Due to the present emission controls on motor vehicles and the projected traffic conditions for the years 2001 and 2011, the EPA's carbon monoxide 1-hour or 8-hour goals are not expected to be exceeded during the operation of the proposed motorway in the vicinity of the surface road.

2. The PM_{10} annual and 24-hour maximum air quality goals, are not likely to be exceeded at nearby residences in the vicinity of the surface road. Short-term lead concentrations are predicted to exceed long-term lead goals at the kerb, but it is extremely unlikely that "worst-case" conditions will prevail for an extended period of time.

3. The predicted increases in concentration of nitrogen dioxide indicate that the EPA's goals would be exceeded at kerbside and at 10 m from the roadway. At residences 30 m and 50 m from the road, however, levels are all below the 1-hour goal in both 2001 and 2011.

4. Predicted concentrations of benzene are not at levels which should pose health effects. However it is recognised that there may be no safe level for exposure to benzene.

5. The results of the vent stack modelling indicate that with stack heights of 15 m the tunnel emission will not result in ground level concentrations of any pollutants in exceedance of respective air quality goals.

6. The regional assessment undertaken as part of this study indicates that there would be an overall slight reduction in most vehicle emissions into the airshed with the Motorway built. This is largely due to a reduction in total VKT for the Sydney road network, resulting from the more direct route which the M5 East Motorway would provide. One exception is nitrogen oxides where there is predicted to be a small increase in emissions, due to increased emissions from individual vehicles travelling at the higher speeds (compared to an equivalent arterial road) which the Motorway will allow.

The introduction of catalytic converters has resulted in a substantial reduction in carbon monoxide and hydrocarbon emissions from motor vehicles. Hence despite the increase in traffic from 2001 to 2011, emissions per vehicle have been reduced. This is also true for nitrogen oxides, as all new passenger vehicles are fitted with three-way catalytic converters which reduce nitrogen oxide emissions. However the increased speed on upgraded roads results in increased nitrogen oxide emissions and this has offset to some extent the gains from the improved technology.

Model predictions indicate that the EPA NO_2 goal may be exceeded at the roadway edge and also 10 m from the roadway edge, although residences 50 m from the motorway are not likely to be effected by levels exceeding that goal. Heavy duty diesel vehicles are estimated to contribute very significantly to these emissions and have also been identified in MAQS as being a major contributor to NO_x emissions into the Sydney airshed.

The general issue of controls on nitrogen oxides and particulate emissions is being addressed by the Government's Air Quality Management Plan, which is currently being developed from information provided from the MAQS study.

The RTA is also developing strategies to heſp reduce greenhouse and other vehicle emissions and is engaging in approaches to encourage the tightening of vehicle emissions standards. These approaches include;

- working with the EPA to implement the State's Motor Vehicle Maintenance Program for lowering emissions, and on the introduction of vehicle emissions testing;

- enhancing the State's vehicle emissions enforcement resources; and,

- continuing its role on ACVEN (Advisory Committee on Vehicle Emissions and Noise) to encourage the early implementation of more stringent Australian Design Rules, including the revision of ADR-37/0X to tighten current light vehicle emission standards. A revision of ADR-70, is also in progress. This will also contribute to controlling emissions from diesel vehicles, which will be particularly important for NO_x and particulate matter emissions (**RTA, 1995**).

This last point is particularly relevant to the M5 East Motorway where a high proportion of NO_x and PM_{10} emissions are estimated to be from heavy duty diesel vehicles.

9.0 REFERENCES

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APPENDIX A
EMISSION CALCULATIONS
(SURFACE ROAD)

VEHICLE EMISSIONS FACTORS

The emissions from vehicles on NSW roads were assumed to all fit into three classes:

1. Light duty petrol vehicles (LDPV)
2. Heavy duty petrol vehicles (HDPV)
3. Heavy duty diesel vehicles (HDDV)

These classes of vehicles account for more than 99% of all vehicle kilometres travelled on Svdney's roads (**Pengilley 1989**). The following assumptions were made regarding the vehicles in the years 2001 and 2011:

- 85% of petrol vehicles were using catalytic converters as emission control in 2001, and 100% in 2011.

- Of the heavy vehicles category, 90% are considered to be HDDV and 10% are considered to be HDPV for all sections.

The emissions of CO, NO_x, hydrocarbons and particulate matter were taken from estimates in the Sydney Metropolitan Air Quality Study (MAQS) (**Carnovale & Tilly, 1995**). It was assumed that traffic on the roadway was in congested arterial travel mode, except for the transit lane which was in freeflowing arterial mode. It was also assumed that the deterioration of catalytic converters was as in the 1992 MAQS estimates of passenger vehicle emission rates.

The emission of particulate matter from vehicles is made up of lead salts, organic and sulphate components. The total emissions comprise exhaust emission plus airborne brake wear particulate emission and airborne tyre wear particulate emissions. In the case of passenger vehicles, the PM_{10} fraction comprises 74% of the total particulate exhaust emissions. The PM_{10} fraction of HDDV and HDPV particulate exhaust emissions is 100% and 64% respectively. Brake and tyre emissions are assumed to be essentially all PM_{10}.

Calculation of vehicle emission rates

Details of emission calculations for the route sections at peak hour for 2001 and 2011 are presented in the following tables.

Emission rates for CO, NO_x, hydrocarbons and particulate matter corresponding to a given section of the route are presented for each class of vehicle and expressed as g/km/vehicle. The total emissions (tot CO etc) during the peak period have been calculated by multiplying the emission rate by the total number of vehicles estimated to be using the road in the one hour peak period. These values are expressed as g/km/h. Finally these values have been converted to kg/km/h and g/vehicle mile (the latter is used as input to the model).

Emissions for 2001 Peak

Section	Fairford to Penshurst - Eastbound					2001						
Arterial			Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle		Number	CO	NOx	HC	PM10	Pb	totCO	tot NOx	tot HC	tot	tot Pb
total no		4482.00									PM10	
total heavy		576.00										
LDPV		3906.00	10.08	1.73	0.78	0.021	0.0028	39372.48	6757.38	3046.68	82.03	10.9368
HDDV		518.40	7.11	15.72	2.58	1.150		3685.82	8149.25	1337.47	596.16	
HDPV		57.60	107.09	4.59	5.82	0.081	0.0322	6168.38	264.38	335.23	4.67	1.85472
Brake & Tyre						0.009					40.34	
Total kg/km/h								49.23	15.17	4.72	0.72	0.012792
g/v-mi								17.57	5.42	1.68	0.26	0.004566
Section	Fairford to Penshurst - Westbound					2001						
Arterial			Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle		Number	CO	NOx	HC	PM10	Pb	totCO	tot NOx	tot HC	tot	tot Pb
total no		2597.00									PM10	
total heavy		694.00										
LDPV		1903.00	10.08	1.73	0.78	0.021	0.0028	19182.24	3292.19	1484.34	39.96	5.3284
HDDV		624.60	7.11	15.72	2.58	1.150		4440.91	9818.71	1611.47	718.29	
HDPV		69.40	107.09	4.59	5.82	0.081	0.0322	7432.05	318.55	403.91	5.62	2.23468
Brake & Tyre						0.009					23.37	
Total kg/km/h								31.06	13.43	3.50	0.79	0.007563
g/v-mi								19.13	8.27	2.16	0.49	0.00466
Section	Penshurst to King Georges - Eastbound					2001						
Arterial			Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle		Number	CO	NOx	HC	PM10	Pb	totCO	tot NOx	tot HC	tot	tot Pb
total no		3757.00									PM10	
total heavy		569.00										
LDPV		3188.00	10.08	1.73	0.78	0.021	0.0028	32135.04	5515.24	2486.64	66.95	8.9264
HDDV		512.10	7.11	15.72	2.58	1.150		3641.03	8050.21	1321.22	588.92	
HDPV		56.90	107.09	4.59	5.82	0.081	0.0322	6093.42	261.17	331.16	4.61	1.83218
Brake & Tyre						0.009					33.81	
Total kg/km/h								41.87	13.83	4.14	0.69	0.010759
g/v-mi								17.83	5.89	1.76	0.30	0.004582

Emissions for 2001 Peak

Section	Penshurst to King Georges - Westboun					2001						
Arterial			Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle		Number	CO	NOx	HC	PM10		totCO	tot NOx	tot HC	tot	tot Pb
total no		2242.00									PM10	
total heavy		663.00										
LDPV		1579.00	10.08	1.73	0.78	0.021	0.0028	15916.32	2731.67	1231.62	33.16	4.4212
HDDV		596.70	7.11	15.72	2.58	1.150		4242.54	9380.12	1539.49	686.21	
HDPV		66.30	107.09	4.59	5.82	0.081	0.0322	7100.07	304.32	385.87	5.37	2.13486
Brake & Tyre						0.009					20.18	
Total kg/km/h								27.26	12.42	3.16	0.74	0.006556
g/v-mi								19.45	8.86	2.25	0.53	0.004679
Section	King Georges to Bexley - Eastbound					2001						
Arterial			Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle		Number	CO	NOx	HC	PM10		totCO	tot NOx	tot HC	tot	tot Pb
total no		4797.00									PM10	
total heavy		774.00										
LDPV		4023.00	12.19	1.34	0.96	0.037	0.0028	49040.37	5390.82	3862.08	148.85	11.2644
HDDV		696.60	9.53	15.72	3.59	2.090		6638.60	10950.55	2500.79	1455.89	
HDPV		77.40	143.49	4.59	8.08	0.147	0.0322	11106.13	355.27	625.39	11.39	2.49228
Brake & Tyre						0.009					43.17	
Total kg/km/h								66.79	16.70	6.99	1.66	0.013757
g/v-mi								22.28	5.57	2.33	0.55	0.004588
Section	King Georges to Bexley - Westbound					2001						
Arterial			Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle		Number	CO	NOx	HC	PM10		totCO	tot NOx	tot HC	tot	tot Pb
total no		2468.00									PM10	
total heavy		822.00										
LDPV		1646.00	10.08	1.73	0.78	0.021	0.0028	16591.68	2847.58	1283.88	34.57	4.6088
HDDV		739.80	7.11	15.72	2.58	1.150		5259.98	11629.66	1908.68	850.77	
HDPV		82.20	107.09	4.59	5.82	0.081	0.0322	8802.80	377.30	478.40	6.66	2.64684
Brake & Tyre						0.009					22.21	
Total kg/km/h								30.65	14.85	3.67	0.91	0.007256
g/v-mi								19.87	9.63	2.38	0.59	0.004704

Emissions for 2001 Peak

Section	Marsh to General Holmes - Eastbound					2001						
Arterial			Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle		Number	CO	NOx	HC	PM10		totCO	tot NOx	tot HC	tot	tot Pb
total no		2700.00									PM10	
total heavy		555.00										
LDPV		2145.00	10.08	1.73	0.78	0.021	0.0028	21621.60	3710.85	1673.10	45.05	6.006
HDDV		499.50	7.11	15.72	2.58	1.150		3551.45	7852.14	1288.71	574.43	
HDPV		55.50	107.09	4.59	5.82	0.081	0.0322	5943.50	254.75	323.01	4.50	1.7871
Brake & Tyre						0.009					24.30	
Total kg/km/h								31.12	11.82	3.28	0.65	0.007793
g/v-mi								18.44	7.00	1.95	0.38	0.004618
Section	Marsh to General Holmes - Westbound					2001						
Arterial			Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle		Number	CO	NOx	HC	PM10		totCO	tot NOx	tot HC	tot	tot Pb
total no		1285.00									PM10	
total heavy		620.00										
LDPV		665.00	10.08	1.73	0.78	0.021	0.0028	6703.20	1150.45	518.70	13.97	1.862
HDDV		558.00	7.11	15.72	2.58	1.150		3967.38	8771.76	1439.64	641.70	
HDPV		62.00	107.09	4.59	5.82	0.081	0.0322	6639.58	284.58	360.84	5.02	1.9964
Brake & Tyre						0.009					11.57	
Total kg/km/h								17.31	10.21	2.32	0.67	0.003858
g/v-mi								21.55	12.71	2.89	0.84	0.004804

Emissions for 2011 Peak

Section	Fairford to Penshurst - Eastbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		5177.00								PM10
total heavy		663.00								
LDPV		4514.00	8.35	1.15	0.60	0.037	37691.90	5191.10	2708.40	167.02
HDDV		596.70	7.11	15.72	2.58	2.090	4242.54	9380.12	1539.49	1247.10
HDPV		66.30	107.09	4.59	5.82	0.147	7100.07	304.32	385.87	9.76
Brake & Tyre						0.009				46.59
Total kg/km/h							49.03	14.88	4.63	1.47
g/v-mi							15.15	4.60	1.43	0.45
Section	Fairford to Penshurst - Westbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		3227.00								PM10
total heavy		836.00								
LDPV		2391.00	7.57	1.51	0.56	0.021	18099.87	3610.41	1338.96	50.21
HDDV		752.40	7.11	15.72	2.58	1.150	5349.56	11827.73	1941.19	865.26
HDPV		83.60	107.09	4.59	5.82	0.081	8952.72	383.72	486.55	6.77
Brake & Tyre						0.009				29.04
Total kg/km/h							32.40	15.82	3.77	0.95
g/v-mi							16.07	7.84	1.87	0.47
Section	Penshurst to King Georges - Eastbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		4350.00								PM10
total heavy		651.00								
LDPV		3699.00	7.57	1.51	0.56	0.021	28001.43	5585.49	2071.44	77.68
HDDV		585.90	7.11	15.72	2.58	1.150	4165.75	9210.35	1511.62	673.79
HDPV		65.10	107.09	4.59	5.82	0.081	6971.56	298.81	378.88	5.27
Brake & Tyre						0.009				39.15
Total kg/km/h							39.14	15.09	3.96	0.80
g/v-mi							14.40	5.55	1.46	0.29
Section	Penshurst to King Georges - Westboun					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		2830.00								PM10
total heavy		800.00								
LDPV		2030.00	7.57	1.51	0.56	0.021	15367.10	3065.30	1136.80	42.63
HDDV		720.00	7.11	15.72	2.58	1.150	5119.20	11318.40	1857.60	828.00
HDPV		80.00	107.09	4.59	5.82	0.081	8567.20	367.20	465.60	6.48
Brake & Tyre						0.009				25.47
Total kg/km/h							29.05	14.75	3.46	0.90
g/v-mi							16.43	8.34	1.96	0.51
Section	King Georges to Bexley - Eastbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		5131.00								PM10
total heavy		830.00								
LDPV		4301.00	8.35	1.15	0.60	0.037	35913.35	4946.15	2580.60	159.14
HDDV		747.00	7.11	15.72	2.58	2.090	5311.17	11742.84	1927.26	1561.23
HDPV		83.00	107.09	4.59	5.82	0.147	8888.47	380.97	483.06	12.22
Brake & Tyre						0.009				46.18
Total kg/km/h							50.11	17.07	4.99	1.78
g/v-mi							15.63	5.32	1.56	0.55

Emissions for 2011 Peak

Section	King Georges to Bexley - Westbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		2812.00								PM10
total heavy		947.00								
LDPV		1865.00	7.57	1.51	0.56	0.021	14118.05	2816.15	1044.40	39.17
HDDV		852.30	7.11	15.72	2.58	1.150	6059.85	13398.16	2198.93	980.15
HDPV		94.70	107.09	4.59	5.82	0.081	10141.42	434.67	551.15	7.67
Brake & Tyre						0.009				25.31
Total kg/km/h							30.32	16.65	3.79	1.05
g/v-mi							17.25	9.47	2.16	0.60
Section	Marsh to General Holmes - Eastbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		3263.00								PM10
total heavy		717.00								
LDPV		2546.00	7.57	1.51	0.56	0.021	19273.22	3844.46	1425.76	53.47
HDDV		645.30	7.11	15.72	2.58	1.150	4588.08	10144.12	1664.87	742.10
HDPV		71.70	107.09	4.59	5.82	0.081	7678.35	329.10	417.29	5.81
Brake & Tyre						0.009				29.37
Total kg/km/h							31.54	14.32	3.51	0.83
g/v-mi							15.47	7.02	1.72	0.41
Section	Marsh to General Holmes - Westbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		1524.00								PM10
total heavy		745.00								
LDPV		779.00	7.57	1.51	0.56	0.021	5897.03	1176.29	436.24	16.36
HDDV		670.50	7.11	15.72	2.58	1.150	4767.26	10540.26	1729.89	771.08
HDPV		74.50	107.09	4.59	5.82	0.081	7978.21	341.96	433.59	6.03
Brake & Tyre						0.009				13.72
Total kg/km/h							18.64	12.06	2.60	0.81
g/v-mi							19.57	12.66	2.73	0.85

APPENDIX B
EMISSION CALCULATIONS
(TUNNEL)

CALCULATION OF EMISSION RATES FROM TUNNEL VENT STACKS

Emission rates for the traffic mix using the tunnel have been determined from MAQS data and are in the attached tables. The concentration of carbon dioxide in the vented air has been assumed to be at the maximum allowable concentration and concentrations of all other pollutants have been assumed to be in proportion to their emission rates.

In addition an attempt has been made to take account of the grade within the tunnel, although the approach cannot be regarded as scientifically rigorous. The approach adopted draws from a report on the evaluation of roadway models by **Williams and others (1994)** which presents equations which relate vehicle emissions to power requirements which in turn are dependent upon the grade of the road.

For cars equipped with catalytic converters the following equations were derived

$$FC = 9.7EC + 8.8Z_t$$
$$CO = f_{cat}(1.65EC + 0.08Z_t)$$
$$HC = f_{cat}(0.165EC + 0.008Z_t)$$
$$NO_x = f_{cat}(0.045EC + 0.12Z_{t)}$$

where,

FC is the fuel consumption in ml/minute
CO, HC and NO_x are the emission rates in g/minute
EC is the engine capacity in litres
Z_t is the instantaneous power requirement in kW
f_{cat} is a factor for catalyst equipped vehicle.

For CO and HC emissions, f_{cat} combines the catalyst performance E_{cat} with a factor which accounts for warm up time as follows:

$$E_{cat} = 0.5(1\text{-}\exp(\text{-}FC_n/120))$$

where FC_n is the normalised instantaneous fuel consumption.

$$f_{cat} = 1/(1 + E_{cat})e^{-SFn/t}/ \quad + E_{cat}$$

where SF_n is the fuel consumed since the engine start (ml) normalised to 2.5 l engine capacity and t is a character warm-up time constant, typically 1 minute.

For NO_x emissions,

$$E_{cat} = 0.3 \text{ for 3-way catalysts}$$
$$E_{cat} = 0.7 \text{ for oxidation catalysts}$$

For the purposes of this assessment, hot start conditions have been assumed, an engine capacity of 2.5 l and speed of 70 km/h. A slope of 5° has been assumed for the tunnel. Interpolation from curves for road slope and power requirements (**Williams and others, 1994**) gives respective values for Z and FC of 32.5 kW and 320 m./minute for a 5° slope.

Substituting in the above equations gives an approximate doubling for a 5° grade of emission rate (compared to flat terrain) for CO and HC and an approximate tripling) of the NO_x emission rates for cars with catalytic converters. For cars without catalytic converters the CO emission rate is estimated to increase by 43% over flat terrain and the emission rate for NO_x is as with catalytic converters. It is assumed that ADV emissions followed the same trend.

No equations are available for PM_{10} , however monitoring data in the Sydney Harbour tunnel (**Max Pengilley, personal communication October 10 1995**) indicate that there could be a 70% increase in PM_{10} emissions due to steep grade when the concentrations in the southbound and northbound sections are compared. Under these conditions the carbon monoxide levels are not very sensitive to grade but the nitrogen oxide levels are increased by over threefold for a steep grade.

The final grade within the M5 East tunnel is not known and will obviously vary along the route. It is therefore not possible to be precise about the change in the relative emission rates of the various pollutants. It should be noted that in this case it is the relative emission rates which will be important, as the tunnel will be ventilated to control CO levels. A conservative approach when taking grade into account is therefore to minimise the increase with grade in CO emission and to maximise the increase for NO_x and PM_{10}. Hydrocarbon emissions will generally follow the CO emissions. It has therefore been assumed that in 2001, the CO and hydrocarbon emissions will increase by 25% with grade, the NO_x emission will increase by a factor of 3 and the PM_{10} by 70%. In 2011, the CO and hydrocarbon emissions are assumed to increase by 50% with grade and the others to remain as in 2001.

Emissions for tunnel 2001

Section	Tunnel - Eastbound				2001						
Arterial		Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle	Number	CO	NOx	HC	PM10	Pb	totCO	tot NOx	tot HC	tot	tot Pb
total no	3745.00									PM10	
total heavy	543.00										
LDPV	3202.00	10.08	1.73	0.78	0.021	0.0028	32276.16	5539.46	2497.56	67.24	8.9656
HDDV	488.70	7.11	15.72	2.58	1.150		3474.66	7682.36	1260.85	562.01	
HDPV	54.30	107.09	4.59	5.82	0.081	0.0322	5814.99	249.24	316.03	4.40	1.74846
Brake & Tyre					0.009					33.71	
Total kg/km/h							41.57	13.47	4.07	0.67	0.010714
g/v-mi							17.76	5.76	1.74	0.29	0.004577
Section	Tunnel - Westbound				2001						
Arterial		Emission rate g/km/vehicle					Total emissions g/km/h				
Vehicle	Number	CO	NOx	HC	PM10	Pb	totCO	tot NOx	tot HC	tot	tot Pb
total no	1750.00									PM10	
total heavy	668.00										
LDPV	1082.00	10.08	1.73	0.78	0.021	0.0028	10906.56	1871.86	843.96	22.72	3.0296
HDDV	601.20	7.11	15.72	2.58	1.150		4274.53	9450.86	1551.10	691.38	
HDPV	66.80	107.09	4.59	5.82	0.081	0.0322	7153.61	306.61	388.78	5.41	2.15096
Brake & Tyre					0.009					15.75	
Total kg/km/h							22.33	11.63	2.78	0.74	0.005181
g/v-mi							20.42	10.63	2.55	0.67	0.004737

Emissions for tunnel 2011

Section	Tunnel - Eastbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		3988.00								PM10
total heavy		587.00								
LDPV		3401.00	8.35	1.15	0.60	0.037	28398.35	3911.15	2040.60	125.84
HDDV		528.30	7.11	15.72	2.58	2.090	3756.21	8304.88	1363.01	1104.15
HDPV		58.70	107.09	4.59	5.82	0.147	6286.18	269.43	341.63	8.64
Brake & Tyre						0.009				35.89
Total kg/km/h							38.44	12.49	3.75	1.27
g/v-mi							15.42	5.01	1.50	0.51
Section	Tunnel - Westbound					2011				
Arterial			Emission rate g/km/vehicle				Total emissions g/km/h			
Vehicle		Number	CO	NOx	HC	PM10	totCO	tot NOx	tot HC	tot
total no		2080.00								PM10
total heavy		819.00								
LDPV		1261.00	7.57	1.51	0.56	0.021	9545.77	1904.11	706.16	26.48
HDDV		737.10	7.11	15.72	2.58	1.150	5240.78	11587.21	1901.72	847.67
HDPV		81.90	107.09	4.59	5.82	0.081	8770.67	375.92	476.66	6.63
Brake & Tyre						0.009				18.72
Total kg/km/h							23.56	13.87	3.08	0.90
g/v-mi							18.12	10.67	2.37	0.69

Emission rate g/km							
	2001			grade allowance			total
	ldpv	hddv	hdpv	ldpv	hddv	hdpv	
CO	10.08	7.11	107.09	12.6	8.8875	133.8625	13.91775
NOx	1.73	15.72	4.59	5.19	47.16	13.77	10.98465
HC	0.78	2.58	5.82	0.975	3.225	7.275	1.37325
PM10	0.021	1.15	0.081	0.0357	1.955	0.1377	0.296336
lead	0.0028		0.0322	0.00476	0	0.05474	0.004867
	2011						
CO	7.57	7.11	15.72	11.355	10.665	23.58	11.44523
NOx	1.51	15.72	4.59	4.53	47.16	13.77	10.42365
HC	0.56	2.58	5.82	0.84	3.87	8.73	1.3674
PM10	0.021	1.15	0.081	0.0357	1.955	0.1377	0.296336

APPENDIX C
AUPLUME MODELLING OUTPUT

Arncliffe - 15 m Stack

```
Concentration or deposition................................ Concentration
Emission rate units........................................ grams/second
Concentration units........................................ micrograms/cubic metre
Units conversion factor.................................... 1.00E+06
Background concentration................................... 0.00E+00
Terrain effects............................................ Egan method
Smooth stability class changes?............................ No
Other stability class adjustments ("urban modes")........... None
Ignore building wake effects?.............................. No
Decay coefficient (unless overridden by met. file)......... 0.000
Anemometer height.......................................... 10 m
Averaging time for sigma-theta values...................... 60 min.
Roughness height at the wind vane site..................... 0.200 m
```

DISPERSION CURVES

```
Horizontal dispersion curves for sources <100m high......... Sigma-theta
Vertical   dispersion  curves for sources <100m high......... Pasquill-Gifford
Horizontal dispersion curves for sources >100m high......... Briggs Rural
Vertical   dispersion  curves for sources >100m high......... Briggs Rural
Enhance horizontal plume spreads for buoyancy?.............. Yes
Enhance  vertical  plume spreads for buoyancy?.............. Yes
Adjust horizontal P-G formulae for roughness height?........ Yes
Adjust  vertical  P-G formulae for roughness height?........ Yes
Roughness height............................................ 1.000m
Adjustment for wind directional shear....................... None
```

PLUME RISE OPTIONS

```
Gradual plume rise?......................................... Yes
Stack-tip downwash included?................................ Yes
Entrainment coefficients for adiabatic & stable lapse rates. 0.60,0.60
Partial penetration of elevated inversions?................. No
Disregard temperature gradients in the hourly met. file?.... No
```

and in the absence of boundary-layer potential temperature gradients given by the hourly met. file, a value from the following table (in K/m) is used:

Wind Speed Category	Stability Class A	B	C	D	E	F
1	0.000	0.000	0.000	0.000	0.020	0.035
2	0.000	0.000	0.000	0.000	0.020	0.035
3	0.000	0.000	0.000	0.000	0.020	0.035
4	0.000	0.000	0.000	0.000	0.020	0.035
5	0.000	0.000	0.000	0.000	0.020	0.035
6	0.000	0.000	0.000	0.000	0.020	0.035

WIND SPEED CATEGORIES

Boundaries between categories (in m/s) are: 1.54, 3.09, 5.14, 8.23, 10.80

WIND PROFILE EXPONENTS: "Irwin Urban" values (unless overridden by met. file)

AVERAGING TIMES

1 hour
8 hours
24 hours
3 months
average over all hours

```
+-------------------------+
|                         |
| Arncliffe - 15 m Stack  |
|                         |
| SOURCE CHARACTERISTICS  |
|                         |
+-------------------------+
```

.... STACK No.   1 ....

X(m)	Y(m)	Ground Elevation	Stack Height	Diameter	Temperature	Speed
328790	6243280	12m	15m	7.00m	298K	15.0m/s

No building wake effects.
(Constant) emission rate = 4.73E+01 grams/second
No gravitational settling or scavenging.

1

```
+-------------------------+
|                         |
| Arncliffe - 15 m Stack  |
|                         |
|   RECEPTOR LOCATIONS    |
|                         |
+-------------------------+
```

The Cartesian receptor grid has the following x-values (or eastings):

```
328500.m  328520.m  328540.m  328560.m  328580.m  328600.m  328620.m  328640.m  328660.m  328680.m
328700.m  328720.m  328740.m  328760.m  328780.m  328800.m  328820.m  328840.m  328860.m  328880.m
328900.m  328920.m  328940.m  328960.m  328980.m  329000.m  329020.m  329040.m  329060.m  329080.m
329100.m  329120.m  329140.m
```

and these y-values (or northings):

```
6242960.m 6242980.m 6243000.m 6243020.m 6243040.m 6243060.m 6243080.m 6243100.m 6243120.m 6243140.m
6243160.m 6243180.m 6243200.m 6243220.m 6243240.m 6243260.m 6243280.m 6243300.m 6243320.m 6243340.m
6243360.m 6243380.m 6243400.m 6243420.m 6243440.m 6243460.m 6243480.m 6243500.m
```

METEOROLOGICAL DATA : 84010101 22 8.7 61 D 1927

1 PEAK VALUES FOR THE 50 WORST CASES (in micrograms/cubic metre) PEAK VALUES FOR TH

AVERAGING TIME = 1 HOUR

RANK	VALUE	TIME RECORDED hour date	COORDINATES (* denotes polar)	RANK	VALUE	TIME RECORDED hour date	COORDINATES (* denotes polar)
1	3.77E+02	12,28/07/84	(3.29E+05, 6.24E+06)	26	2.20E+02	08,01/01/84	(3.29E+05, 6.24E+06)
2	3.71E+02	11,28/07/84	(3.29E+05, 6.24E+06)	27	2.18E+02	11,20/03/84	(3.29E+05, 6.24E+06)
3	3.70E+02	09,28/07/84	(3.29E+05, 6.24E+06)	28	2.17E+02	17,27/11/84	(3.29E+05, 6.24E+06)
4	3.65E+02	10,28/07/84	(3.29E+05, 6.24E+06)	29	2.17E+02	14,25/08/84	(3.29E+05, 6.24E+06)
5	3.49E+02	13,28/07/84	(3.29E+05, 6.24E+06)	30	2.16E+02	12,16/10/84	(3.29E+05, 6.24E+06)
6	3.27E+02	12,25/08/84	(3.29E+05, 6.24E+06)	31	2.13E+02	21,04/07/84	(3.29E+05, 6.24E+06)
7	3.26E+02	14,28/07/84	(3.29E+05, 6.24E+06)	32	2.13E+02	13,24/10/84	(3.29E+05, 6.24E+06)
8	3.08E+02	15,28/07/84	(3.29E+05, 6.24E+06)	33	2.12E+02	24,04/07/84	(3.29E+05, 6.24E+06)
9	2.93E+02	16,28/07/84	(3.29E+05, 6.24E+06)	34	2.11E+02	23,04/07/84	(3.29E+05, 6.24E+06)
10	2.87E+02	13,25/08/84	(3.29E+05, 6.24E+06)	35	2.11E+02	22,04/07/84	(3.29E+05, 6.24E+06)
11	2.85E+02	14,28/02/84	(3.29E+05, 6.24E+06)	36	2.10E+02	08,28/07/84	(3.29E+05, 6.24E+06)
12	2.74E+02	17,28/07/84	(3.29E+05, 6.24E+06)	37	2.09E+02	14,26/11/84	(3.29E+05, 6.24E+06)
13	2.61E+02	18,28/07/84	(3.29E+05, 6.24E+06)	38	2.08E+02	13,21/11/84	(3.29E+05, 6.24E+06)
14	2.59E+02	15,28/02/84	(3.29E+05, 6.24E+06)	39	2.07E+02	16,29/07/84	(3.29E+05, 6.24E+06)
15	2.58E+02	12,20/03/84	(3.29E+05, 6.24E+06)	40	2.07E+02	20,20/01/84	(3.29E+05, 6.24E+06)
16	2.52E+02	17,28/02/84	(3.29E+05, 6.24E+06)	41	2.04E+02	16,25/12/84	(3.29E+05, 6.24E+06)
17	2.51E+02	15,29/07/84	(3.29E+05, 6.24E+06)	42	2.04E+02	03,08/04/84	(3.29E+05, 6.24E+06)
18	2.42E+02	16,28/02/84	(3.29E+05, 6.24E+06)	43	2.04E+02	12,24/10/84	(3.29E+05, 6.24E+06)
19	2.37E+02	09,11/09/84	(3.29E+05, 6.24E+06)	44	2.03E+02	21,20/03/84	(3.29E+05, 6.24E+06)
20	2.36E+02	11,25/08/84	(3.29E+05, 6.24E+06)	45	2.01E+02	13,20/03/84	(3.29E+05, 6.24E+06)
21	2.34E+02	13,16/10/84	(3.29E+05, 6.24E+06)	46	1.98E+02	14,29/07/84	(3.29E+05, 6.24E+06)
22	2.26E+02	15,12/08/84	(3.29E+05, 6.24E+06)	47	1.94E+02	15,27/07/84	(3.29E+05, 6.24E+06)
23	2.23E+02	14,12/01/84	(3.29E+05, 6.24E+06)	48	1.92E+02	10,20/03/84	(3.29E+05, 6.24E+06)
24	2.22E+02	18,27/03/84	(3.29E+05, 6.24E+06)	49	1.92E+02	14,27/11/84	(3.29E+05, 6.24E+06)
25	2.20E+02	17,25/12/84	(3.29E+05, 6.24E+06)	50	1.92E+02	13,21/08/84	(3.29E+05, 6.24E+06)

```
+----------------------------------------------+
|                                              |
|   Cnr. Royal Pl. and Bardwell Rd. - 15 m Stack  |
|                                              |
+----------------------------------------------+
```

```
  Concentration or deposition................................. Concentration
  Emission rate units......................................... grams/second
  Concentration units......................................... micrograms/cubic metre
  Units conversion factor..................................... 1.00E+06
  Background concentration.................................... 0.00E+00
  Terrain effects............................................. Egan method
  Smooth stability class changes?............................. No
  Other stability class adjustments ("urban modes")........... None
  Ignore building wake effects?............................... No
  Decay coefficient (unless overridden by met. file).......... 0.000
  Anemometer height...........................................  10 m
  Averaging time for sigma-theta values....................... 60 min.
  Roughness height at the wind vane site...................... 0.200 m

DISPERSION CURVES
  Horizontal dispersion curves for sources <100m high......... Sigma-theta
  Vertical   dispersion  curves for sources <100m high......... Pasquill-Gifford
  Horizontal dispersion curves for sources >100m high......... Briggs Rural
  Vertical   dispersion  curves for sources >100m high......... Briggs Rural
  Enhance horizontal plume spreads for buoyancy?.............. Yes
  Enhance  vertical  plume spreads for buoyancy?.............. Yes
  Adjust horizontal P-G formulae for roughness height?........ Yes
  Adjust  vertical  P-G formulae for roughness height?........ Yes
  Roughness height............................................ 1.000m
  Adjustment for wind directional shear....................... None

PLUME RISE OPTIONS
  Gradual plume rise?......................................... Yes
  Stack-tip downwash included?................................ Yes
  Entrainment coefficients for adiabatic & stable lapse rates. 0.60,0.60
  Partial penetration of elevated inversions?................. No
  Disregard temperature gradients in the hourly met. file?.... No

  and in the absence of boundary-layer potential temperature gradients
  given by the hourly met. file, a value from the following table
  (in K/m) is used:
```

Wind Speed Category	A	B	C	D	E	F
1	0.000	0.000	0.000	0.000	0.020	0.035
2	0.000	0.000	0.000	0.000	0.020	0.035
3	0.000	0.000	0.000	0.000	0.020	0.035
4	0.000	0.000	0.000	0.000	0.020	0.035
5	0.000	0.000	0.000	0.000	0.020	0.035
6	0.000	0.000	0.000	0.000	0.020	0.035

(Columns A–F: Stability Class)

```
WIND SPEED CATEGORIES
  Boundaries between categories (in m/s) are:  1.54,  3.09,  5.14,  8.23, 10.80

WIND PROFILE EXPONENTS: "Irwin Urban" values (unless overridden by met. file)

AVERAGING TIMES
  1 hour
 24 hours
  3 months
  average over all hours
```

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```
+------------------------------------------------+
|                                                |
| Cnr. Royal Pl. and Bardwell Rd. - 15 m Stack   |
|                                                |
|          SOURCE CHARACTERISTICS                |
|                                                |
+------------------------------------------------+
```

.... STACK No. 1 ....

X(m)	Y(m)	Ground Elevation	Stack Height	Diameter	Temperature	Speed
327000	6243285	44m	15m	9.20m	298K	15.0m/s

No building wake effects.
(Constant) emission rate = 8.52E+01 grams/second
No gravitational settling or scavenging.

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+------------------------------------------------+
|                                                |
| Cnr. Royal Pl. and Bardwell Rd. - 15 m Stack   |
|                                                |
|             RECEPTOR LOCATIONS                 |
|                                                |
+------------------------------------------------+
```

The Cartesian receptor grid has the following x-values (or eastings):

326250.m 326300.m 326350.m 326400.m 326450.m 326500.m 326550.m 326600.m 326650.m 326700.m
326750.m 326800.m 326850.m 326900.m 326950.m 327000.m 327050.m 327100.m 327150.m 327200.m
327250.m 327300.m 327350.m 327400.m 327450.m 327500.m 327550.m 327600.m 327650.m 327700.m
327750.m

and these y-values (or northings):

6242800.m 6242850.m 6242900.m 6242950.m 6243000.m 6243050.m 6243100.m 6243150.m 6243200.m 6243250.m
6243300.m 6243350.m 6243400.m 6243450.m 6243500.m 6243550.m 6243600.m 6243650.m 6243700.m 6243750.m
6243800.m 6243850.m 6243900.m 6243950.m 6244000.m

METEOROLOGICAL DATA : 84010101 22 8.7 61 D 1927

1 PEAK VALUES FOR THE 50 WORST CASES (in micrograms/cubic metre) PEAK VALUES FOR TH
AVERAGING TIME = 1 HOUR

RANK	VALUE	TIME RECORDED hour date	COORDINATES (* denotes polar)	RANK	VALUE	TIME RECORDED hour date	COORDINATES (* denotes polar)
1	8.79E+02	05,25/12/84	(3.26E+05, 6.24E+06)	26	3.11E+02	24,19/06/84	(3.27E+05, 6.24E+06)
2	7.10E+02	05,17/12/84	(3.26E+05, 6.24E+06)	27	3.10E+02	03,21/03/84	(3.27E+05, 6.24E+06)
3	4.66E+02	14,28/02/84	(3.27E+05, 6.24E+06)	28	3.09E+02	05,30/11/84	(3.26E+05, 6.24E+06)
4	4.42E+02	05,09/01/84	(3.27E+05, 6.24E+06)	29	2.98E+02	04,21/03/84	(3.27E+05, 6.24E+06)
5	4.33E+02	18,27/03/84	(3.27E+05, 6.24E+06)	30	2.96E+02	16,08/04/84	(3.27E+05, 6.24E+06)
6	4.32E+02	15,28/02/84	(3.27E+05, 6.24E+06)	31	2.82E+02	11,20/03/84	(3.27E+05, 6.24E+06)
7	4.14E+02	12,20/03/84	(3.27E+05, 6.24E+06)	32	2.81E+02	01,05/07/84	(3.27E+05, 6.24E+06)
8	4.11E+02	21,04/07/84	(3.27E+05, 6.24E+06)	33	2.79E+02	18,29/09/84	(3.27E+05, 6.24E+06)
9	3.93E+02	16,28/02/84	(3.27E+05, 6.24E+06)	34	2.75E+02	03,08/04/84	(3.27E+05, 6.24E+06)
10	3.90E+02	24,04/07/84	(3.27E+05, 6.24E+06)	35	2.72E+02	19,20/03/84	(3.27E+05, 6.24E+06)
11	3.81E+02	13,20/03/84	(3.27E+05, 6.24E+06)	36	2.67E+02	22,20/03/84	(3.27E+05, 6.24E+06)
12	3.78E+02	22,04/07/84	(3.27E+05, 6.24E+06)	37	2.59E+02	01,20/06/84	(3.27E+05, 6.24E+06)
13	3.62E+02	21,20/03/84	(3.27E+05, 6.24E+06)	38	2.59E+02	17,08/04/84	(3.27E+05, 6.24E+06)
14	3.54E+02	12,05/07/84	(3.27E+05, 6.24E+06)	39	2.56E+02	18,20/03/84	(3.27E+05, 6.24E+06)
15	3.48E+02	15,29/09/84	(3.27E+05, 6.24E+06)	40	2.56E+02	15,27/07/84	(3.27E+05, 6.24E+06)
16	3.47E+02	14,20/03/84	(3.27E+05, 6.24E+06)	41	2.54E+02	20,04/07/84	(3.27E+05, 6.24E+06)
17	3.46E+02	17,28/02/84	(3.27E+05, 6.24E+06)	42	2.45E+02	18,19/03/84	(3.27E+05, 6.24E+06)
18	3.32E+02	16,29/09/84	(3.27E+05, 6.24E+06)	43	2.43E+02	04,08/04/84	(3.27E+05, 6.24E+06)
19	3.26E+02	20,20/03/84	(3.27E+05, 6.24E+06)	44	2.42E+02	19,04/07/84	(3.27E+05, 6.24E+06)
20	3.21E+02	12,08/04/84	(3.27E+05, 6.24E+06)	45	2.42E+02	15,20/03/84	(3.27E+05, 6.24E+06)
21	3.21E+02	13,08/04/84	(3.27E+05, 6.24E+06)	46	2.42E+02	05,21/03/84	(3.27E+05, 6.24E+06)
22	3.21E+02	15,08/04/84	(3.27E+05, 6.24E+06)	47	2.39E+02	14,29/09/84	(3.27E+05, 6.24E+06)
23	3.20E+02	23,04/07/84	(3.27E+05, 6.24E+06)	48	2.37E+02	06,21/03/84	(3.27E+05, 6.24E+06)
24	3.17E+02	14,08/04/84	(3.27E+05, 6.24E+06)	49	2.36E+02	16,20/03/84	(3.27E+05, 6.24E+06)
25	3.15E+02	17,29/09/84	(3.27E+05, 6.24E+06)	50	2.34E+02	05,08/04/84	(3.27E+05, 6.24E+06)

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+----------------------------+
|                            |
| Duff Street - 15 m Stack   |
|                            |
+----------------------------+
```

```
  Concentration or deposition................................ Concentration
  Emission rate units........................................ grams/second
  Concentration units........................................ micrograms/cubic metre
  Units conversion factor.................................... 1.00E+06
  Background concentration................................... 0.00E+00
  Terrain effects............................................ Egan method
  Smooth stability class changes?............................ No
  Other stability class adjustments ("urban modes").......... None
  Ignore building wake effects?.............................. No
  Decay coefficient (unless overridden by met. file)......... 0.000
  Anemometer height..........................................  10 m
  Averaging time for sigma-theta values...................... 60 min.
  Roughness height at the wind vane site..................... 0.200 m

DISPERSION CURVES
  Horizontal dispersion curves for sources <100m high......... Sigma-theta
  Vertical   dispersion  curves for sources <100m high......... Pasquill-Gifford
  Horizontal dispersion curves for sources >100m high......... Briggs Rural
  Vertical   dispersion  curves for sources >100m high......... Briggs Rural
  Enhance horizontal plume spreads for buoyancy?.............. Yes
  Enhance  vertical  plume spreads for buoyancy?.............. Yes
  Adjust horizontal P-G formulae for roughness height?........ Yes
  Adjust  vertical  P-G formulae for roughness height?........ Yes
  Roughness height............................................ 1.000m
  Adjustment for wind directional shear....................... None

PLUME RISE OPTIONS
  Gradual plume rise?......................................... Yes
  Stack-tip downwash included?................................ Yes
  Entrainment coefficients for adiabatic & stable lapse rates. 0.60,0.60
  Partial penetration of elevated inversions?................. No
  Disregard temperature gradients in the hourly met. file?.... No

  and in the absence of boundary-layer potential temperature gradients
  given by the hourly met. file, a value from the following table
  (in K/m) is used:
```

Wind Speed Category	Stability Class A	B	C	D	E	F
1	0.000	0.000	0.000	0.000	0.020	0.035
2	0.000	0.000	0.000	0.000	0.020	0.035
3	0.000	0.000	0.000	0.000	0.020	0.035
4	0.000	0.000	0.000	0.000	0.020	0.035
5	0.000	0.000	0.000	0.000	0.020	0.035
6	0.000	0.000	0.000	0.000	0.020	0.035

```
WIND SPEED CATEGORIES
  Boundaries between categories (in m/s) are:  1.54,  3.09,  5.14,  8.23, 10.80

WIND PROFILE EXPONENTS: "Irwin Urban" values (unless overridden by met. file)

AVERAGING TIMES
  1 hour
 24 hours
  3 months
  average over all hours
```

1

```
+----------------------------+
|                            |
|  Duff Street - 15 m Stack  |
|                            |
|  SOURCE CHARACTERISTICS    |
|                            |
+----------------------------+
```

.... STACK No. 1 ....

X(m)	Y(m)	Ground Elevation	Stack Height	Diameter	Temperature	Speed
327815	6243400	45m	15m	9.00m	298K	16.0m/s

No building wake effects.
(Constant) emission rate = 1.13E+02 grams/second
No gravitational settling or scavenging.

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+----------------------------+
|                            |
|  Duff Street - 15 m Stack  |
|                            |
|  RECEPTOR LOCATIONS        |
|                            |
+----------------------------+
```

The Cartesian receptor grid has the following x-values (or eastings):
327000.m 327050.m 327100.m 327150.m 327200.m 327250.m 327300.m 327350.m 327400.m 327450.m
327500.m 327550.m 327600.m 327650.m 327700.m 327750.m 327800.m 327850.m 327900.m 327950.m
328000.m 328050.m 328100.m 328150.m 328200.m 328250.m 328300.m 328350.m 328400.m 328450.m
328500.m

and these y-values (or northings):
6243000.m 6243050.m 6243100.m 6243150.m 6243200.m 6243250.m 6243300.m 6243350.m 6243400.m 6243450.m
6243500.m 6243550.m 6243600.m 6243650.m 6243700.m 6243750.m 6243800.m 6243850.m 6243900.m 6243950.m
6244000.m

METEOROLOGICAL DATA : 84010101 22 8.7 61 D 1927

1 PEAK VALUES FOR THE 50 WORST CASES (in micrograms/cubic metre) PEAK VALUES FOR TH

AVERAGING TIME = 1 HOUR

RANK	VALUE	TIME RECORDED hour date	COORDINATES (* denotes polar)	RANK	VALUE	TIME RECORDED hour date	COORDINATES (* denotes polar)
1	1.08E+03	05,25/12/84	(3.27E+05, 6.24E+06)	26	2.11E+02	14,12/01/84	(3.28E+05, 6.24E+06)
2	5.94E+02	12,20/03/84	(3.28E+05, 6.24E+06)	27	2.04E+02	15,29/09/84	(3.28E+05, 6.24E+06)
3	5.00E+02	11,20/03/84	(3.28E+05, 6.24E+06)	28	2.00E+02	12,24/10/84	(3.28E+05, 6.24E+06)
4	4.89E+02	23,04/07/84	(3.28E+05, 6.24E+06)	29	1.96E+02	02,05/07/84	(3.28E+05, 6.24E+06)
5	4.53E+02	22,04/07/84	(3.28E+05, 6.24E+06)	30	1.93E+02	18,29/09/84	(3.28E+05, 6.24E+06)
6	4.41E+02	24,04/07/84	(3.28E+05, 6.24E+06)	31	1.93E+02	15,28/02/84	(3.28E+05, 6.24E+06)
7	4.25E+02	20,04/07/84	(3.28E+05, 6.24E+06)	32	1.92E+02	14,28/02/84	(3.28E+05, 6.24E+06)
8	4.11E+02	21,04/07/84	(3.28E+05, 6.24E+06)	33	1.91E+02	16,28/02/84	(3.28E+05, 6.24E+06)
9	3.97E+02	10,20/03/84	(3.28E+05, 6.24E+06)	34	1.89E+02	21,20/03/84	(3.28E+05, 6.24E+06)
10	3.69E+02	19,04/07/84	(3.28E+05, 6.24E+06)	35	1.87E+02	14,28/07/84	(3.28E+05, 6.24E+06)
11	3.29E+02	05,30/11/84	(3.27E+05, 6.24E+06)	36	1.79E+02	14,27/11/84	(3.28E+05, 6.24E+06)
12	3.25E+02	10,28/07/84	(3.28E+05, 6.24E+06)	37	1.77E+02	20,20/03/84	(3.28E+05, 6.24E+06)
13	3.22E+02	11,28/07/84	(3.28E+05, 6.24E+06)	38	1.75E+02	13,26/11/84	(3.28E+05, 6.24E+06)
14	3.20E+02	09,28/07/84	(3.28E+05, 6.24E+06)	39	1.72E+02	16,29/09/84	(3.28E+05, 6.24E+06)
15	3.19E+02	18,04/07/84	(3.28E+05, 6.24E+06)	40	1.71E+02	14,19/12/84	(3.28E+05, 6.24E+06)
16	3.14E+02	13,20/03/84	(3.28E+05, 6.24E+06)	41	1.68E+02	14,18/12/84	(3.28E+05, 6.24E+06)
17	3.14E+02	12,28/07/84	(3.28E+05, 6.24E+06)	42	1.68E+02	13,20/01/84	(3.28E+05, 6.24E+06)
18	3.13E+02	12,05/07/84	(3.28E+05, 6.24E+06)	43	1.68E+02	13,12/01/84	(3.28E+05, 6.24E+06)
19	3.10E+02	09,20/03/84	(3.28E+05, 6.24E+06)	44	1.66E+02	13,07/11/84	(3.27E+05, 6.24E+06)
20	2.93E+02	01,05/07/84	(3.28E+05, 6.24E+06)	45	1.65E+02	14,07/01/84	(3.28E+05, 6.24E+06)
21	2.56E+02	18,27/03/84	(3.28E+05, 6.24E+06)	46	1.64E+02	09,21/03/84	(3.28E+05, 6.24E+06)
22	2.54E+02	13,28/07/84	(3.28E+05, 6.24E+06)	47	1.63E+02	13,23/10/84	(3.28E+05, 6.24E+06)
23	2.28E+02	14,26/11/84	(3.28E+05, 6.24E+06)	48	1.61E+02	17,25/12/84	(3.27E+05, 6.24E+06)
24	2.17E+02	14,20/03/84	(3.28E+05, 6.24E+06)	49	1.59E+02	23,17/02/84	(3.27E+05, 6.24E+06)
25	2.12E+02	13,24/10/84	(3.28E+05, 6.24E+06)	50	1.59E+02	14,07/11/84	(3.27E+05, 6.24E+06)

APPENDIX D
REGIONAL EMISSION CALCULATIONS

CALCULATION OF VEHICLE EMISSION RATES FOR THE SYDNEY NETWORK, 2001

.

The following presents the calculations of vehicle emission rates for the Sydney road network in 2001, with and without construction of the M5 East Motorway. The purpose of the calculations was to determine the contribution the new roadway would make to total roadway emissions into the Sydney airshed.

Traffic data in the form of vehicle kilometres travelled (VKT) the different road categories was supplied by **Masson & Wilson**. The emissions data for the vehicle fleet in 2001 was derived from studies by **Carnovale and others (1995)** and summarised in MAQS.

Emissions from light commercial vehicles, heavy duty vehicles, diesel and LPG powered vehicles, diesel cars and motor cycles were as used in MAQS. Emissions from petrol-powered passenger vehicles were determined from emissions presented in MAQS assuming mix of ages of vehicles and deterioration of catalytic converters as presented below.

It was assumed that in 2001, the proportion of cars by age in the passenger vehicle fleet was as follows:

1976-1985	1986-1990	post 1990
0.15	0.31	0.54

These proportions were determined by interpolation from Victorian traffic data (**VEPA, 1991**). It was also assumed that post-1990 cars were fitted with 3-way catalytic converters. Cars of the vintage 1986-1990 were assumed to have a mean age of 13 years and those from 1991-2001 were assumed to have a mean age of 5 years.

Emission rates for passenger vehicles were estimated as in MAQS taking into account different deterioration rates for the post 1985 proportion of the fleet. In addition, differences in summer and winter time emissions were taken into account as were evaporative hydrocarbon emissions. These values are presented in the attached tables and are taken from MAQS calculations, assuming the same ratio of wintertime to summertime emissions as for the 1992 MAQS estimates.

Emissions of CO_2 were determined on the basis of fuel consumption, assuming an emission rate of 2714 g/l of fuel (**Beer and others 1994**). Consumption rates for passenger vehicles for different road categories were supplied by Dr D Williams (personal communications determined from work carried out for the RTA, **CSIRO, 1994**) and the NRMA. The market share of makes and models was assumed to be as presented in MAQS and the percentage of post 1986 vehicles was assumed to be 85% in 2001. Fuel consumption for other vehicles was taken from **ABS (1991)**.

Total emissions into the Sydney airshed from the road network in 2001 were determined from fleet emissions for different road categories and the corresponding VKT. It should be noted that the roadway classifications used in the M5 East traffic modelling study were not the same as those used in MAQS. It has been assumed that the centroid connector and collector local road categories were equivalent to the MAQS suburban/residential roads, and that 56% of the freeway/tollways were commercial roads. The M5 East sub-arterial and arterial surface roads were combined and roads. The M5 East sub-arterial and arterial surface roads were combined and considered to be equivalent to the MAQS arterial road classification of which 45% were assumed to be commercial roads.

VKT for Sydney network with and without M5 East Motorway

Annual VKT 2001 with M5 East high demand						
M5 EAST ROAD CATEGORY	Hourly	Annual	corrected to MAQS	MAQS ROAD CATEGORY	VKT	
centroid connector	1.11E+05	4.49E+08	2.15E+09	local	7.182E+09	
collector	2.59E+05	1.05E+09	5.03E+09	arterial	1.197E+10	
subarterial	3.00E+05	1.22E+09	5.83E+09	arterial commercial	9.031E+09	
4 lane arterial	3.97E+05	1.61E+09	7.71E+09	freeway	1.270E+09	
6 lane arterial	3.84E+05	1.56E+09	7.46E+09	freeway commercial	1.616E+09	
tollway/freeway	8.90E+03	3.61E+07	1.73E+08			
tollway	1.37E+05	5.57E+08	2.67E+09			
freeway	2.29E+03	9.29E+06	4.45E+07			
Total	1.60E+06	6.49E+09	3.11E+10		3.107E+10	
Annual VKT 2001 without M5 East high demand					VKT	
M5 EAST ROAD CATEGORY	Hourly	Annual	corrected to MAQS	MAQS ROAD CATEGORY		
centroid connector	1.12E+05	4.53E+08	2.17E+09	local	7.600E+09	
collector	2.80E+05	1.13E+09	5.43E+09	arterial	1.263E+10	
subarterial	3.27E+05	1.32E+09	6.34E+09	arterial commercial	9.527E+09	
4 lane arterial	4.25E+05	1.72E+09	8.25E+09	freeway	6.829E+08	
6 lane arterial	3.90E+05	1.58E+09	7.56E+09	freeway commercial	8.692E+08	
tollway/freeway	6.51E+03	2.64E+07	1.26E+08			
tollway	7.34E+04	2.98E+08	1.43E+09			
freeway		0.00E+00	0.00E+00			
Total	1.61E+06	6.54E+09	3.13E+10		3.131E+10	

	Motor vehicle emissions with deterioration in 2001 g/km				
`	pre 1976	1976-1985	post 1985	fleet 1996	
proportion	0	0.15	0.85		
HC					
Freeway	3.08	2.05	0.82	1.00	
Arterial	3.48	2.32	0.77	1.00	
Congested	4.48	3.02	0.86	1.18	
Residential	4.01	2.69	1.07	1.31	
NOx					
Freeway	3.25	2.95	1.75	1.93	
Arterial	1.73	2.01	1.3	1.41	
Congested	2.43	2.44	1.38	1.54	
Residential	2.27	2.35	1.44	1.58	
CO					
Freeway	32.66	24.29	11.95	13.80	
Arterial	38.05	28.12	11.96	14.38	
Congested	46.26	33.98	12.73	15.92	
Residential	45.81	33.67	16.48	19.06	
Exhaust emissions for arterial roads					
Category	Fuel	Emission rate	VKT	Composite	Emission
		g/km	% fleet	g/km	% Fleet
HC					
Passenger vehicles	Petrol	1	75.4	0.75	63.86
Passenger vehicles	Diesel	0.5	2	0.01	0.85
Passenger vehicles	LPG	0.94	2.3	0.02	1.83
Light commercial	Petrol	1.33	10.3	0.14	11.60
Light commercial	Diesel	0.5	2.8	0.01	1.19
Light commercial	LPG	0.94	0.3	0.00	0.24
Heavy duty vehicles	Petrol	6.3	0.5	0.03	2.67
Heavy duty vehicles	Diesel	2.8	5.4	0.15	12.81
Heavy duty vehicles	LPG	3.78	0.1	0.00	0.32
Motor cycles	Petrol	6.08	0.9	0.05	4.63
		total	100	1.18	100.00
NOx					
Passenger vehicles	Petrol	1.41	75.4	1.06	47.69
Passenger vehicles	Diesel	1.01	2	0.02	0.91
Passenger vehicles	LPG	1.93	2.3	0.04	1.99
Light commercial	Petrol	1.76	10.3	0.18	8.13
Light commercial	Diesel	1.16	2.8	0.03	1.46
Light commercial	LPG	2.21	0.3	0.01	0.30
Heavy duty vehicles	Petrol	4.59	0.5	0.02	1.03
Heavy duty vehicles	Diesel	15.72	5.4	0.85	38.08
Heavy duty vehicles	LPG	5.74	0.1	0.01	0.26
Motor cycles	Petrol	0.39	0.9	0.00	0.16
		total	100	2.23	100.00
CO					
Passenger vehicles	Petrol	14.38	75.4	10.84	76.22
Passenger vehicles	Diesel	1.08	2	0.02	0.15
Passenger vehicles	LPG	8.66	2.3	0.20	1.40
Light commercial	Petrol	17.75	10.3	1.83	12.85
Light commercial	Diesel	1.08	2.8	0.03	0.21
Light commercial	LPG	8.66	0.3	0.03	0.18
Heavy duty vehicles	Petrol	120.62	0.5	0.60	4.24
Heavy duty vehicles	Diesel	8.01	5.4	0.43	3.04
Heavy duty vehicles	LPG	54.28	0.1	0.05	0.38
Motor cycles	Petrol	20.88	0.9	0.19	1.32
			100	14.23	100.00

Exhaust emissions for freeway/highway roads					
Category	Fuel	Emission rate	VKT	Composite	Emission
		g/km	% fleet	g/km	% Fleet
HC					
Passenger vehicles	Petrol	1	75.4	0.75	65.47
Passenger vehicles	Diesel	0.46	2	0.01	0.80
Passenger vehicles	LPG	0.86	2.3	0.02	1.72
Light commercial	Petrol	1.27	10.3	0.13	11.36
Light commercial	Diesel	0.46	2.8	0.01	1.12
Light commercial	LPG	0.86	0.3	0.00	0.22
Heavy duty vehicles	Petrol	5.82	0.5	0.03	2.53
Heavy duty vehicles	Diesel	2.58	5.4	0.14	12.10
Heavy duty vehicles	LPG	3.49	0.1	0.00	0.30
Motor cycles	Petrol	5.61	0.9	0.05	4.38
		total	100	1.15	100.00
NOx					
Passenger vehicles	Petrol	1.93	75.4	1.46	53.46
Passenger vehicles	Diesel	1.01	2	0.02	0.74
Passenger vehicles	LPG	2.86	2.3	0.07	2.42
Light commercial	Petrol	2.5	10.3	0.26	9.46
Light commercial	Diesel	1.16	2.8	0.03	1.19
Light commercial	LPG	3.29	0.3	0.01	0.36
Heavy duty vehicles	Petrol	4.59	0.5	0.02	0.84
Heavy duty vehicles	Diesel	15.72	5.4	0.85	31.18
Heavy duty vehicles	LPG	5.74	0.1	0.01	0.21
Motor cycles	Petrol	0.39	0.9	0.00	0.13
		total	100	2.72	100.00
CO					
Passenger vehicles	Petrol	13.8	75.4	10.41	77.22
Passenger vehicles	Diesel	0.96	2	0.02	0.14
Passenger vehicles	LPG	7.69	2.3	0.18	1.31
Light commercial	Petrol	16.4	10.3	1.69	12.54
Light commercial	Diesel	0.96	2.8	0.03	0.20
Light commercial	LPG	7.69	0.3	0.02	0.17
Heavy duty vehicles	Petrol	107.09	0.5	0.54	3.97
Heavy duty vehicles	Diesel	7.11	5.4	0.38	2.85
Heavy duty vehicles	LPG	48.19	0.1	0.05	0.36
Motor cycles	Petrol	18.54	0.9	0.17	1.24
			100	13.47	100.00

Exhaust emissions for commercial arterial roads					
Category	Fuel	Emission rate	VKT	Composite	Emission
		g/km	% fleet	g/km	% Fleet
HC					
Passenger vehicles	Petrol	1	71.1	0.71	55.67
Passenger vehicles	Diesel	0.5	1.9	0.01	0.74
Passenger vehicles	LPG	0.94	2.2	0.02	1.62
Light commercial	Petrol	1.33	10.3	0.14	10.73
Light commercial	Diesel	0.5	2.8	0.01	1.10
Light commercial	LPG	0.94	0.3	0.00	0.22
Heavy duty vehicles	Petrol	6.3	0.9	0.06	4.44
Heavy duty vehicles	Diesel	2.8	9.4	0.26	20.61
Heavy duty vehicles	LPG	3.78	0.2	0.01	0.59
Motor cycles	Petrol	6.08	0.9	0.05	4.28
		total	100	1.28	100.00
NOx					
Passenger vehicles	Petrol	1.41	71.1	1.00	35.57
Passenger vehicles	Diesel	1.01	1.9	0.02	0.68
Passenger vehicles	LPG	1.93	2.2	0.04	1.51
Light commercial	Petrol	1.76	10.3	0.18	6.43
Light commercial	Diesel	1.16	2.8	0.03	1.15
Light commercial	LPG	2.21	0.3	0.01	0.24
Heavy duty vehicles	Petrol	4.59	0.9	0.04	1.47
Heavy duty vehicles	Diesel	15.72	9.4	1.48	52.43
Heavy duty vehicles	LPG	5.74	0.2	0.01	0.41
Motor cycles	Petrol	0.39	0.9	0.00	0.12
		total	100	2.82	100.00
CO					
Passenger vehicles	Petrol	14.38	71.1	10.22	70.73
Passenger vehicles	Diesel	1.08	1.9	0.02	0.14
Passenger vehicles	LPG	8.66	2.2	0.19	1.32
Light commercial	Petrol	17.75	10.3	1.83	12.65
Light commercial	Diesel	1.08	2.8	0.03	0.21
Light commercial	LPG	8.66	0.3	0.03	0.18
Heavy duty vehicles	Petrol	120.62	0.9	1.09	7.51
Heavy duty vehicles	Diesel	8.01	9.4	0.75	5.21
Heavy duty vehicles	LPG	54.28	0.2	0.11	0.75
Motor cycles	Petrol	20.88	0.9	0.19	1.30
			100	14.45	100.00

Exhaust emissions for commercial freeway/highway roads					
Category	Fuel	Emission rate	VKT	Composite	Emission
		g/km	% fleet	g/km	% Fleet
HC					
Passenger vehicles	Petrol	1	71.1	0.71	57.46
Passenger vehicles	Diesel	0.46	1.9	0.01	0.71
Passenger vehicles	LPG	0.86	2.2	0.02	1.53
Light commercial	Petrol	1.27	10.3	0.13	10.57
Light commercial	Diesel	0.46	2.8	0.01	1.04
Light commercial	LPG	0.86	0.3	0.00	0.21
Heavy duty vehicles	Petrol	5.82	0.9	0.05	4.23
Heavy duty vehicles	Diesel	2.58	9.4	0.24	19.60
Heavy duty vehicles	LPG	3.49	0.2	0.01	0.56
Motor cycles	Petrol	5.61	0.9	0.05	4.08
		total	100	1.24	100.00
NOx					
Passenger vehicles	Petrol	1.93	71.1	1.37	41.73
Passenger vehicles	Diesel	1.01	1.9	0.02	0.58
Passenger vehicles	LPG	2.86	2.2	0.06	1.91
Light commercial	Petrol	2.5	10.3	0.26	7.83
Light commercial	Diesel	1.16	2.8	0.03	0.99
Light commercial	LPG	3.29	0.3	0.01	0.30
Heavy duty vehicles	Petrol	4.59	0.9	0.04	1.26
Heavy duty vehicles	Diesel	15.72	9.4	1.48	44.94
Heavy duty vehicles	LPG	5.74	0.2	0.01	0.35
Motor cycles	Petrol	0.39	0.9	0.00	0.11
		total	100	3.29	100.00
CO					
Passenger vehicles	Petrol	13.8	71.1	9.81	71.97
Passenger vehicles	Diesel	0.96	1.9	0.02	0.13
Passenger vehicles	LPG	7.69	2.2	0.17	1.24
Light commercial	Petrol	16.4	10.3	1.69	12.39
Light commercial	Diesel	0.96	2.8	0.03	0.20
Light commercial	LPG	7.69	0.3	0.02	0.17
Heavy duty vehicles	Petrol	107.09	0.9	0.96	7.07
Heavy duty vehicles	Diesel	7.11	9.4	0.67	4.90
Heavy duty vehicles	LPG	48.19	0.2	0.10	0.71
Motor cycles	Petrol	18.54	0.9	0.17	1.22
			100	13.63	100.00

Exhaust emissions for residential/minor roads					
Category	Fuel	Emission rate	VKT	Composite	Emission
		g/km	% fleet	g/km	% Fleet
HC					
Passenger vehicles	Petrol	1.31	84.6	1.11	77.58
Passenger vehicles	Diesel	0.62	2.2	0.01	0.95
Passenger vehicles	LPG	1.15	2.6	0.03	2.09
Light commercial	Petrol	1.66	5.2	0.09	6.04
Light commercial	Diesel	0.62	1.4	0.01	0.61
Light commercial	LPG	1.15	0.1	0.00	0.08
Heavy duty vehicles	Petrol	7.75	0.2	0.02	1.09
Heavy duty vehicles	Diesel	3.45	2.7	0.09	6.52
Heavy duty vehicles	LPG	4.65	0.1	0.00	0.33
Motor cycles	Petrol	7.48	0.9	0.07	4.71
		total	100	1.43	100.00
NOx					
Passenger vehicles	Petrol	1.58	84.6	1.34	67.39
Passenger vehicles	Diesel	1.01	2.2	0.02	1.12
Passenger vehicles	LPG	2.25	2.6	0.06	2.95
Light commercial	Petrol	2.01	5.2	0.10	5.27
Light commercial	Diesel	1.16	1.4	0.02	0.82
Light commercial	LPG	2.59	0.1	0.00	0.13
Heavy duty vehicles	Petrol	4.59	0.2	0.01	0.46
Heavy duty vehicles	Diesel	15.72	2.7	0.42	21.40
Heavy duty vehicles	LPG	5.74	0.1	0.01	0.29
Motor cycles	Petrol	0.39	0.9	0.00	0.18
		total	100	1.98	100.00
CO					
Passenger vehicles	Petrol	19.06	84.6	16.12	86.96
Passenger vehicles	Diesel	1.38	2.2	0.03	0.16
Passenger vehicles	LPG	11.03	2.6	0.29	1.55
Light commercial	Petrol	22.67	5.2	1.18	6.36
Light commercial	Diesel	1.38	1.4	0.02	0.10
Light commercial	LPG	11.03	0.1	0.01	0.06
Heavy duty vehicles	Petrol	153.58	0.2	0.31	1.66
Heavy duty vehicles	Diesel	10.2	2.7	0.28	1.49
Heavy duty vehicles	LPG	69.11	0.1	0.07	0.37
Motor cycles	Petrol	26.59	0.9	0.24	1.29
			100	18.54	100.00

Exhaust emissions for congested arterial roads					
Category	Fuel	Emission rate	VKT	Composite	Emission
		g/km	% fleet	g/km	% Fleet
HC					
Passenger vehicles	Petrol	1.18	75.4	0.89	62.23
Passenger vehicles	Diesel	0.64	2	0.01	0.90
Passenger vehicles	LPG	1.2	2.3	0.03	1.93
Light commercial	Petrol	1.64	10.3	0.17	11.81
Light commercial	Diesel	0.64	2.8	0.02	1.25
Light commercial	LPG	1.2	0.3	0.00	0.25
Heavy duty vehicles	Petrol	8.08	0.5	0.04	2.83
Heavy duty vehicles	Diesel	3.59	5.4	0.19	13.56
Heavy duty vehicles	LPG	4.85	0.1	0.00	0.34
Motor cycles	Petrol	7.79	0.9	0.07	4.90
		total	100	1.43	100.00
NOx					
Passenger vehicles	Petrol	1.54	75.4	1.16	49.18
Passenger vehicles	Diesel	1.01	2	0.02	0.86
Passenger vehicles	LPG	2.28	2.3	0.05	2.22
Light commercial	Petrol	2	10.3	0.21	8.72
Light commercial	Diesel	1.16	2.8	0.03	1.38
Light commercial	LPG	2.62	0.3	0.01	0.33
Heavy duty vehicles	Petrol	4.59	0.5	0.02	0.97
Heavy duty vehicles	Diesel	15.72	5.4	0.85	35.95
Heavy duty vehicles	LPG	5.74	0.1	0.01	0.24
Motor cycles	Petrol	0.39	0.9	0.00	0.15
		total	100	2.36	100.00
CO					
Passenger vehicles	Petrol	15.92	75.4	12.00	75.28
Passenger vehicles	Diesel	1.28	2	0.03	0.16
Passenger vehicles	LPG	10.31	2.3	0.24	1.49
Light commercial	Petrol	20.32	10.3	2.09	13.13
Light commercial	Diesel	1.28	2.8	0.04	0.22
Light commercial	LPG	10.31	0.3	0.03	0.19
Heavy duty vehicles	Petrol	143.49	0.5	0.72	4.50
Heavy duty vehicles	Diesel	9.53	5.4	0.51	3.23
Heavy duty vehicles	LPG	64.57	0.1	0.06	0.40
Motor cycles	Petrol	24.84	0.9	0.22	1.40
			100	15.95	100.00

Exhaust emissions for congested commercial arterial roads					
Category	Fuel	Emission rate	VKT	Composite	Emission
		g/km	% fleet	g/km	% Fleet
HC					
Passenger vehicles	Petrol	1.18	71.1	0.84	53.85
Passenger vehicles	Diesel	0.64	1.9	0.01	0.78
Passenger vehicles	LPG	1.2	2.2	0.03	1.69
Light commercial	Petrol	1.64	10.3	0.17	10.84
Light commercial	Diesel	0.64	2.8	0.02	1.15
Light commercial	LPG	1.2	0.3	0.00	0.23
Heavy duty vehicles	Petrol	8.08	0.9	0.07	4.67
Heavy duty vehicles	Diesel	3.59	9.4	0.34	21.66
Heavy duty vehicles	LPG	4.85	0.2	0.01	0.62
Motor cycles	Petrol	7.79	0.9	0.07	4.50
		total	100	1.56	100.00
NOx					
Passenger vehicles	Petrol	1.54	71.1	1.09	37.18
Passenger vehicles	Diesel	1.01	1.9	0.02	0.65
Passenger vehicles	LPG	2.28	2.2	0.05	1.70
Light commercial	Petrol	2	10.3	0.21	7.00
Light commercial	Diesel	1.16	2.8	0.03	1.10
Light commercial	LPG	2.62	0.3	0.01	0.27
Heavy duty vehicles	Petrol	4.59	0.9	0.04	1.40
Heavy duty vehicles	Diesel	15.72	9.4	1.48	50.18
Heavy duty vehicles	LPG	5.74	0.2	0.01	0.39
Motor cycles	Petrol	0.39	0.9	0.00	0.12
		total	100	2.94	100.00
CO					
Passenger vehicles	Petrol	15.92	71.1	11.32	69.57
Passenger vehicles	Diesel	1.28	1.9	0.02	0.15
Passenger vehicles	LPG	10.31	2.2	0.23	1.39
Light commercial	Petrol	20.32	10.3	2.09	12.86
Light commercial	Diesel	1.28	2.8	0.04	0.22
Light commercial	LPG	10.31	0.3	0.03	0.19
Heavy duty vehicles	Petrol	143.49	0.9	1.29	7.94
Heavy duty vehicles	Diesel	9.53	9.4	0.90	5.51
Heavy duty vehicles	LPG	64.57	0.2	0.13	0.79
Motor cycles	Petrol	24.84	0.9	0.22	1.37
			100	16.27	100.00

Fuel consumption for major makes and models

Pre 1986									
Make	% Reg		Fuel efficiency l/100km			Composite			
		Freeway	Arterial	Congested	ADR 27	Freeway	Arterial	Congested	ADR 27
Ford Falcon/Fairmont	19.3	12.92	15.92	21.17	8.42	2.49	3.07	4.09	1.63
Holden Commodore/Kingswood	19.3	12.06	14.20	18.70	7.55	2.33	2.74	3.61	1.46
Mitsubishi Sigma	10.3	9.66	10.22	13.10	5.49	0.99	1.05	1.35	0.57
Toyota Corona	8.4	8.00	7.82	9.85	4.24	0.67	0.66	0.83	0.36
Ford Laser/Cortina	8.3	11.19	13.20	17.38	7.01	0.93	1.10	1.44	0.58
Toyota Corolla	8.2	8.87	8.95	11.35	4.84	0.73	0.73	0.93	0.40
Mazda 626/323	7.5	16.35	17.95	23.20	9.60	1.23	1.35	1.74	0.72
Nissan Bluebird/200B	7.5	18.5	20.27	26.40	10.90	1.39	1.52	1.98	0.82
Holden Gemini/Torana	5.7	8.87	8.95	11.35	4.84	0.51	0.51	0.65	0.28
Holden Camira	5.5	9.33	9.46	11.98	5.10	0.51	0.52	0.66	0.28
Total	100.0				Average	11.78	13.25	17.27	7.08

Post 1986									
Make	% Reg		Fuel efficiency l/100km			Composite			
		Freeway	Arterial	Congested	ADR 27	Freeway	Arterial	Congested	ADR 27
Holden Commodore/Calais	22.0	12.69	15.83	21.04	8.34	2.79	3.48	4.63	1.83
Ford Falcon/Fairmont	20.0	12.61	15.43	20.40	8.14	2.52	3.09	4.08	1.63
Ford Laser	11.9	8.27	8.59	10.96	4.62	0.98	1.02	1.30	0.55
Mitsubishi Magna	11.2	10.72	12.28	15.97	6.52	1.20	1.38	1.79	0.73
Toyota Corolla	10.3	8.22	8.77	11.22	4.69	0.85	0.90	1.16	0.48
Toyota Camry	9.5	10.44	11.62	14.99	6.18	0.99	1.10	1.42	0.59
Nissan Pulsar	5.7	12.47	14.29	18.54	7.60	0.71	0.81	1.06	0.43
Nissan Pintara	3.8	19.68	23.12	30.01	12.30	0.75	0.88	1.14	0.47
Ford Telstar	2.8	9.69	10.75	13.90	5.73	0.27	0.30	0.39	0.16
Nissan Skyline	2.8	16.4	19.27	25.01	10.25	0.46	0.54	0.70	0.29
Total	100.0				Average	11.53	13.51	17.67	7.16

CO2 g/km				Aver CO2			
Freeway	Arterial	Congested	ADR 27	Freeway	Arterial	Congested	ADR 27
284.35	351.86	464.41	174.11				
269.65	316.27	413.29	158.56				
222.19	231.42	294.58	119.79				
185.78	178.50	223.26	94.29				
250.44	294.34	384.45	147.62				
388.50	203.58	256.49	106.67				
205.29	203.58	256.49	106.67				
216.53	215.68	271.34	113.07				
252.8413	249.4038	320.5388	127.5975				

CO2 g/km				Aver CO2			
Freeway	Arterial	Congested	ADR 27	Freeway	Arterial	Congested	ADR 27
296.81	373.93	496.95	189.67				
295.32	364.61	482.16	185.70				
195.34	203.28	259.40	106.98				
252.44	290.50	377.57	150.03				
194.24	207.55	265.51	108.72				
246.19	274.85	354.46	142.79				
228.47	254.40	328.83	132.17				

CO_2 emissions with and without the M5 East Motorway

Exhaust emissions for arterial roads						
Category	Fuel	FE	VKT	CO2	Emission	
		l/100 km	% fleet	g/km	% Fleet	
CO2						
Passenger vehicles	Petrol	13.47	75.4	275.64	68.97	85% unleaded
Passenger vehicles	Diesel	13.1	2	7.11	1.78	
Passenger vehicles	LPG	16.6	2.3	10.36	2.59	
Light commercial	Petrol	13.47	10.3	37.65	9.42	
Light commercial	Diesel	12.3	2.8	9.35	2.34	
Light commercial	LPG	16.9	0.3	1.38	0.34	
Heavy duty vehicles	Petrol	20.8	0.5	2.82	0.71	86% Rigid 14% buses
Heavy duty vehicles	Diesel	36.3	5.4	53.20	13.31	51% Rigid 37% Articulated 12% buses
Heavy duty vehicles	LPG	28.9	0.1	0.78	0.20	100% Rigid
Motor cycles	Petrol	5.6	0.9	1.37	0.34	
			100	399.67	100.00	

Exhaust emissions for freeway/highway roads					
Category	Fuel	FE	VKT	CO2	Emission
		l/100 km	% fleet	g/km	% Fleet
CO2					
Passenger vehicles	Petrol	11.57	75.4	236.76	65.62
Passenger vehicles	Diesel	13.1	2	7.11	1.97
Passenger vehicles	LPG	16.6	2.3	10.36	2.87
Light commercial	Petrol	13.47	10.3	37.65	10.44
Light commercial	Diesel	12.3	2.8	9.35	2.59
Light commercial	LPG	16.9	0.3	1.38	0.38
Heavy duty vehicles	Petrol	20.8	0.5	2.82	0.78
Heavy duty vehicles	Diesel	36.3	5.4	53.20	14.75
Heavy duty vehicles	LPG	28.9	0.1	0.78	0.22
Motor cycles	Petrol	5.6	0.9	1.37	0.38
			100	360.79	100.00

Exhaust emissions for commercial arterial roads					
Category	Fuel	FE	VKT	CO2	Emission
		l/100 km	% fleet	g/km	% Fleet
CO2					
Passenger vehicles	Petrol	13.47	71.1	259.92	61.07
Passenger vehicles	Diesel	13.1	1.9	6.76	1.59
Passenger vehicles	LPG	16.6	2.2	9.91	2.33
Light commercial	Petrol	13.47	10.3	37.65	8.85
Light commercial	Diesel	12.3	2.8	9.35	2.20
Light commercial	LPG	16.9	0.3	1.38	0.32
Heavy duty vehicles	Petrol	20.8	0.9	5.08	1.19
Heavy duty vehicles	Diesel	36.3	9.4	92.61	21.76
Heavy duty vehicles	LPG	28.9	0.2	1.57	0.37
Motor cycles	Petrol	5.6	0.9	1.37	0.32
			100	425.59	100.00

CO2 emissions with and without the M5 East Motorway

Exhaust emissions for commercial freeway/highway roads					
Category	Fuel	FE	VKT	CO2	Emission
		l/100 km	% fleet	g/km	% Fleet
CO2					
Passenger vehicles	Petrol	11.57	71.1	223.26	57.40
Passenger vehicles	Diesel	13.1	1.9	6.76	1.74
Passenger vehicles	LPG	16.6	2.2	9.91	2.55
Light commercial	Petrol	13.47	10.3	37.65	9.68
Light commercial	Diesel	12.3	2.8	9.35	2.40
Light commercial	LPG	16.9	0.3	1.38	0.35
Heavy duty vehicles	Petrol	20.8	0.9	5.08	1.31
Heavy duty vehicles	Diesel	36.3	9.4	92.61	23.81
Heavy duty vehicles	LPG	28.9	0.2	1.57	0.40
Motor cycles	Petrol	5.6	0.9	1.37	0.35
			100	388.93	100.00

Exhaust emissions for residential/minor roads					
Category	Fuel	FE	VKT	CO2	Emission
		l/100 km	% fleet	g/km	% Fleet
CO2					
Passenger vehicles	Petrol	7.15	84.6	164.17	69.06
Passenger vehicles	Diesel	13.1	2.2	7.82	3.29
Passenger vehicles	LPG	16.6	2.6	11.71	4.93
Light commercial	Petrol	13.47	5.2	19.01	8.00
Light commercial	Diesel	12.3	1.4	4.67	1.97
Light commercial	LPG	16.9	0.1	0.46	0.19
Heavy duty vehicles	Petrol	20.8	0.2	1.13	0.47
Heavy duty vehicles	Diesel	36.3	2.7	26.60	11.19
Heavy duty vehicles	LPG	28.9	0.1	0.78	0.33
Motor cycles	Petrol	5.6	0.9	1.37	0.58
			100	237.73	100.00

Exhaust emissions for congested arterial roads					
Category	Fuel	FE	VKT	CO2	Emission
		l/100 km	% fleet	g/km	% Fleet
CO2					
Passenger vehicles	Petrol	17.61	75.4	360.36	74.40
Passenger vehicles	Diesel	13.1	2	7.11	1.47
Passenger vehicles	LPG	16.6	2.3	10.36	2.14
Light commercial	Petrol	13.47	10.3	37.65	7.77
Light commercial	Diesel	12.3	2.8	9.35	1.93
Light commercial	LPG	16.9	0.3	1.38	0.28
Heavy duty vehicles	Petrol	20.8	0.5	2.82	0.58
Heavy duty vehicles	Diesel	36.3	5.4	53.20	10.98
Heavy duty vehicles	LPG	28.9	0.1	0.78	0.16
Motor cycles	Petrol	5.6	0.9	1.37	0.28
			100	484.39	100.00

CO2 emissions with and without the M5 East Motorway

Exhaust emissions for congested commercial arterial roads					
Category	Fuel	FE	VKT	CO2	Emission
		l/100 km	% fleet	g/km	% Fleet
CO					
Passenger vehicles	Petrol	17.61	71.1	339.81	67.23
Passenger vehicles	Diesel	13.1	1.9	6.76	1.34
Passenger vehicles	LPG	16.6	2.2	9.91	1.96
Light commercial	Petrol	13.47	10.3	37.65	7.45
Light commercial	Diesel	12.3	2.8	9.35	1.85
Light commercial	LPG	16.9	0.3	1.38	0.27
Heavy duty vehicles	Petrol	20.8	0.9	5.08	1.01
Heavy duty vehicles	Diesel	36.3	9.4	92.61	18.32
Heavy duty vehicles	LPG	28.9	0.2	1.57	0.31
Motor cycles	Petrol	5.6	0.9	1.37	0.27
			100	505.48	100.00

Annual											
	2001 with M5 East										
	VKT	Emission rate g/km									
	billions	HC exhaust		evaporative		NOx		CO		Particulates	
		summer	winter	summer	winter	summer	winter	summer	winter	summer	winter
Arterial	11.97	1.18	1.75	1.08	0.57	2.23	2.41	14.23	21.06	0.16	0.18
Freeway	1.27	1.15	1.70	0.63	0.45	2.72	2.94	13.37	19.79	0.09	0.10
Commercial Arterial	9.03	1.28	1.89	1.08	0.57	2.82	3.05	14.45	21.39	0.24	0.27
Commercial Highway	1.62	1.24	1.84	0.63	0.45	3.29	3.55	13.63	20.17	0.13	0.15
Residential	7.18	1.43	2.12	1.08	0.57	1.98	2.14	18.54	27.44	0.10	0.14
Total	31.07										

Annual											
	2001 without M5 East										
	VKT	Emission rate g/km									
	billions	HC exhaust		evaporative		NOx		CO		Particulates	
		summer	winter	summer	winter	summer	winter	summer	winter	summer	winter
Arterial	12.63	1.18	1.75	1.08	0.57	2.23	2.41	14.23	21.06	0.16	0.18
Freeway	0.68	1.15	1.70	0.63	0.45	2.72	2.94	13.37	19.79	0.09	0.10
Commercial Arterial	9.53	1.28	1.89	1.08	0.57	2.82	3.05	14.45	21.39	0.24	0.27
Commercial Highway	0.87	1.24	1.84	0.63	0.45	3.29	3.55	13.63	20.17	0.13	0.15
Residential	7.60	1.43	2.12	1.08	0.57	1.98	2.14	18.54	27.44	0.10	0.14
Total	31.31										

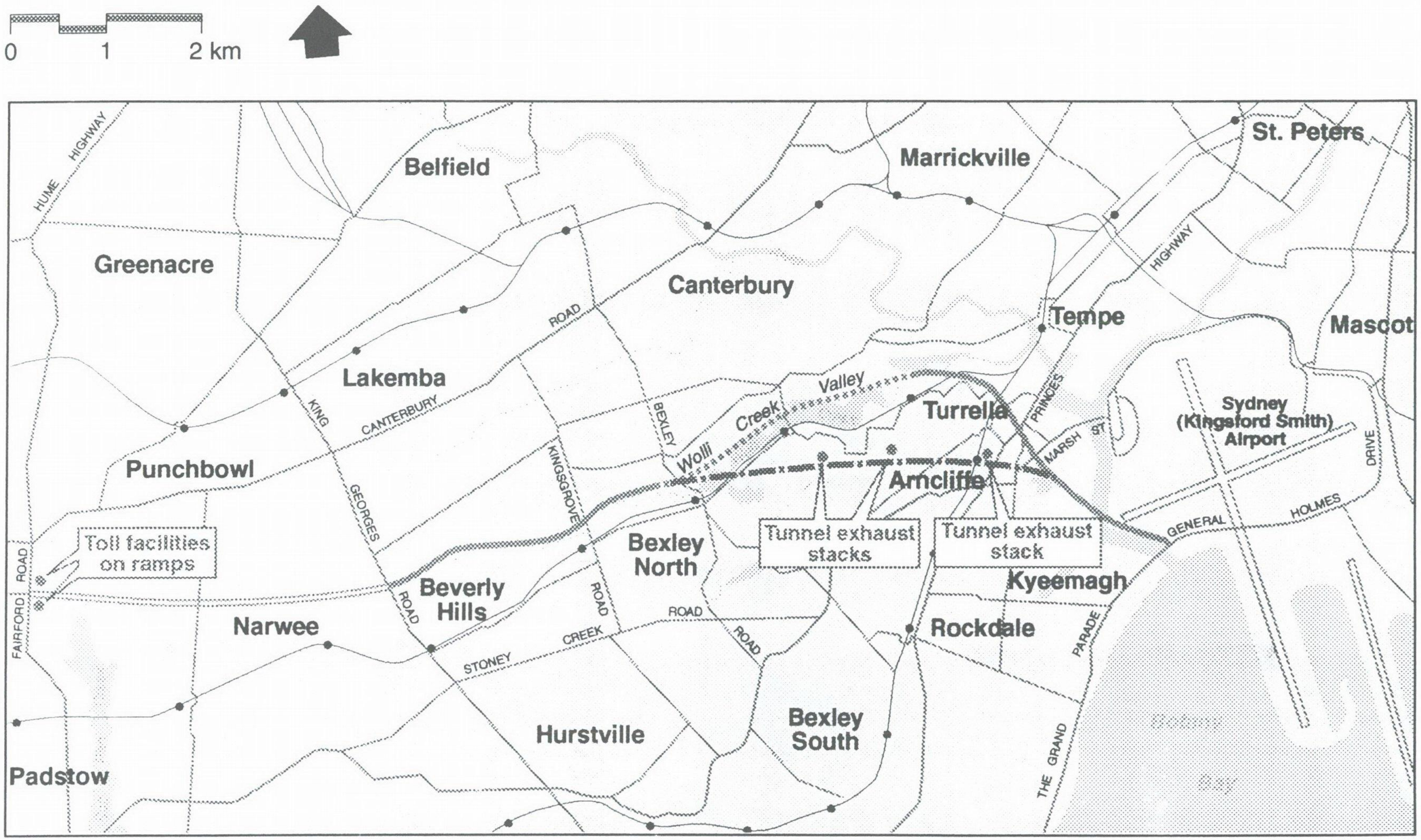
Composite emission rate				Total emissions			
HC	NOx	CO	PM10	HC	NOx	CO	Particulates
				tonnes x 1000			
2.29	2.32	17.65	0.17	27.39	27.76	211.21	2.04
1.97	2.83	16.58	0.09	2.50	3.59	21.06	0.12
2.41	2.93	17.92	0.26	21.78	26.48	161.80	2.32
2.08	3.42	16.90	0.14	3.36	5.53	27.31	0.23
2.60	2.06	22.99	0.12	18.66	14.79	165.11	0.88
				73.69	78.16	586.49	5.59

Composite emission rate				Total emissions			
HC	NOx	CO	PM10	HC	NOx	CO	Particulates
				tonnes x 1000			
2.29	2.32	17.65	0.17	28.90	29.29	222.86	2.15
1.97	2.83	16.58	0.09	1.34	1.93	11.32	0.06
2.41	2.93	17.92	0.26	22.98	27.94	170.70	2.45
2.08	3.42	16.90	0.14	1.81	2.97	14.69	0.12
2.60	2.06	22.99	0.12	19.75	15.65	174.72	0.93
				74.78	77.79	594.30	5.72

Annual				
		2001 with M5 East		
		VKT	CO2	Total
		billions	g/km	tonnes
Arterial		11.97	399.67	4784.05
Freeway		1.27	360.79	453.2033
Commercial	Arterial	9.03	425.59	3843.078
Commercial	Highway	1.62	388.93	628.5109
Residential		7.18	237.73	1707.377
Total		31.07		11421.22

Annual				
		2001 without M5 East		
		VKT	CO2	Total
		billions	g/km	tonnes
Arterial		12.63	399.67	5047.832
Freeway		0.68	360.79	246.4196
Commercial	Arterial	9.53	425.59	4054.596
Commercial	Highway	0.87	388.93	338.058
Residential		7.60	237.73	1806.748
Total		31.31		11493.65

FIGURES



Proposed duplication

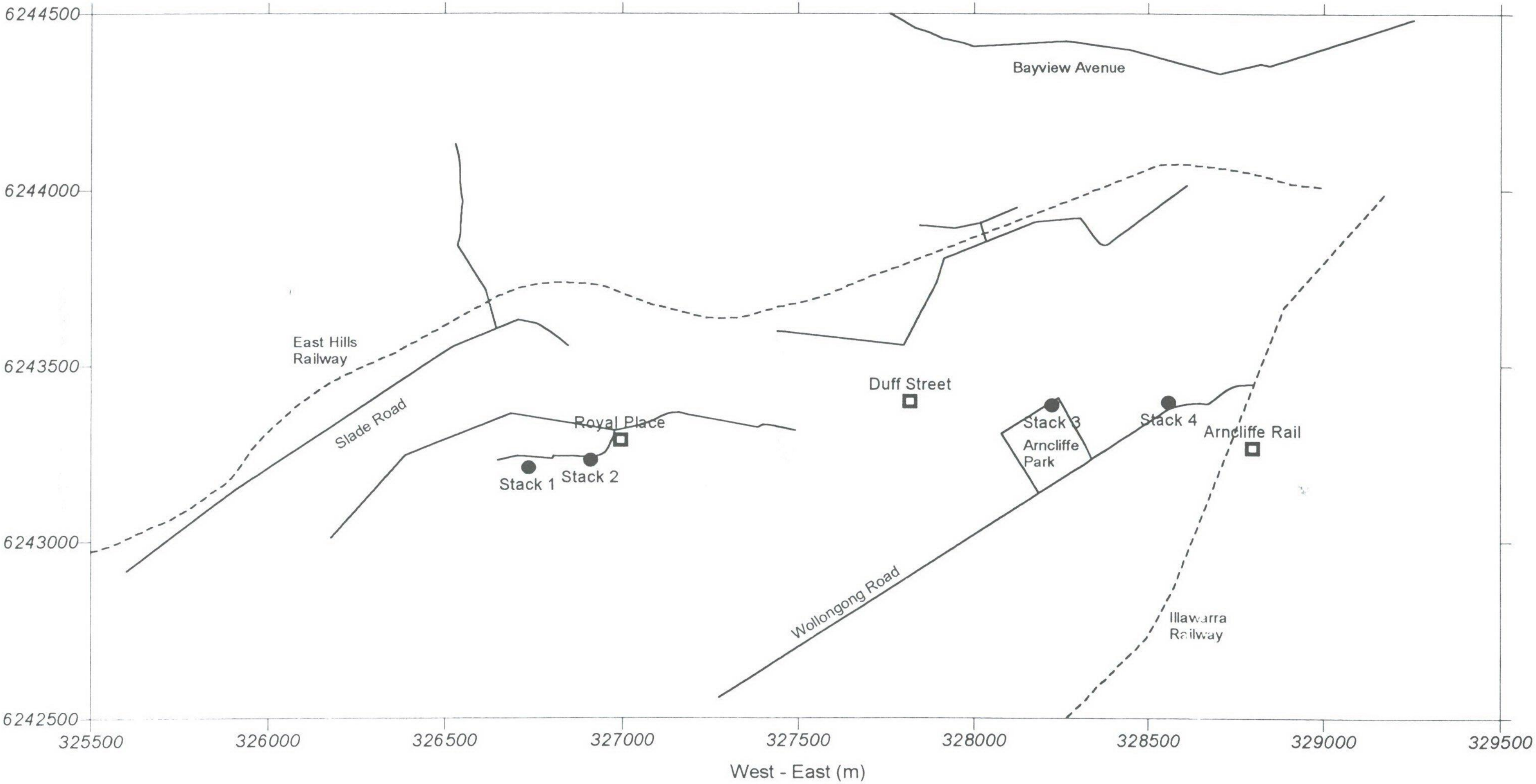
1994 M5 East Motorway proposal

1994 M5 East EIS tunnel proposal (the 'shorter tunnel')

} extended tunnel on the same alignment

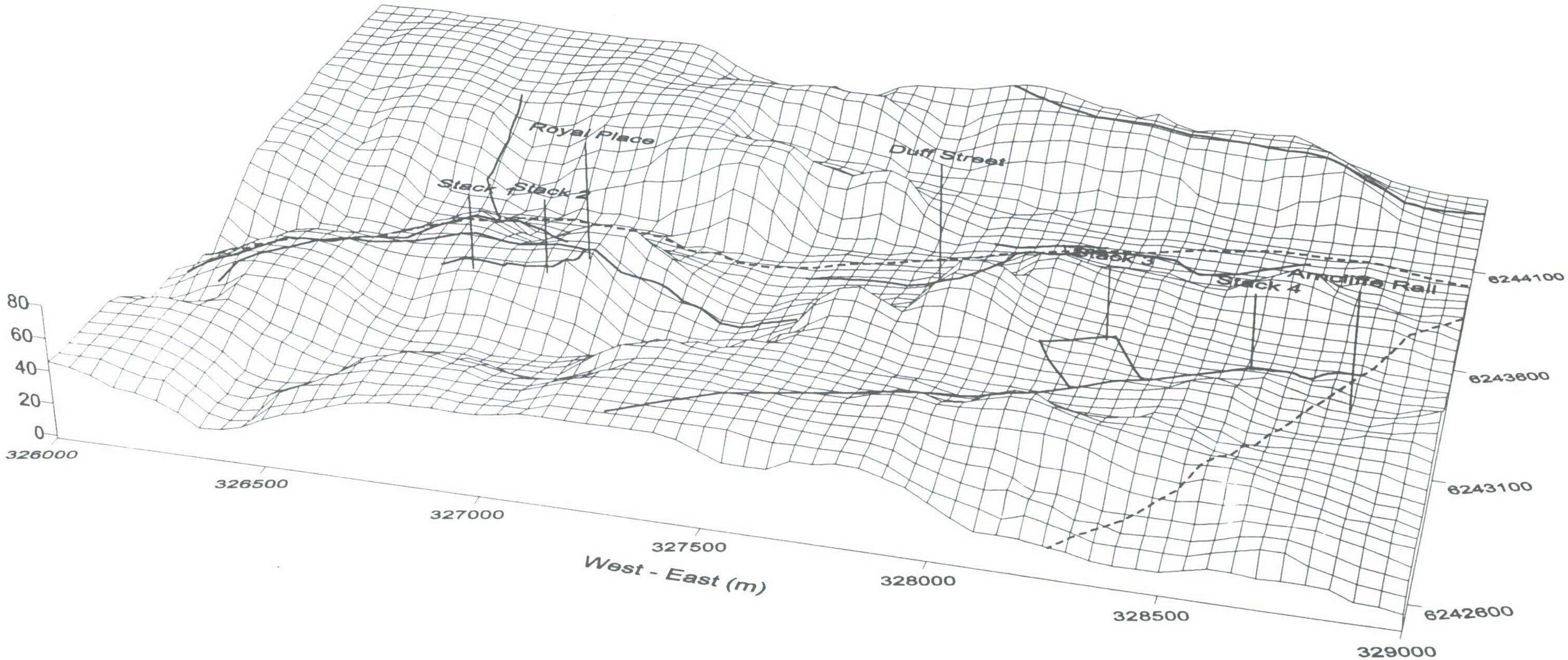
The Variation (also referred to as the proposal, the preferred alternative, the direct tunnel or Alternative H)

Figure 1 —The 1994 M5 East EIS Proposal and the Variation



LOCATION OF VENT STACKS

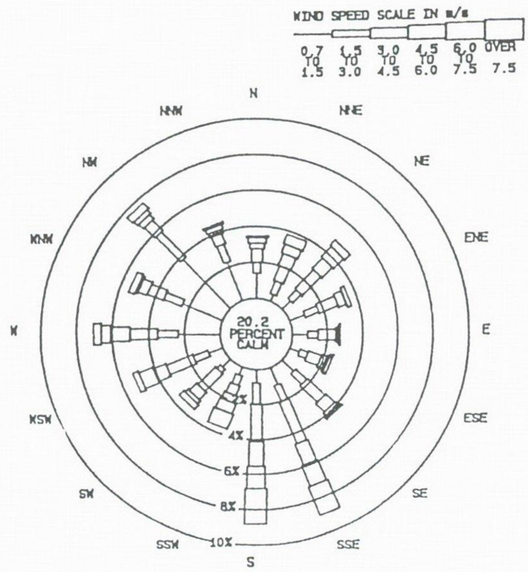
FIGURE 2



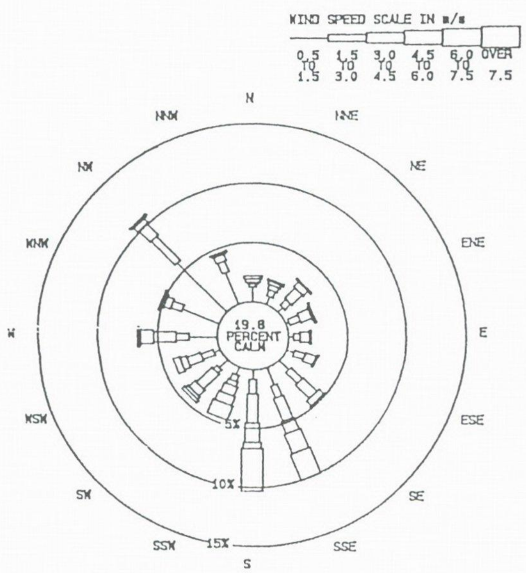
LOCAL TERRAIN

FIGURE 3

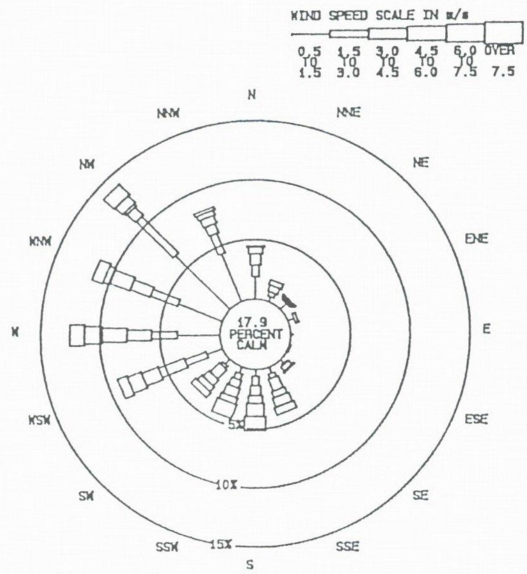
ANNUAL AND SEASONAL WIND ROSES FROM MASCOT



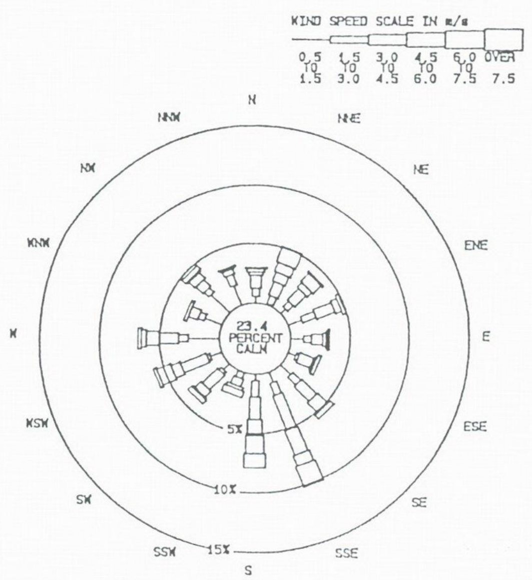
DISTRIBUTION OF WINDS
FREQUENCY OF OCCURRENCE IN PERCENT
Mascot 1984



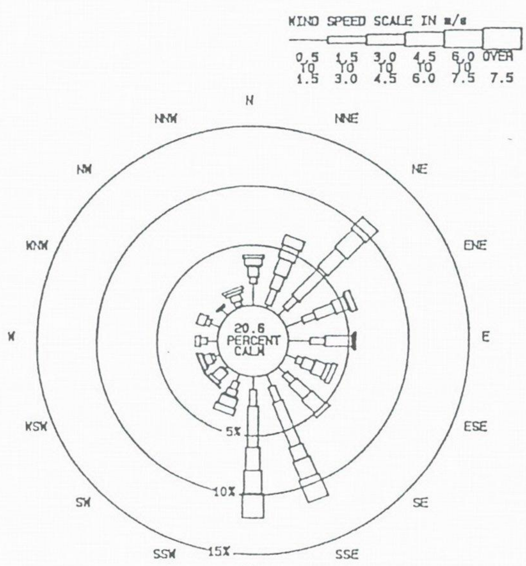
DISTRIBUTION OF WINDS
FREQUENCY OF OCCURRENCE IN PERCENT
Mascot Autumn 1984



DISTRIBUTION OF WINDS
FREQUENCY OF OCCURRENCE IN PERCENT
Mascot Winter 1984



DISTRIBUTION OF WINDS
FREQUENCY OF OCCURRENCE IN PERCENT
Mascot Spring 1984



DISTRIBUTION OF WINDS
FREQUENCY OF OCCURRENCE IN PERCENT
Mascot Summer 1984

FIGURE 4

EMISSION RATE OF CO vs SPEED FOR LIGHT DUTY PETROL VEHICLES - YEARS 1988 AND 2000

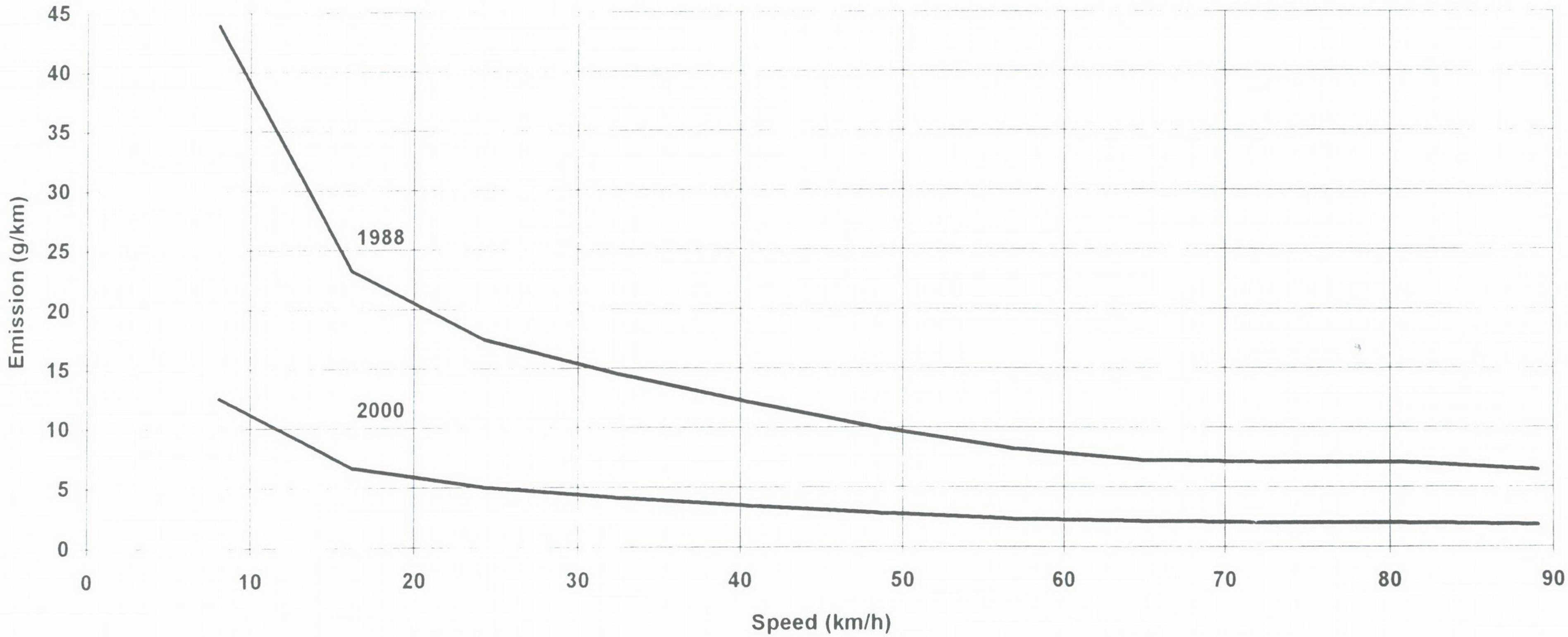


FIGURE 5

EMISSION RATE OF NO_x vs SPEED FOR LIGHT DUTY PETROL VEHICLES - YEARS 1988 AND 2000

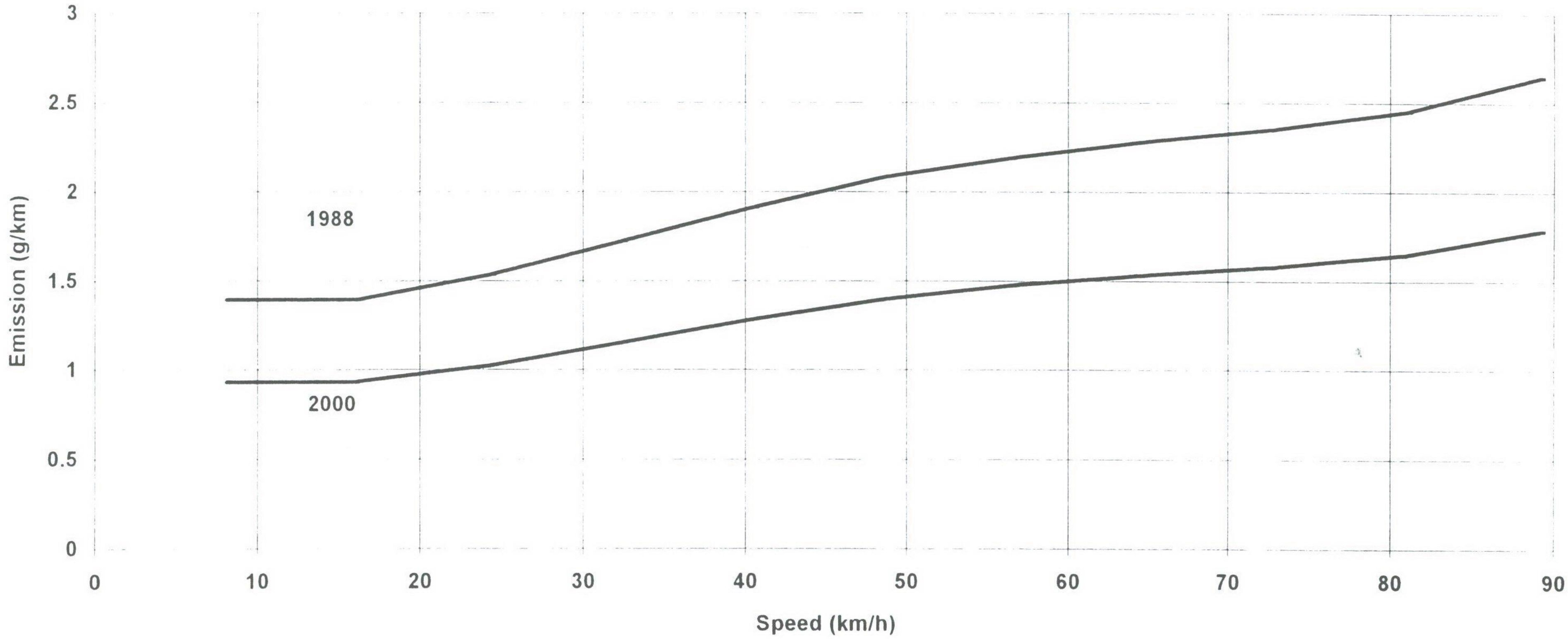
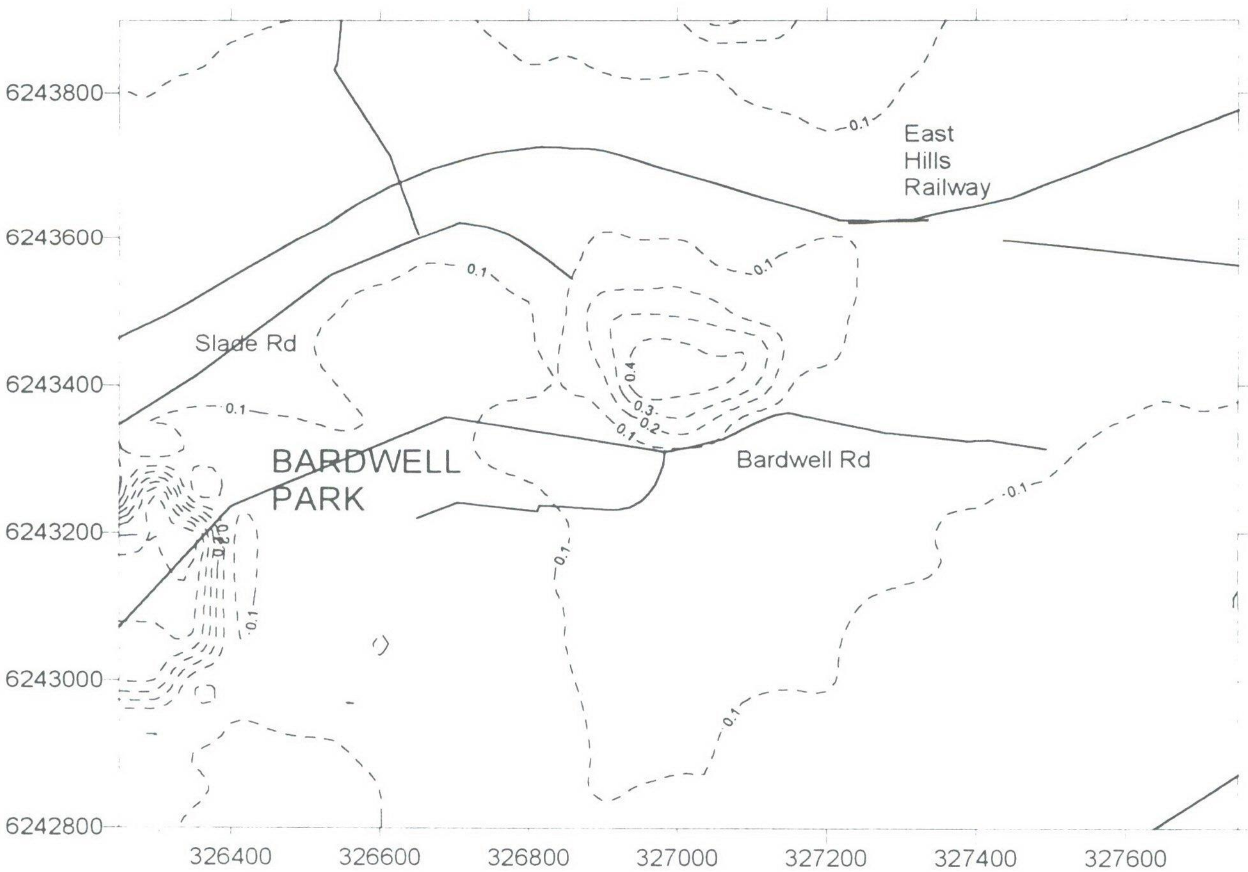
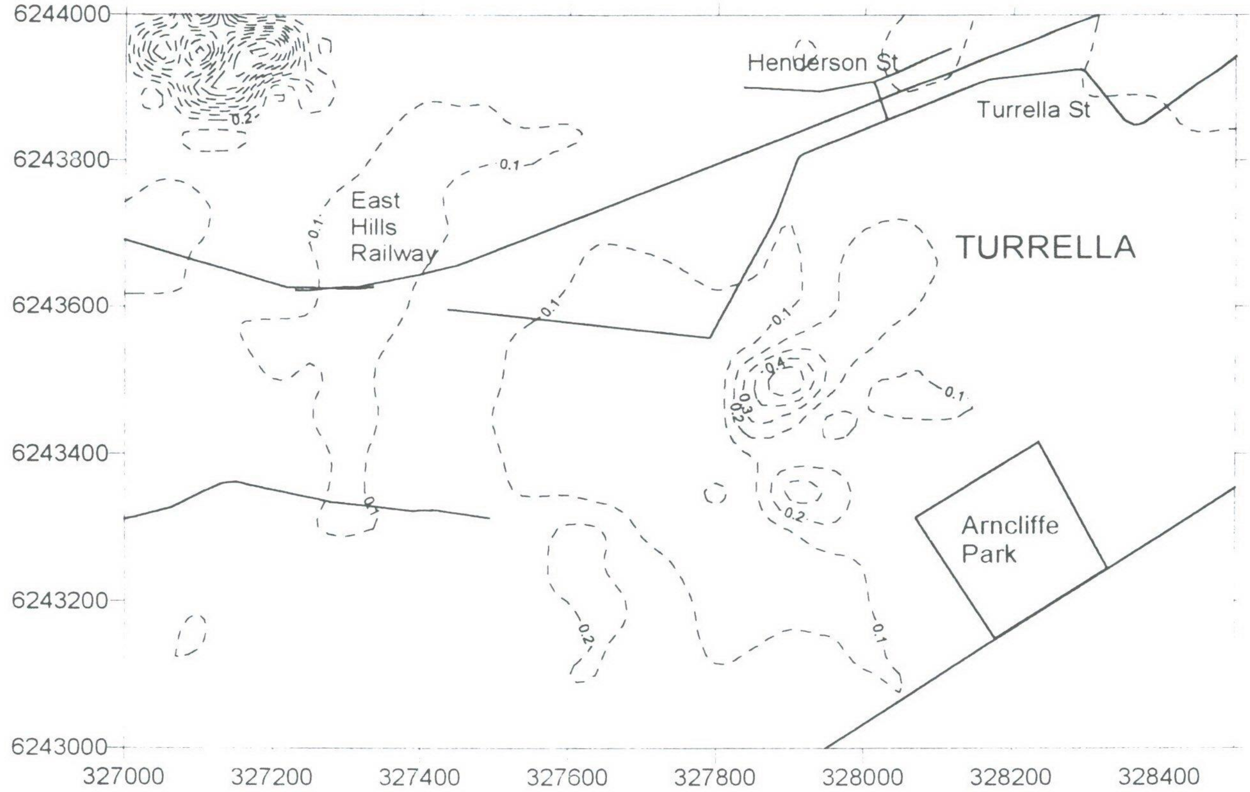


FIGURE 6



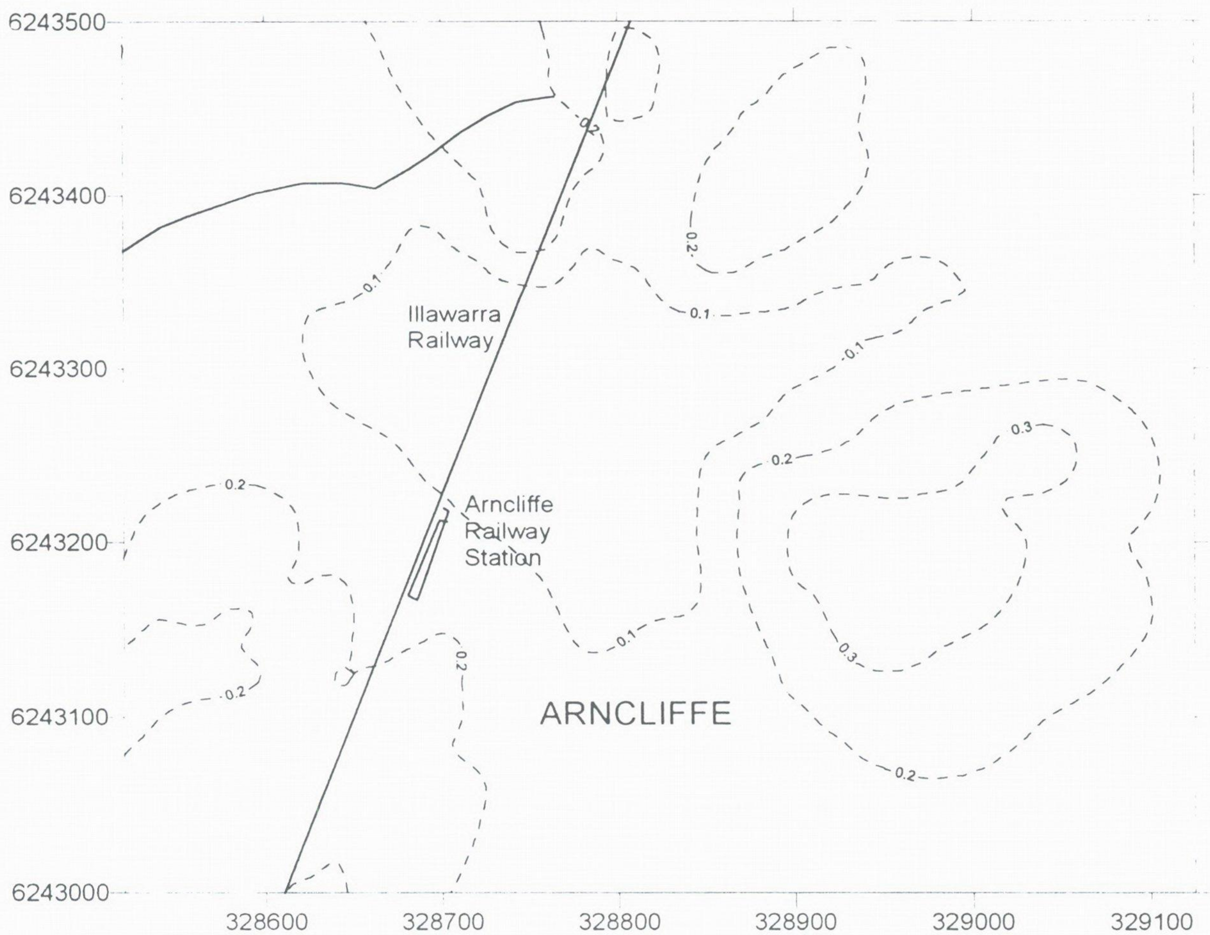
PREDICTED MAXIMUM 1-HOUR AVERAGE GROUND LEVEL CONCENTRATION OF CARBON MONOXIDE FOR ROYAL PLACE - mg/m^3

FIGURE 7



PREDICTED MAXIMUM 1-HOUR AVERAGE GROUND LEVEL CONCENTRATION OF CARBON MONOXIDE FOR DUFF STREET - mg/m^3

FIGURE 8



PREDICTED MAXIMUM 1-HOUR AVERAGE GROUND LEVEL CONCENTRATION OF CARBON MONOXIDE FOR ARNCLIFFE RAIL - mg/m^3

FIGURE 9

ROADS AND TRAFFIC AUTHORITY

M5 EAST MOTORWAY SUPPLEMENTARY EIS

VISUAL ASSESSMENT OF PROPOSED VARIATIONS

REPORT

DECEMBER 1995

prepared by

MANIDIS ROBERTS CONSULTANTS
Level 5, 88-90 Foveaux Street
SURRY HILLS NSW 2010
AUSTRALIA

Tel: (61-2) 281 5199
Fax: (61-2) 281 9406

Our ref: 930013

Contents

Tables

1

Introduction

Since the publication and exhibition of the 1994 M5 East Motorway Environmental Impact Statement, the Roads and Traffic Authority (RTA) has investigated possible changes to the alignment and configuration of the proposed motorway between Bexley North and Arncliffe. A new scheme, referred to in this report as 'the Variation', has been proposed for this section of the motorway. The Variation has two possible alignment options between Bexley Road and Marsh Street, referred to in this document as the 'Northern Variation' and the 'Southern Variation'. This report assesses the visual impacts of the two Variation options, and compares them with the visual impacts of the 1994 M5 East Motorway EIS option (the preferred option from the 1994 EIS, referred to in this report as the shorter tunnel) and the extended tunnel option (investigated in **Chapter 30** of the 1994 EIS as an alternative to the preferred option).

The reader should note that a reference to an illustration contained in this report is a reference to that illustration in the EIS Supplement, which is contained in **Volume 1** accompanying this volume. The illustrations are in colour, and for reasons associated with reproduction of the documents, it was not possible to include colour reproduction in this document.

1.1 Background

The M5 East Motorway, if constructed, will be a significant addition to the urban landscape of southern and south-western Sydney. Its significance can be gauged by the level of public interest and involvement in the environmental impact assessment process carried out to date. Much of the public debate has centred on the tangible aspects of the proposal such as its potential visual impact on the areas through which it would pass. The proposed changes to the design of the motorway east of Bexley Road, Bexley North are largely attributable to the community's response to the perceived visual and other impacts of the previous proposal, assessed in the 1994 M5 East Motorway Environmental Impact Statement (EIS).

The purpose of this report is to assess the visual impacts of the variation to the design of the proposed motorway, as it affects that part of the study area east of Bexley Road, Bexley North (see **Volume 1, Figure A**). This section will also assess the visual impacts of three tunnel exhaust stacks and three tunnel air intakes which would be constructed in the vicinity of the proposed tunnel alignment for each of the variation options. The assessment will focus on two aspects of the proposal:

- The visual impacts of the variation itself, including tunnel exhaust stacks and air intakes.
- A comparison between the visual impacts of the variation, the 1994 M5 East Motorway EIS option and the extended tunnel option.

A systematic approach, comprising three stages, has been taken in order to assess the visual impacts of the variation: (i) Analysis and Assessment; (ii) Visual Impacts; and (iii) Mitigative Measures.

1.2 Method of assessment

The method of visual impact assessment for the proposed motorway, including the tunnel and its associated air intakes and exhaust stacks, involved the following steps:

- Division of the route into discrete units for assessment.
- Determination of the visual catchment of the proposal for each unit, and important viewpoints.
- Determination of the visual character of the landscape in which the proposal will be situated.
- Determination of the visual sensitivity of the viewer, from significant viewpoints.
- Assessment of the ability of the landscape to absorb the changes proposed.
- Ranking of visual sensitivity of viewpoints, and of absorption capability (ie high, medium, low).
- Statement of visual impact.

Using the above method, a high or significant visual impact results from a combination of high viewer sensitivity and low absorption capability. For each unit a matrix will be prepared, measuring sensitivity against absorption capability in order to demonstrate visual impacts. High impact areas would then be described in some detail, and appropriate mitigation measures recommended.

2

Existing conditions

For the purposes of the visual impact assessment, the study area has been divided into three units:

1. From Bexley Road to the Princes Highway, including the proposed tunnel exhaust stack and air intake locations.
2. Princes Highway to the Cooks River.
3. Cooks River to General Holmes Drive.

The following is a brief physical description of each of the above units.

2.1 Bexley Road to Princes Highway

This section of the study area follows the drainage catchment of Wolli Creek which flows into the Cooks River and Botany Bay. In places, the landform is a steep-sided valley with up to 40% gradients, based on underlying Hawkesbury sandstone geology. Along the steepest section of the valley (between Bexley North and Turrella) the banks of the creek are heavily wooded, and the valley is overlooked on both sides by established residential neighbourhoods. As the valley widens approaching the Cooks River, mudflats, mangroves and saltmarsh communities dominate the floodplain.

Turrella is essentially a ridge running parallel to Wolli Creek, descending to the Cooks River floodplain at its eastern end. Land use is a mixture of established industrial and residential areas, in both Turrella and neighbouring Arncliffe. Both suburbs are served by the East Hills and Illawarra railway lines, respectively.

Key visual features are the creek valley itself, the line of the ridge tops on both sides of the valley, and the views from the ridges, especially to the north. The elevated parts of Turrella afford uninterrupted views of the city, the airport and Botany Bay.

2.2 Princes Highway to Cooks River

Between the Princes Highway and the Cooks River, the roadway alignment traverses a residential area in North Arncliffe, before entering open space along the alignment of the South Western and Southern Ocean Outfall Sewer (SWSOOS). The road alignment divides the Kogarah Golf Course from an area of locally significant wetlands and open space, known as the Riverine Park and the Eve Street Wetlands.

From the Princes Highway to Marsh Street, the road alignment crosses a hilltop. East of Marsh Street, the land is almost totally flat, mainly with grasslands and vegetation associated with the golf course and other open space. Key visual features are the ridge top between the Princes Highway and Marsh Street, the Eve Street Wetlands and the Cooks River and its floodplain.

2.3 Cooks River to General Holmes Drive

In this section of the study area, the road alignment follows the eastern bank of the Cooks River alongside Sydney (Kingsford Smith) Airport. This is a flat, open landscape, dominated by the airport. Residential areas dominate the western side of the river in this section.

The key visual feature of this area is the flat, open expanse of space and almost complete absence of relief or elevated features, either of the landform or man-made.

3

The proposal

3.1 The motorway

3.1.1 Proposed new alignment and configuration

The proposed M5 East Motorway was comprehensively assessed in the 1994 M5 East Motorway EIS, however as a result of that assessment, the proposed alignment and configuration of the motorway east of Bexley Road, Bexley North, have been changed substantially. Two alternative alignments for a tunnel have been arrived at, referred to respectively as the Northern Variation and the Southern Variation. The two variation options, and the 1994 M5 East Motorway EIS option, are shown in **Volume 1, Figure A**. The major difference between the 1994 M5 East EIS option and the variation is in the length and alignment of the proposed tunnel. It is now proposed to construct the section of the motorway between Bexley Road and Marsh Street entirely in tunnel.

For the Northern Variation, the tunnel would follow the alignment of the Wolli Creek valley in a wide arc, crossing the creek and the East Hills Rail Line at Turrella and continuing towards Marsh Street. The Southern Variation would follow more or less a straight line between Bexley North and Arncliffe. Both the Northern and Southern Variations would break the surface in identical locations, and would appear exactly the same if viewed from the surface. The only visible difference between the Northern and Southern Variations would be in the locations of tunnel exhaust stacks and air intakes (see **Section 3.2.2** below).

The western tunnel portal at Bexley Road would remain as planned for the 1994 M5 East EIS option. The Princes Highway interchange would, under both Variation options, be comprised of separate ramps descending into tunnel for each of the three planned interchange movements; two entrance ramps (for the left and right turns from the Princes Highway into the west bound tunnel), and one exit ramp (for the left turn from the east bound tunnel into the Princes Highway). **Figure 17** in **Volume 1** shows an artist's impression of the proposed Princes Highway interchange.

At Marsh Street, the Variation would provide a grade separated full diamond interchange, as illustrated by the artist's impression in **Volume 1, Figure 18**. The motorway would emerge from tunnel on the eastern side of Marsh Street, with two ramps (one entrance, one exit) emerging from the motorway tunnel on the western side of Marsh Street.

East of the tunnel, it is proposed to construct the motorway at ground level in a similar configuration to that examined in the 1994 M5 East EIS. The proposed motorway interchange with General Holmes Drive has been redesigned with a new system of flyovers and a new merge configuration with General Holmes Drive. The Variation, illustrated by the artist's impression in **Volume 1, Figure 19**, includes the addition of an extra traffic lane in each carriageway of General Holmes Drive, east of the interchange.

3.1.2 Noise walls

The interchanges at the Princes Highway and at Marsh Street, where the tunnel meets the surface, may require barriers to be constructed to attenuate noise from the motorway. The noise walls would be located around the ramps and portals for the tunnel. The proposed wall height is four metres but this would vary according to acoustic criteria and location. Therefore, they would be highly visible, and would add significantly to the overall visual impact of the proposal. The likely locations of noise walls for the Northern and Southern Variations are shown in **Volume 1, Figures 29** and **31**.

3.2 Tunnel exhaust stack and air intake locations

3.2.1 Air intake and exhaust requirements

For both the Northern and Southern Variations, three tunnel exhaust stacks would be constructed, and three air intake vents. Three exhaust stacks are required to be constructed due to the length of the proposed tunnel, and the stacks would be of a height sufficient for dispersal of exhaust gases. They would be located on the basis that the length of the tunnel is divided into quarters, and that exhaust stacks be located approximately at each one-quarter interval along the tunnel's overall length. The air intakes would be located according to similar principles.

Description of typical air exhaust stack

In order to be effective, exhaust stacks for the tunnel are required to be between eight and ten metres in diameter, and high enough to permit exhaust gases to disperse rapidly under all atmospheric conditions in a given landscape. Therefore it is anticipated that the vent stacks for the M5 East Motorway tunnel would generally be cylindrical structures 15 to 25 metres high, depending on the location and topography of the chosen site. The resulting structures would therefore be of a substantial bulk, and have a significant visual presence depending on the viewer's situation relative to them.

Description of typical air intake

Air intakes would be much smaller structures than the exhaust stacks. Typically, intakes would be no more than three metres in height, the height being dictated chiefly by the need for the vent opening to be vandal proof. For a tunnel such as that proposed, the air intakes would require a surface area of approximately 80 square metres. Therefore they would be square or rectangular structures approximately ten metres by eight metres wide. Owing to their smaller size, air intakes would be considerably easier to camouflage than exhaust stacks, and can be 'built in' to their surroundings so as to minimise their visual impact. Apart from being physically smaller, the air intakes do not expel fumes or give off any kind of gas or noise. Consequently, there is greater flexibility in selecting suitable locations for the intakes than for the exhaust stacks.

3.2.2 Evaluation of potential locations

In order to ensure that the best solution is provided, 16 different options for the location of tunnel exhaust stacks were assessed, and seven possible locations for the air intakes. Evaluation of the options was based on a number of criteria including visual impact, engineering and cost viability, air quality, land use and community impact. The locations assessed are shown in **Volume 1, Figure 5**.

After preliminary assessment of each location according to the above criteria, the list of options for the exhaust stacks was reduced to three preferred options for each of the Northern and Southern Variations. The preferred options are also shown in **Volume 1, Figure 5**. The selection of potential locations and preferred options was made as part of the overall process of developing the concept of the Variation. The preferred options were selected according to the criteria listed below.

- Engineering and cost considerations.
- Air quality considerations.
- Land use impacts.
- Visual impacts.
- Impacts on adjacent communities.

For the Northern Variation, the preferred locations for tunnel exhaust stacks (and their required dimensions) are:

- Earlwood shopping centre car park (15m high, 10m diameter)
- The western end of Henderson Street, Turrella (25m high, 9m diameter)
- Arncliffe Army Reserve Depot (15m high, 9m diameter)

For the Southern Variation, the preferred locations for tunnel exhaust stacks (and their required dimensions) are:

- The corner of Bardwell Road and Royal Place, Bardwell Park, overlooking the Bardwell Valley Golf Club 15m high, 10m diameter)
- Below the corner of Duff Street and Hill Street, Arncliffe (15m high, 9m diameter)
- Arncliffe Army Reserve Depot (15m high, 9m diameter)

4

Results of visual assessment

4.1 The motorway variation

This section deals only with the proposed motorway itself, the location of the roadway, the tunnel portals, noise walls and interchanges. The tunnel exhaust stacks and air intakes are discussed in **Sections 4.2** and **4.3**.

4.1.1 Visual character of the landscape

The following is a brief description of the visual character of the sections of the study area affected visually by the variation. 'Visual character' refers to the nature of the landscape; the landform, the land cover, and the combined visual influence of the features that make up the landscape.

Ignoring for the moment the locations of the exhaust stacks and air intakes, the Variation would have a visual presence in only two locations along the length of the proposed tunnel. These two locations are at its interchanges with the Princes Highway and with Marsh Street. Along the section of the proposed motorway between Marsh Street and General Holmes Drive, the Variation would be virtually identical to that of the 1994 M5 East EIS option, and the visual character of the landscape in that section is as described in a working paper (Context Landscape Design, 1994) which accompanied the 1994 EIS.

The following is a description of the visual character of the Princes Highway and Marsh Street interchange sites.

Princes Highway

The location of the Princes Highway interchange is characterised by hard surfaces, very few trees, and the predominantly commercial nature of existing land uses. The landscape is generally flat, and dominated by the visual clutter of signs, advertising, lightpoles and other structures associated with the highway itself.

On the western side of the highway, the interchange would affect an area characterised by the existing Army Reserve Depot adjoining Burrows and Arncliffe Streets, which in contrast to the highway is a mostly grassed area surrounded by trees. There are also a number of older detached brick and fibro single dwellings of no particular aesthetic value, and more recent blocks of four storey walk-up flats. Visually, these land uses give the locality a residential character that reflects its relationship with two major transport corridors of the Princes Highway and the Illawarra Rail Line.

Marsh Street

The visual landscape in the vicinity of the proposed Marsh Street interchange is described in the M5 East Motorway Visual and Urban Design Study (Context Landscape Design, 1994). The locality is characterised by open space which dominates the eastern side of Marsh Street, and the low hill, some 25 metres above the surrounding landscape on the western side from which a number of residences overlook this open space.

The open space areas at Marsh Street present three distinct visual entities. The northern sector contains the carefully laid out fairways of the Kogarah Golf Course. Adjacent to that is the scrub through which the SWSOOS passes and which broadens to become the Riverine Park, and on the southern side is the Marsh Street wetlands which are overgrown, polluted and generally degraded.

Riverine Park and Cooks River to General Holmes Drive

The visual landscape of this section of the proposed motorway is also described in the M5 East Motorway Visual and Urban Design Study (Context Landscape Design, 1994). This area is characterised by flat open landscapes, the Cooks River and Sydney Airport. There are no landmarks or relief features apart from the line of the SWSOOS and its bridge across the Cooks River.

4.1.2 Absorptive capability of the landscape

The visual impact of the variation is directly related to the ability of the affected landscapes to absorb visual change. In other words, the ability of the landscape to absorb change without altering its visual character.

Aspects of a particular site which will influence its ability to absorb change include the extent to which it has been modified, its situation in the landscape (i.e. is it on a ridgeline, or in a valley floor?), the influence or absence of other prominent visual features, and the influence of adjoining or surrounding landscapes.

Table 1, below, is a summary of the visual absorption capability of each of the locations described in **Section 4.1.1** in relation to the proposed variation.

Table 1. Visual absorption capability of locations affected by the Variation

Visual absorption capability	Princes Highway	Marsh Street	Riverine Park – General Holmes Drive
High	✔		
High-Med			✔
Medium			
Med-Low		✔	
Low			

4.1.3 Visibility of the proposed Variation

The Variation would be in tunnel over most of its route, and therefore would not have any visual impact except for those locations where the motorway would intersect with surface roads. Therefore, the Variation would only cause a visual impact at those locations from which the tunnel portals would be visible. Those locations are described below, in relation to the variation.

The section of the proposed motorway from Marsh Street to General Holmes Drive is not dealt with here. An assessment of visual sensitivity and visual absorption capability of this section can be found in **Section 4.2.12** of the Context Landscape Design report (1994).

Princes Highway

As discussed in **Section 4.1.2** and **Table 1** above, the area around the proposed ramps and ramp portals for the Princes Highway interchange has a high visual absorption capability, due mostly to the highly modified and visually 'hard' nature of the environment. The proposed ramps and ramp portals would have a very small visual catchment, due to the fact that they would not protrude above the ground, in a built up landscape where lines of sight are short and there are no elevated vantage points from which the portals would be visible. The noise walls would have a wider visual catchment, and would be a visual as well as an acoustic barrier, interrupting lines of sight. However, existing lines of sight are short due to the dense, built up nature of the location.

Visually sensitive viewpoints are in the vicinity of the east bound off-ramp (into the north bound lanes of the Princes Highway) and the west bound on-ramp (feeding from the north bound lanes of the Princes Highway). The off-ramp would emerge from the ground close to a number of home units in Allen Street, Ann Street and Argyle Street, and commercial premises fronting the Princes Highway and Allen Street. The on-ramp would descend through the location of an existing row of houses, and into the site of an existing Army Reserve Depot.

At these viewer locations, the landscape would change considerably. The ramps and portals would not be visually intrusive, but the noise walls would create visual barriers. A number of buildings would be demolished to allow construction of the ramps and portals and this change, illustrated by the artist's impression in **Figure 3**, would have a significant visual impact itself through the reduction of visual 'clutter' associated with the existing densely developed, disparate mix of land uses. Visually, the impact of the removal of structures would be positive. However, the social impact of displaced residents and businesses would be significant.

Marsh Street

The proposed Marsh Street interchange would be visible only from those residences fronting Marsh Street and the Marsh Street slip road, and a small section of West Botany Street, over the alignment of the variation. A number of dwellings in Marsh and West Botany Streets would be demolished to allow construction of the portals and cut-and-cover section of the tunnel. The change to the visual landscape at Marsh Street would be significant, and the visual impact on surrounding residences would be high. The motorway would transform the landscape between Marsh Street and West Botany Street, and would isolate those properties that would remain in the triangle of land that would be formed between Marsh Street, West Botany Street and the motorway. The change that would occur at this location is illustrated by the artist's impression in **Figure 4**.

General Holmes Drive

The design of the Variation includes a revised design and configuration for the General Holmes Drive interchange. The proposal assessed in the 1994 M5 East EIS was for the motorway to meet General Holmes Drive at a T-junction intersection, with an underpass carrying traffic from the south bound lanes of General Holmes Drive, under the Endeavour Bridge to merge with the motorway west bound. All works would be carried out at or below existing ground level, and visual impact would be minimal.

The Variation, however, is for a grade separated system of flyovers where the motorway would rise up onto structure as it approaches General Holmes Drive, and start to curve until both roads are aligned. The motorway would then descend to ground level and merge with General Holmes Drive. The proposed interchange is illustrated by the artist's impression in **Figure 5**. The flyovers would increase the visibility of the proposal such that the interchange would have a wider visual catchment than the interchange assessed in the 1994 M5 East EIS.

4.1.4 Statement of visual impact

From the above discussion, it can be seen that the Variation itself would not have a significant visual impact, as it would for the most part be invisible. There are three locations where the variation would cause visual impacts, the Princes Highway interchange, the Marsh Street interchange and the General Holmes Drive interchange.

The tunnel portals, their associated ramps and noise walls, and the widened roadway required at Marsh Street, would each alter the appearance of the landscape. At the Princes Highway, the landscape has a high absorption capability and the variation by itself would not have a high visual impact. However, the change that would result from removal of a number of buildings from the landscape would be visually significant, although this would be regarded as a negative social impact rather than a negative visual impact.

At Marsh Street, where the visual landscape is dominated by open space, the visual absorption capability is lower and the proposed change will have a significant visual impact. The severance caused by the demolition of properties associated with the cut-and-cover sections of tunnel would also cause a significant visual impact.

At General Holmes Drive, the flyovers associated with the proposed interchange would widen the visual catchment such that the interchange would be visible to those residents of Kyeemagh who look out over the Cooks River, and recreational and other users of the river. However the nearest residences are approximately 250 metres from the location of the flyovers, and this distance would help to minimise the visual impact. The maximum height of the flyovers would be seven metres (height of the road surface above General Holmes Drive), plus approximately one metre for kerb safety barriers. Street lighting may also be provided and this would potentially be visually intrusive at night time. However, the airport is heavily lit at night, and it is not considered that street lighting would increase the overall flood of light from all sources.

When all factors are taken into account, the visual impact of the proposed General Holmes Drive interchange would be minimal, due to its distance from visually sensitive locations, and the existing visual environment which is dominated by Sydney Airport when viewed from any point on the southern or western side of the Cooks River.

4.2 Tunnel exhaust stacks

As discussed in **Section 3.2** above, the proposed tunnel would require the construction of three exhaust stacks, and three air intakes. **Section 3.2** also described the process of arriving at preferred options for potential locations for the exhaust stacks and air intakes. The following section of the report, and **Section 4.3** below, contain the visual assessment of those preferred locations.

4.2.1 Visual character of the landscape

The following is a brief description of the visual character of the landscape for the preferred tunnel exhaust stack locations.

Northern Variation

Earlwood car park

The Earlwood shopping centre car park is located on the edge of an escarpment on the northern side of Girrahween Park, overlooking the Wolli Creek Valley. The site is characterised by the expanse of bushland it overlooks, an urban bushland corridor that is considered rare and significant within the urban context. It is also characterised by the commercial and other developments of the shopping centre itself.

Henderson Street Turrella

A possible location for a tunnel exhaust vent stack would be in the vicinity of the western end of Henderson Street, Turrella, next to the East Hills Rail Line. This area is characterised by the low-rise, somewhat run down industrial ribbon development fronting Henderson Street, and the dense vegetation lining the banks of Wolli Creek next to the railway line. On the northern side of Wolli Creek, the landform consists of the gently sloping floodplain at the foot of Nanny Goat Hill, a rocky outcrop at the edge of the valley escarpment.

Arncliffe Army Reserve Depot

This site is characterised by its present use, which is as a depot for a unit of the Army Reserve. The eastern half of the site consists of a number of buildings housing equipment storage, meeting, administration and mess areas, whilst the western half is a grassed parade area with trees planted around the perimeter. Along the northern side of the site are a small number of houses for defence personnel. The site is flat, and adjacent to the Illawarra Rail Line and a residential area consisting of a mixture of older style detached dwellings and more recent three and four storey walk up flats.

Southern Variation

Royal Place, Bardwell Park

This location is characterised by the escarpment on which it is situated, the dense tree cover lining the escarpment, and the open space of the golf course which spreads out beneath. Detached residential dwellings also line the top of the escarpment, although when viewed from the south or from in the valley, only the rooftops are visible behind the trees. When viewed from above, in Bardwell Road, the landscape and vegetation hide the escarpment from view such that its presence is not easily detected.

Duff Street, Arncliffe

Duff Street climbs to the top of a high knoll above Arncliffe. The exhaust stack would be located at the top of Duff Street where it meets Hill Street, on the western side of the knoll overlooking Turrella, Bardwell Creek and Wolli Creek. The location is characterised by its elevation some 20 metres above the surrounding landscape and the predominantly residential surrounding land use. The edge of the knoll where the stack would be located is hidden somewhat by trees, which would serve to disguise the stack when viewed from the west.

Arncliffe Army Reserve Depot

See the description for the Northern Variation, above.

4.2.2 Absorptive capability of short listed sites

The visual impact of the proposed tunnel air exhaust stacks is directly related to the ability of the short listed sites to absorb visual change. In other words, the ability of the landscape to absorb change without altering its visual character.

Aspects of a particular site which will influence its ability to absorb change include the extent to which it has been modified, its situation in the landscape (i.e. is it on a ridgeline, or in a valley floor?), the influence or absence of other prominent visual features, and the influence of adjoining or surrounding landscapes.

Table 2, below, is a summary of the visual absorption capability of each of the short listed exhaust stack locations.

Table 2. Visual absorption capability of preferred tunnel exhaust stack locations

	Earlwood car park	Henderson St Turrella	Arncliffe Army Depot	Royal Place	Duff Street
High					
High-Med				✔	
Medium		✔			✔
Med-Low	✔		✔		
Low					

4.2.3 Visual sensitivity of viewer locations

For each of the short listed tunnel air exhaust stack locations, 'visual sensitivity' was assessed for a number of locations from which the exhaust stacks would be visible. 'Visual sensitivity' refers to the sensitivity of a given view point to change as a result of the addition of an exhaust stack structure in the landscape. The criteria by which visual sensitivity is measured are land use and land form, and the distance between the viewer and the site that is undergoing change. For example, residential areas that are elevated and which therefore enjoy a view over a wide landscape, would be sensitive to any interruption of that view.

The viewer locations selected were both nearby and distant from each short listed site, and were chosen because they each have a clear view to one of the short listed sites. Visual sensitivity for each preferred site and appropriate viewer locations are summarised in **Tables 3** to **7** below.

Northern Variation

Table 3. Visual sensitivity: Earlwood car park

Viewed From:	Earlwood shops	Bardwell Park – top of ridge	Bardwell Park – Slade Rd
High	✔		
Medium		✔	✔
Low			

Table 4. Visual sensitivity: Henderson Street Turrella

Viewed From:	Hill St	Wolli Ck Reserve	Wavell Pde	Highcliff Rd	Turrella Station
High	✔		✔		
Medium		✔		✔	✔
Low					

Table 5. Visual sensitivity: Arncliffe Army Reserve Depot

Viewed From:	Burrows St	Arncliffe Station	Duncan St	Wollongong Rd
High	✔			
Medium		✔		
Low			✔	✔

Southern Variation

Table 6. Visual sensitivity: Royal Place Bardwell Park

Viewed From:	Bardwell Road	Alsace Avenue	Jubilee Park	Pile Street South	Lapis Cres	East Street
High	✔					
Medium					✔	✔
Low		✔	✔	✔		

Table 7. Visual sensitivity: Duff Street Arncliffe

Viewed From:	Hill Street	Wentworth Street	Bardwell Road	Minnamorra Ave/ Girrahween Park
High	✔			
Medium		✔		✔
Low			✔	

4.2.4 Statement of visual impact

Based on the results of the assessment and the information contained in the above tables, each of the short listed sites can be evaluated against each other to arrive at conclusions regarding the potential visual impact that would result from construction of an air exhaust stack at each site, relative to each other. This technique of visual assessment predicts visual impact by relating the visual sensitivity of a site to its capability for absorbing change. For example, construction of an exhaust stack at a location with high visual sensitivity and low absorption capability would result in a high visual impact. The following is a statement of impact for each of the preferred exhaust stack locations.

Earlwood car park

Table 2 shows this site to have a medium to low absorption capability. **Table 3** shows medium to high visual sensitivity for the chosen viewer locations. Therefore, the overall visual impact of an exhaust stack at this location would be medium to high.

Henderson Street Turrella

As shown in **Table 2**, the area between the western end of Henderson Street and Wolli Creek has a medium capability to absorb visual change. **Table 4** shows high sensitivity of viewer locations, the most sensitive being those on the northern escarpment of the valley in Undercliffe, and from the opposite direction, at Hill Street. The site is situated such that it is surrounded by residential areas overlooking the valley, and a 25 metre high stack would be highly visible. Therefore, the overall visual impact of an exhaust stack at this location would be high.

Arncliffe Army depot

As shown in **Table 2**, this site has a medium to low absorption capability. **Table 5** shows this site to have mostly low visual sensitivity, unless viewed from the immediate vicinity. Therefore, the visual impact of an exhaust stack at this location would be medium.

Royal Place Bardwell Park

As shown in **Table 2**, the Royal Place site has a medium to high capability to absorb the visual change associated with the construction of an exhaust stack. **Table 6** shows that visual sensitivity of most viewer locations is low. Therefore, the overall visual impact of an exhaust stack at this location would be low when viewed from the Bardwell Valley, but higher when viewed from above the rim of the escarpment such as from Bardwell Road in the vicinity of Royal Place.

Duff Street Arncliffe

As shown in **Table 2**, the Duff Street site has a medium capacity to absorb the visual change associated with the construction of an air exhaust stack. **Table 7** shows that visual sensitivity of viewer locations diminishes with distance from the site, and the 'average' viewer sensitivity is medium. Therefore, the overall visual impact of an exhaust stack at this location would be medium, although it would be high for residences in Hill Street and Duff Street and low for those viewers on the far side of Bardwell Creek or Wolli Creek.

4.2.5 Conclusions

Comparing the results of the above assessment, it can be seen that the Henderson Street Turrella site would produce the highest visual impact if it were to be used as a location for a tunnel exhaust stack. This is because it would be the highest of all the stacks (25 metres), and would be visible from a wide area, much of which is residential and oriented to take advantage of views over the Wolli Creek valley.

Of the other four locations, the following observations can be made.

➤ A tunnel exhaust stack at Earlwood car park would result in a high to medium visual impact, because of the visual prominence of the northern escarpment of the Wolli Creek Valley. Immediate surrounding land uses, such as the shops and other businesses of Earlwood, would not be sensitive to this visual impact, but the site itself would be overshadowed by the physical bulk of the stack. A stack at this location would also be highly visible from a wide area on the southern side of the Wolli Creek Valley.

➤ The Arncliffe Army Reserve Depot also rated as having a medium visual impact. Although surrounding streets would be sensitive to the visual impact of an exhaust stack, the area is highly modified and developed, and of those land uses that would be affected, only nearby residential uses would be visually impacted in a negative manner.

- Royal Place has a wide visual catchment, but because of the manner in which the escarpment is hidden by trees, an exhaust stack would be relatively easily camouflaged. Visual impact on the Bardwell Valley would be minimal, however residences within the visual catchment in Bardwell Road, above the site, would experience a high visual impact if a stack were located at this site.

- Duff Street, Arncliffe is in a similar situation as Royal Place. It has a wide visual catchment, partially screened by existing vegetation. An exhaust stack would be widely visible from the west of Duff Street, given that it would protrude above what is already a prominent landscape feature. Visual impacts would also be high on those residences in Duff and Hill Streets that are physically close to the stack location.

4.3 Tunnel air intakes

As discussed in **Section 3.2**, the tunnel air intakes would be considerably smaller structures than the exhaust stacks, and therefore have much less of a visual impact. They would be significantly easier to disguise, and therefore there is greater flexibility in the choice of potential locations, at least in terms of visual impact.

Consequently, the potential visual impact of the air intakes has not been used as a major criterion for selecting a preferred tunnel alignment, and nor will it be a major determining factor in deciding the preferred locations of the air intakes. Therefore, the following is a brief assessment of the preferred locations for air intakes, which makes a statement of the potential visual impacts, but does not make comparisons between them or state preferences.

4.3.1 Visual character of the landscape

The following is a brief description of the visual character of the landscape for the possible tunnel air intake locations for the Northern and Southern Variations. Each of the preferred locations is discussed below.

Hartill-Law Avenue, Bardwell Park

On the eastern side of Hartill-Law Avenue adjacent to Wolli Creek, an area of open space exists which is virtually surrounded by the dense bushland found along this section of Wolli Creek. There is a small pocket of residential development on the northern side, but otherwise this location is characterised by bushland and the creek valley, and Hartill-Law Avenue itself which, being the only link across the creek in this vicinity, forms a visual barrier between the sections of the creek valley which it divides.

Heath Street, Turrella

The short listed air intake vent site at Heath Street, Turrella is a residual triangle of land in between the East Hills Rail Line and the residences which back onto the railway. It is an unused piece of land with no particular value either visually or functionally, and a limited visual catchment.

Arncliffe Army depot

This location is described in **Section 4.2.1**, and is common to both the Northern and Southern Variations

Royal Place at Golf Course

This location is described in **Section 4.2.1**. The air intake would be located nearer to May Street than Royal Place, however its situation with regard to terrain, vegetation cover and visual catchment is similar.

Duff Street, Arncliffe

This location is described in **Section 4.2.1**.

4.3.2 Absorptive capability of short listed sites

This section of the visual assessment adopts the same procedure for assessing visual impacts as that used for the tunnel exhaust vent stacks, described in **Section 4.2.2**. The visual absorption capability of the short listed air intake vent locations is shown in **Table 8**.

Table 8. Visual absorption capability of preferred air intake locations

	Hartill-Law Ave	Heath St Turrella	Arncliffe Army depot	Royal Pl. at golf course	Duff St Arncliffe
High		✔		✔	✔
High-Med	✔				
Medium			✔		
Med-Low					
Low					

The above table reflects the relative ease with which the air intake vents would be absorbed into the landscape. As discussed in **Section 3.2.1**, the air intake vents are small structures that would not be visible from a great distance, and which could be easily camouflaged to minimise any potential visual intrusion on the surrounding landscape. It also follows that there would be significantly less 'viewer sensitivity' towards the air intake vents, and fewer locations which would be sensitive to their visual impact.

4.3.3 Visual sensitivity of viewer locations

The procedure adopted in **Section 4.2.3** for assessing the visual sensitivity of various viewer locations in regard to the proposed tunnel exhaust stacks is not appropriate for applying to the air intake vents. This is because the air intake vents would have a much smaller visual catchment than the exhaust stacks, and the visual sensitivity of all viewer locations (i.e. locations from which the intake vents would be visible) would be the same, being within this small visual catchment.

Therefore, the main indicator of potential visual impact of air intake vents is the visual absorption capability of each short listed location. For the air intake vents, the higher the absorption capability, the lower the potential visual impact, and visual sensitivity of viewer locations is no longer part of the equation.

4.3.4 Statement of visual impact

Based upon the assessment of visual absorption capability in **Section 4.3.2** above, all but one of the short listed locations are capable of accommodating an air intake without causing a significant visual impact. The only location where some negative visual impact might result is the Arncliffe Army Reserve Depot. However, it is likely that this site will be redeveloped following completion of the motorway, and an air intake could be easily camouflaged or accommodated within another structure.

4.3.4 Conclusions

Apart from the Arncliffe Army Reserve Depot, none of the other preferred locations would be impacted adversely in a visual sense by the erection of an air intake. The sites are not widely visible, and none apart from the Arncliffe Army Reserve Depot would appear to be of value for alternative uses. In conclusion therefore, all of the preferred locations would be capable of absorbing visually a structure the size and shape of the proposed air intakes.

5

Mitigative measures

Mitigative measures for reducing or minimising visual impacts resulting from the construction of the proposed variation would be the same as those detailed in the 1994 M5 East Motorway EIS. In addition, measures are also proposed for the tunnel exhaust vent stacks.

5.1 Mitigative measures set out in the 1994 EIS

Mitigative measures set out in **Appendix I** of the 1994 EIS are specifically related to the 1994 M5 East EIS shorter tunnel and extended tunnel alternatives, and would be reviewed for their applicability to the Variation, should it proceed. Impacts on Wolli Creek and its valley are substantially reduced for the Variations under examination. In the case of the Riverine Wetlands, the Roads and Traffic Authority would establish a Riverine Park Plan of Management Committee to assess and determine the appropriate uses for the Park, as detailed in **Chapter 8** of the EIS Supplement.

5.2 Mitigative measures for tunnel exhaust stacks

The tunnel exhaust stacks would be a significant visual feature of the proposed Variation. It would not be possible to completely disguise or camouflage the stacks. However, they could be designed and the surface treated so as to help them fit into the visual landscape.

The following mitigative measures were not set out in the 1994 M5 East EIS.

The Roads and Traffic Authority would require the contractor to:

- Appoint an urban designer to ensure that the visible portions of the tunnel exhaust stacks and intake vents are designed and screened in response to their urban context.
- Consider measures such as painting the stacks a suitable colour, and use of trees and shrubs, to further reduce the visual impact of the exhaust vent stacks.

The Roads and Traffic Authority would also consider the possibility of fully enclosing exhaust stacks and air intakes within a purpose-built structure (where possible or appropriate) to mitigate the visual impact. This would apply particularly in the case of the Arncliffe site.

6

Conclusions

The Variation's potential to affect the visual quality of the area east of Bexley Road would be significantly less than either of the two options given detailed consideration in the 1994 M5 East EIS, for the sole reason that the longer tunnels associated with both the Northern and Southern Variations would put most of the motorway underground and out of sight.

The 1994 M5 East EIS shorter tunnel alternative would have resulted in the construction of a motorway viaduct through Turrella and Arncliffe, between Wolli Creek and West Botany Street. As discussed in **Chapter 24** of the 1994 M5 East EIS, the visual impact of the viaduct would have altered the landscape of Arncliffe substantially.

The 1994 M5 East extended tunnel alternative partially addressed the visual impacts, and was a significant improvement over the shorter tunnel alternative. However the extended tunnel alternative would have required substantial acquisition of properties for demolition, and would have left sections of open slot which would still have had a greater impact than the Northern and Southern Variations.

The Northern and Southern Variations would effectively resolve this issue of visual intrusion in Arncliffe such that the motorway would be mostly invisible.

At the few locations where the Variation is above ground and configured differently to the 1994 M5 East EIS shorter tunnel and extended tunnel alternatives, impacts would be caused by the ramps, the Marsh Street interchange structure, the General Holmes Drive interchange and the noise walls. For the length of the Variation east of Marsh Street, visual impacts would not differ significantly from those described in the 1994 M5 East EIS except for the General Holmes Drive interchange.

The major difference in visual impact between the Northern and Southern Variations and the shorter tunnel and extended tunnel alternatives is that there would be three tunnel exhaust stacks instead of one (shorter tunnel alternative) or two (extended tunnel alternative). Their visual impact, though not great, would be magnified because in most cases they would have a large visual catchment area and would be visible from a considerable distance.

Noise walls would be a visual feature of the Variation, but there would be significantly less requirement for noise walls than for the 1994 M5 East EIS or extended tunnel alternatives, and therefore less visual impact as a result.

TRAFFIC ANALYSIS
WORKING PAPER

M5 East Motorway - Supplementary Traffic Analysis for the Variation

November 1996

Prepared for
Roads and Traffic Authority

Masson & Wilson Pty Limited
Traffic and Transport Consultants
Suite 47, "Chatswood Village"
47 Neridah Street
Chatswood NSW 2067
Telephone (02) 9415 2844
Fax (02) 9415 2944
Email massonwilson@ans.com.au

Contents

1. Introduction

This working paper has been prepared to examine the traffic and transport implications of a variation on the preferred option for the M5 East Motorway project.

The M5 East Motorway is proposed to extend from the present termination of the motorway at King Georges Road, Beverley Hills through to Princes Highway/General Holmes Drive near Sydney Airport.

An environmental impact assessment of the proposal was undertaken during 1993 and 1994 and culminated in the publication and exhibition of a detailed Environmental Impact Statement (EIS) in June 1994.

Following the three month public exhibition period, a number of aspects of the proposal required review, partly in response to public submissions. These matters were not specifically related to traffic impacts but rather to the built form of the Motorway.

As a consequence, the EIS proposal has been modified with respect to its alignment between Bexley Road and General Holmes Drive. The motorway will take a more direct route with the inclusion of a grade separated interchange at Marsh Street. The overall length of the route will now be almost 700 metres shorter.

An additional factor which also requires assessment is the decision by the State Government to consider the M5 East Motorway as a toll free road project. This has implications with respect to the level of traffic capture to the motorway compared to the proposal examined in the 1994 EIS.

The purpose of this working paper is to assess the traffic implications of the modifications to the design form and the deletion of the toll plaza by building upon the traffic assessment work undertaken for the preparation of the 1994 EIS.

It is not the purpose of this paper to repeat in detail the travel demand forecasting processes and methodologies reported in:

- Traffic Analysis Working Paper No 1, Existing Situation - Sinclair Knight, May 1994
- Traffic Analysis Working Paper No 2, Analysis of Options - Sinclair Knight, May 1994

This paper takes the form of extending that work by employing those same methodologies to examine the changed proposal now designated as the "Variation". Accordingly this paper should be read in conjunction with the two above-mentioned working papers.

2. Description of the Variation

As indicated at the outset, the proposal now under examination is a variation to the EIS preferred option. For clarity, both proposals are described.

2.1 1994 EIS Proposal

- Two new lanes added to the existing M5 between Fairford Road and King Georges Road plus an eastbound on ramp and a west bound off ramp at Fairford Road
- Grade separated interchange at King Georges Road with on and off ramps provided in both travel directions
- Four new lanes from King Georges Road to Bexley Road built at ground level
- Grade separated interchange at Bexley Road with an east bound off ramp and a west bound on ramp
- Toll plaza located approximately mid way between King Georges Road and Bexley Road - toll nominally set at $2 for passenger cars in each direction of travel
- Twin two lane tunnels from Bexley Road to just north of Turella railway station
- An elevated four lane road over the Illawarra rail line to Princes Highway
- Grade separation at Princes Highway with a west bound on ramp and an east bound off ramp
- Four new lanes from Princes Highway following the sewer pipeline and ending at General Holmes Drive just east of the Cooks River
- At grade signal controlled intersection at Marsh Street
- Grade separated intersection with General Holmes Drive - no provision for right turn from M5 to General Holmes Drive south bound.

A variation canvassed in the EIS was the extension of the tunnel from Turrella through to Princes Highway and then "cut and cover" tunnel between Princes Highway and Marsh Street. In terms of traffic and transport implications, the tunnel extension has no impact.

2.2 The Variation

The Variation proposal is in essence a refinement of the EIS proposal. From a traffic viewpoint, there are four significant changes:

- inclusion of toll collection facilities on the two new east facing ramps at the Fairford Road interchange
- deletion of the toll plaza between King Georges Road and Bexley Road providing toll free travel east of King Georges Road
- a decrease in the length of the route between Bexley Road interchange and Princes Highway. This is a result of a straighter tunnel alignment between these two locations
- grade separation of the Marsh Street intersection whereby the motorway will pass under Marsh Street. On and off ramps from Marsh Street will be provided in both travel directions.

All other aspects of the proposal remain the same as that described in the 1994 EIS.

In simple terms, these changes result in:

- travel time savings in excess of one minute arising out of the shorter length and grade separation at Marsh Street
- higher forecast traffic volumes due to the exclusion of the then proposed $2 toll.

In summary, the Variation would produce a travel time savings of about five percent for an average vehicle trip duration of 20 minutes in addition to attracting higher levels of traffic with the absence of a toll.

The extent to which this causes changes in the forecast traffic patterns for the M5 East is discussed in Chapter 4.

3. Overview of Traffic Assessment Procedures

Before describing the traffic impact analysis for the Variation proposal, it is appropriate to discuss the updating of the traffic model with information that was not available when the 1994 EIS traffic model was prepared.

3.1 Travel Demand Forecasts

For the purpose of maintaining consistency with previous analysis, the travel demand forecasts used in the 1994 EIS have been adopted for analysis of the Variation.

However, it is recognised that more recent forecasts published by the Department of Urban Affairs and Planning in its revised Urban Development Program indicates a slower rate of growth for Sydney's population along with changes in the distribution of urban development. Population assumptions are key inputs in determining future travel demands on the road network.

With respect to the modelled study area, the main contributing factor to this slow down is the lower rate of development in Menai and Sutherland Shire as a whole than was assumed when the EIS model land use forecasts were prepared in 1993.

However, forecasts for 2011 are considered to be still valid for the M5 corridor. Even though the previously forecast population level for Sydney of 4.473 million is not expected to be reached until 2016, no allowance was made in the 1994 EIS forecasts for significant redevelopment in the South Sydney Central Industrial Area. The construction of the New Southern Railway from Sydney via the airport (now under construction) is expected to provide the impetus for redevelopment. Any deferral of population growth in the M5 corridor is therefore likely to be offset by this redevelopment.

In summary, the forecasts for 2001 and 2001 are considered acceptable, and for consistency with previous work, are appropriate to adopt in this re-analysis.

3.2 Changes in the Road System

A number of changes have occurred to the configuration of M5 West since the analysis for M5 East project was undertaken. These are:

- opening of the "Casula link" from the South Western Freeway at Prestons through to the commencement of the M5 West Motorway at Casula
- the addition of ramps to M5 Motorway at Heathcote Road
- the addition of east facing tolled ramps at Henry Lawson Drive
- the existing toll was subject to a fifty cent increase to $2.50 in March 1996

These items have now been incorporated in the base traffic model which has now been updated to reflect 1996 base traffic flows.

Other factors which were assumed to occur in future scenarios but were not explicitly modelled in previous analysis included:

- tolling of the proposed east facing ramps at Fairford Road
- widening of General Holmes Drive to 8 lanes (4 lanes each direction) from M5 connection through to Foreshore Road
- construction of Eastern Distributor Tunnel
- centre loading ramps for M5 connection to General Holmes Drive which would reduce vehicle weaving and improve capacity.

The previous analysis did not include tolling of the Fairford Road east facing ramps. As such the traffic model predicted significant volumes of short distance traffic on this untolled section of M5 between the Fairford Road and King Georges Road interchanges. This resulted in traffic congestion in this section of M5 which discouraged use by potential toll paying motorists. This aspect of the model was rectified in the modelling of the Variation.

One other additional factor which was considered important to review was the treatment of Stoney Creek Road. Upon opening of M5 East, (should it proceed) it is assumed that Stoney Creek Road would be traffic calmed by means of restricting traffic flow to one lane in each direction and re-introducing kerbside parking. This would be needed to limit the amount of traffic that might divert from M5 East because of the toll. Traffic calming in the modelling analysis is replicated by a maximum specified speed. Previous modelling assumed 30km/hr which produced forecast morning peak flows of 300 to 400 vehicles per hour in 1996 with M5 East in place. This was a very significant reduction from the 1993 base flow of 2,330 vehicles per hour which upon review was considered an unlikely outcome.

Having regard to this situation and the fact that the Variation does not now include a toll, the specified maximum speed in the model was increased to 50km/hr which in hindsight is more likely to be achievable within the context of local community concerns for good local access but without heavy through traffic volumes.

3.3 Toll Modelling

3.3.1 Replicating Existing Toll Charges

Replicating the effects of toll charges in the traffic model was achieved by means of imposing a delay penalty to motorists at the point where the toll booths are located on the motorway. Previous modelling for the 1994 EIS replicated the toll by imposing a 6 minute delay penalty to the motorist for each dollar of toll paid.

Through other projects such as M4, M5 West, and the Eastern Distributor Tunnel, more information has become available with respect to the levels of diversion of traffic away from a tolled road for a given charge. This data indicates that 9 minutes delay per dollar of toll is more appropriate in forecasting usage for the M5 Motorway. The consequence of this change are the more representative diversionary effects of the existing toll arrangements on M5 West Motorway.

3.3.2 Toll Rebate Scheme

Recently the State Government announced that as of 1 January 1997, motorists using privately registered vehicles on the M5 and M4 tollways will be eligible for a rebate of the tolls paid under a 'Cashback Scheme'.

Under this scheme, motorists will be eligible to apply for an account card from the operators of those motorways. The card is to be used to pay tolls at the tollway plazas, and will be associated with a credit account under which private motorists will receive monthly statements of the tolls paid. At the end of each three month period the RTA will rebate the tolls paid to the motorist upon application and presentation of the statements as proof of payment of the tolls.

The Cashback Scheme will be available for all journeys by the eligible motorists for all journeys, seven days a week.

As the scheme does not start until January 1997 and the first applications for rebate will not be lodged until April 1997, the implications of this scheme on the usage of the motorway remain unknown. Little information is available to enable an estimate of the number of motorists who will avail themselves to the scheme. Factors that will influence this include:

- the number of privately registered vehicles - business or company registered vehicles driven by private motorists are not eligible
- commercial vans and trucks are not eligible - these usually represent in excess of 20% of traffic flow on an arterial road
- the frequency which eligible motorists use the tollway - the less frequent user may find it too inconvenient to apply for the toll account and thus not participate in the rebate scheme.

At this stage estimating the proportion of motorists participating in the rebate scheme is somewhat subjective however for the purposes of this analysis it was assumed 25% of vehicles using the M5 West will travel toll free.

Under these circumstances the traffic model predicts a ten percent increase in flows on M5 West. Additional modelling indicated that variations of up to ±10% in rebate participants were required to effect a 2% change in the forecast traffic flows on the motorway.

Given the relative insensitivity of changes to forecast traffic flows on M5 West to variations in the number of motorists participating the toll rebate scheme, the 25% level was considered a reasonable assumption for taking into account the effects of the 'Cashback Scheme'.

3.4 Updating the Base Traffic Model

The abovementioned matters (particularly the tolling arrangements) have resulted in a significant change in the traffic flow regime on the road network in the M5 corridor. The usually expected growth in travel demand on the road network has also added to these changes.

The existing situation is now quite different to that described in the 1994 EIS documentation.

To enable a proper assessment of the impacts of the M5 East Motorway, the 1993 Base Model as reported in previous traffic working papers required updating. Accordingly a new 1996 Base model has been produced.

Apart from general increases inc traffic flow across the road network resulting from 'normal' traffic growth, there are some more significant changes worth noting.

- The M5 West in the updated 1996 model is likely to attract longer distant trips as a result of additional access ramps at Heathcote Road and the opening of the Casula Link. This is particularly for those trips moving between south western Sydney and areas to the north along King Georges Road including those to and from Bankstown and Chullora. The 'Cashback Scheme' will add to this growth.

- Stoney Creek Road - Forest Road - Bestic Street/Bay Street route shows strong growth in traffic in relation to the 1993 base case. This occurs because of the increased usage of M5 West.

- Bexley Road forecast flows have increased significantly due through traffic which is moving between Canterbury Road and Princes Highway. This appears to be the consequence of increased traffic congestion on King Georges Road.

Appendix A contains computer plots of the 1996 Base Network detailing the traffic flows on roads within the M5 corridor.

4. Results of Option Analysis

This section adopts a similar format to that contained in Traffic Analysis Working Paper No 2. However discussion is mainly focussed on the Variation scheme with comparison made to the 'Do Minimal' (designated as Option 1A in the 1994 EIS). Some comparisons between the Variation and the 1994 EIS Proposal are discussed however this is limited having regard to the changed circumstances with respect to tolling arrangements and other developments within the road network.

4.1 Traffic Flows

Traffic flows on the road network were forecast by the use of the NETANAL[1] traffic assignment model discussed in Chapter 3 and application of similar assessment procedures that were used in examining the original EIS options. As outlined in the previous chapter, the updating work has incorporated data pertaining to the implications of the 'Casula Link' in the M5 West and ramp tolling at Henry Lawson Drive. The Variation scheme will be discussed in terms of its changes from the 1996 Base Case as well as comparative reference to the 'Do Minimal' scenario.

Appendix A contains the computer plots of the M5 East corridor road network detailing the forecast morning peak hour traffic flows for the years 1996, 2001 and 2011.

Should the M5 East Motorway proceed, the nominal opening date is June 2000. For the purposes of this analysis, the 2001 forecasts are assumed to be the 'on opening' scenarios given the relative small difference between the two reference dates.

Table 4.1 summarises these results for 1996, 2001, and 2011 for the 42 reference roads[2] used to report the traffic forecasting results in the 1994 EIS. The results compare the 'Do Minimal' and the Variation scheme compared to the 1996 Base Case. Figures 1a to 2b illustrate these results graphically.

Table 4.2 details the volume changes from 1996 Base year.

In general terms M5 East is a highly attractive route carrying near capacity traffic volumes on opening. Substantial reductions in traffic volumes on numerous other roads across the network result although some arterial roads leading to the M5 East interchanging experience slight increases.

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[1] NETANAL is the new release version of NODELAY, the model cited in the 1994 EIS Traffic Working Papers. NETANAL is now an enhanced traffic model with improved assignment algorithms and congestion modelling.

[2] The 42 reference roads were compiled during the community consultation phase of the 1994 EIS. They represent the roads which drew the most inquiries regarding impacts resulting from the construction of the M5 East. The list is by no means a comprehensive representation of all roads susceptible to changes in traffic flows on the road network. However the list does reflect the extent and variability of change that would arise from the M5 East.

A more detailed discussion is now provided on the relative impacts on selected roads during the morning peak hour.

4.1.1 Do Minimal Scenario

This scenario will see few major road improvements undertaken in the M5 East corridor over the next ten to fifteen years. The only road improvements that may bring traffic congestion relief to the arterial roads will be:

- development of the Southern Arterial Road through South Sydney
- upgrading of intersections around Sydney Airport (the intersection of O'Riordan Street and Joyce Drive has now been completed)
- tidal flow on Princes Highway through Tempe
- re-alignment of the Marsh Street/Wickham Street/West Botany Street intersection to eliminate the 'dog-leg' movement.

Table 4.1 - Forecast Total Vehicle Volumes - AM Peak Hour Medium Demand Scenario

Road	Location	1996 Base Case	2001 Do Minimal	2001 Variation	2011 Do Minimal	2011 Variation
		Volume	Volume	Volume	Volume	Volume
M5	West Of Princes Hwy	0	0	5290	0	5748
Princes Hwy	At Cooks River Bridge	5310	5699	6210	6584	7106
Qantas Drive	East of Link Rd	5162	5494	4920	6324	5838
General Holmes	At Airport Tunnel	7403	7776	9880	9058	11079
Bestic Street	West of Grand Pde	2168	2389	1497	2898	1553
Bay Street	West of Grand Pde	1776	1874	1381	2073	1663
President Ave	West of Grand Pde	292	270	215	407	248
Forest Road	North of Bexley Rd	3193	3440	2357	3886	2863
Stoney Creek Rd	West of Forest Rd	1509	1677	907	1955	1141
Bexley Road	West of Forest Rd	2721	2854	2053	3423	2439
King Georges Rd	North of M5	4861	5091	4836	5509	5646
King Georges Rd	South of M5	5494	5804	4783	6748	5722
Homer Street	East of Bayview Av	1285	1245	1493	1458	1623
Bayview Street	East of Homer Street	1586	1803	1285	2238	1813
Morgan Street	West of Kingsgrove Rd	541	587	524	681	606
Vanessa Street	West of Kingsgrove Rd	1460	1601	344	2193	778
Moorefields Rd	West of Kingsgrove Rd	3275	3346	2347	3806	2765
Canterbury Rd	West of Kingsgrove Rd	1895	1953	1513	2197	1698
King Street	South of Enmore Rd	1629	1781	1727	2452	2649
Edgeware Road	South of Enmore Rd	999	1047	1126	1228	1292
Sydenham Road	East of Victoria Rd	1731	1854	1811	2064	2071
Marrickville Rd	East of Victoria Rd	1072	1143	1070	1218	1251
Unwins Bridge Rd	South of Railway Pde	2906	3178	2529	3922	3653
Railway Rd	West of Princes Hwy	2525	2627	2474	2727	2763
Enmore Rd	West of King St	4597	4751	4522	5644	5226
Livingstone Rd	North of Addison Rd	1253	1340	1198	1440	1367
Gordon St	North of Canterbury Rd	2374	2410	2312	3212	3128
Slade Rd	West of Harthill-Law Av	1336	1402	1196	1543	1753
Harthill-Law Av	North of Slade Rd	2201	2287	2138	2491	2700
William St	West of Bexley Rd	1453	1452	752	1742	957
Fairford Rd	North of M5	3451	3812	3768	4338	4274
Fairford Rd	South of M5	3141	3332	3700	3708	4156
The River Rd	North of M5	1803	1911	1881	2385	2305
The River Rd	South of M5	1852	1974	1936	2392	2344
Foreshore Rd	East of GHD	1961	2079	2479	2374	2815
O'Riordan St	North of Robey St	3448	3745	3840	4286	4579
Coward St	East of Kent St	2241	2421	2152	2883	2701
Coward St	West of O'Riordan St	314	343	272	312	268
Euston Rd	North of Huntley St	1741	1878	1787	2088	2048
McEvoy St	West of Wyndham St	2705	2852	2595	3142	3013
West Botany St	South of Princes Hwy	1932	2240	1962	2503	2375
West Botany St	South of Wickham St	2369	2758	2465	3115	3103

Table 4.2 - Forecast Total Vehicle Volume CHANGES From Base Year 1996 AM Peak Hour Medium Demand Scenario

Road	Location	1996 Base Case	2001 Do Minimal	2001 Variation	2011 Do Minimal	2011 Variation
		Volume	Volume	Volume	Volume	Volume
M5	West Of Princes Hwy	0	0	5290	0	5748
Princes Hwy	At Cooks River Bridge	5310	389	900	1274	1796
Qantas Drive	East of Link Rd	5162	332	-242	1162	676
General Holmes	At Airport Tunnel	7403	373	2477	1655	3676
Bestic Street	West of Grand Pde	2168	221	-671	730	-615
Bay Street	West of Grand Pde	1776	98	-395	297	-113
President Ave	West of Grand Pde	292	-22	77	115	-44
Forest Road	North of Bexley Rd	3193	247	-836	693	-330
Stoney Creek Rd	West of Forest Rd	1509	168	-602	446	-368
Bexley Road	West of Forest Rd	2721	133	-668	702	-282
King Georges Rd	North of M5	4861	230	-25	648	785
King Georges Rd	South of M5	5494	310	-711	1254	228
Homer Street	East of Bayview Av	1285	-40	208	173	338
Bayview Street	East of Homer Street	1586	217	-301	652	227
Morgan Street	West of Kingsgrove Rd	541	46	-17	140	65
Vanessa Street	West of Kingsgrove Rd	1460	141	-1116	733	-682
Moorefields Rd	West of Kingsgrove Rd	3275	71	-928	531	-510
Canterbury Rd	West of Kingsgrove Rd	1895	58	-382	302	-197
King Street	South of Enmore Rd	1629	152	98	823	1020
Edgeware Road	South of Enmore Rd	999	48	127	229	293
Sydenham Road	East of Victoria Rd	1731	123	80	333	340
Marrickville Rd	East of Victoria Rd	1072	71	-2	146	179
Unwins Bridge Rd	South of Railway Pde	2906	272	-377	1016	747
Railway Rd	West of Princes Hwy	2525	102	-51	202	238
Enmore Rd	West of King St	4597	154	-75	1047	629
Livingstone Rd	North of Addison Rd	1253	87	-55	187	114
Gordon St	North of Canterbury Rd	2374	36	-62	838	754
Slade Rd	West of Harthill-Law Av	1336	66	-140	207	417
Harthill-Law Av	North of Slade Rd	2201	86	-63	290	499
William St	West of Bexley Rd	1453	-1	-701	289	-496
Fairford Rd	North of M5	3451	361	317	887	823
Fairford Rd	South of M5	3141	191	559	567	1015
The River Rd	North of M5	1803	108	78	582	502
The River Rd	South of M5	1852	122	84	540	492
Foreshore Rd	East of GHD	1961	118	518	413	854
O'Riordan St	North of Robey St	3448	297	392	838	1131
Coward St	East of Kent St	2241	180	-89	642	460
Coward St	West of O'Riordan St	314	29	-42	-2	-46
Euston Rd	North of Huntley St	1741	137	46	347	307
McEvoy St	West of Wyndham St	2705	147	-110	437	308
West Botany St	South of Princes Hwy	1932	308	30	571	443
West Botany St	South of Wickham St	2369	389	96	746	734

Under these circumstances, Table 4.1 shows that morning peak hour traffic will continue to grow from 1996 to 2011 on nearly all routes with strong growth (in relative terms) on:

- Princes Highway Tempe (+1,273 vph)
- Qantas Drive (+1,162 vph)
- Stoney Creek Road (+446 vph)
- King Georges Road (+1,254 vph)
- Moorefields Road/Morgan Road/Vanessa Street (+1,560 vph)
- Unwins Bridge Road/King Street/Enmore Road (+1,016, +820, +1,047 vph)

The increased traffic on streets through Marrickville and Newtown is, to a certain extent, growth which should otherwise be on Princes Highway if it had more capacity.

4.1.2 M5 Motorway

Upon opening, the Variation with its shorter length and grade separated interchange at Marsh Street, attracts a some 5,300 vph during the morning peak hour and 5,750 vph in 2011 west of Princes Highway interchange. In the peak flow direction the volumes are 3,654 and 3,864 vph respectively which are approaching the 4,400 vph nominal capacity of the motorway.

Further to the west between King Georges Road and Bexley Road the forecast peak flow exceeds capacity principally due to short distance/local trips joining motorway at King Georges Road and exiting at Bexley Road. This traffic is being drawn off local routes such as Moorefields Road, Morgan Street and Canterbury Road. Under the 1994 EIS Proposal this situation did not eventuate owing to travel resistance through the toll plaza which was to be located on this section of the motorway.

Overall the M5 East provides the missing link between the termination of the M5 West and the Botany/South Sydney area and as such attracts considerable traffic volumes away from:

- Canterbury Road
- Stoney Creek Road/Forest Road
- Moorefields Road/Morgan Road
- Bay Street/Bestic Street

The Variation attracts traffic away from Canterbury Road thus reducing traffic filtering through streets in Marrickville local government area which is moving to and from Princes Highway, Tempe. Once on the Motorway, more traffic proceeds onto General Holmes Drive rather than exiting to use Princes Highway and Qantas Drive. As a consequence forecast volumes increase significantly on General Holmes Drive north of the M5 East connection.

To a certain extent, the proposed Eastern Distributor is also driving this traffic pattern.

4.1.3 Canterbury Road

Canterbury Road is the nearest parallel arterial route to the north of the proposed M5 East Motorway. It caters for a significant proportion of east-west traffic movements that are either destined for or originate from the South Sydney/Botany area. In the absence of an adequate arterial road connection from Canterbury Road to Princes Highway, Tempe, this traffic filters through streets in the Marrickville local government area.

Present congestion levels on Canterbury Road are high, and travel speeds average less than 30km/hour during peak periods. Without any significant upgrading to Canterbury Road or to other roads in the corridor, traffic conditions are forecast to further deteriorate. However increases in traffic volumes are modest (+300 vph by 2011) owing to the fact that the route is now operating at capacity.

The Variation produces an initial reduction of 380 vph or 4,000 vehicles per day on the 1996 base flow and would moderate growth to the point that the forecast 2011 traffic volume would be still below the 1996 level.

4.1.4 Stoney Creek Road

Along with Canterbury Road, Stoney Creek Road is the second major arterial route through the study corridor. Located to the south of the proposed M5 Motorway, it forms the 'defacto' link from the existing M5 West at King Georges Road through to Princes Highway Rockdale via Forest Road.

Forecasts indicate that Stoney Creek Road will be subject to strong growth into the future without M5 East. Between 1996 and 2011, volumes are expected to grow by about 30%.

Under the Variation proposal significant reductions in traffic flows are forecast. In 2011 the morning peak period is forecast to be 1,140 vph compared to the 1996 level of 2,140 vph. This equivalent to a reduction of about 10,000 vehicles per day.

4.1.5 Forest Road

Previous analysis indicated traffic growth on Forest Road will be limited by capacity constraints at the Bexley Road/Stoney Creek Road/Harrow Road intersections. Growth is constrained to about 700 additional vehicles during the morning peak hour in 2011 should M5 East not proceed.

The Variation provides long term relief to Forest Road by containing growth to the point where the morning peak hour in 2011 will still be some 330 vph or 3,500 vehicles per day less than the 1996 flow.

4.1.6 Bexley Road

Bexley Road crosses the M5 corridor in a generally north-south direction providing an important connecting route between Canterbury Road and Princes Highway. Without M5 East, Bexley Road is predicted to have strong traffic growth in the ensuring years. By 2011 volumes are expected to be 700 vph above current levels

The efficient Variation scheme attracts longer distant traffic to the Motorway, reducing the long term growth potential for Bexley Road. By 2011 the forecast flows are 2,440 vph which is slightly less than current levels. This is a direct result of the reduced traffic demands on Canterbury Road as discussed under that previous subheading.

4.1.7 Moorefields Road - William Street - Homer Street

Previous traffic working papers to the 1994 EIS identified this route as one on which adjoining residential uses, schools and local shops suffer impacts from high traffic volumes.

Under the Do Minimal scenario, traffic on this route is expected to grow despite attempts by the local council and Roads and Traffic Authority to suppress growth through traffic calming schemes.

The Variation scheme will moderate traffic growth on this route with the western section of this route (Moorefields Road) having forecast 2011 traffic flows less than current levels.

In the eastern section (Homer Street), the growth eventuates principally as a result of local traffic accessing the Sydenham/Tempe area via Bayview Street and Unwins Bridge Road. This is the result of M5 East freeing up routes through Marrickville thus allowing easier access from the Earlwood area.

As such no significant direct relief is forecast under the Variation for this route. However the anticipated reduction to traffic on Canterbury Road and Bexley Road opens up an opportunity to displace traffic from this route through calming works. The reason why past traffic calming works have not achieved significant traffic relief is that there was no suitable parallel route with spare capacity onto which traffic could divert.

Spare capacity created on Canterbury Road, Bexley Road by the M5 would now present this opportunity.

4.1.8 President Avenue - Bay Street - Bestic Street

This group of streets provides two distinct functions in the sub-regional road network:

- a defacto arterial route from Port Botany area and the airport to the west via Harrow Road, Stoney Creek Road and Bexley Road, and
- a north-south arterial cross link which allows traffic to switch between Princes Highway and General Holmes Drive.

Table 4.1 and Table 4.2 show that significant growth would take place on this corridor even if no road improvements were undertaken.

M5 East would reduce traffic levels on all these streets upon its opening as it directly intercepts the traffic patterns described above. Under the Variation scheme, 2001 forecast volumes on these streets would be down 25% on the 1996 base flows. This relief is sustained over time with 2011 traffic forecast still 18% down in the 1996 flows.

4.1.9 General Holmes Drive - Qantas Drive - Princes Highway

As discussed in previous working papers, these three routes convey the major proportion of traffic at the eastern end of the M5 East corridor. Regardless of whether M5 is built, strong traffic growth is expected as Port Botany, Sydney Airport and South Sydney Central Industrial Area develop.

Table 4.1 shows traffic growth on all three roads irrespective of the road network improvement options.

Under the M5 East Variation Scheme, which includes General Holmes Drive widened to eight lanes, some relief is forecast for Qantas Drive. Instead of an expected flow in 2011 of 6,325 vehicles per hour under the 'Do Minimal' scenario, the motorway is forecast to reduce this to 5,840 vehicles per hour. This is in excess of 60,000 vehicles per day and suggests Qantas Drive should be widened to six lanes, with three lanes in each direction. Certainly under the 'Do Minimal' scenario the widening will need to take place.

General Holmes Drive experiences significant traffic growth as a result of M5 East focussing traffic towards this route. In 2001 morning peak hour volumes will increase to 9,000 vehicles per hour compared to the 1996 base flow of 7,400 vehicles per hour. This is within the capacity of an eight lane road, however by 2011 flows are forecast to increase to 11,080 vph (8,800 vph in the peak direction) which is at the capacity limit of General Holmes Drive.

The majority of the traffic increase on General Holmes is not associated with the diversion of traffic from Qantas Drive and Princes Highway. Rather it would arise from traffic that has been attracted to M5 from Canterbury Road and roads through Marrickville as well as from the Bestic Street/Bay Street/President Avenue routes.

Regardless of whether M5 East proceeds, consideration will need to be given to improving the capacity of Princes Highway between the M5 interchange and Canal Road. It is likely that four lanes in each direction with tidal flow operating in peak periods is required some time in the near future. Upgrading Qantas Drive to six lanes may delay this need, but would not avoid it.

4.1.10 Edgeware Road - Sydenham Road - Marrickville Road

This collection of roads provides access from South Sydney CIA, the airport and Port Botany up through Marrickville onto Canterbury Road, Parramatta Road and routes to the north-west. These routes are of poor geometric design and are not appropriate for high volumes of traffic and large vehicles. Further, they pass through residential areas. They presently operate at a level close to capacity.

Previous analysis indicated that traffic demands will continue to grow in this area, probably as a result of the capacity constraints on Princes Highway.

The Variation brings about some minor relief for roads in the Marrickville/Newtown area over the Do Minimal option. However it is unlikely that significant relief will eventuate without a direct arterial link from the Tempe area through to Parramatta Road. Whatever relief that is provided by M5 East is taken up by other traffic demands in the sub-region.

4.2 Commercial Vehicle Flows

The commercial vehicle patterns forecast for the M5 East Variation scheme vary significantly from those forecast for the 1994 EIS Proposal. Without the toll, the Variation scheme attracts nearly twice the volume of commercial vehicles to M5 East and brings about a sustained reduction on the environmentally sensitive parallel routes.

As discussed in Working Paper 2 of the 1994 EIS, commercial vehicles predominantly move across the study area in a north-west and south-west direction from the Airport, Port Botany, and South Sydney CIA. The consequence of these movements is relatively heavy volumes of commercial vehicles on roads such as Bay Street, Brighton-Le-Sands; Harrow Road, Rockdale; Forest Road - Bexley Road, Bexley; Stoney Creek Road, Kingsgrove; Canterbury Road; and many streets through Marrickville and South Sydney local government areas.

The results of the commercial vehicle forecasting for future years are detailed in Table 4.3, which shows total morning peak hour flows for the 42 reference roads in the study area. Table 4.4 shows the variations from the 1996 base year.

Table 4.3 - Forecast Commercial Vehicle Volumes - AM Peak Hour Medium Demand Scenario

Road	Location	1996 Base Case	2001 Do Minimal	2001 Variation	2011 Do Minimal	2011 Variation
		Volume	Volume	Volume	Volume	Volume
M5	West Of Princes Hwy	0	0	1150	0	1301
Princes Hwy	At Cooks River Bridge	460	503	851	565	961
Qantas Drive	East of Link Rd	269	291	206	387	241
General Holmes	At Airport Tunnel	937	970	1355	1092	1541
Bestic Street	West of Grand Pde	753	784	232	937	248
Bay Street	West of Grand Pde	163	163	0	140	0
President Ave	West of Grand Pde	4	5	5	5	5
Forest Road	North of Bexley Rd	205	227	143	267	216
Stoney Creek Rd	West of Forest Rd	235	267	83	329	113
Bexley Road	West of Forest Rd	416	440	139	514	189
King Georges Rd	North of M5	510	522	447	612	512
King Georges Rd	South of M5	457	500	221	564	306
Homer Street	East of Bayview Av	274	245	333	288	379
Bayview Street	East of Homer Street	89	125	54	154	109
Morgan Street	West of Kingsgrove Rd	144	151	157	175	175
Vanessa Street	West of Kingsgrove Rd	187	236	13	227	67
Moorefields Rd	West of Kingsgrove Rd	573	579	129	714	168
Canterbury Rd	West of Kingsgrove Rd	363	396	284	477	295
King Street	South of Enmore Rd	293	395	351	450	520
Edgeware Road	South of Enmore Rd	145	98	197	111	160
Sydenham Road	East of Victoria Rd	77	79	174	93	251
Marrickville Rd	East of Victoria Rd	147	161	69	149	89
Unwins Bridge Rd	South of Railway Pde	222	241	211	309	443
Railway Rd	West of Princes Hwy	195	226	236	216	231
Enmore Rd	West of King St	880	943	832	1078	961
Livingstone Rd	North of Addison Rd	5	5	2	9	10
Gordon St	North of Canterbury Rd	191	124	144	264	202
Slade Rd	West of Harthill-Law Av	118	113	104	131	170
Harthill-Law Av	North of Slade Rd	150	151	169	194	223
William St	West of Bexley Rd	349	345	62	425	78
Fairford Rd	North of M5	476	505	500	513	531
Fairford Rd	South of M5	410	433	503	399	521
The River Rd	North of M5	998	1047	1039	1343	1323
The River Rd	South of M5	1093	1147	1139	1458	1438
Foreshore Rd	East of GHD	845	884	1096	977	1240
O'Riordan St	North of Robey St	251	268	267	312	311
Coward St	East of Kent St	193	211	199	276	244
Coward St	West of O'Riordan St	74	72	29	89	32
Euston Rd	North of Huntley St	123	127	121	129	134
McEvoy St	West of Wyndham St	420	436	380	487	440
West Botany St	South of Princes Hwy	208	228	288	260	290
West Botany St	South of Wickham St	210	230	155	267	147

The M5 East would bring about significant reductions in commercial vehicle use of the Bay Street - Bestic Street - President Avenue routes such that in 2011 commercial vehicle numbers would still be less than 1996 levels.

However, as highlighted in Working Paper 2, further benefits could be attained by management of routes parallel to the Motorway to discourage their use. As the Motorway improves travel times on these roads, such roads may still be attractive for use by commercial vehicles. This includes such routes as Homer Street/Bayview Street, and Unwins Bridge Road

Management by such measures as 'load limits' and a well defined heavy vehicle network would improve the effectiveness of the M5 East in attracting commercial vehicles out of local streets and confine them to the arterial roads.

Table 4.4 - Forecast Commercial Vehicle Volume CHANGES From Base Year 1996

Road	Location	1996 Base Case	2001 Do Minimal	2001 Variation	2011 Do Minimal	2011 Variation
		Volume	Volume	Volume	Volume	Volume
M5	West Of Princes Hwy	0	0	1150	0	1301
Princes Hwy	At Cooks River Bridge	460	43	391	105	501
Qantas Drive	East of Link Rd	269	22	-63	118	-28
General Holmes	At Airport Tunnel	937	33	418	155	604
Bestic Street	West of Grand Pde	753	31	-521	184	-505
Bay Street	West of Grand Pde	163	0	-163	-23	-163
President Ave	West of Grand Pde	4	1	1	1	1
Forest Road	North of Bexley Rd	205	22	-62	62	11
Stoney Creek Rd	West of Forest Rd	235	32	-152	94	-122
Bexley Road	West of Forest Rd	416	24	-277	98	-227
King Georges Rd	North of M5	510	12	-63	102	2
King Georges Rd	South of M5	457	43	-236	107	-151
Homer Street	East of Bayview Av	274	-29	59	14	105
Bayview Street	East of Homer Street	89	36	-35	65	20
Morgan Street	West of Kingsgrove Rd	144	7	13	31	31
Vanessa Street	West of Kingsgrove Rd	187	49	-174	40	-120
Moorefields Rd	West of Kingsgrove Rd	573	6	-444	141	-405
Canterbury Rd	West of Kingsgrove Rd	363	33	-79	114	-68
King Street	South of Enmore Rd	293	102	58	157	227
Edgeware Road	South of Enmore Rd	145	-47	52	-34	15
Sydenham Road	East of Victoria Rd	77	2	97	16	174
Marrickville Rd	East of Victoria Rd	147	14	-78	2	-58
Unwins Bridge Rd	South of Railway Pde	222	19	-11	87	221
Railway Rd	West of Princes Hwy	195	31	41	21	36
Enmore Rd	West of King St	880	63	-48	198	81
Livingstone Rd	North of Addison Rd	5	0	-3	4	5
Gordon St	North of Canterbury Rd	191	-67	-47	73	11
Slade Rd	West of Harthill-Law Av	118	-5	-14	13	52
Harthill-Law Av	North of Slade Rd	150	1	19	44	73
William St	West of Bexley Rd	349	-4	-287	76	-271
Fairford Rd	North of M5	476	29	24	37	55
Fairford Rd	South of M5	410	23	93	-11	111
The River Rd	North of M5	998	49	41	345	325
The River Rd	South of M5	1093	54	46	365	345
Foreshore Rd	East of GHD	845	39	251	132	395
O'Riordan St	North of Robey St	251	17	16	61	60
Coward St	East of Kent St	193	18	6	83	51
Coward St	West of O'Riordan St	74	-2	-45	15	-42
Euston Rd	North of Huntley St	123	4	-2	6	11
McEvoy St	West of Wyndham St	420	16	-40	67	20
West Botany St	South of Princes Hwy	208	20	80	52	82
West Botany St	South of Wickham St	210	20	-55	57	-63

4.3 Intersection Performance

Working Papers 1 and 2 reported that the performance of an urban road network is greatly dependent on the capacity of its intersections. Table 4.5 reports forecast intersection performance based on intersection 'degree of saturation' as outlined in Working Paper 1.

Table 4.5 - Intersection Performance - Level of Service

Intersection	1996 Base Case	2001 Do Minimal	2001 The Variation
Canterbury/King Georges	F	F	E
Canterbury/Canary's	C	C	A
Canterbury/Bexley	F	F	B
King Georges/Stoney Creek	B	B	A
Forest/Stoney Creek	A	A	A
Forest/Bexley	F	F	F
Princes/President	F	F	E
Princes/Bay	D	D	A
Princes/Forest	F	F	A
Princes/West Botany	E	E	D
Wickham/West Botany	E	F	B
Princes/Railway	F	E	E
Princes/Canal	F	E	D
Princes/King	D	F	E
Grand/President	E	E	D
Grand/Bay	F	F	C
General Holmes/Bestic	F	F	E
O'Riordan/Robey	C	D	D
O'Riordan/Gardeners	C	C	A
O'Riordan/Bourke	A	B	B
Average	D	E	B

Note: Based on intersection 'Degree of Saturation' criteria
A - Little or no delay B - Short traffic delays
C - Average traffic delays D - Long traffic delays
E - Very long traffic delays F - Extreme delay, extra capacity required

Intersections in Table 4.5 are generally the key intersections in the study area and are the more heavily trafficked. They are not a representative sample of all intersections and do not reflect average performance.

In general there is improved performance between the previously reported 1994 EIS Proposal and the Variation. Considerable improvement from the Do Minimal option can be expected along Forest Road and Stoney Creek Road as well as along Princes Highway through Rockdale. These are traditional trouble spots in the road network.

In global terms, the computer analysis reports estimated delays at all intersections throughout the study area by accumulating time delays for each vehicle at all intersections. The result is expressed in 'vehicle delay hours'. Table 4.6 reports the relative delays savings for the Variation.

Table 4.6 - Network Vehicle Delays AM Peak Hour

Year	Do Minimal Delay Hours	The Variation Savings
2001	40,970	1,443 (3.5%)
2011	52,519	1,975 (3.8%)

Total road network delays can be seen to escalate over time with significant savings accumulating in 2011.

4.4 Network Efficiency Measures

This section deals with global changes to the road network as opposed to looking at changes on individual roads or at intersections. Global changes provide an overall performance measure of the proposal, taking into account changes to all roads and intersections within the modelled road network.

The following reviews performance measures in relation to travel time benefits, vehicle operating costs and accident reductions (or increases).

The measures relate to the modelled road network bounded by Georges River to the south; Hume Highway to the west; Hume Highway, Parramatta Road and Cleveland Street to the north; and, South Dowling Street - Anzac Parade to the east. Excluding local streets, the network contains approximately 650 kilometres of roads.

4.4.1 Travel Time Benefits

The computer modelling analysis provides specific measures in terms of:

- total distance travelled by vehicles on the network
- total delays encountered at all intersections by all vehicles
- total travel time measures.

Table 4.7 summarises the travel performance measures for each scenario.

Table 4.7 - AM Peak Hour Network Performance

Performance Measure	Do Minimal	The Variation Savings
2001		
Vehicle Km Travelled	1,505,229	11,872
Vehicle Hours of Delay	40,970	1,443
Vehicle Hours of Travel	66,452	2,452
2011		
Vehicle Km Travelled	1,740,537	13,651
Vehicle Hours of Delay	52,519	1,975
Vehicle Hours of Travel	83,355	3,523

As noted in Working Paper 2, the system performance for the Do Minimal scenario deteriorates considerably by 2011. With some 150,600 vehicles in the morning peak hour study corridor road network in 2001 and 173,400 in 2011 (Refer Table 3.1 Working Paper 2), average delays at intersections increases by 11% from 16.3 minutes per vehicle to 18.2 minutes per vehicle.

For the Variation, considerable savings are achieved compared to the Do Minimal option. An average of 18.2 minutes delay per vehicle is forecast for the Do Minimal scheme. The M5 East would reduce this delay by 41 seconds representing a 3.7% reduction. While this may seem small, it is significant in relation to a less than 2% increase in the length of road within the modelled network.

4.4.2 Vehicle Operating Cost Benefits

The above section outlines savings in terms of travel time and distance. These savings bring benefits to the community with respect to vehicle operating costs, improved efficiency to transport, commercial time savings and so on.

Table 4.7 forms the basis for input to estimating the economic savings. This analysis is detailed in the Supplementary EIS document.

It is pertinent to note that these modelled savings are for the morning peak hour only but can be projected to describe the savings over the whole day. Appendix 6 of Working Paper 2 detailed a methodology for this process where traffic volumes, delays, and vehicle kilometres travel are expanded to 24 hour profiles.

4.4.3 Accident Reductions

The construction of a new road to freeway standard in an urban network will bring about a reduction in accidents due to the safer operating conditions arising from reduced vehicle conflicts and the absence of intersections.

The Roads and Traffic Authority has recently updated its data on representative accident rates on the urban road network derived from statistics the Road Safety Bureau collects. These are detailed in Table 4.8.

Table 4.8 - Accident Cost Data

Road Category	Accident Rate per Million Vehicle Kilometres	Accident Cost per Million Vehicle Kilometres
Local/sub-arterial Roads	1.510	$62,200
Arterial	1.100	$45,300
Freeway	0.343	$14,100

Source: RTA Economics Analysis Manual - Appendix D - March 1996 Revision

From the modelling analysis the changes in usage of each category of road can be estimated and expanded to annual vehicle kilometres travelled. This is detailed in Table 4.9.

Table 4.9 - Modelled Annual VKT By Road Category

Road Category	Do Minimal 2001	Do Minimal 2011	Variation 2001	Variation 2011
Peak Hr Factor	11.5	12	11.5	12
Freeway	-	-	8.9	10.5
Motorway	284.7	353.9	535.9	647.3
Motorway Ramps	25.8	31.1	35.0	41.6
6 Lane Arterials	1,554.5	1,840.6	1,527.7	1,797.7
4 Lane Arterials	1,673.7	2,006.4	1,563.4	1,880.9
Sub-Arterials	1,262.7	1,539.0	1,164.5	1,425.0
Collectors	1,080.6	1,327.1	999.7	1,239.9
Residential	436.1	525.6	433.2	520.9
Total VKT	6,318.2	7,623.6	6,268.4	7,563.8

Currently the M5 West traffic flow profile indicates the morning peak hour represents 9% of the average daily flow. As discussed in Working Paper 1, this figure would probably drop to about 8% by 2011 as the off peak period becomes busier and represents a greater proportion of the daily flow. The peak hour factors detailed in Table 4.9 reflect these proportions.

As can be observed in Table 4.9, the effect of the M5 East Motorway is to attract traffic off the arterial and sub-arterial road system onto a freeway standard road thus providing a safer form of travel.

Accident savings can thus be calculated from Table 4.9 by application of the accident data detailed in Table 4.8. The differences between the Do Minimal and the Variation scenarios are the savings. These are detailed in Table 4.10.

Table 4.10 - Annual Accident Event Savings with M5 East

Year	Reduced Number of Accidents	Accident Cost Reduction
2001	333	$13.7 million
2011	388	$16.0 million

Table 4.10 indicates that upon opening of the M5 East, at least six serious accidents per week would be avoided on the road network while by 2011, 388 accidents would be avoided per year. This represents a significant $16 million savings to the community.

4.5 Comparison of the Variation Scheme to the 1994 EIS Proposal

The foregoing discussion predominantly relates the Variation Scheme to the newly developed 1996 base case and the 'Do Minimal'. In order to place this scheme into some sort of context with the previous 1994 EIS Proposal, some comparisons are set out in the following discussion.

However it should be noted that circumstances have changed considerably since the 1994 EIS work and direct and valid comparisons are difficult to make. Each analysis has been undertaken in a different set circumstances The differences were outlined in Chapter 3 and included:

- the project is now a toll free motorway
- changes in tolling arrangements for M5 West
- introduction of the Cashback Scheme
- newly committed road works such as the Eastern Distributor
- traffic growth since 1994
- improvements in modelling techniques

With these aspects in mind, Table 4.11 provides a comparison of the two projects.

Table 4.11 - Comparison Between 1994 EIS Proposal and the Variation - Forecast AM Peak Hour Traffic Flows

Road	Location	Variation minus 94 EIS Proposal			
		Total Vehicles		Commercial Vehicles	
		2001	2011	2001	2011
		Difference	Difference	Difference	Difference
M5	West Of Princes Hwy	1543	1471	596	598
Princes Hwy	At Cooks River Bridge	-1027	-615	439	514
Qantas Drive	East of Link Rd	-797	-1888	7	34
General Holmes	At Airport Tunnel	2144	2709	571	475
Bestic Street	West of Grand Pde	343	529	64	82
Bay Street	West of Grand Pde	530	689	-80	-93
President Ave	West of Grand Pde	-721	-595	-64	-55
Forest Road	North of Bexley Rd	-351	-847	-15	-6
Stoney Creek Rd	West of Forest Rd	457	215	17	0
Bexley Road	West of Forest Rd	-734	-913	7	4
King Georges Rd	North of M5	584	1102	58	-30
King Georges Rd	South of M5	-685	-129	69	126
Homer Street	East of Bayview Av	941	693	222	222
Bayview Street	East of Homer Street	468	444	-3	-83
Morgan Street	West of Kingsgrove Rd	133	159	1	-10
Vanessa Street	West of Kingsgrove Rd	-1006	-626	-58	-14
Moorefields Rd	West of Kingsgrove Rd	967	734	-68	-138
Canterbury Rd	West of Kingsgrove Rd	-2210	-2539	161	144
King Street	South of Enmore Rd	-1524	-1130	156	189
Edgeware Road	South of Enmore Rd	295	276	83	16
Sydenham Road	East of Victoria Rd	-1376	-1596	-44	84
Marrickville Rd	East of Victoria Rd	248	321	34	29
Unwins Bridge Rd	South of Railway Pde	427	1271	52	202
Railway Rd	West of Princes Hwy	1634	1814	189	179
Enmore Rd	West of King St	536	1000	513	599
Livingstone Rd	North of Addison Rd	-1620	-1487	-169	-123
Gordon St	North of Canterbury Rd	-2054	-1792	-137	-146
Slade Rd	West of Harthill-Law Av	-140	-141	-23	-33
Harthill-Law Av	North of Slade Rd	100	232	-89	16
William St	West of Bexley Rd	12	-136	-10	-62
Fairford Rd	South of M5	-41	170	333	367
The River Rd	North of M5	360	531	711	925
The River Rd	South of M5	663	783	972	1216
Foreshore Rd	East of GHD	39	-97	452	354
O'Riordan St	North of Robey St	-1133	-1914	-7	-46
Coward St	East of Kent St	-443	-63	31	69
Coward St	West of O'Riordan St	-211	-812	-26	-86
Euston Rd	North of Huntley St	-789	-542	-48	-36
McEvoy St	West of Wyndham St	-1413	-578	70	94
West Botany St	South of Princes Hwy	648	1381	216	240
West Botany St	South of Wickham St	-411	-354	-3	-12

Figures 3a to 4b detail the comparisons graphically.

The principal differences to note are the significant increases in the forecast traffic flows on the M5 East Motorway largely due to the removal of the toll.

This has a significant impact on the level of capture of commercial vehicles to M5 East. The Variation attracts nearly twice the number of commercial vehicles compared to the 1994 EIS Proposal.

Without the toll the Variation now taps into the major origins and destinations of commercial vehicles in the Port Botany and South Sydney Central Industrial Areas. Commercial vehicle forecasts for Princes Highway through Tempe and General Holmes Drive have increased significantly as these provide the connecting routes between the M5 East and the subject areas.

There are changes arising out of the Variation scheme for many of the reference roads. Those roads with significant changes are now discussed.

4.5.1 General Holmes Drive

As a result of the removal of the toll and providing additional lanes on General Holmes Drive and 'centre load' ramps from the M5, significantly higher traffic volumes are forecast. The project now focuses traffic onto the General Holmes Drive/Southern Cross Drive corridor. By 2011 this amounts to an additional 2,700 vehicles per hour (two way) compared to the previous EIS predictions.

4.5.2 Stoney Creek Road - Forest Road - Bestic Street/Bay Street Route

This route shows a slight increase in traffic compared to previous forecasts. This occurs because of the changed traffic calming assumptions for Stoney Creek Road. Notwithstanding, there would still be significant traffic reductions on this route resulting from the building of the M5 East compared to present traffic levels.

4.5.3 Bexley Road

Bexley Road forecast flows have reduced by about 25% in 2001 and can be attributed to M5 East attracting through traffic which is moving between Canterbury Road and Princes Highway. This traffic would divert to the M5 East via the King Georges Road interchange.

In the longer term the difference is negligible having regard to be build up of congestion in the road network

4.5.4 King Georges Road - North of M5

The M5 East in the Variation would be more efficient in attracting longer distant trips, particularly those moving between Port Botany/South Sydney Central Industrial Area and areas to the north-west along King Georges Road including those to and from Bankstown. This traffic would principally be drawn off Canterbury Road and routes through Marrickville local government area to and from Port Botany and South Sydney.

4.5.5 Vanessa Street/Moorefields Road

Moorefields Road has higher forecast traffic flows than the earlier EIS predictions for 2001. However, this is nearly completely offset by reductions in traffic on Vanessa Street, a nearby parallel route to the south.

This redistribution of traffic appears to arise out of the higher congestion levels forecast for the King Georges Road/M5 interchange. Traffic destined for or originating from the north along King Georges Road would now utilise Moorefields Road rather than proceeding through the busy M5 interchange to access Vanessa Street.

However by 2011 this redistribution has evened itself out.

4.5.6 Canterbury Road

As detailed above, M5 East would be more efficient in attracting long distance trips from the surrounding road system particularly in relation to Canterbury Road from Lakemba through to Lewisham. Forecast volumes in the morning period are now more than 2,000 vehicles per hour less than previously predicted for 2001 and 2011.

4.5.7 King Street and Sydenham Road Newtown

Traffic reductions on these streets in the Variation are a direct result of the reduction predicted for Canterbury Road. Traffic would no longer filter across Marrickville municipality between Canterbury Road/Parramatta Road and Princes Highway to the extent previously predicted.

4.5.8 Railway Parade, Tempe

Traffic increases predicted for Railway Parade arise out of the changed traffic patterns discussed above. With more traffic predicted to use M5 East in preference to Canterbury Road, access into Marrickville municipality is achieved from the south from Princes Highway via Railway Parade and Bayview Street.

4.5.9 O'Riordan Street, Mascot

Significant reductions of traffic are predicted for O'Riordan Street compared to that previously indicated in the 1994 EIS. This results from the provision of four lanes in each direction on General Holmes Drive between the M5 ramps and Foreshore Road and from the centre load ramp arrangement at the M5 interchange. Improved traffic flow conditions would attract more traffic travelling to or from the Port Botany area.

More east-west traffic is now predicted to move south of the airport to the M5 rather than to the north of the airport via O'Riordan Street to then filter through Marrickville municipality to Canterbury Road.

4.6 Summary

This section examined the broad implications of the Variation scheme compared to the Do Minimal and with some qualified comparisons made to the 1994 EIS Proposal. The salient points to arise out of this examination include:

- The 'Do Minimal' option shows traffic continuing to grow across the road network with strong growth on Qantas Drive, Forest Road, Stoney Creek Road, Moorefields Road and Sydenham Road.
- The Variation is a relatively efficient scheme with forecast 'on opening' volumes approaching the capacity of the motorway and wide spread reductions of traffic resulting on the rest of the road network. A major proportion of the traffic on the motorway continues on to General Holmes Drive rather than exiting at Princes Highway.
- Traffic is attracted away from Canterbury Road, thus reducing traffic filtering through streets in Marrickville local government area.
- Future growth in traffic will require the upgrading of Princes Highway through Tempe and may be Qantas Drive. M5 East will not produce sufficient traffic relief to avoid this need.
- Bexley Road initially will experience good reduction in traffic flow with the Variation but will return to current levels by 2011.
- The commercial vehicle patterns forecast for the Variation scheme vary significantly from those forecast for the 1994 EIS proposal. The M5 will attract a greater proportion of commercial vehicles to use the full length of the Motorway, commencing from General Holmes Drive.
- In general, intersection performance will improve considerably over the Do Minimal option. Improvements can be expected along Forest Road and Stoney Creek Road as well as along the Princes Highway through Rockdale.
- Travel time savings over the road network for the Variation will exceed 3.5% compared to the Do Minimal option.
- It is estimated that upon opening of the M5 East, at least six serious accidents per week would be avoided on the road network, while by 2011, approximately 388 serious accidents would be avoided per year. This equates to $16 million per annum savings to the community.
- In general terms, the Variation produces greater benefits compared to the 1994 EIS proposal. This results from a combination of factors, the most significant being the 'no toll' arrangements.

5. Summary and Conclusions

This working paper has examined the traffic and transport implications of a Variation of the preferred option for the M5 East Motorway project, building upon the traffic assessment work undertaken for the preparation of the 1994 EIS.

The Variation scheme is a refinement of the 1994 EIS Proposal, with the four most significant changes in terms of traffic being:

- inclusion of toll collection facilities on the two new east facing ramps at the Fairford Road interchange
- deletion of the toll plaza between King Georges Road and Bexley Road providing toll free travel east of King Georges Road
- a decrease in the length of the route between Bexley Road interchange and Princes Highway. This is a result of a straighter tunnel alignment between these two locations
- grade separation of the Marsh Street intersection whereby the motorway will pass under Marsh Street. On and off ramps from Marsh Street will be provided in both travel directions.

The traffic model was updated to take into account information that was not available when the 1994 EIS was prepared. The following aspects were considered in updating the model.

- The configuration of the M5 West has changed. Changes include opening of the Casula link, and the addition of ramps at Heathcote Road and Henry Lawson Drive
- Tolls on the M5 West have increased to $2.50 and as from January 1997 a 'Cashback Scheme' will operate
- Traffic on the road network has generally grown in the ensuring years since 1993 when the model was prepared.

The Variation scheme has been compared to the Do Minimal scenario with some comparison made to the 1994 EIS Proposal. The Variation is a relatively efficient scheme with forecast 'on opening' volumes approaching the capacity of the motorway and wide spread reductions of traffic resulting on the rest of the road network. A major proportion of the traffic on the motorway continues on to General Holmes Drive rather than exiting at Princes Highway. Reductions in the amount of traffic filtering through streets in Marrickville local government area are forecast.

The commercial vehicle patterns forecast for the Variation scheme vary significantly from those forecast for the 1994 EIS proposal. The M5 will attract a greater proportion of commercial vehicles to use the full length of the Motorway, commencing from General Holmes Drive. This results in significant reductions in commercial vehicular traffic through Rockdale and Bexley.

There would also be improvements in intersection performance over the Do Minimal scheme and reduced delays can be expected along Forest Road and Stoney Creek Road as well as along the Princes Highway through Rockdale. Overall travel time savings are in the order of 3.7% in 2011.

Significant reductions in traffic accidents are forecast to result from M5 East under the Variation scheme. By 2011 these could represent $16 million savings to the community.

Overall, the Variation Scheme produces greater benefits compared to the 1994 EIS proposal. This results from a combination of factors, the most significant being the 'no toll' arrangements.

Figure 1a - M5 East Motorway on Opening in 2001
Comparison of Forecast Flows on Selected Roads - AM Peak Hour

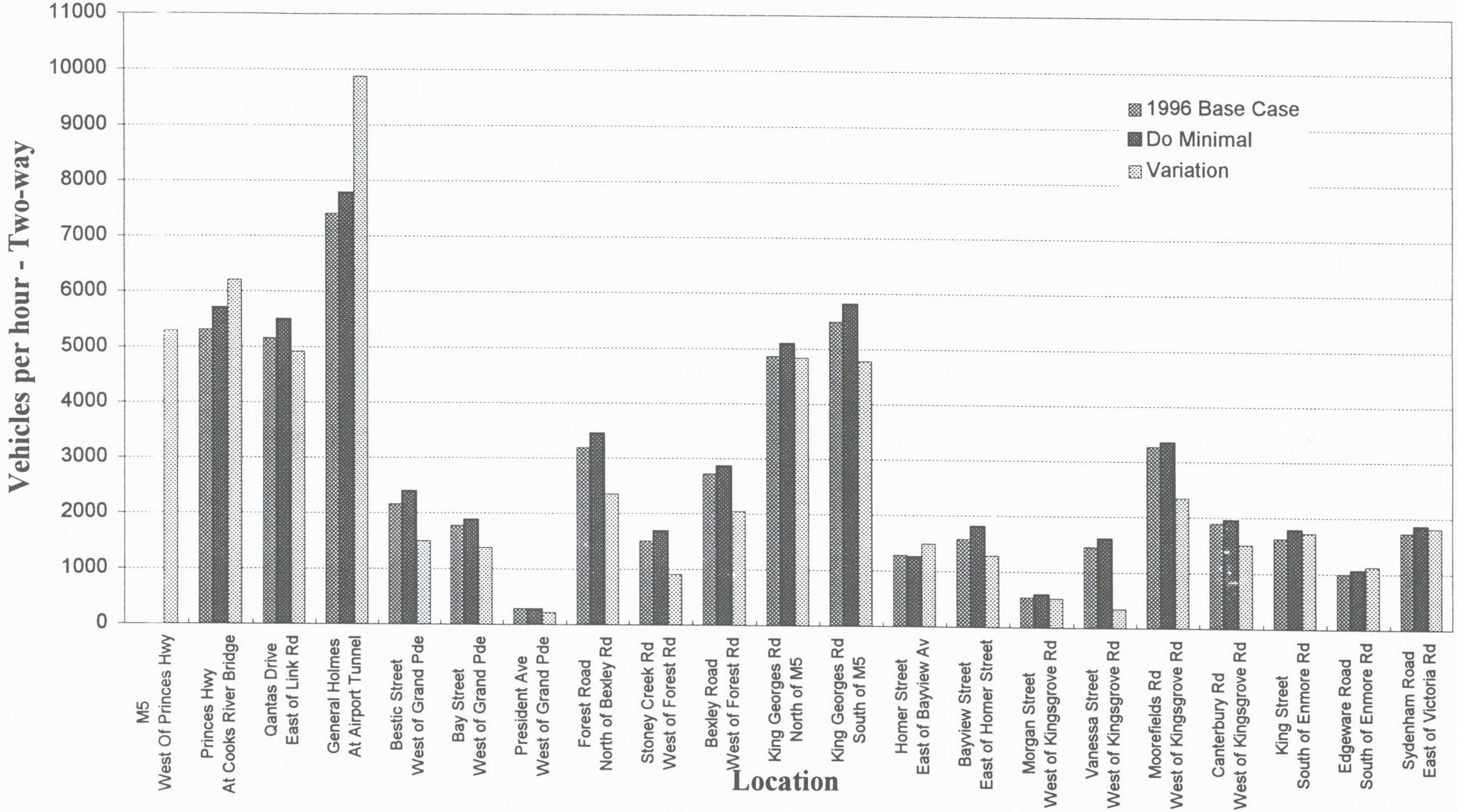


Figure 1b - M5 East Motorway on Opening in 2001
Comparison of Forecast Flows on Selected Roads - AM Peak Hour

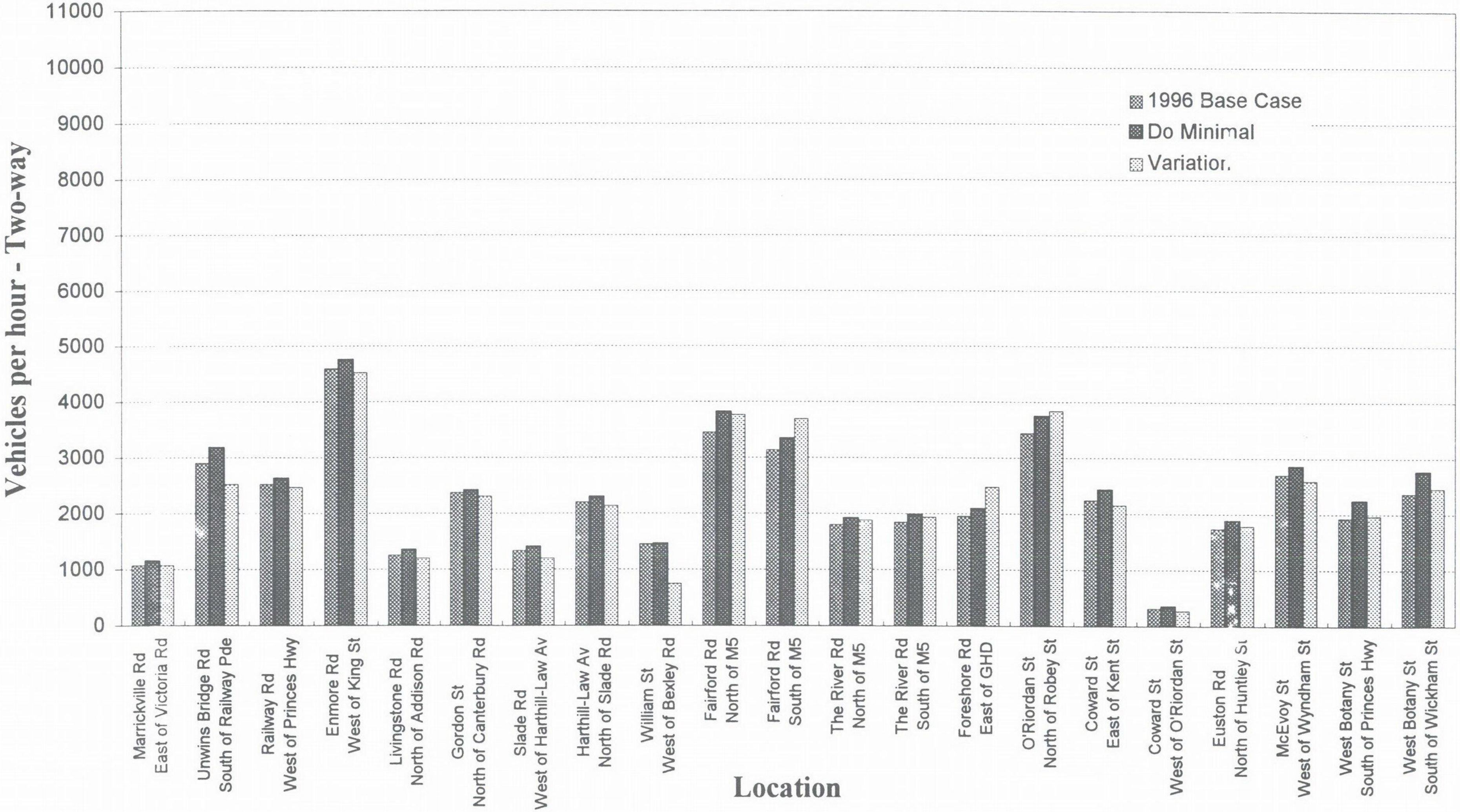


Figure 2a - M5 East Motorway in 2011
Comparison of Forecast Flows on Selected Roads - AM Peak Hour

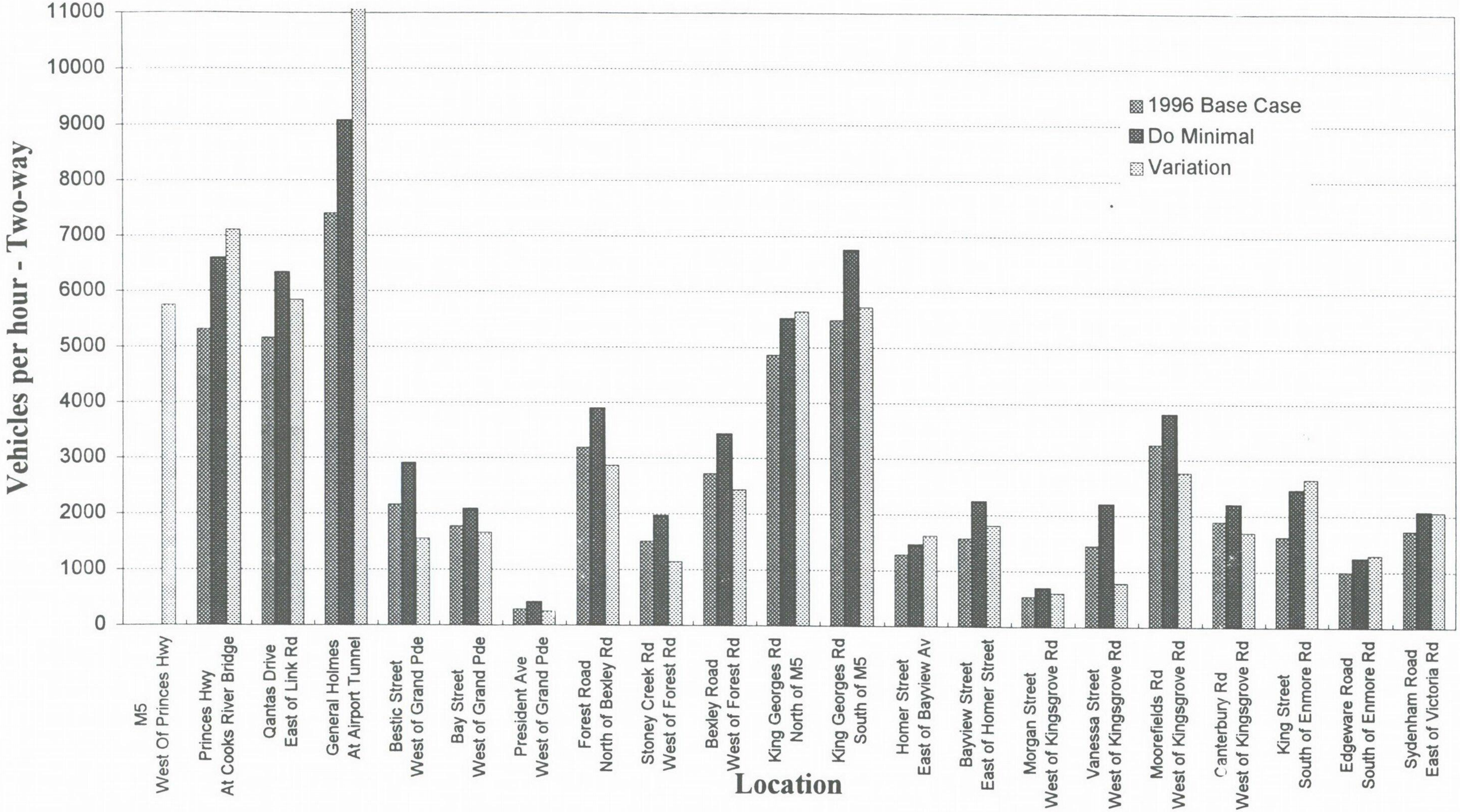


Figure 2b - M5 East Motorway in 2011
Comparison of Forecast Flows on Selected Roads - AM Peak Hour

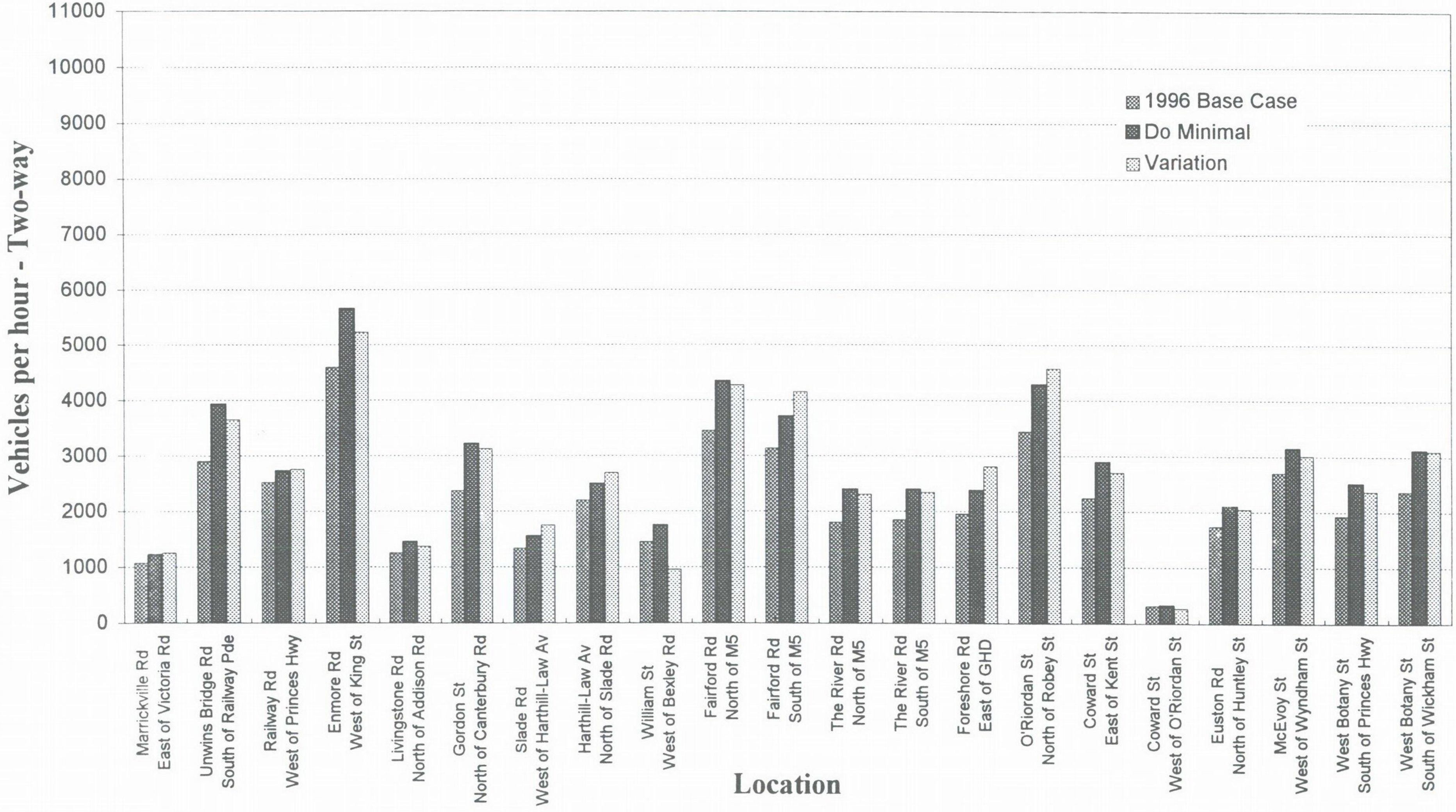


Figure 3a - M5 East Motorway - 2001
Comparison Between 1994 EIS Proposal and 1996 Variation

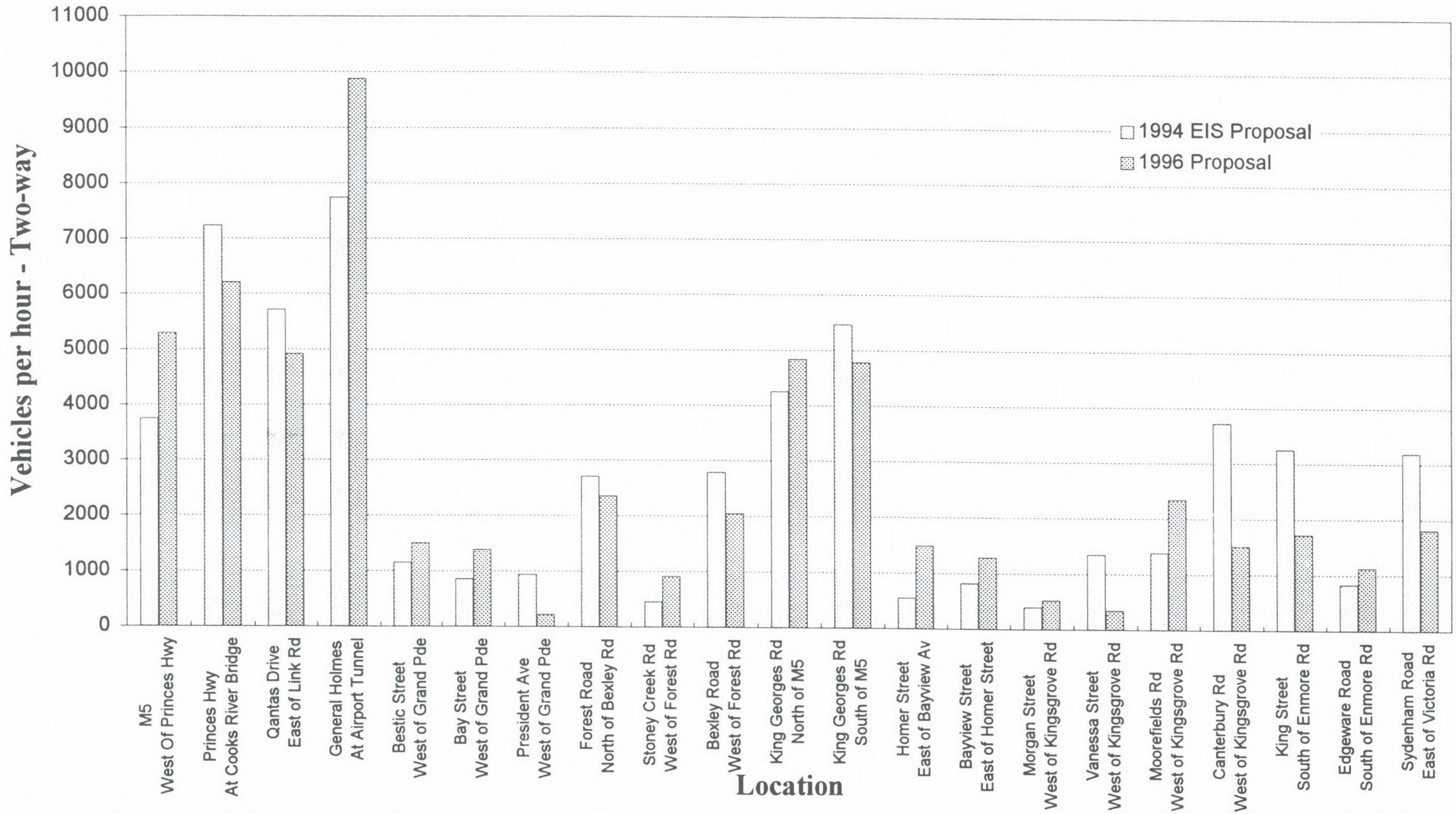


Figure 3b - M5 East Motorway - 2001
Comparison Between 1994 EIS Proposal and 1996 Variation

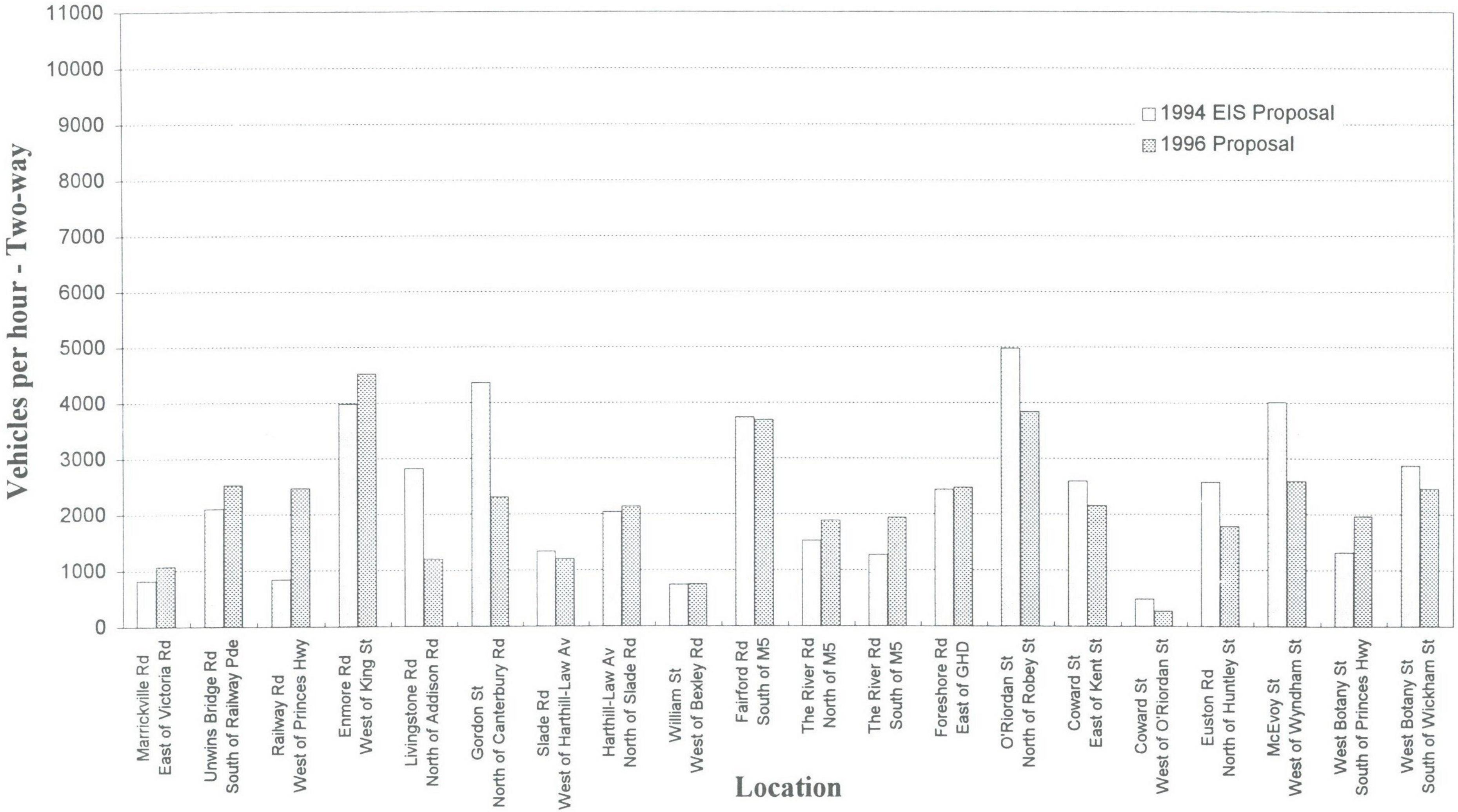


Figure 4a - M5 East Motorway - 2011
Comparison Between 1994 EIS Proposal and 1996 Variation

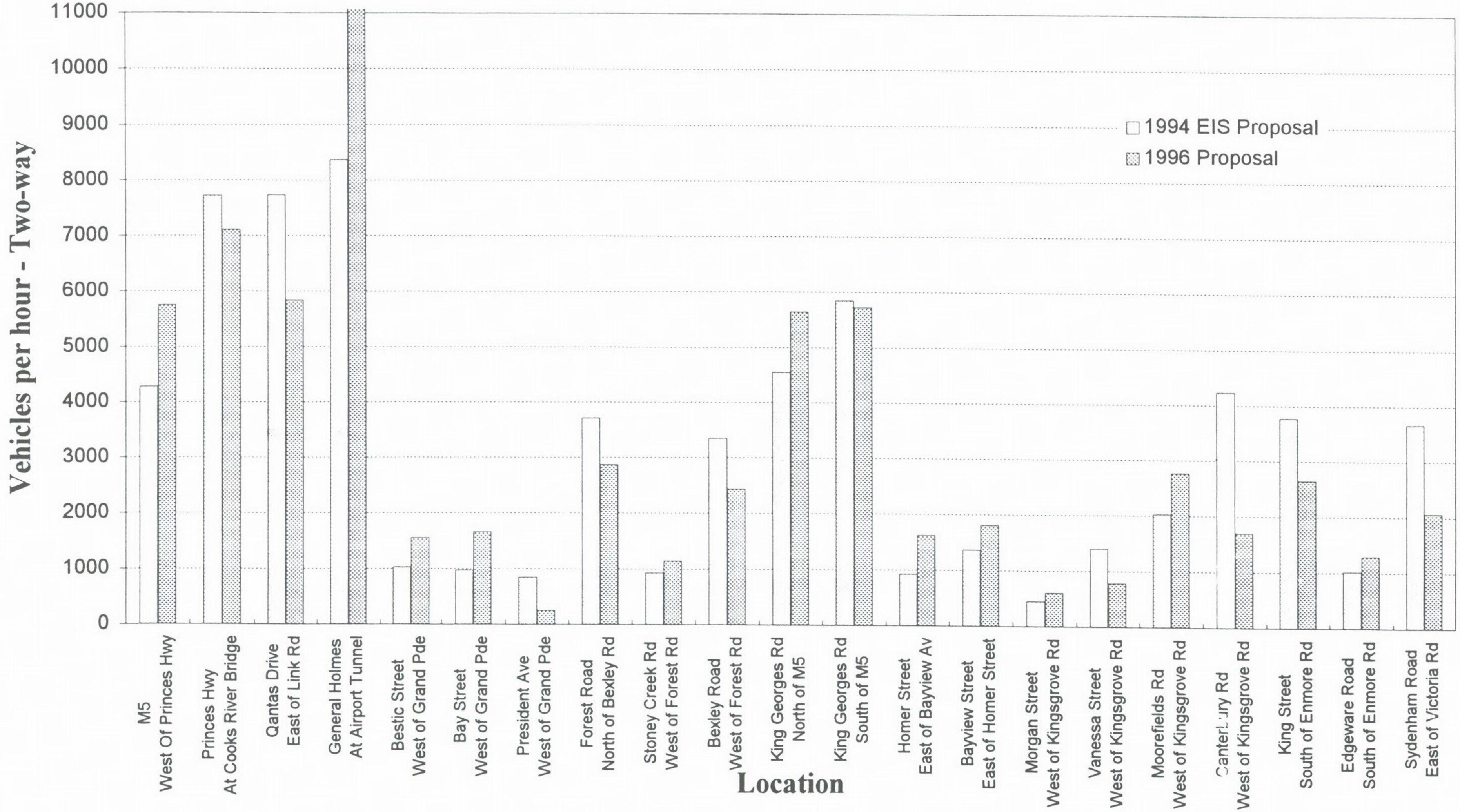
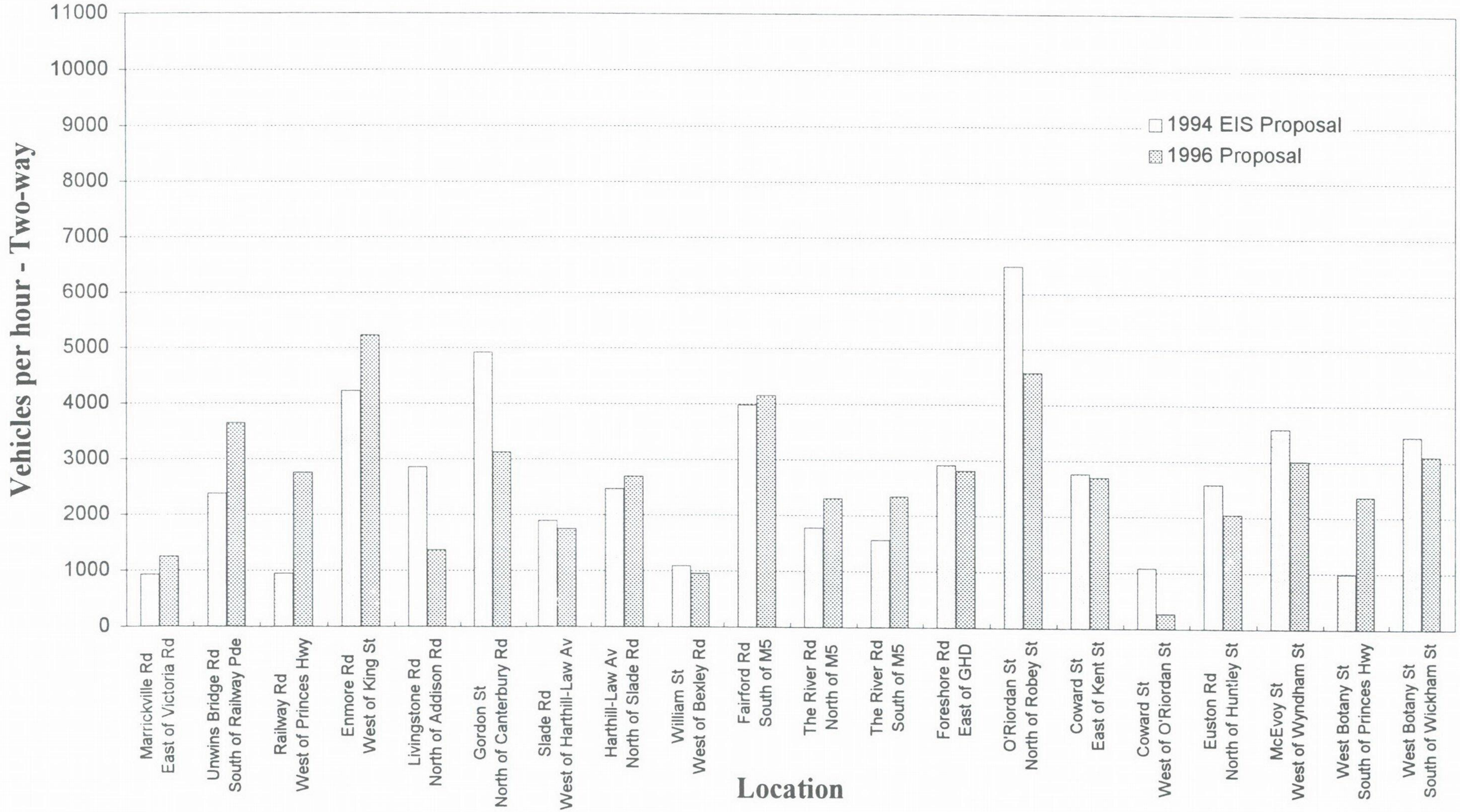


Figure 4b - M5 East Motorway - 2011
Comparison Between 1994 EIS Proposal and 1996 Variation



Appendix A - Model Outputs

Computer Plots of the M5 East Corridor Road Network

Morning Peak Hours for the years 1996, 2001 and 2011

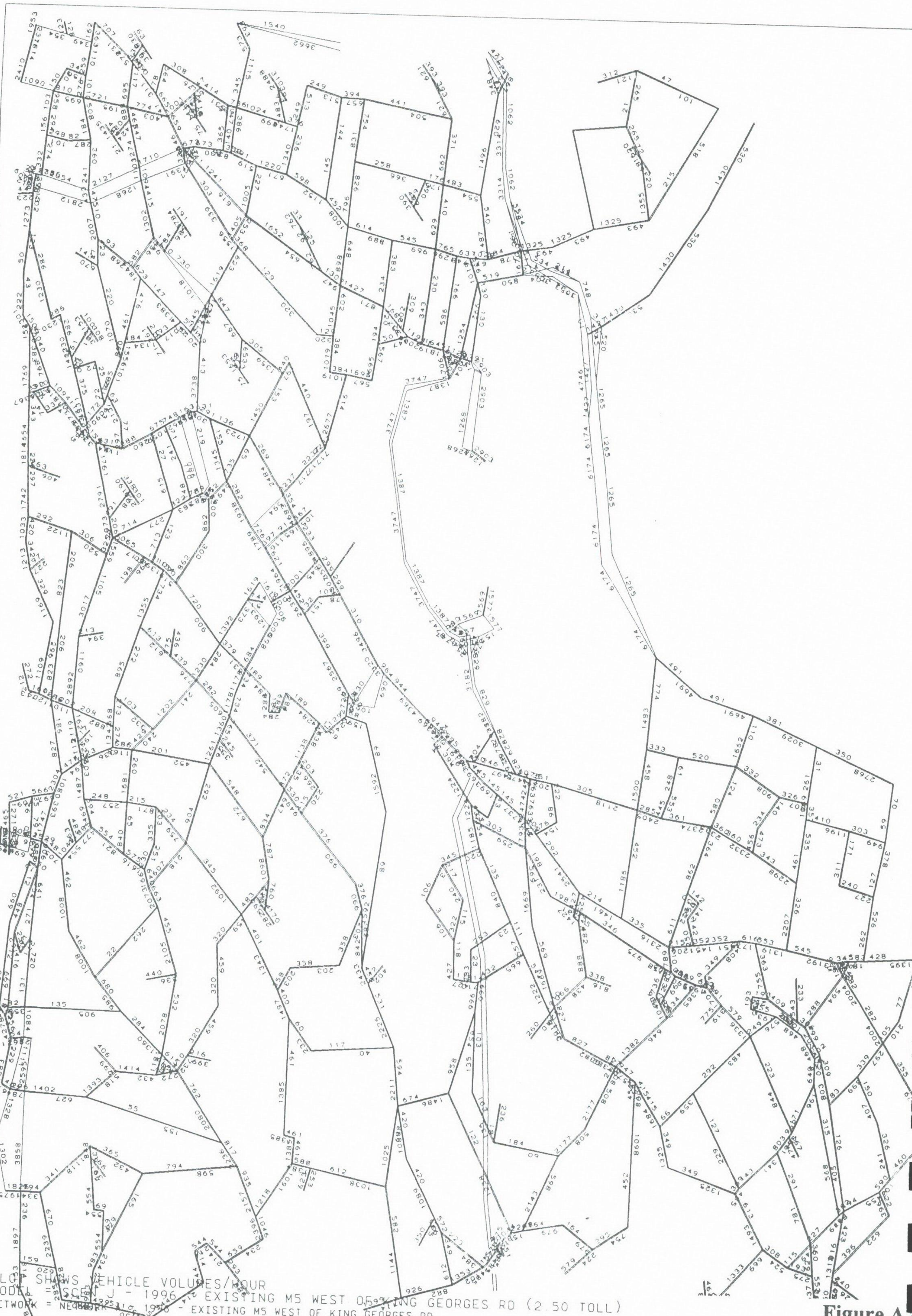
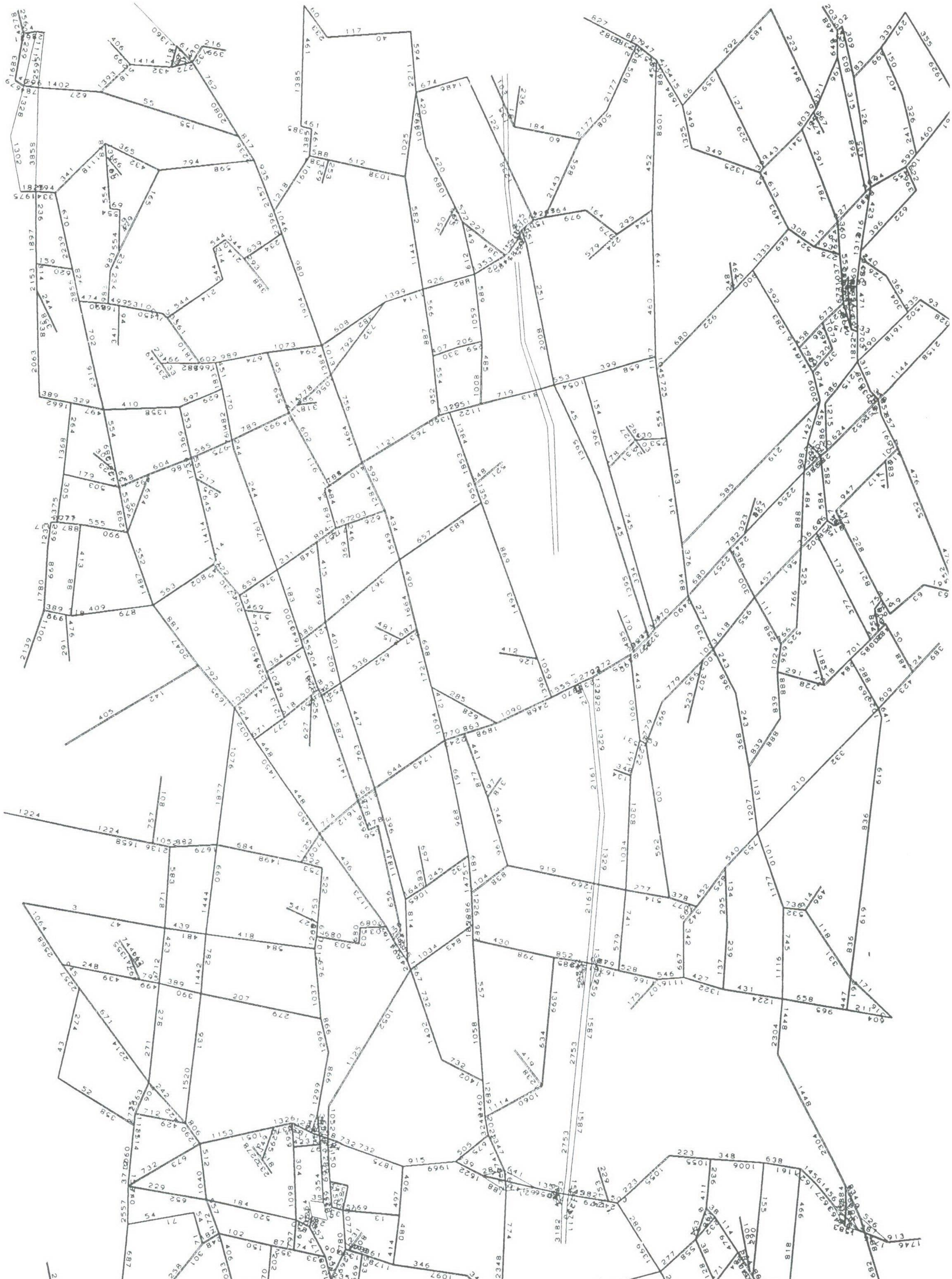


Figure A
1996 Existin
AM Peak Hour East Sect



PLOT SHOWS VEHICLE VOLUMES/HOUR
MODEL = SCEN J - 1996 - EXISTING M5 WEST OF KING GEORGES RD (2.50 TOLL)
NETWORK = NETWORK A - 1996 - EXISTING M5 WEST OF KING GEORGES RD

Model Run Date = 19/ 8/96 5:23p Model = M596J250 Co-ordinates Benefit was requested.
X Scale Factor = 1. Y Scale Factor = 1. Plot File = M596J250.XEV Network = M596J OLD = M595

Figure A1.2
1996 Existing
AM Peak Hour West Section

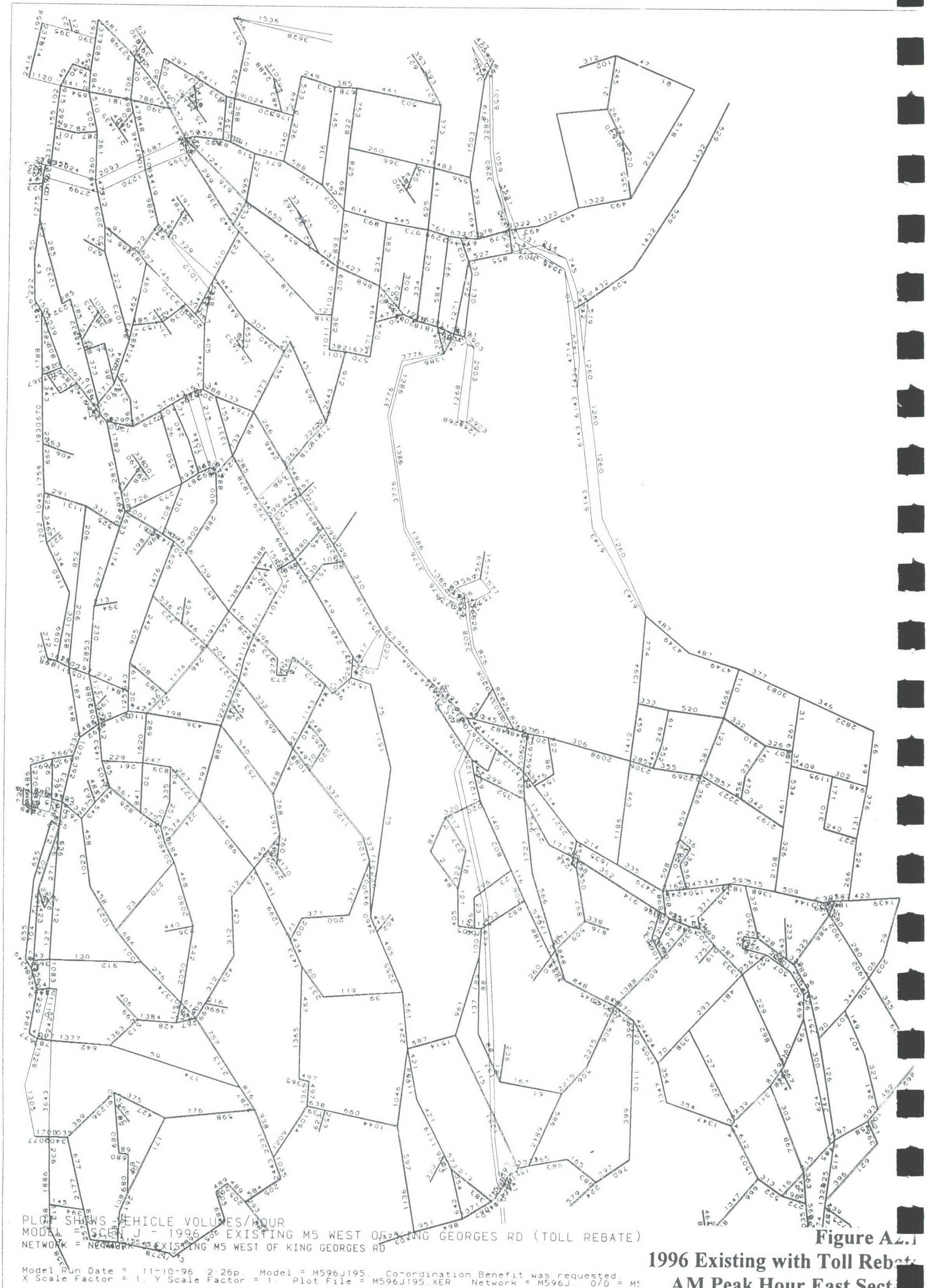


Figure A2.1
1996 Existing with Toll Rebate
AM Peak Hour East Section

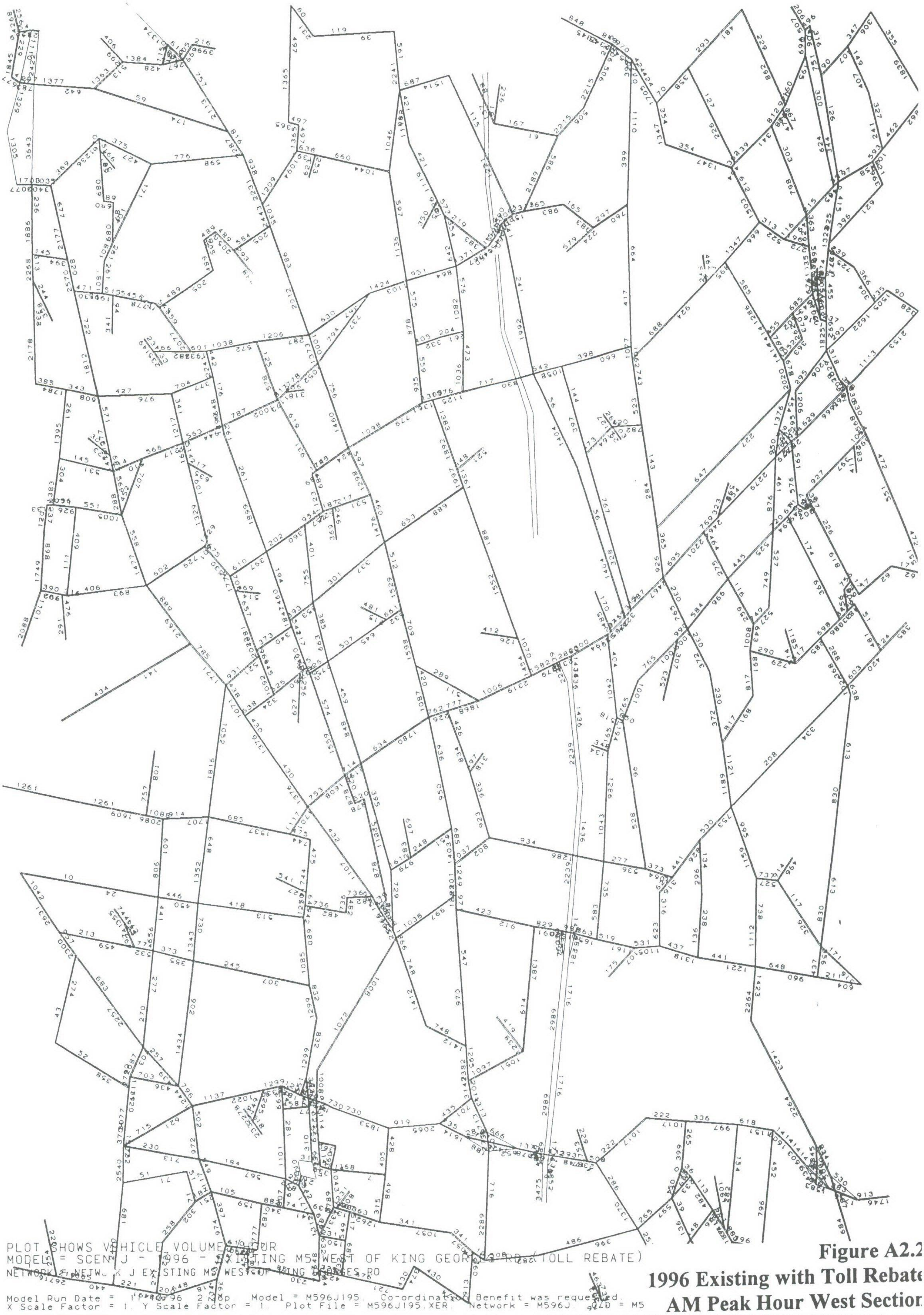
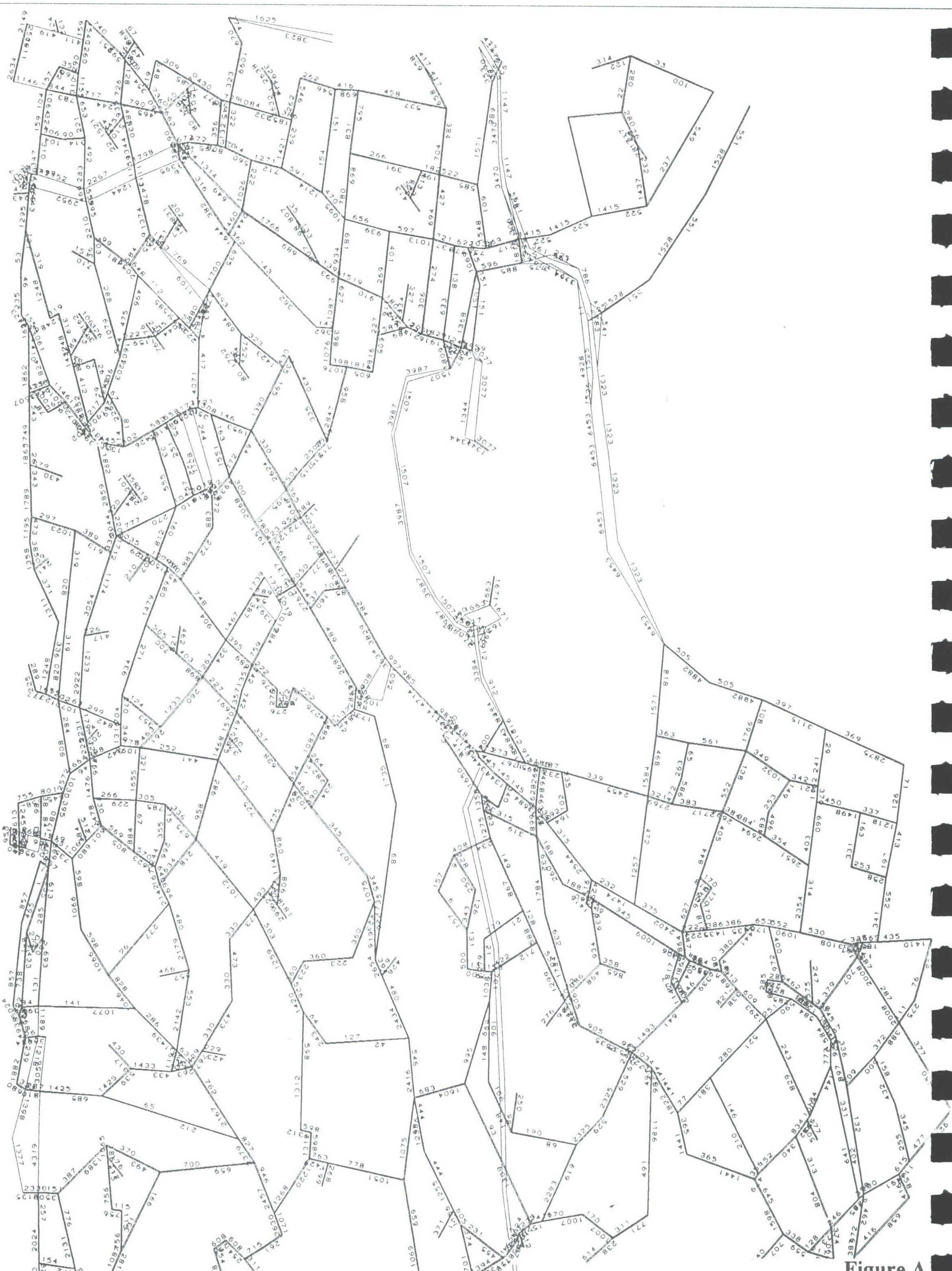


Figure A2.2
1996 Existing with Toll Rebate
AM Peak Hour West Section



PLOT SHOWS VEHICLE VOLUMES/HOUR
MODEL = SCEN J - 2001 MEDIUM - EXISTING M5 WEST OF KING GEORGES RD (TOLL REB/
NETWORK = NETWORK EXISTING M5 WEST OF KING GEORGES RD

Model Run Date = 11-11-96 7:03p Model = M501J195 Co-ordination Benefit was requested.
X Scale Factor = 1. Y Scale Factor = 1 Plot File = M501J195.XEV Network = M596J O/D = M501AM

Figure A
2001 "Do Minimal"
Medium Demand Scena
AM Peak Hour East Sectio

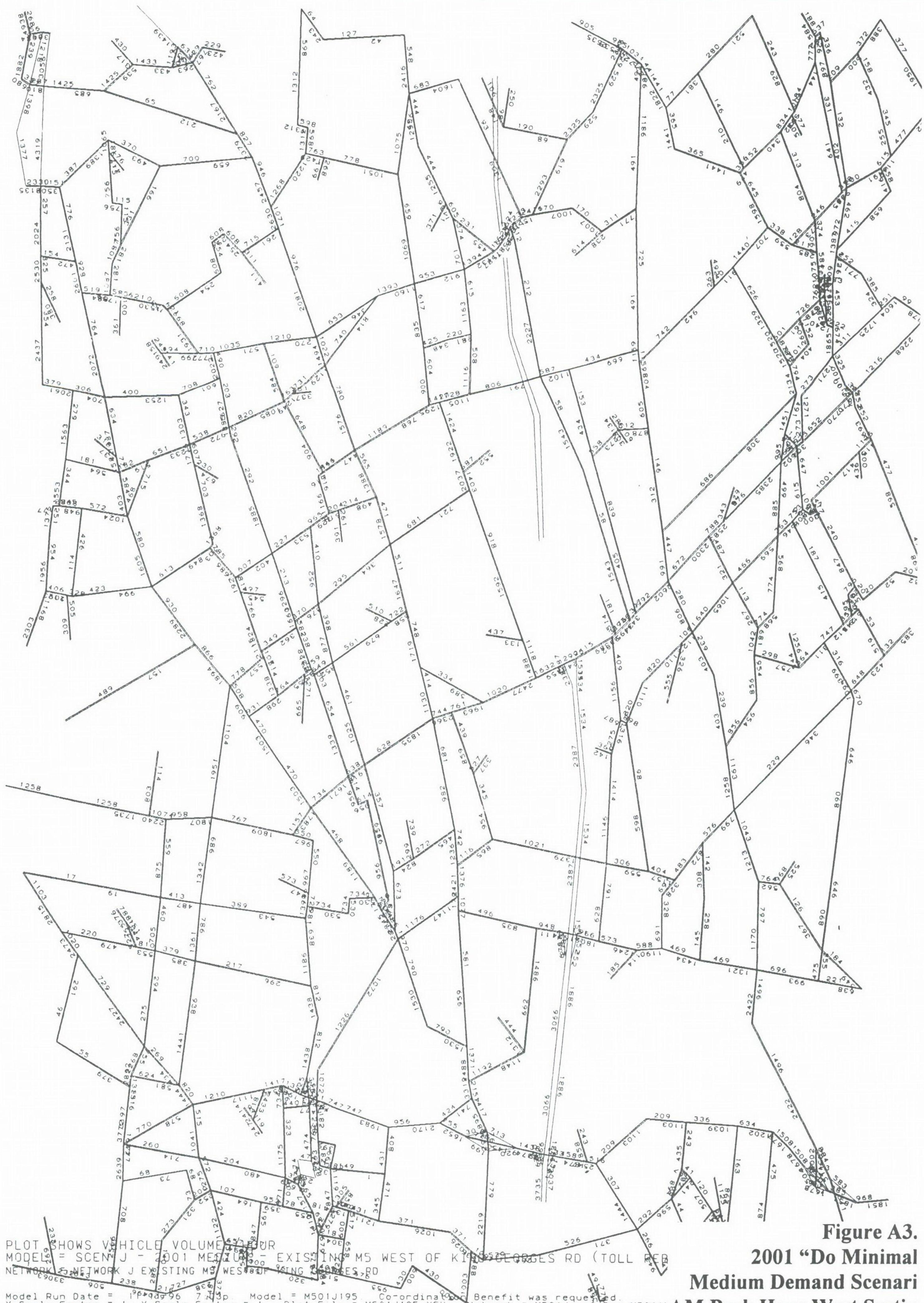
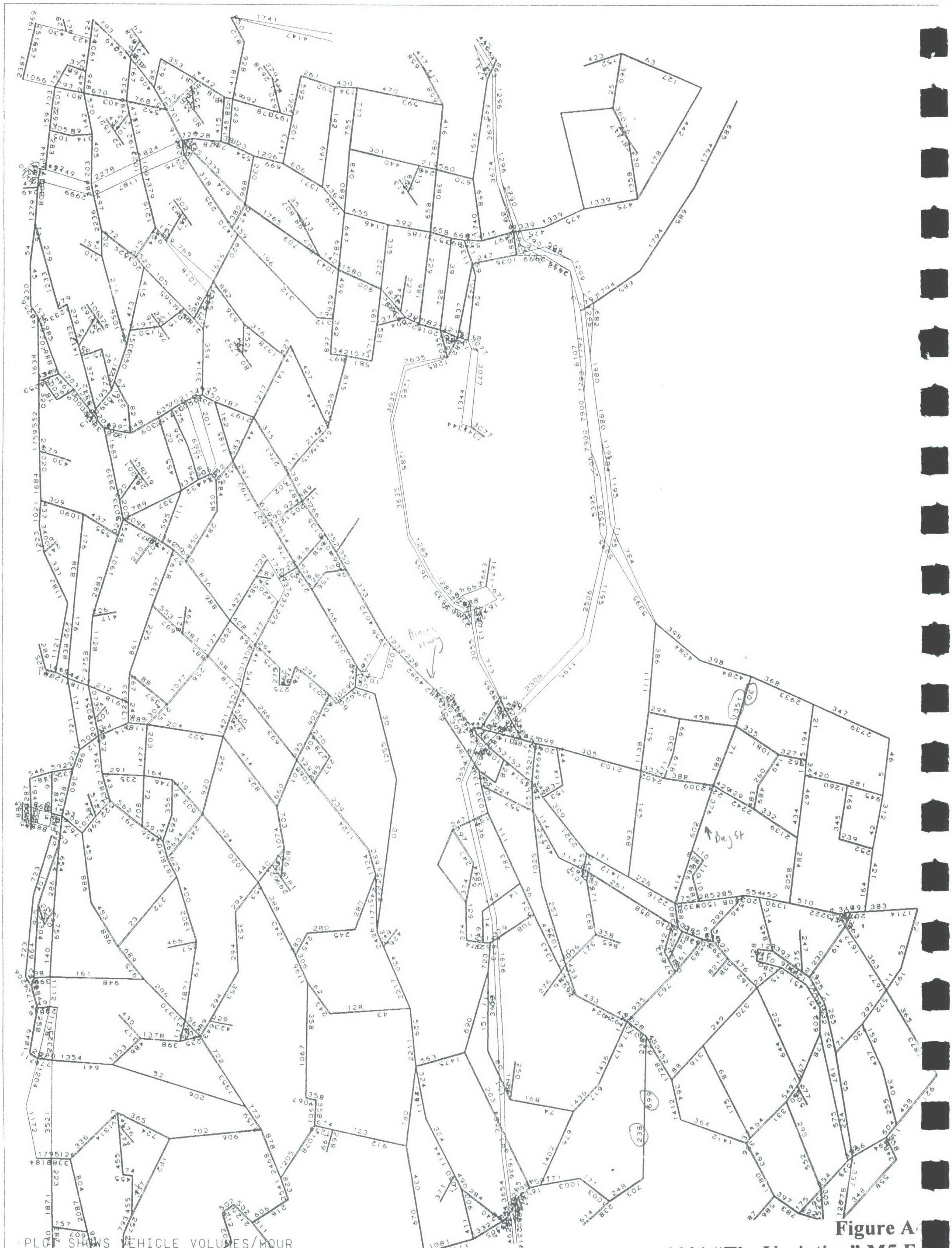


Figure A3.
2001 "Do Minimal
Medium Demand Scenari
AM Peak Hour West Sectio



PLOT SHOWS VEHICLE VOLUMES/HOUR
MODEL = SCEN L - 2001 MEDIUM - M5 EAST WITH NO TOLLS
NETWORK = NETWORK & M5 EAST AND WEST

Model Run Date = 11-11-96 6:19p Model = M501LM00 Co-ordination Benefit was requested
X Scale Factor = 1. Y Scale Factor = 1. Plot File = M501LM00.XEV Network = M596L O/D = M50

Figure A
2001 "The Variation" M5 East
Medium Demand Scena
AM Peak Hour East Sect

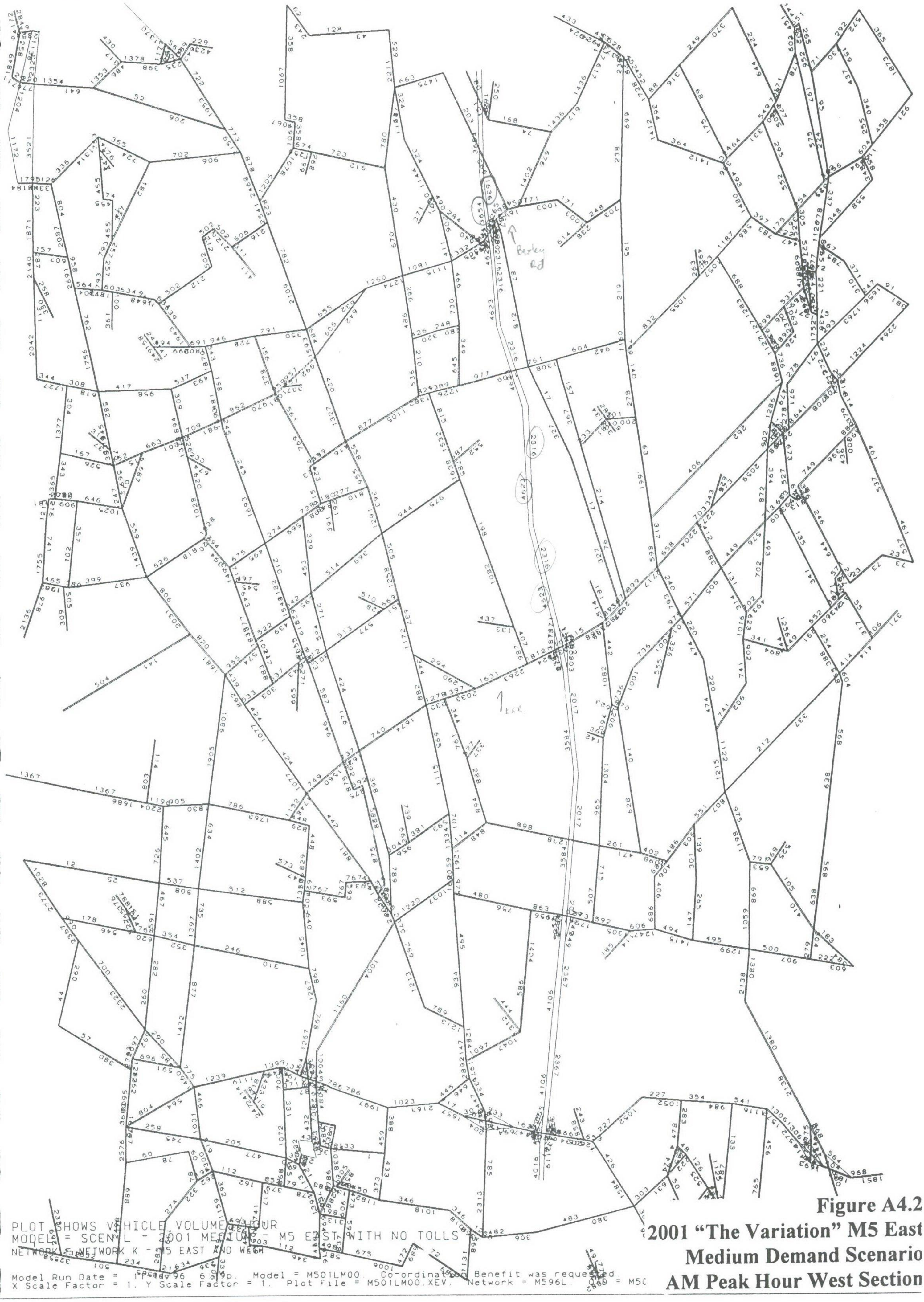


Figure A4.2
2001 "The Variation" M5 East
Medium Demand Scenario
AM Peak Hour West Section

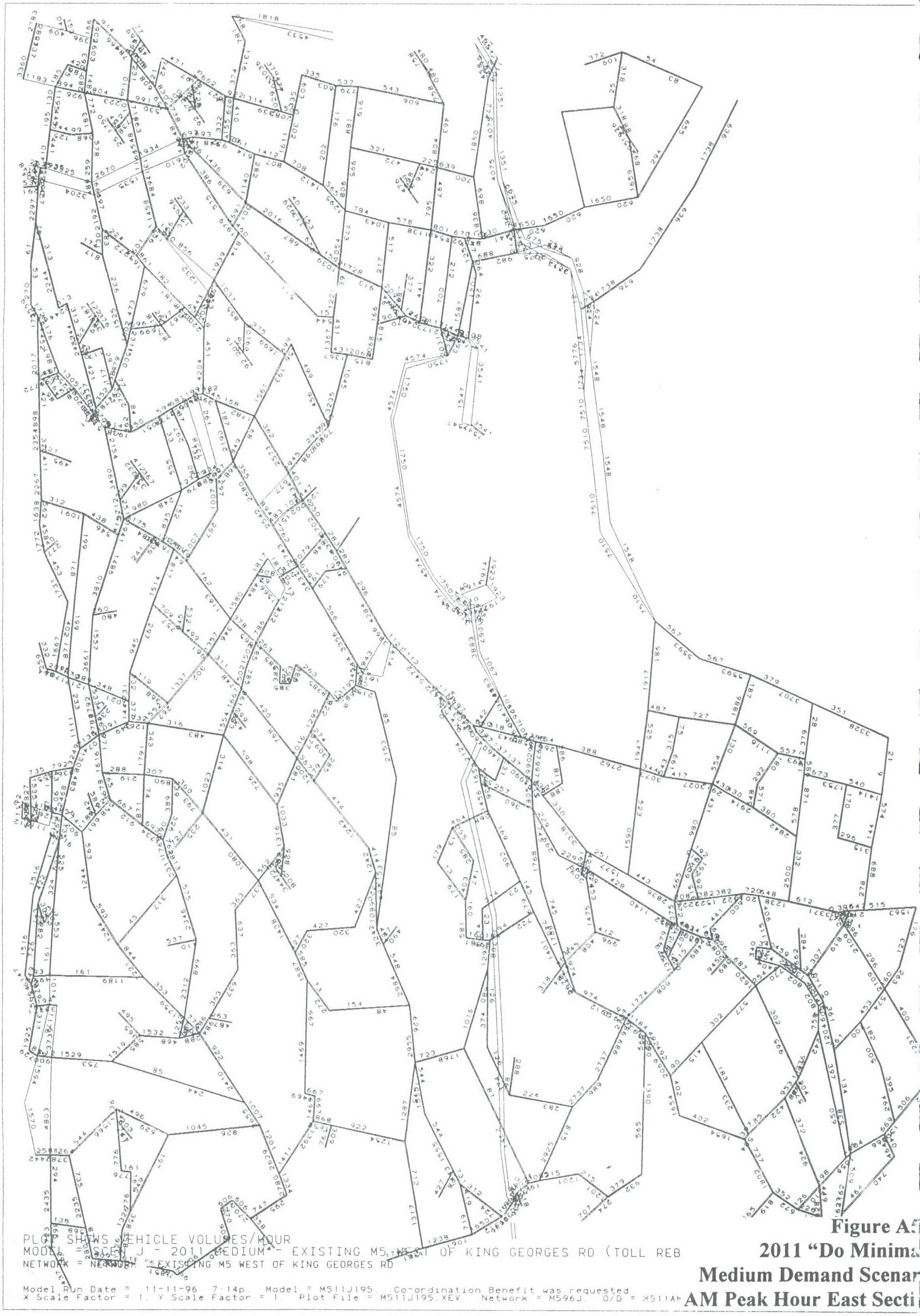


Figure A5
2011 "Do Minimal"
Medium Demand Scenario
AM Peak Hour East Secti

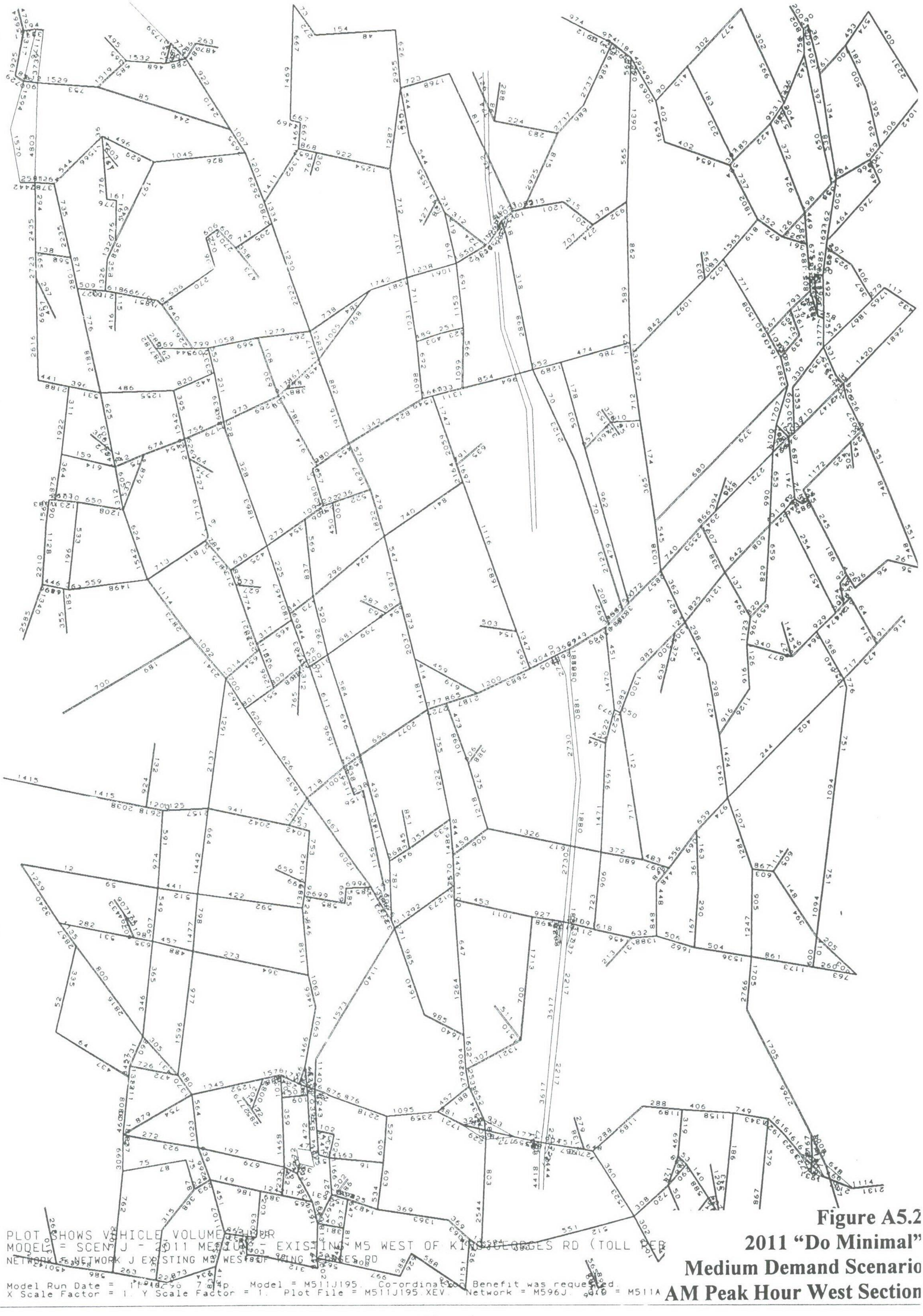


Figure A5.2
2011 "Do Minimal"
Medium Demand Scenario
AM Peak Hour West Section

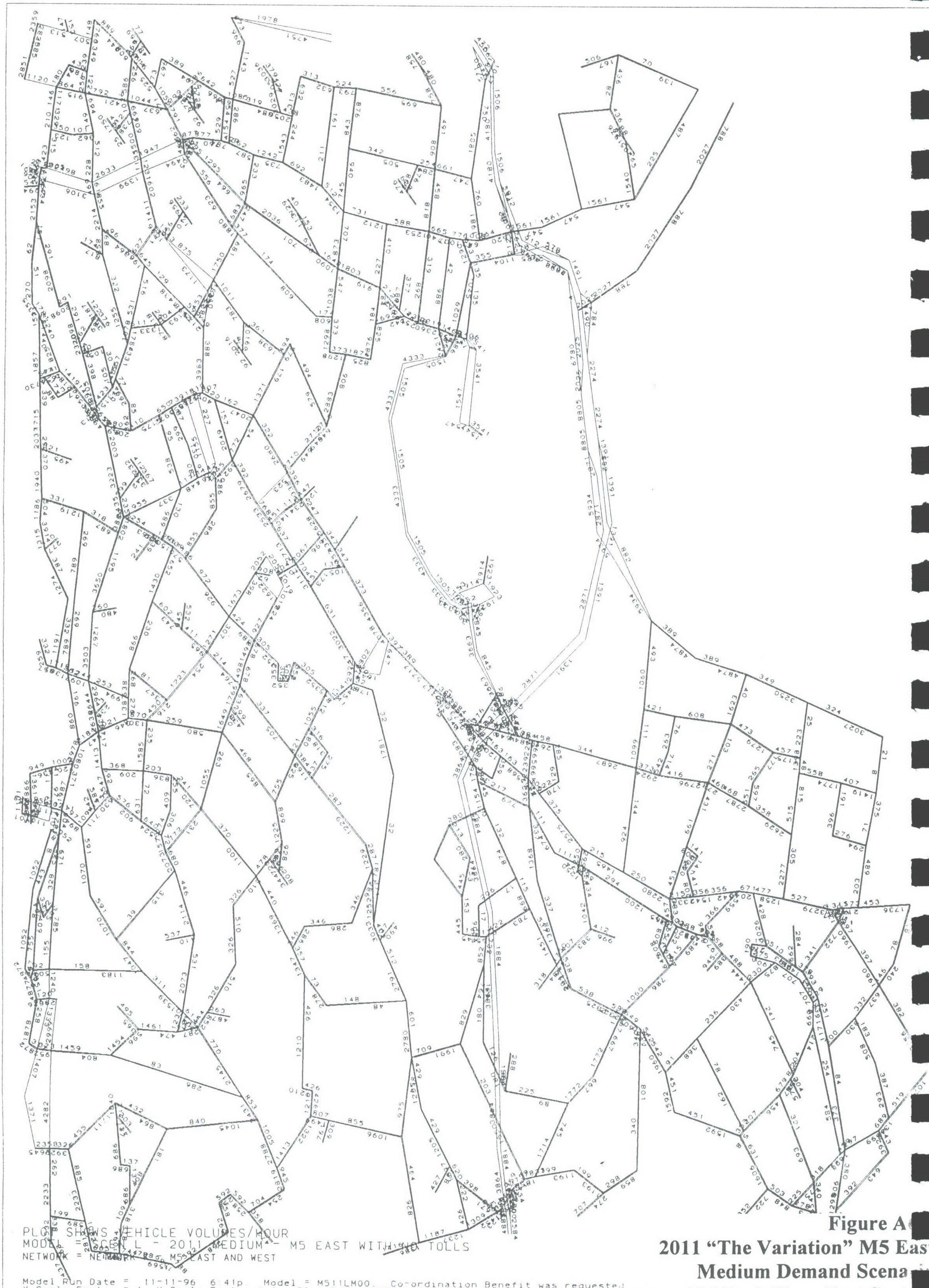


Figure A
2011 "The Variation" M5 Eas
Medium Demand Scena
AM Peak Hour East Sect

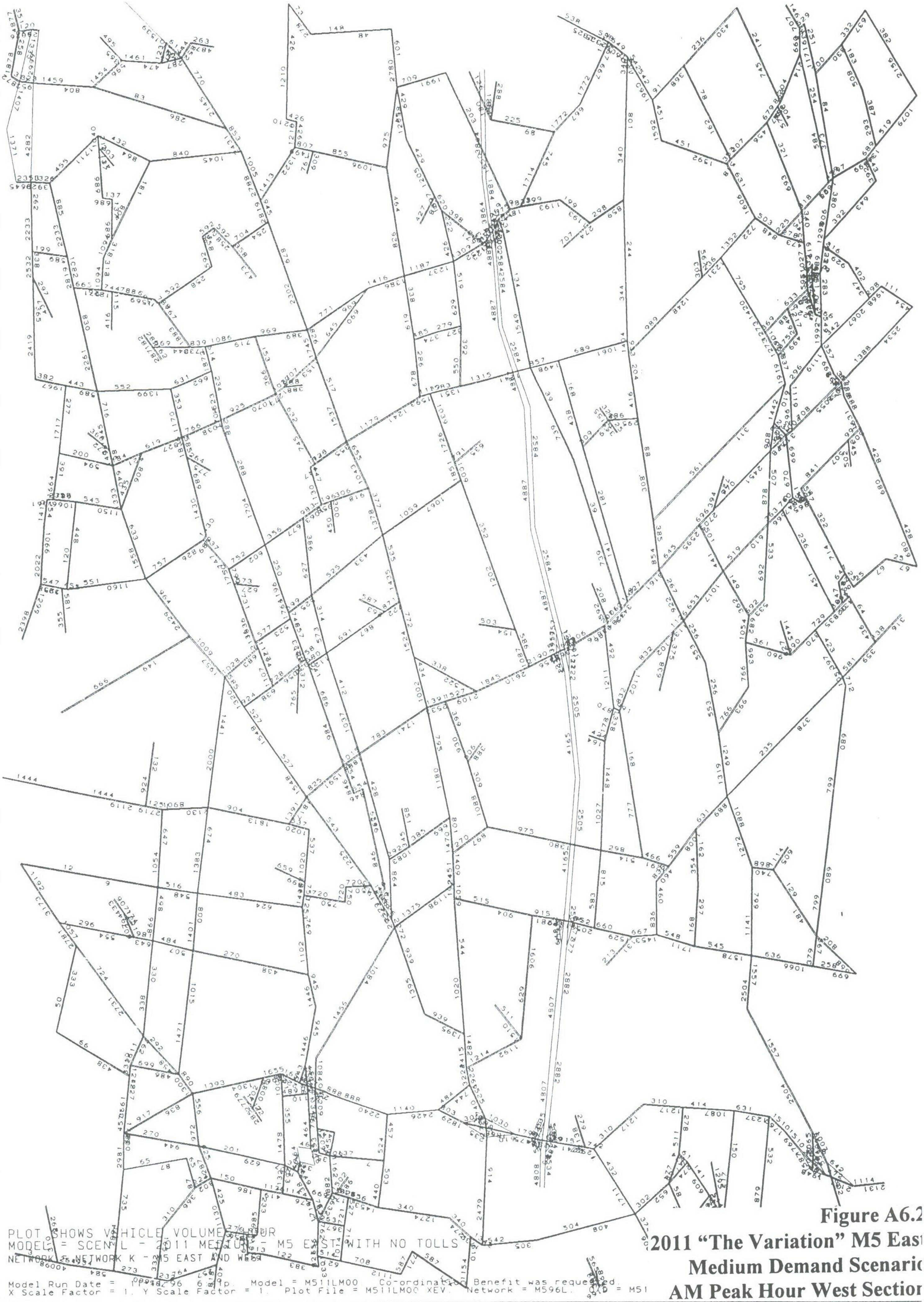


Figure A6.2
2011 "The Variation" M5 East
Medium Demand Scenario
AM Peak Hour West Section

M5 EAST MOTORWAY - ASSESSMENT OF VARIATION OF ROUTE BETWEEN BEXLEY ROAD AND COOKS RIVER

FLORA AND FAUNA - SUPPLEMENTARY WORKING PAPER

by

MOUNT KING ECOLOGICAL SURVEYS

"Oorong"
Bathurst Road
OBERON, NSW, 2787

Phone/fax: 063-362244

4 December, 1995

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CONTENTS:

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by MOUNT KING ECOLOGICAL SURVEYS

1.0 GENERAL BACKGROUND

Following consideration of public submissions to the EIS for the construction of the M5 East Motorway, the RTA is considering a more direct tunnel alignment between Bexley Road and Cooks River. At present (November, 1995), there are two alternatives considered for such an alignment (Northern Variation and Southern Variation), both in tunnel from Bexley Road to Marsh Street. As a consequence of this variation of the route, there will be a need to construct additional exhaust vents and additional air intake vents. Twenty-three alternative sites for these vents have been assessed, and three sites for each exhaust vent stack and air intake vents have been recommended for each alignment.

This report describes the flora and fauna known and expected at each site, assesses the likely impacts, recommends mitigation measures and assesses the need for a Fauna Impact Statement (7-point test) in response to the changes in route alignment.

2.0 METHODS

Alternative sites were inspected by Roger Lembit and Dr Martin Denny during August and November, 1995, and an assessment undertaken of the flora and fauna values of each site. As the area had already been surveyed and described as part of the original studies for the EIS, it was possible to use the information to supplement that obtained during the present site visit. In addition, any additional information which had been produced since the EIS was incorporated into this report.

3.0 DESCRIPTION OF THE EXHAUST VENT STACK AND AIR INTAKE VENT SITES

The sites for the exhaust vent stacks and air intake vents are considered as two groups - those associated with the Northern Alignment and those associated with the Southern Alignment. Table 1 describes these sites.

TABLE 1: SITES FOR EXHAUST STACKS AND AIR VENTS

NORTHERN ALIGNMENT

Exhaust Stacks at:

4 Top of Girrahween Park, Earlwood
8 Henderson Street, Turrella
16 Arncliffe army depot, Arncliffe Street

Air Intakes at:

i4 Next to Hartill-Law Avenue (Girrahween Park)
i5 East of Heath Street, Turrella
i7 Arncliffe army depot, Arncliffe Street

SOUTHERN ALIGNMENT

Exhaust Stacks at:

6 Royal Place
9 Corner Duff Street and Hill Street, Arncliffe
16 Arncliffe army depot, Arncliffe Street

Air Intakes at:

i1 Bardwell Golf Course, near Royal Place
i6 Corner Duff Street and Gipps Street, Arncliffe
i7 Arncliffe army depot, Arncliffe Street

3.1 Flora Value of Sites for Exhaust Stacks and Intake Vents

A. EXHAUST VENT STACKS

Northern Route

4 Top of Girrahween Park, Earlwood

This site is located within a car parking area associated with playing fields and other recreation areas. It comprises mowed grassland without any planted trees or shrubs.

8 Henderson Street, Turrella

This site is located between Henderson Street and East Hills Railway and comprises mown grass with a single *Acacia* tree nearby.

16 Arncliffe army depot, Arncliffe Street

This site is within the army depot and mainly consists of mowed grassland with a line of planted trees (e.g. coral tree, flooded gum, rusty fig) around the fenced edge of the site.

Southern Route

6 Royal Place

The site of this stack appears to be within a group of houses and there is no undisturbed native bushland within this site

9 Corner Duff Street and Hill Street, Arncliffe

The site of this stack appears to be within a group of house and there is no undisturbed native bushland within this site

16 Arncliffe army depot, Arncliffe Street

This site is within the army depot and mainly consists of mowed grassland with a line of planted trees (e.g. coral tree, flooded gum, rusty fig) around the fenced edge of the site.

B. AIR INTAKE VENTS

Northern Route

i4 Next to Hartill-Law Avenue (Girrahween Park)

This site is within an area of mown grassland next to a car parking area (Fauna Street).

i5 East of Heath Street, Turrella

This site is next to the East Hills Railway Line and comprises a small unused plot of land supporting planted trees (e.g. jacaranda).

i7 Arncliffe army depot, Arncliffe Street

This site is within the army depot and mainly consists of mowed grassland with a line of planted trees (e.g. coral tree, flooded gum, rusty fig) around the fenced edge of the site.

Southern Route

i1 Bardwell Golf Course, near Royal Place

This site is located within the golf course[1] which comprises mowed grassland. However, the site is very close to an area of ridgeline vegetation associated with Bardwell Valley and classed by Clouston (1993)[2] as "bushland, virtually free of exotic plants" and recommended as a bushland area worthy of conservation in their management plan.

i6 Corner Duff Street and Hill Street, Arncliffe

Although the exhaust stack appears to be located within a group of houses, the air intake vent appears to be located within a small area of native vegetation comprising several rainforest and sandstone species. Although weeds are present in this area, the site could possibly be classed urban bushland. There is a need for further investigation of this site, if the vent is to be located within the bushland.

i7 Arncliffe army depot, Arncliffe Street

This site is within the army depot and mainly consists of mowed grassland with a line of planted trees (e.g. coral tree, flooded gum, rusty fig) around the fenced edge of the site.

3.2 Wildlife Habitat Value of the Exhaust Stack and Air Vent Sites

A. EXHAUST VENT STACKS

Northern Route

4 Top of Girrahween Park, Earlwood

This mown grassland site has a low habitat value.

8 Henderson Street, Turrella

This mown grassland site has a low habitat value.

16 Arncliffe army depot, Arncliffe Street

The scatter of trees around the edge of this site may have limited habitat value to birds using the blossoms for food. The mown grassland has a low habitat value.

[1] Fax from Manidis Roberts Pty Ltd, dated 15 November, 1995, describes this site as "on the low ground in the golf course"

[2] "Bardwell Valley Draft Management Plan" prepared for Rockdale Municipal Council by Clouston in association with Willing and Partners and Ian Perkins.

Southern Route

6 Royal Place

The site of this stack appears to be within a group of houses and has low habitat value.

9 Corner Duff Street and Hill Street, Arncliffe

The site of this stack appears to be within a group of houses and has low habitat value.

16 Arncliffe army depot, Arncliffe Street

The scatter of trees around the edge of this site may have limited habitat value to birds using the blossoms for food. The mown grassland has a low habitat value

B. AIR INTAKE VENTS

Northern Route

i4 Next to Hartill-Law Avenue (Girrahween Park)

This site is within an area of mown grassland with low habitat value.

i5 East of Heath Street, Turrella

This site comprises a small unused plot of land supporting planted trees which have a limited value as a food source when flowering.

i7 Arncliffe army depot, Arncliffe Street

The scatter of trees around the edge of this site may have limited habitat value to birds using the blossoms for food. The mown grassland has a low habitat value.

Southern Route

i1 Bardwell Golf Course, near Royal Place

The location of this site needs to be very carefully assessed. Within the mowed grassland of the golf course, the vent may indirectly affect the surrounding ridgeline bushland (considered of conservation importance in the Bardwell Valley Plan of Management) by generating noise and vibration, thus disturbing native fauna nearby. Also, care would need to taken during construction to ensure there is no disturbance of the bushland close by.

i6 Corner Duff Street and Hill Street, Arncliffe

The location of the air vent appears to be within a small area of bushland which can be considered of moderate to high habitat value, particularly as the site is located within a sandstone ridge. The presence of an air vent at this site could affect the movement patterns of fauna along this ridgeline, as well as resulting in the loss of a habitat having a restricted distribution in south-western Sydney. Noise and vibration possibly generated from the air vent could also disturb native fauna in the adjoining bushland.

i7 Arncliffe army depot, Arncliffe Street

The scatter of trees around the edge of this site may have limited habitat value to birds using the blossoms for food. The mown grassland has a low habitat value.

3.3 Recent Sightings of Avifauna in Wolli Creek Valley

Since the production of the M5 East EIS and the Fauna Impact Statement, there have been reports of sightings of several birds not recorded for many years in the area. These reports have been by Justin Cahill and have been published in the NSW Field Ornithologists Club Inc Newsletter. In December, 1993 (Issue 140) Cahill reported the presence of "the first local records of the Swift Parrot"[3] in Bardwell valley (in Coolabah Reserve). He also reported the presence of Red-rumped Parrots at North Barton Park and Yellow-tailed Black-cockatoos feeding of seed-cones of *Banksia serrata* and *Allocasuarina littoralis* at Nannygoat Hill and Girraween Park. In the April, 1994 issue of the Newsletter, Cahill reported the presence of the Mistletoebird at Girraween Park and a single Noisy Miner at Stotts Reserve (the Noisy Miner had not been recorded from the area since 1989). In the June, 1994, issue, the presence of the Masked Woodswallow was reported at Turrella Reserve. This is the first record of this bird from the area, and was not listed in the original EIS. Also recorded was the Grey Goshawk from Turrella Reserve. In October, 1994, the Yellow-tailed Black-cockatoos were again reported, as well as the Azure Kingfisher, Tree Martin, Mangrove Heron (all at Turrella Reserve) and the Little Grassbird at Muddy Creek.

These recent records reinforce the statement in the Flora and Fauna report that bird communities in residential areas are dynamic and their composition is constantly changing (p.22). None of the changes proposed for the route corridor of the M5 East will affect the status of the species mentioned above. Although an alternative site for an air vent was originally proposed for Coolabah Reserve, none of the flowering trees presumably used by the endangered Swift Parrot would have been affected.

4.0 ASSESSMENT OF THE EXHAUST STACK AND AIR VENT SITES

Although most of the exhaust stack and air vent sites can be considered of low botanical and fauna value, the air vent sites at Bardwell Valley golf course and at

[3] The Swift Parrot is listed as an Endangered Species in NSW

Duff Street are of concern. The site at the golf course is very close to an area bushland considered of conservation value and care will be needed to avoid disturbing the area during construction of the vent. In addition, the noise and vibration generated by this vent could disturb the native fauna using the bushland area. In their plan of management for Bardwell Valley, Clouston (1993) recommend that this area of bushland be expanded and consolidated with other bushland areas. The construction of an air vent at this site may restrict such plans.

The location of an air vent within the bushland along the ridgeline near Duff Street would result in the loss of native vegetation and wildlife habitat. This habitat type has a restricted distribution in the region and any loss can be considered significant. The actual amount of loss can not calculated until details of the exact location of the vent and the degree of construction activity associated with the vent are known. Also, the presence of a vent could result in the restriction of fauna movement along this ridgeline corridor. Again, the possible generation of noise and vibration could affect native fauna using the area.

5.0 ASSESSMENT OF NEW ROUTE CORRIDORS

The two route alignments locations take the roadway closer to the Marsh Street wetlands and close to Eve Street wetlands. The two wetland areas have values as remnants of the extensive mudflat, saltmarsh and mangrove flats which previously existed in the area (Benson and Howell, 1990[4]). Also, the habitat within Eve Street wetlands is limited in the Sydney region and several migratory bird species use the area. The Green and Golden Bell-frog is known to occur at the Marsh Street wetlands. The Marsh Street area supports a variety of exotic and native plants and provides a relatively dense vegetation cover for native fauna. Any loss of this cover from the area may affect the faunal biodiversity within a habitat having a restricted distribution in south-western Sydney.

According to the report by Osborne[5], the proposed new route and its construction activity will severely impact on the Eve Street and Marsh Street wetland areas. As both areas have State significance (presence of species endangered in NSW), and Eve Street wetland has international significance (presence of migratory waders listed in JAMBA and CAMBA), it is important that neither of the two areas be impacted by M5 East. If the proposed route change did occur, then there would be a need to produce a Fauna Impact Statement addressing those endangered species using the two wetlands.

It is the opinion of Mount King Ecological Surveys that further consideration needs to be given to the desirability of locating the road so close to this wetland.

---

[4] Benson, D. and J.Howell 1990 "Taken for Granted: The bushland of Sydney and its suburbs." Kangaroo Press and Royal Botanical Gardens, Sydney

[5] Osborne, P.L. 1995 "M5 Expressway - Wetland habitats Addendum to reports by P.Adcock and P.L. Osborne"

6.0 IS THERE ANY NEED FOR A SUPPLEMENT TO THE EXISTING FAUNA IMPACT STATEMENT?

The Fauna Impact Statement produced for the EIS in 1994 addressed the likely affects from the route alignment of the motorway, as described in the EIS. However, with the changes now proposed there may need to be a supplementary Fauna Impact Statement which addresses any changed conditions resulting from the new alignments. A supplement to the original Fauna Impact Statement will be required if:

(a) There are any species of fauna along the route which, since the 1994 EIS, have been declared to be endangered fauna; or

(b) The current proposed route alignments and construction of exhaust stacks and intake vents involve changes which will or may significantly affect the habitat of any of the five previously identified species of endangered fauna.

There have been no additions to the list of endangered fauna (Schedule 12 of the National Parks & Wildlife Act) since 1994, but some of the proposed changes to the route alignment may affect the habitat of one of the previously identified endangered species. This is the Green and Golden Bell-frog, which is known to occur in a small area in the Marsh Street wetlands. The new alignments of the motorway route could affect the habitat of this species at Marsh Street.

Guidelines for assessment of the significance of the likely effect upon the environment of endangered fauna have been set out in Section 4A of the amended EPA Act. By applying the "seven point test" it is possible to assess the need for a Fauna Impact Statement i.e. to assess whether the new proposal will significantly affect the habitats of any endangered species.

The following seven factors must be considered under Section 4A of the Act to decide whether there is likely to be a significant effect on the environment of endangered fauna:

a) The extent of modification or removal of habitat.

The total extent of modification or removal of habitat as a consequence of the construction of the exhaust stacks and intake vents will be small, but the exact amount of disturbance requires further details about the site location of the air vent at Bardwell Valley golf course and at Duff Street, as well as further information on the degree of disturbance during construction of these two vents. If any sandstone cliff-lines are to be affected e.g. at the Duff Street site, then the potential impact upon the endangered cliff-roosting bat, the Common Bentwing Bat, would need to be assessed.

There appears to be some loss of habitat used by the endangered Green and Golden Bell-frog at the Marsh Street wetland. This frog utilizes a small pond near the sewerage pipe and this area will be affected by the new alignment of the motorway. Although the extent of habitat will be small (in the order of a hundred square metres), the construction of the motorway could result in the total loss of the habitat used by this endangered species in the Marsh Street area. Either of the proposed variations may indirectly affect the habitat in the Eve Street wetlands.

b) The sensitivity of the species of fauna to removal or modification of its habitat.

All the species of endangered fauna known from the general area (Osprey, Swift Parrot, Common Bentwing Bat, Green and Golden Bell-frog, Red-crowned Toadlet, Little Tern) are sensitive to removal or modification of habitat. The habitat to be modified by the construction of the vents and the construction site is not considered to be critical to any endangered species, but the habitat of the Green and Golden Bell-frog at Marsh Street is likely to be affected.

c) The time required to regenerate critical habitat i.e. the whole or any part of the habitat which is essential for the survival of that species.

As no critical habitat will be lost as a consequence of the stacks and vents, regeneration time is not relevant. Any ground cover lost will regenerate rapidly, possibly within 1 to 2 years, whilst rehabilitated middle to upper strata vegetation will take from 10 to more than 100 years to mature. Regeneration of Green and Golden Bell-frog habitat is possible within a shorter time span, possibly within several years.

d) The effect on the ability of the fauna population to recover, including interactions between the subject land and adjacent habitat that may influence the population beyond the area proposed for development or activities.

There is the potential for the Common Bentwing Bat to be affected by the construction and operation of two of the air intake vents, but further details on vent site location and construction methods are required before a complete assessment can be undertaken. It would appear that the Green and Golden Bell-frog will be affected by the re-alignment of the route. Provided an alternative area of preferred habitat is available, it is possible for this species to recover. The Green and Golden Bell-frog is known to occupy man-made habitat and appears to be able to utilize areas specifically constructed for this species. However, there is limited knowledge of the long-term use of sites specifically constructed for this frog and any such amelioration measure must regarded as a having an element of risk.

e) Any proposal to ameliorate the impact.

Plantings of selected local native vegetation will be part of the rehabilitation strategy proposed for the M5 East development. It may be possible to develop an alternative area of preferred habitat for the Green and Golden Bell-frog e.g. within Eve Street wetlands. A plan of management for the Green and Golden Bell-frog will be developed.

f) Whether the land is currently being assessed for wilderness by the N.P.W.S.,

No.

g) Any adverse effect on the survival of that species of endangered fauna or of populations of that fauna.

The construction and operation of the exhaust vent stacks should not have any significant effect upon any endangered species. However the construction and operation of two of the air intake vents could have an impact upon the habitat of the Common Bentwing Bat. However, there is insufficient information available about the exact location of the air vent sites and the degree of disturbance of any habitat as a consequence of their construction. The location of the motorway close to Marsh Street wetland may affect the habitat of the Green and Golden Bell-frog and result in an adverse effect on the survival of this endangered species. The construction of the motorway on an embankment near Eve Street wetland could possibly present a barrier to birds, such as the endangered Little Tern. However, use of screening along the motorway would advertise its presence to birds.

Taking all these points into consideration, it is concluded that there is a need for a supplementary Fauna Impact Statement i.e. the proposal will significantly affect the habitat of an endangered species.

The supplement to the Fauna Impact Statement is provided as Appendix 1 to this report.

Dr Martin Denny BSc (Hons) PhD MEIA
4 December, 1995

APPENDIX 1: M5 East - Supplement to Fauna Impact Statement

1.0 INTRODUCTION

As a consequence of the suggested re-alignment of the route of the M5 East, it has been assessed that part of the new route alignment will pass through an area of wetland near Marsh Street. There is evidence that the endangered Green and Golden Bell-frog (*Litoria aurea*) exists in this area (about 14 individuals are known from the site, A.White, *pers.comm.*) and it is possible that the construction of M5 East Motorway could significantly affect the habitat of this species. Consequently, it was decided that there was a need for a supplement to the original Fauna Impact Statement published in 1994. This supplement addresses in greater detail those aspects of the biology of the Green and Golden Bell-frog which are relevant to any assessment of impacts from the proposed M5 East Motorway.

This supplement should be read in conjunction with the original Fauna Impact Statement, Environmental Impact Statement and Supplementary EIS.

2.0 PROFILE OF THE GREEN AND GOLDEN BELL-FROG

1. Species Name: Green and Golden Bell-frog Litoria aurea

2. Distribution:

Australia: South-eastern Australia
NSW: Coast and Tablelands. "The main known centres of population for remianing Green and Golden Bell Frogs in New South Wales are near large urban areas (such as Sydney, Nowra and Wollongong)." (White, 1995)
Sydney: Scattered records throughout Sydney (Australian Museum, 1993; White, 1995), including the following sites: proposed Olympic Games site at Homebush, Kingsford Smith Airport, Eastlakes, Australian Paper Manufacturers factory site at Matraville, Caltex Oil Refinery, Kurnell, Rosebery, Greenacre and in the Tempe-Arncliffe area.

3. Population Status:

Range: Common [Tyler, 1992] but declining (Australian Museum, 1993)
NSW: Not known, but considered to be declining. White (1995) states "There has been a virtual elimination of Green and Golden Bell Frogs from highland areas". Osborne (1990) regrads this species as locally extinct in the southern highlands and the ACT.

4. Conservation Status: Listed in Part 1 [Threatened] of interim Schedule 12 on the basis of "population and distribution reduced to a critical level; concentrates; threatening processes severe" (NP&WS 1992). Considered secure by Tyler (1992).

5. Habitat Preferences: A report by The Australian Museum describes the habitat of this species as follows: "It occupies and breeds in permanent bodies of still water, typically those with high sediment loads and well-developed edge vegetation of native grasses and sedges, and with aquatic vegetation of grasses, lilies, sedges and rushes. Most productive sites are in open native grassland or forest edges, with high solar exposure. However the species also occupies artificial sites with similar water quality and exposure characteristics, such as farm dams or large garden ponds with either native or non-native vegetation." (The Australian Museum, 1993).

Such a description covers a wide range of natural and man-made habitats, and this range of habitats is emphasised in the following description of preferences of this frog by CSIRO Division of Wildlife and Ecology (1994):

"This information suggests that *L.aurea* requires recently formed water supplies to successfully breed, and in fact individuals have been recorded travelling large distances to locate these ponds, passing other unsuitable ponds in the process. Thus the large numbers *L. aurea* recorded 10+ years ago, relative to recent numbers, could be explained in terms of an effect of the construction of numerous new farm dams on soldier settlement blocks in south-eastern Australia after the second World War. In combination with the very extensive flooding that occurred eastern Australia in the 1950s, these probably provided a sudden and extensive supply of new breeding sites. The adult frogs are long-lived, and after the initial successful recruitment, would continue to live in the substantial growth of reed beds as these became established in farm dams (Mahony, South Australian Museum, Adelaide, personal communication)".

This frog occupies and breeds in permanent bodies of still water, both natural and artificial. These bodies of water are typically those with high sediment loads and well-developed edge vegetation of native grasses and sedges, and with aquatic vegetation of grasses, lilies, sedges and rushes.

Recent surveys (Frog and Tadpole Study Group Inc in White, 1995) have shown that : all currently known sites are coastal or near coastal; the majority of sites are on sandy soil; the majority of sites are temporary in nature and are less than 20 years old; many of the sites are highly disturbed and have major habitat alterations; the water bodies are mostly ephemeral and may lack a well developed emergent plant cover; the sites lack fish and are generally free of chemical pollutants.

6. Expected Impacts from Development: The loss of a relatively restricted area of preferred habitat near the sewerage pipeline at Marsh Street could result in the loss of this small population from the Sydney region. Because of the declining status of this frog and the increasing dependence upon restricted areas of largely artificial habitat, such a loss can be considered significant. However, there is the opportunity to create similar preferred habitat for the frogs within other, more protected lands near to their present habitat. Such potential sites would include Eve Street wetlands and other wetlands in the North Barton Park area. At present, the long-term success of relocating Green and Golden Bell-frogs has not been fully assessed and there is an element of risk in such a measure.

There is the potential for run-off from the motorway during construction and operation to pollute both the Marsh Street and Eve Street wetlands. Such pollution and increased sedimentation could affect existing conditions and reduce the value of these wetlands as waterbird and amphibian habitat. The use of appropriate amelioration measures would reduce such effects.

7. Amelioration Measures: It would be possible to develop sites of preferred habitat on land close to the present frog site, and to transfer the animals to such sites. Such a process is currently being undertaken at the Homebush Olympic site and the knowledge obtained from this exercise could be utilized at Marsh Street. At present, the long-term success of relocating Green and Golden Bell-frogs has not been fully assessed and there is an element of risk in such a measure. A plan of management for the Green and Golden Bell-frog will be developed by a suitably qualified biologist.
It would appear that the ramp leaving the M5 will pass through the Marsh Street wetland site. It may be possible to design a ramp which incorporates a viaduct which would allow the retention of the frog site. Otherwise the relocation of the M5 route in this area should be seriously considered.

At present the Green and Golden Bell-frog at Marsh Street moves across the sewerage pipe onto the adjoining golf-course to feed (A.White, *pers.comm.*). If the M5 is constructed, the roadway will present a barrier to movement to and from the golf-course. If the frog site at Marsh Street is retained and the M5 passes along the sewerage pipeline route, there will be a need to provide an underpass to allow movement to and from the golf-course. The underpass could be a tunnel (possibly one metre diameter would be sufficient) associated with a small water course.

Amelioration measures to be undertaken to reduce any effects upon Eve Street and Marsh Street wetlands include the use of Gross Pollutant Traps to trap sediment, treatment of run-off with constructed wetlands, reduction of trash and oils entering the wetlands, revegetation of any wetlands affected by the construction of the motorway and the production of a Wetland Management Plan (see Osborne, 1995, for further details about wetland amelioration measures).

Dr Martin Denny BSc (Hons) PhD MEIA

5 December, 1995

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M5 East Expressway - Wetland habitats

Addendum to reports by P. Adcock and P.L. Osborne

P.L. Osborne
Water Research Laboratory,
University of Western Sydney,
Richmond,
New South Wales 2753.

September 1995

Executive Summary

1. The proposed new route will remove the impact of the former preferred route on the wetlands of Wolli Creek.
2. The wetlands affected by the proposed route are those adjacent to Barton Park: the Eve Street and Marsh Street Wetlands. The Eve Street Wetlands, in particular, have a high conservation value and are recognised as significant by the local community, wetland scientists and by statutory bodies responsible for wetland conservation.
3. The proposed new route and its associated construction activity will severely impact approximately 30-35% of the Eve Street Wetland area. More importantly, the proposed route will alter the hydrology of the Eve Street Wetland as the weir controlling water inflow and outflow to the wetland will not operate effectively during construction. This could result in the complete loss of the wetland unless remedial measures are taken. The Marsh Street Wetland will also be severely impacted. It is, therefore, strongly recommended that a re-evaluation of the route, in this region, be undertaken.
4. The impact from the construction of the new route on the remnants of the Eve Street and Marsh Street Wetlands will be enhanced simply through the fact that the route will pass through both wetlands. With the currently proposed route, the proximity of construction activity to the wetlands leaves no space for measures to reduce sediment and pollutant inflows to these wetlands.
5. If there is justification for the proposed route through these wetlands, mitigative and restorative measures will be required. It should be clearly understood that the wetland mitigative and restorative measures should be applied to any route that enters the catchment areas of the Eve Street and Marsh Street Wetlands.
6. If the proposed route goes ahead, prior to construction activity, the weir controlling water levels in the Eve Street Wetland will need to be moved and a drainage channel linking the wetland to the creek into which it currently drains constructed.

7. Great care will be needed to minimise sediment and pollutant inflows to the wetland basins. Construction of a bund around the remnant wetland areas will be required.
8. Construction of the proposed route could effectively destroy the Eve Street and Marsh Street Wetlands. Wetland re-creation will, therefore, be required once construction is complete. No net loss of wetland area should be the guiding principle and, indeed, it would be highly desirable to increase the area of wetlands adjacent to Barton Park. A major risk in following this path of wetland destroy-and-recreate is the loss of rare and endangered species from the site.
9. There is significant scope for further terrestrial rehabilitation work in the vicinity of the Eve Street and Marsh Street Wetlands.
10. Run-off from the expressway should not be allowed to drain into the re-created Eve Street and Marsh Street Wetland basins. The run-off should be directed towards the Kogarah Golf Course and receive suitable treatment before disposal into the Cooks River.
11. The expressway should have a low profile in the vicinity of the Marsh Street and Eve Street Wetlands. Noise barriers, if required should be disguised with appropriate vegetation.

1.0 Introduction

This report provides comments on the proposal to consider a new route for the M5 expressway. The report assesses the ecological costs and benefits to wetland habitats that will accrue as a result of the proposed route change. The report is an addendum to Adcock and Osborne (1994a and 1994b). Some material from these earlier reports is presented here as background information.

1.1 Ecological considerations of wetlands in general

Important ecological features of all wetlands include:

- An intimate relationship with its catchment area.
- Wetlands are dynamic systems and conservation measures will only succeed if successional processes are allowed to proceed.
- Wetlands are subject to climatic influences and may be ephemeral, seasonal or permanent.

Freshwater wetlands in urban settings are ecologically important and play significant roles in:

- Controlling water flow and in flood mitigation.
- Trapping, immobilising and/or recycling nutrients.
- Trapping and potentially immobilising pollutants.
- Providing a diverse habitat for birds and aquatic fauna and flora.

Furthermore wetlands can have significant recreational value for bird-watching and in providing a focus of aesthetic appeal for urban dwellers. They can also provide significant sites for conservation education. Australia has an obligation to conserve wetlands because it is signatory to international treaties which are designed to protect the habitats of migratory waders (the Convention on Wetlands of International Importance (RAMSAR), the Japan Australian Migratory Bird Agreement (JAMBA) and the Chinese Australian Migratory Bird Agreement (CAMBA)). There are also nomadic species within Australia which range over great distances as opportunities and environmental conditions dictate.

Typically, major threats to the ecological integrity of urban wetlands include:

- Drainage and other developments involving reclamation or modification of wetlands for road construction, housing and refuse disposal sites.
- Nutrient enrichment.
- Discharge of industrial effluents.
- Oil discharge and oil spills.
- Run-off from roads and storm water drains.
- Enhanced inputs of suspended solids.
- Engineered structures such as concrete walls along river and creek beds which eliminate fringing vegetation.
- Weed invasions, particularly of exotic plants such as *Salvinia molesta*, *Eichhornia crassipes* (Water Hyacinth) and *Ludwigia peruviana*.
- Feral animals.

2.0 Aims and objectives of this study

The aims of this study are to:

- Assess the benefits to wetlands through rejection of the former route.
- Assess the potential impacts of construction of the proposed route on wetlands proximal to the expressway.
- Assess the potential impacts of expressway operation on the wetlands receiving run-off from the expressway.
- Recommend means to mitigate environmental effects on wetlands during expressway construction.
- Recommend means to mitigate environmental effects on wetlands during expressway operation.

3.0 Benefits to wetlands of rejection of the former route

The major impact of the former route on wetlands was through the construction of a cut and cover section of the expressway under Wolli Creek just downstream of the weir at Turella.

A summary of the major features of Wolli Creek in the vicinity of Turella is provided below. Further detail can be obtained from Adcock and Osborne (1994a). Wolli Creek is a tributary of the Cooks River which flows into Botany Bay. A small concrete weir at Turella separates the estuarine, lower Wolli Creek from the upper freshwater reaches. The lower creek is tidal to the weir and habitats consist of a small area of saltmarsh (1.5 ha) and mangroves (2.5 ha) with a few clumps of *Phragmites australis*. On the northern bank of Wolli Creek there is a saltmarsh dominated by *Suaeda australis* (Austral Seablite), *Phragmites australis* (Common Reed) and *Sarcocornia quinqueflora* (Samphire or Beaded Glasswort). The northern limit of the saltmarsh is separated by a bund from an artificially-created freshwater wetland dominated by *Typha orientalis* and *Scirpus* spp.

The mangroves in Wolli Creek, dominated by *Avicennia marina* (Grey Mangrove), (*Aegiceras corniculatum* (River Mangrove) has also been recorded) appear to be thriving. Canopy height averages about 3 m and understorey plants are sparse and restricted to the edges of the dense mangrove stands. Species present are those which are found in the nearby saltmarsh.

The stretch of Wolli Creek above Turella Weir, is a slow-moving creek approximately one metre deep with near-vertical banks. The banks have dense tree cover and the water in the creek is turbid. Therefore this stretch of the river has a poorly developed aquatic plant flora. *Triglochin* sp was found in small isolated clumps. The plants were densely covered in biofilms and this again may indicate poor water quality. These biofilms are detrimental to submerged plant growth.

One kilometre upstream of the weir, aquatic plant diversity increases. This could be due to less shading from overhanging trees and also shallower water and less steep banks. Species present included *Myriophyllum aquaticum* (Brazilian Water Milfoil), *Phragmites australis* (Common Reed), *Eleocharis sphacelata* (Tall Spikerush), *Spirodela* sp (Duckweed), *Schoenoplectus validus,* (River Clubrush) *Triglochin procera* (Water Ribbons), *Typha spp* (Cumbungi), *Paspalum paspalodes* (Water Couch), *Callitriche stagnalis* (Common Starwort), *Zantedeschia aethiopica* (Arum Lily), *Tradescantia albiflora* (Wandering Jew) and *Ranunculus* (Buttercup).

Rejection of the former preferred route will remove any threat to this wetland from expressway construction and operation.

4.0 Regional significance of wetlands proximal to the proposed route of the expressway

4.1 Wetland sites

The wetlands affected by the proposed route are those adjacent to Barton Park and, in particular, the Eve Street and Marsh Street Wetlands (collectively referred to as the Barton Park Wetlands).

4.1.1 Eve Street Wetlands

The Eve Street Wetlands are located east of Eve Street, Arncliffe, and are bordered to the north by the access road to the Rockdale Council Depot, to the north east by the S&WSOOS Sewer main, and to the south-south-east by an elevated disused Sewer Aqueduct and fence. The area is traversed, from west-south-west to east-north-east, by the North Georges River Submain. This submain is elevated 2-3 m above the wetland until it reaches the S&WSOOS Main. The wetland is roughly trapezoidal and is connected to the Cooks River Diversion. Several studies and revegetation programs have been carried out on the Eve Street wetland and Blick (1990) recorded 51 native and 95 exotic plant species (see Adcock and Osborne, 1994b).

This wetland is held in high regard by local residents and is recognised as having significant aesthetic, scientific and heritage values. Rehabilitation works on the wetland have recently been completed with the installation of a weir to maintain the low tide levels across the mudflats for the wading birds and saltmarsh plants. Migratory waders and less common plants returned in summer 1994/95 (Jay Stricker, Australian Society for Limnology Newsletter 33(1), 15).

4.1.2 Marsh Street Wetlands

A small wetland is located between the Kogarah Golf Course and the Main Western Outfall Sewer which runs perpendicular to Marsh Street. A second, small wetland lies adjacent to Marsh Street opposite the intersection of Marsh Street with Valda Avenue. Both these wetlands are in a degraded condition and provide significant scope for an extension of the excellent rehabilitation work that has been carried out on the Eve Street Wetland. One endangered species (*Litoria aurea*, Green and Golden Bell-frog) is recorded from this wetland. This species is listed on Part 1 (Vulnerable) of the revised interim schedule 12 of the National Parks and Wildlife Act.

4.1.3 Muddy Creek Drainage Channel

This area is characterised by a network of drainage channels feeding into Muddy Creek. The channels are tidal, hence they are dominated by plants tolerant of high salinities. This wetland area is unlikely to be impacted by the proposed expressway.

4.2 Regional significance of the wetland sites

The regional significance of wetland sites in this region of Sydney is discussed by Osborne and Adcock (1994a). Like the Botany Wetlands (see Gutteridge, Haskins and Davey 1993), the Barton Park Wetlands provide habitat for migratory wading birds and this confers on them both a regional and international significance. However, because of their small size, the Barton Park Wetlands are, in some respects, less significant than the more extensive Botany Wetlands. However, the Eve Street wetland is tidal and shallow and therefore differs as a habitat from that provided by the Botany Wetlands. As a result of this habitat difference, the Eve Street Wetland attracts a range of birds not usually found at the Botany Wetlands and this is particularly true of some of the migratory waders (for example, Greenshank, Sharp-tailed Sandpiper). The bird species attracted to this wetland, complement those attracted to the Botany Wetlands and this, therefore raises its conservation value. The Botany Wetlands provide a more suitable habitat for Black Swans and ducks. There is some anecdotal evidence that water-fowl numbers utilising the Eve Street Wetlands have increased following the construction of the third runway at Sydney Airport (Jay Stricker, personal communication). Significant loss of tidal wetland occurred through the construction of this runway. The Barton Park Wetlands are also a valuable natural haven in an otherwise urbanised landscape. Therefore they constitute a resource highly valued by the people that use them for recreation and relaxation.

Conservation of the Barton Park Wetlands takes on further significance as the neighbouring Botany Wetlands continue to undergo rehabilitation. This may incur a temporary loss of wetland habitat within this region, which may result in increased utilisation of the Barton Park wetlands by, for example, water-fowl. There also has been a reduction in the extent of freshwater wetlands in the region, so it is important that remaining areas be given a high priority so that wetland plant and animal populations may remain viable.

5.0 Potential impacts of construction of the proposed route on wetlands proximal to the expressway

5.1 Expressway construction phase

Construction of the proposed Expressway route has two major impacts on the Marsh Street and Eve Street Wetlands. The first is a direct reduction in wetland habitat area. The proposed route, together with access required during construction will severely reduce the area of these wetlands. Of even greater concern is the impact of construction on the hydrology of the Eve Street Wetland. Construction activity will alter the hydrology of this wetland to such an extent that, without remedial measures, it may cease to exist as a wetland. The importance of the hydrological regime has been demonstrated through the recent installation of a weir allowing fine control of water levels. This management intervention has significantly enhanced this wetland habitat (Jay Stricker, Australian Society for Limnology Newsletter 33(1), 15). The route will also markedly reduce the area of the Marsh Street Wetlands.

Within drainage channels, wetlands present aesthetic value as well as benefiting water quality by providing filtration for suspended solids and reducing BOD. The Eve Street Wetland is connected to the channel system and probably plays a role in enhancing water quality. Furthermore, this wetland is of major regional significance owing to its aesthetic, scientific and heritage values.

The second major area of concern during construction is run-off. Run-off from the site has the potential to cause damage to sites downstream of construction activity through elevated levels of suspended solids. High levels of suspended solids will reduce the clarity of receiving waters, and if sustained for long periods will affect submerged plants by reducing their photosynthetic capacity. True emergent species such as: *Eleocharis sphacelata, Juncus usitatus, Phragmites australis, Typha spp, Avicennia,* will be less affected as for most of their life history they are not reliant on light penetrating the water column for growth. They are however susceptible to contaminants in the run-off, which should be carefully monitored, with loads on receiving waters minimised. What will remain of the Marsh Street and Eve Street Wetlands will be threatened by run-off from the site during construction. Both sites will require protection from sediments and pollutants throughout construction activity and during expressway operation.

5.2 Expressway operation

The major environmental problem impacting wetlands from expressway operation is run-off. A four lane expressway, as a catchment area, will accumulate pollutants associated with vehicles, including oil, grease, rubber, brake pad dust and particulate exhaust material. Drainage from this area will be concentrated into disposal points and released into natural water courses. If left untreated this run-off has the potential to pollute receiving waters. Such pollution could be minimised by simple pre-treatment of the water, possibly via a series of constructed wetlands. This has the dual benefit of polishing the run-off while increasing wetland habitat in the region.

Some run-off from the expressway will drain into the Barton Park Wetlands. If this increased run-off could be diverted through an appropriate polishing system the impact could be significantly reduced. The water quality in the Cooks River downstream of these wetlands may well be improved by reducing the level of contaminants which previously entered this system untreated.

The Barton Park Wetlands constitute a significant area of water-fowl habitat. The avifauna of the area is described by Mount King Ecological Surveys (1994). The most important conclusion from that report was that the physical presence of the expressway will have an impact on wetland birds through restricting their line of sight. Therefore, structures should be as close to ground level as possible. This requirement may have conflicts with noise control if noise barriers are to be used along this section. A natural barrier should be established between the expressway and the Eve Street and Marsh Street Wetlands to “soften” the appearance of expressway structure.

6. Recommendations

6.1 Route selection

From a wetland conservation perspective, a route that remains outside the catchment area of these wetlands is strongly recommended. A route that does not reduce the area of wetland and is at least 50 m from them would be a compromise position (see Conclusions 2 and 3). In light of the above statements, the current proposal to re-align the route closer to the Marsh Street and Eve Street Wetlands will need to be very carefully justified.

6.2 Wetland Management Plan

It is recommended that a Wetland Management Plan be produced prior to commencement of construction which determines the extent of wetland loss, detailed, site-specific mitigative measures to be used during expressway construction and operation and details of wetland rehabilitation to be undertaken following completion of the expressway.

6.3 Sediment loads

Sediment loads on wetlands during expressway construction and operation need to be minimised. How this may be achieved requires further work. Coarse sediments can be trapped in Gross Pollutant Traps (GPTs). These traps require regular maintenance and removal of accumulated sediments. Finer particles are not retained by these structures and it is recommended that a small wetland be constructed for removal of fine sediment and nutrient polishing. Appropriate point source disposal sites should be selected and appropriate control measures instituted. Sediment loss to water courses should be reduced by revegetation of denuded areas.

Run-off from the expressway should be directed away from the Eve Street Wetland and the use of constructed wetlands to treat the run-off should be investigated. It may well be necessary to include a sediment trap, trash rack and oil interceptor to treat the run-off before it enters the constructed wetland.

6.4 Trash and oils

Trash and oils cause both aesthetic and water quality problems in wetlands. A number of measures can be taken to reduce this problem:

- Installation of litter traps at run-off sites.
- Installation of first-flush devices and oil-traps at key locations to trap floating material and oils.
- Regular cleaning and maintenance of these installations.

As litter is a problem in wetlands of the region, installation and regular maintenance of these devices would benefit the catchments through which the expressway passes. Some oil slicks were observed in the Marsh Street Wetland and there are indications that some oil may seep from the Rockdale Council Depot adjacent to the Eve Street Wetland.

6.5 Run-off monitoring program

It is recommended that during construction, environmental scientists should monitor run-off. An effective monitoring program should be designed, providing details of sampling sites, sampling frequency and water quality measurements. Effectiveness of instituted pollution control measures should be assessed following opening of the expressway to traffic. A monitoring program should be designed to carry out this assessment.

6.6 Revegetation programs

Sound soil conservation measures adopted, particularly during construction, will reduce sediment loads on the wetlands adjacent to the expressway. Any wetlands impacted during construction should be revegetated and appropriately landscaped. Specifications for wetland site remediation should be detailed before construction begins (see 6.7 below).

6.7 Wetland habitat protection and rehabilitation

The Eve Street Wetland is clearly a significant wetland habitat and worthy of conservation. The proximity of the proposed route to this wetland is a cause of major concern. In terms of habitat impact, perhaps the most serious is to the waders and other waterfowl that utilise this habitat. Consideration needs to be given in expressway design to reduce the impact of the structure on birds approaching the wetland. It is important the expressway has a low profile in the vicinity of the Marsh Street and Eve Street Wetlands. Such a profile will have less impact on birds approaching the wetland as their line of sight will be less restricted. If the wetlands are to be conserved, it may be necessary to develop a protective bund around them prior to commencement of construction.

Wetland rehabilitation is already an issue in this region. This is indicative of the strong community support for the conservation of "their" wetlands. Development, before expressway construction begins, of a wetland rehabilitation plan for the wetlands proximal to the expressway is essential. This will ease the perceived potential impact of construction on existing wetlands. Rehabilitation work could significantly enhance the aesthetic value of the local landscape and "soften" the visual impact of the expressway. There is significant scope for both wetland and terrestrial rehabilitation work in the vicinity of the Rockdale City Council Depot near Eve Street. It is likely that the degraded Marsh Street Wetland already provides some protection in terms of water quality flowing into the Eve Street Wetland. Rehabilitation of the Marsh Street Wetland could enhance its performance in both nutrient and pollutant removal. Furthermore the creek into which the Eve Street Wetland drains to the Cooks River provides a significant opportunity for wetland rehabilitation. This rehabilitation work would not only enhance wetland habitat values but also could, with careful design, provide a capacity for pollutant removal.

7.0 Conclusions

1. The proposed new route will remove the impact of the former preferred route on the wetlands of Wolli Creek.
2. However, the proposed new route and its associated construction activity will severely impact approximately 30-35% of the Eve Street Wetland area. More importantly, the proposed route will alter the hydrology of the Eve Street Wetland as the weir controlling water inflow and outflow to the wetland will not operate effectively during construction. This could result in the complete loss of the wetland unless remedial measures are taken or until wetland restoration can be undertaken (see 6 below). It is, therefore, strongly recommended that a re-evaluation of the route, in this region, be undertaken. The Eve Street Wetlands have a high conservation value and are recognised as significant by the local community, wetland scientists and by statutory bodies responsible for wetland conservation. Either a re-evaluation of the route in the vicinity of these wetlands be undertaken or detailed justification (on, for example economic or engineering grounds), for the selection of this route needs to be provided. Wetland habitat

protection is required under various treaties regarding migratory birds. While these wetlands are small they must be viewed in a regional and historical context. Significant wetland loss has occurred within the Sydney basin and these losses enhance the value of those that remain. Access to a variety of habitats is particularly important for the maintenance of bird diversity and population numbers. Wetlands as refuges for migratory and nomadic birds become even more important during droughts.

3. The impact from the construction of the new route on the remnants of the Eve Street and Marsh Street Wetlands will potentially be enhanced simply through the fact that the route will pass through both wetlands. With the currently proposed route, the proximity of construction activity to the wetlands leaves no space for measures to reduce sediment and pollutant inflows to these wetlands. Furthermore, the route through the wetlands will significantly enhance the impact on any birds that may continue to utilise these habitats.

4. If there is justification for the proposed route through these wetlands, mitigative and restorative measures will be required. Suggested measures are provided below. It should be clearly understood that the wetland mitigative and restorative measures described below should be applied to any route that enters the catchment areas of the Eve Street and Marsh Street Wetlands. Furthermore these measures are provided on the understanding that the proposed route can be justified on grounds that compensate for the wetland loss that will ensue.

5. Prior to construction activity, the weir controlling water levels in the Eve Street Wetland will need to be moved and a drainage channel linking the wetland to the creek into which it currently drains constructed. This may facilitate conservation of part of the Eve Street Wetland.

6. Great care will be needed to minimise sediment and pollutant inflows to the wetland basins. Construction of a bund around the remnant wetland areas will be required.

7. Notwithstanding (5) above, construction of the proposed route could effectively destroy the Eve Street and Marsh Street Wetlands. Wetland re-creation will, therefore, be required once construction is complete. Wetland construction and restoration techniques are available and, with adequate funding, wetlands similar

(albeit smaller) to those that exist there now could be created at the remanant site. However, no net loss of wetland area should be the guiding principle and, indeed, it would be highly desirable to increase the area of wetlands adjacent to Barton Park. Restoration of a larger area would provide a greater opportunity to enhance habitat diversity and this, in turn, would increase the likelihood of re-establishment of the previous fauna and flora. Furthermore, additional area would counterbalance the adverse impacts of the expressway. Replacement of the lost wetlands and/or their restoration would cost in region of $100,000-250,000 (excluding land purchase). A major risk in following this path of wetland destroy-and-recreate is the loss of rare and endangered species from the site.

8. There is significant scope for further terrestrial rehabilitation work in the vicinity of the Eve Street and Marsh Street Wetlands. A proposal for this work should be developed prior to the start of construction activity. Rehabilitation efforts should be co-ordinated with relevant authorities and this should include production of a Site Management Plan. These activities should be undertaken even if the former preferred route is followed.

9. Run-off from the expressway should not be allowed to drain into the re-created Eve Street and Marsh Street Wetland basins. The run-off should be directed towards the Kogarah Golf Course and receive suitable treatment before disposal into the Cooks River. A linear wetland should be developed to receive this run-off. This wetland should fulfil a number of objectives but should primarily be designed for effective pollutant immobilisation. An oil interceptor, trash rack and sediment trap may be necessary. This will depend upon the length of the expressway draining to this area. If run-off is directed to the golf course, it is unlikely that this will significantly alter the current hydrology of the Marsh Street and Eve Street Wetlands.

10. The expressway should have a low profile in the vicinity of the Marsh Street and Eve Street Wetlands. Noise barriers, if required should be disguised with appropriate vegetation. The low profile will have less impact on birds approaching these wetlands.

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M5 EAST MOTORWAY
TUNNEL EXHAUST STACK DESIGNS

Report prepared for the Roads and Traffic Authority by
Richard Goodwin Pty Ltd, 61 James Street, Leichhardt 2040

November 1996

M5 EAST TUNNEL EXHAUST STACK DESIGNS

Introduction.
After research of the locations for the 3 stacks, and their relative scale, a number of priorities emerged. The massive vertical dimension of 15m coupled with the diameters of 6.5m and 9.5m immediately puts each structure at odds with the domestic environment. One site allows for some celebration of this height but for the others the issue of breaking this vertical emphasis is paramount. Such height lends itself to sculptural manipulation but not in an arbitrary fashion. I have sought to find justification for modulation of these structures through their locations and a use of materials which reflects the "genius loci".

MATERIALS
I have chosen a palette of materials which reflect the location and technology appropriate to the task. ie:

Steel mesh growing frames to facilitate the growth of climbing plants indigenous to the area and thus disguising scale.
Sandstone facing to concrete structures to reflect the natural stone foundation of Sydney.
Aluminium faced plywood on steel frames as a contemporary material lending itself to sculptural shapes and a range of anodised colours. Its reflective qualities can also be used as a way of diminishing scale.

HILL STREET STACK
This location emerging as it does from the escarpment and bushland setting on a prominent ridge provides the opportunity for some celebration of scale and organic growth.
The central stack structure would be a concrete cylinder clad in steel mesh growing frames making deep cuts into the girth of the form. Three organically curved steel structures embrace the cylinder and are faced in reflective aluminium clad plywood.
The result is like a high tech tree trunk reflecting the sky as it reaches upwards. This could become a valued landmark if done with excellence and not merely as a functional vent pipe.

BARDWELL ROAD STACK
This is the largest stack in diameter and lies within a typical suburban setting. I have attempted to use the vertical zones related to the area to create some articulation of the height. ie: wall zone, roof zone and sky zone.
The base is clad with stone and houses a large planter bed. The vertically curved sweeps of the main structure would use different coloured aluminium to reflect the building zones.
Separating these planes will be vertical growing frames breaking the massive scale in diameter.
The result is an exciting built form which contrasts but marries with the surroundings in its breakdown of elements.

ARNCLIFFE STREET STACK
Here the stack forms part of what could be either a park or building complex. To marry this vent with a building would be preferable but otherwise I see this structure as part of a park setting.
Here the palette of materials has been employed to break the vertical scale and create a sense of shelter with an overhanging form. The growing frames would completely disguise the structure from the street. The stone cladding would reach out from the structure and create a level change for seating in the park.
The cantilevered cam shaped form would reflect the sky.

It must be remembered that for all these forms the use of robust materials to withstand their public function has been considered. Also the issue of scaleability and safety have had to be of key importance.

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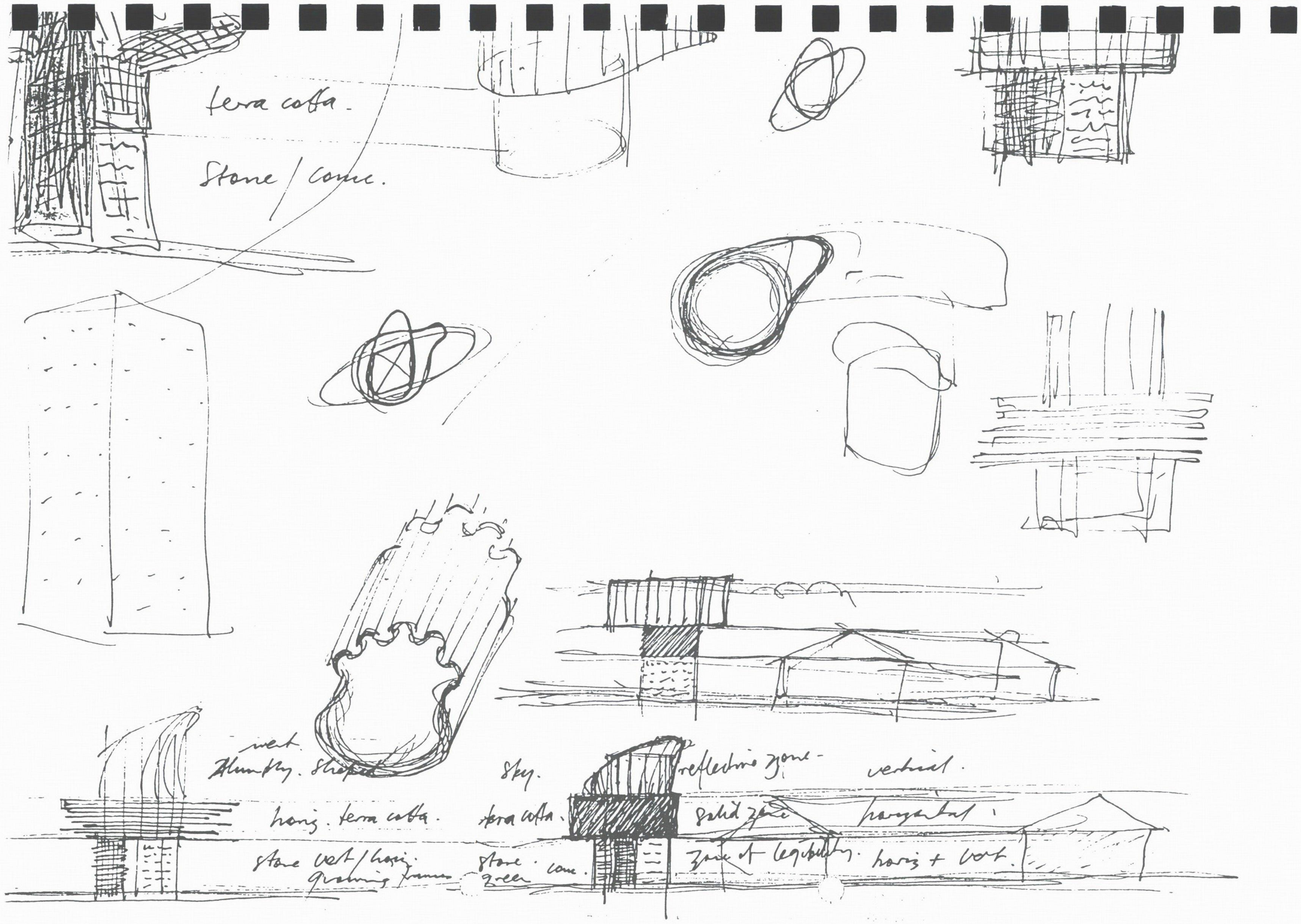
E-MAIL:



terra cotta.
Stone / conc.
wet
Humpty. shaped
sky.
reflective zone -
vertical.
horiz. terra cotta.
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glazing frames
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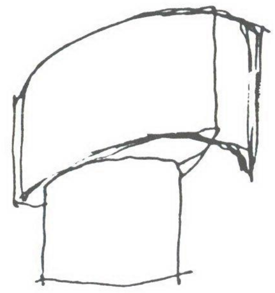
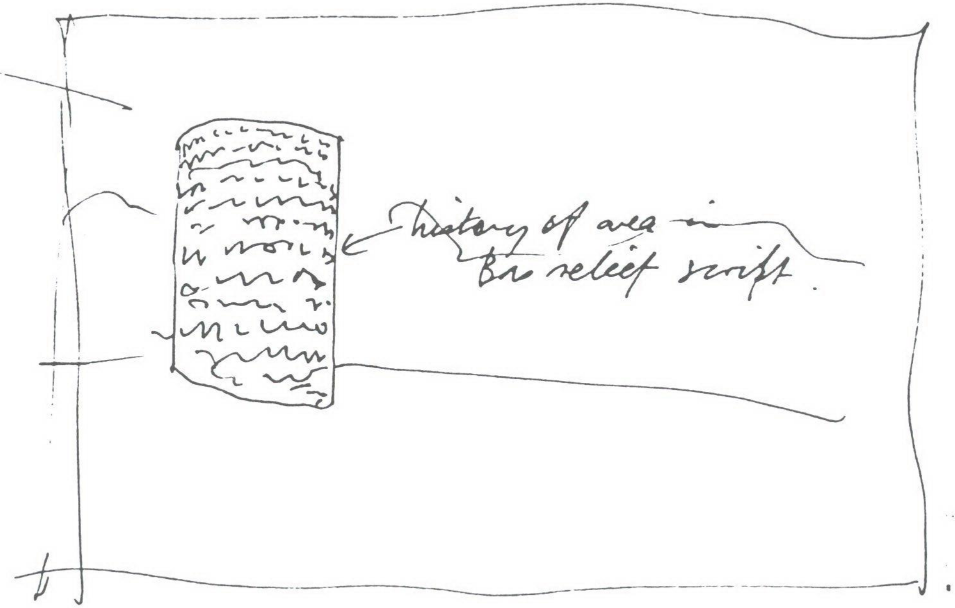
zone of legibility.
horiz + vert.

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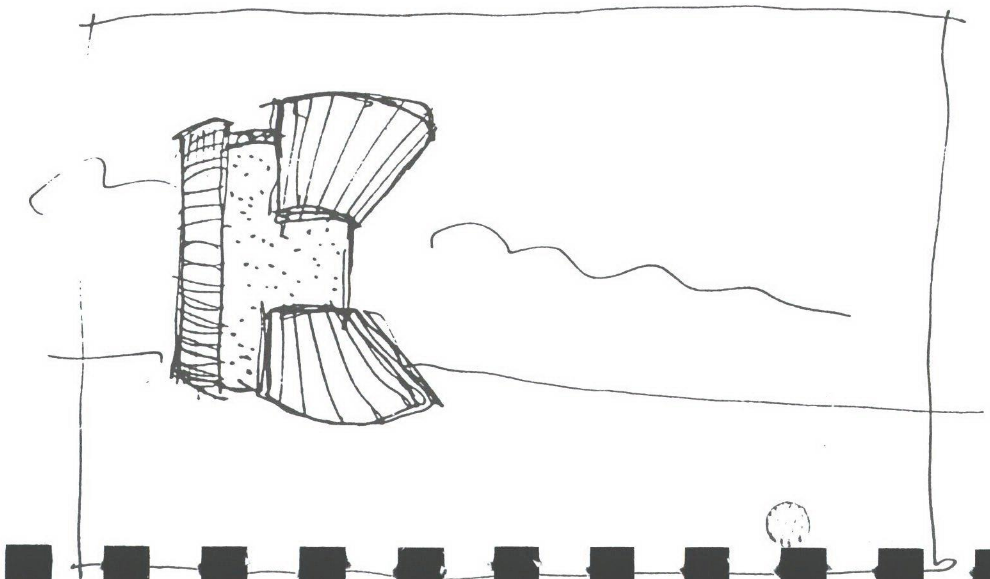
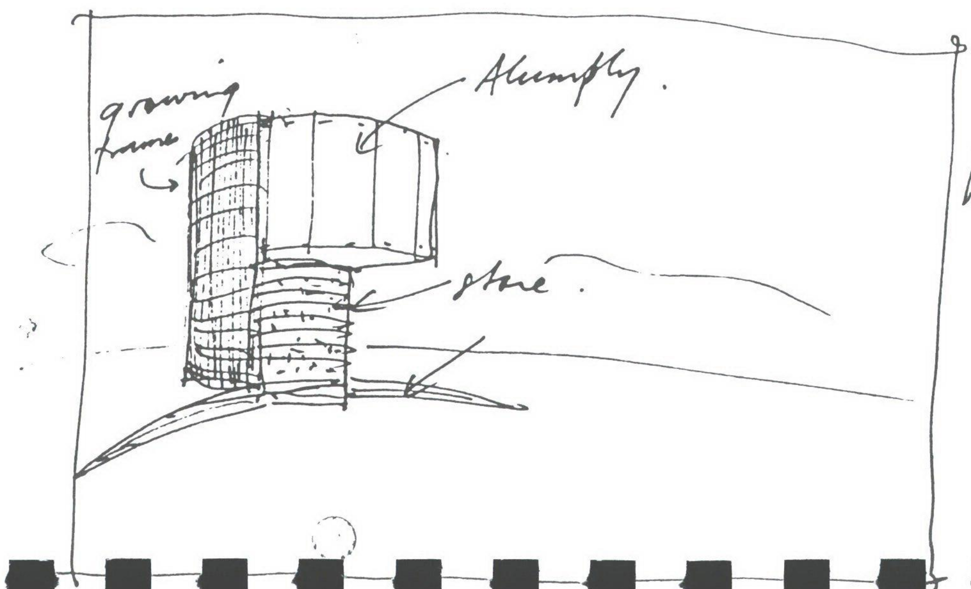
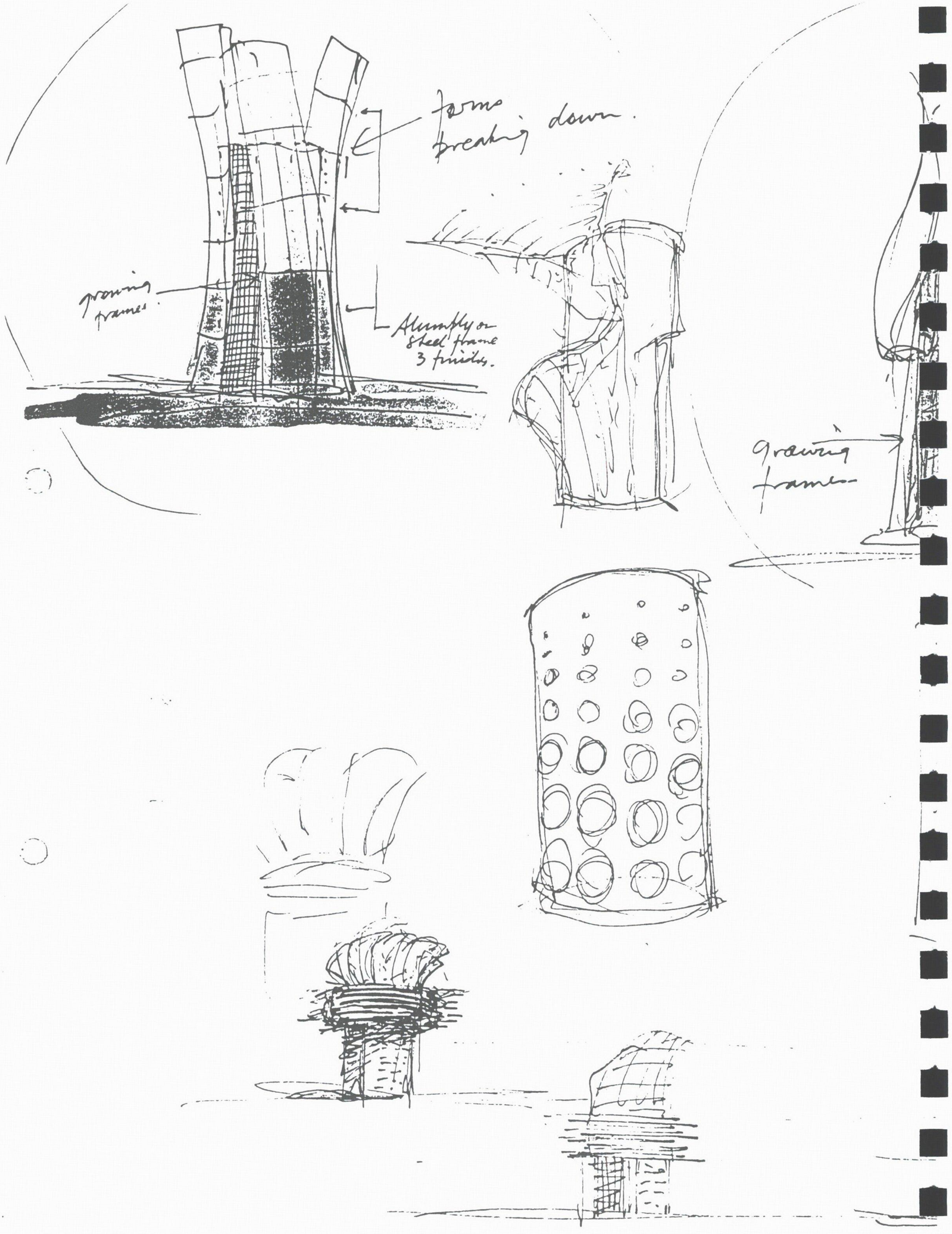
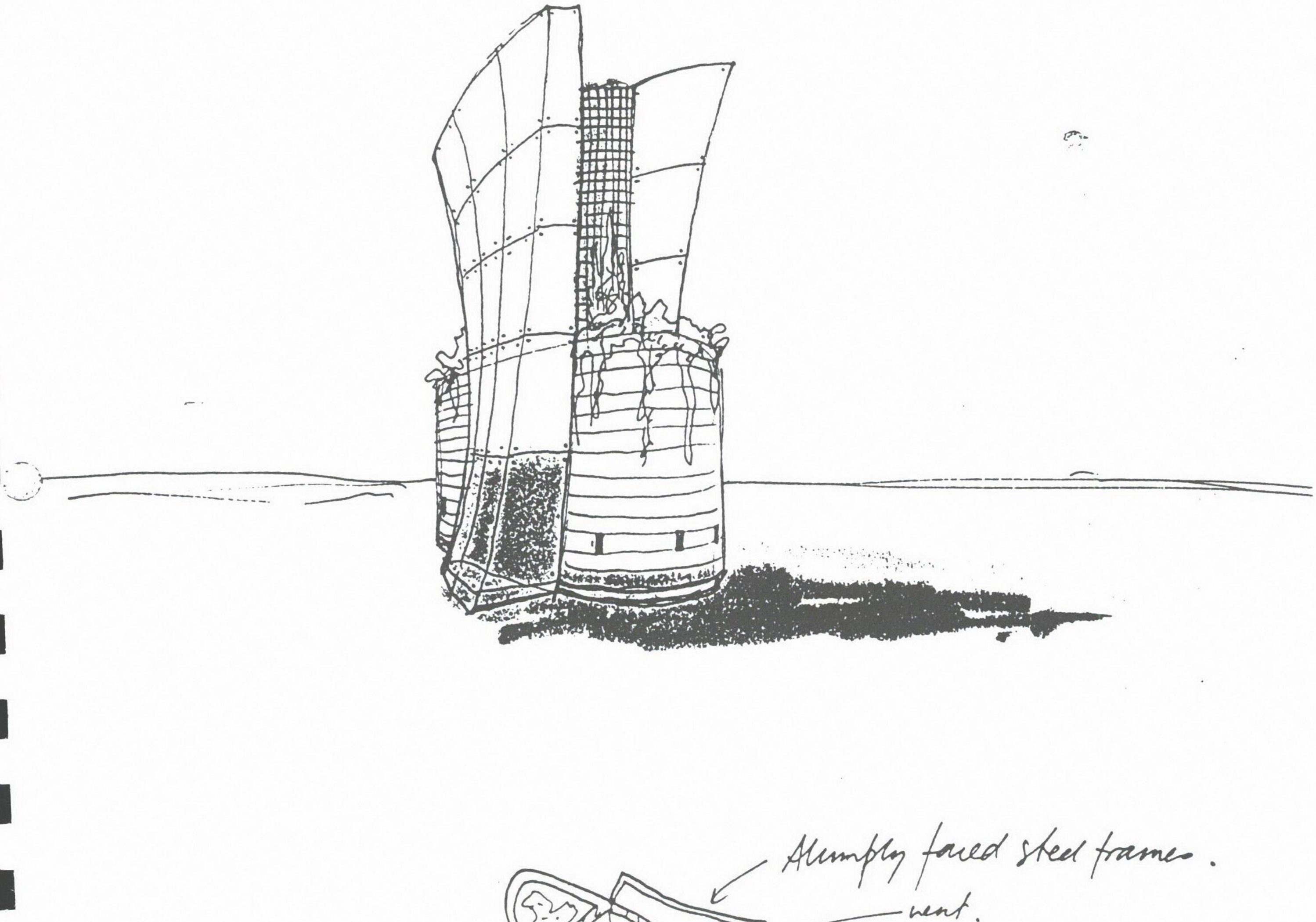
Bas relief script.



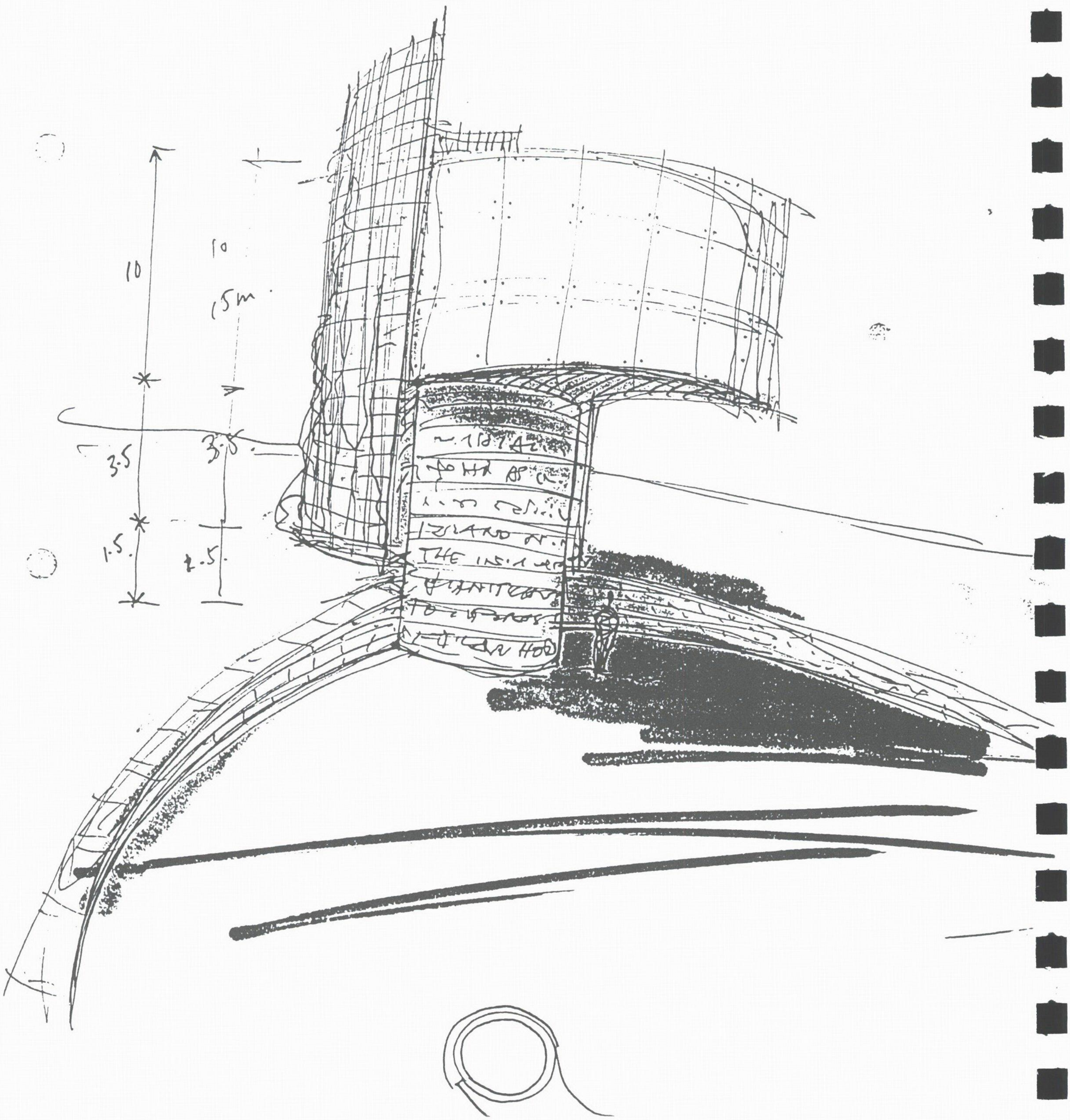

Aluminium.
growing frame
stone.

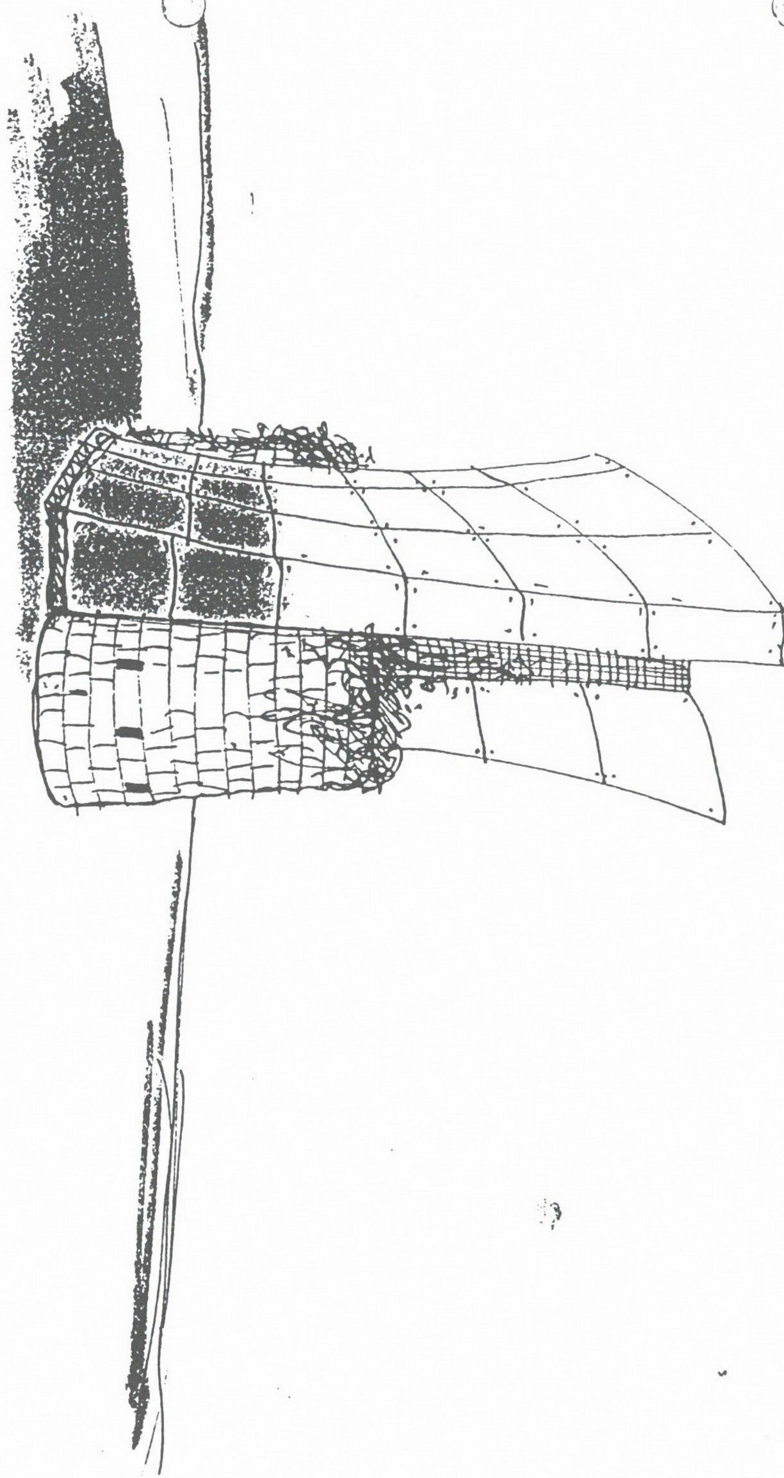

forms breaking down.
growing frames.
Aluminium or Steel frame 3 finishes.
growing frames

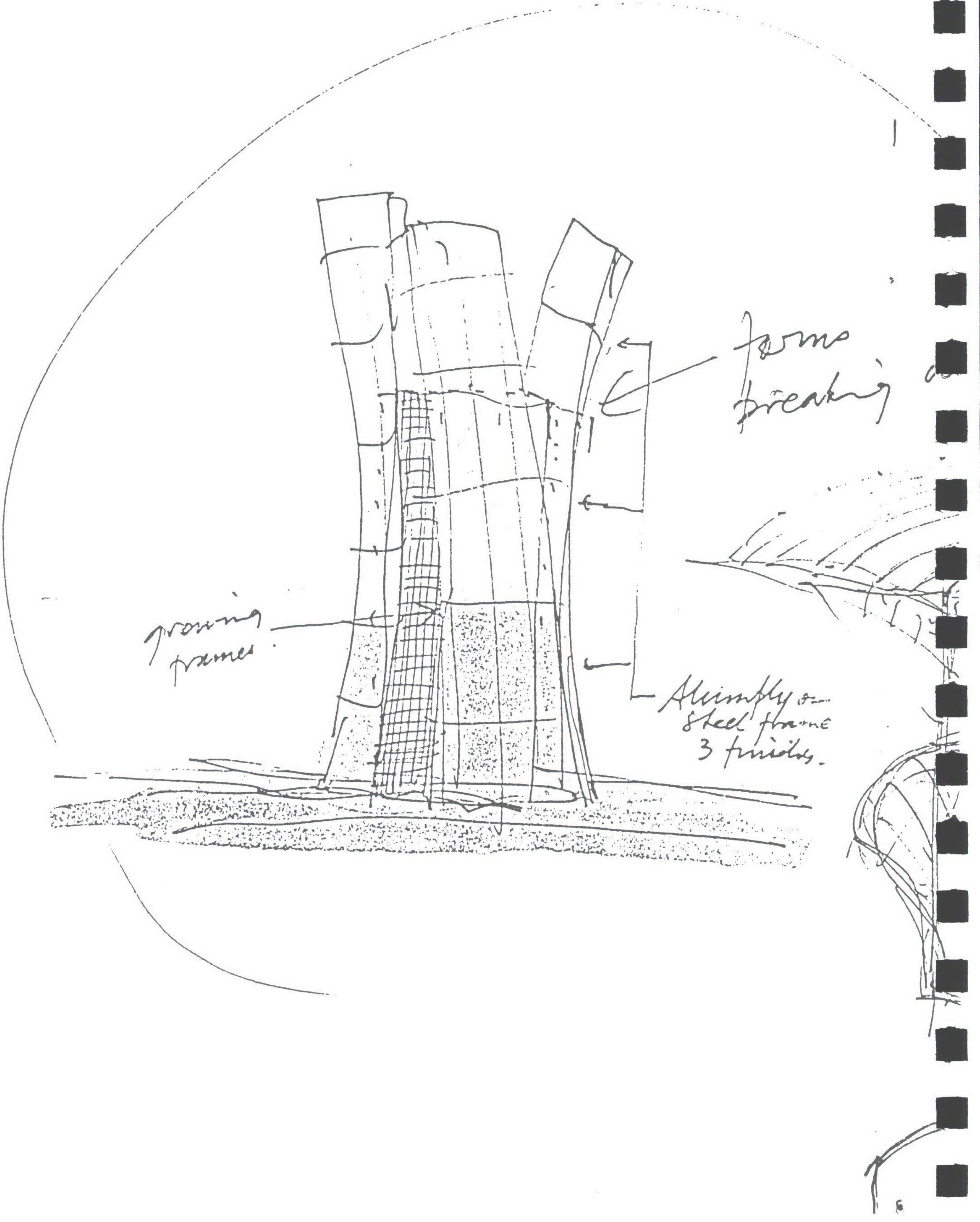


Alumply faced steel frames.
vent.
Stone faced concrete.
Plants.

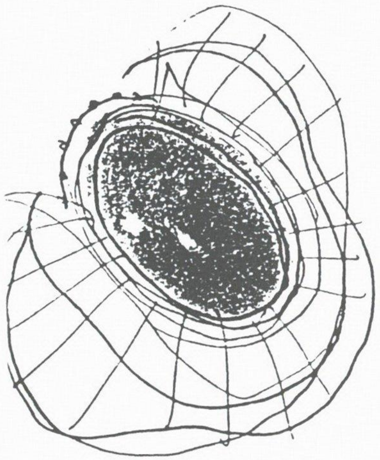
Attention: John Chang. fax *Marie Geisler 3805737

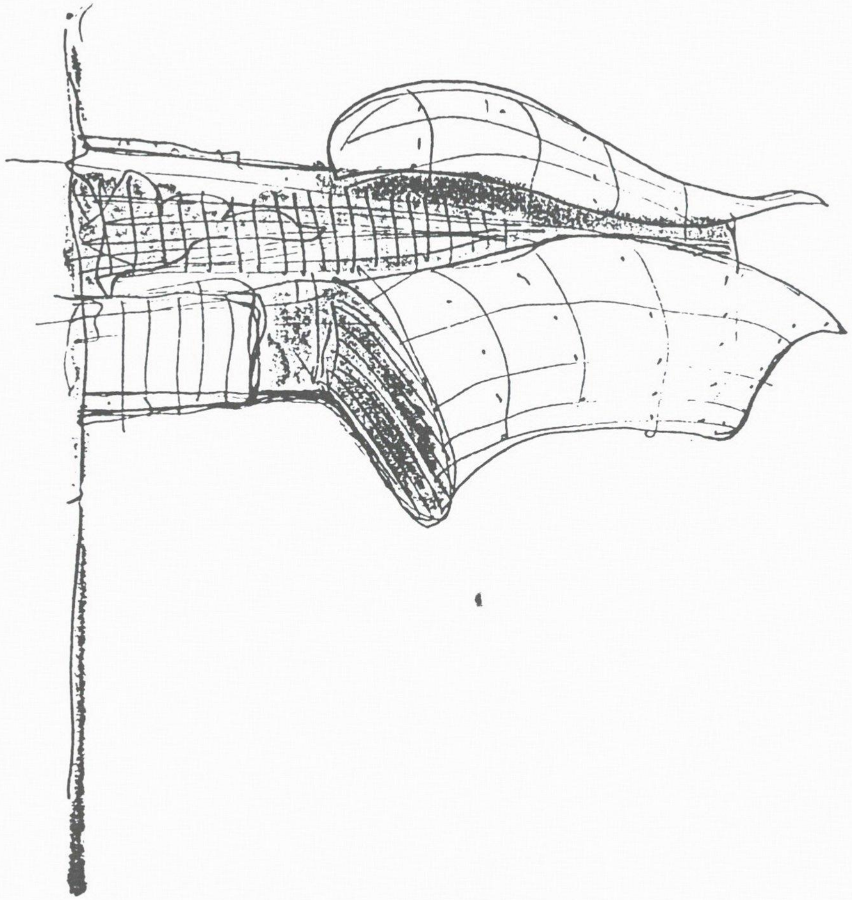


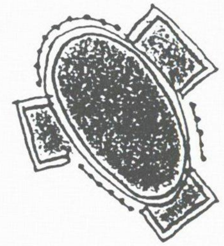


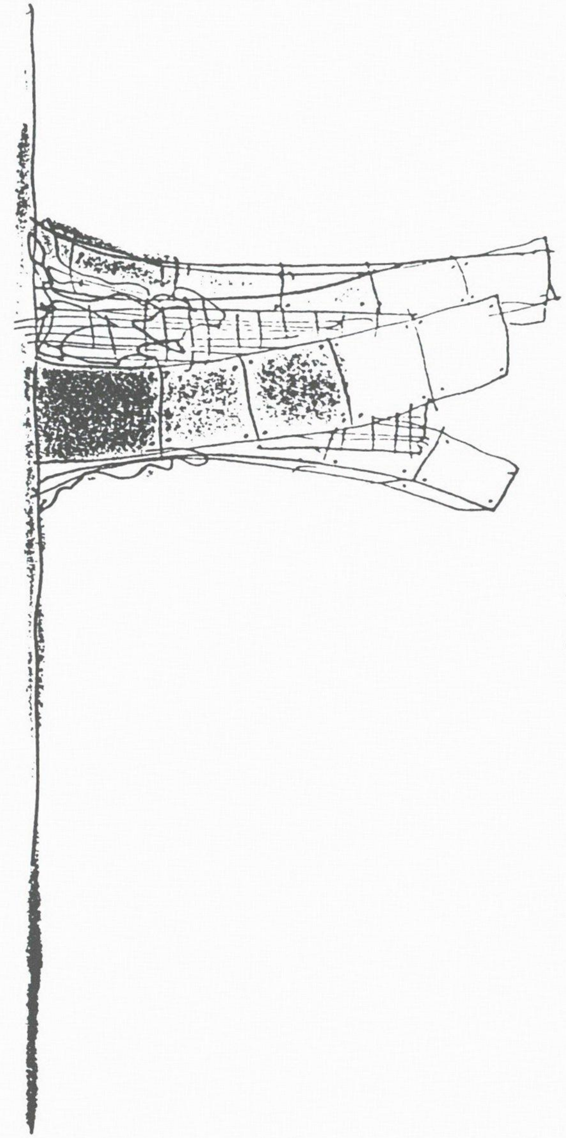


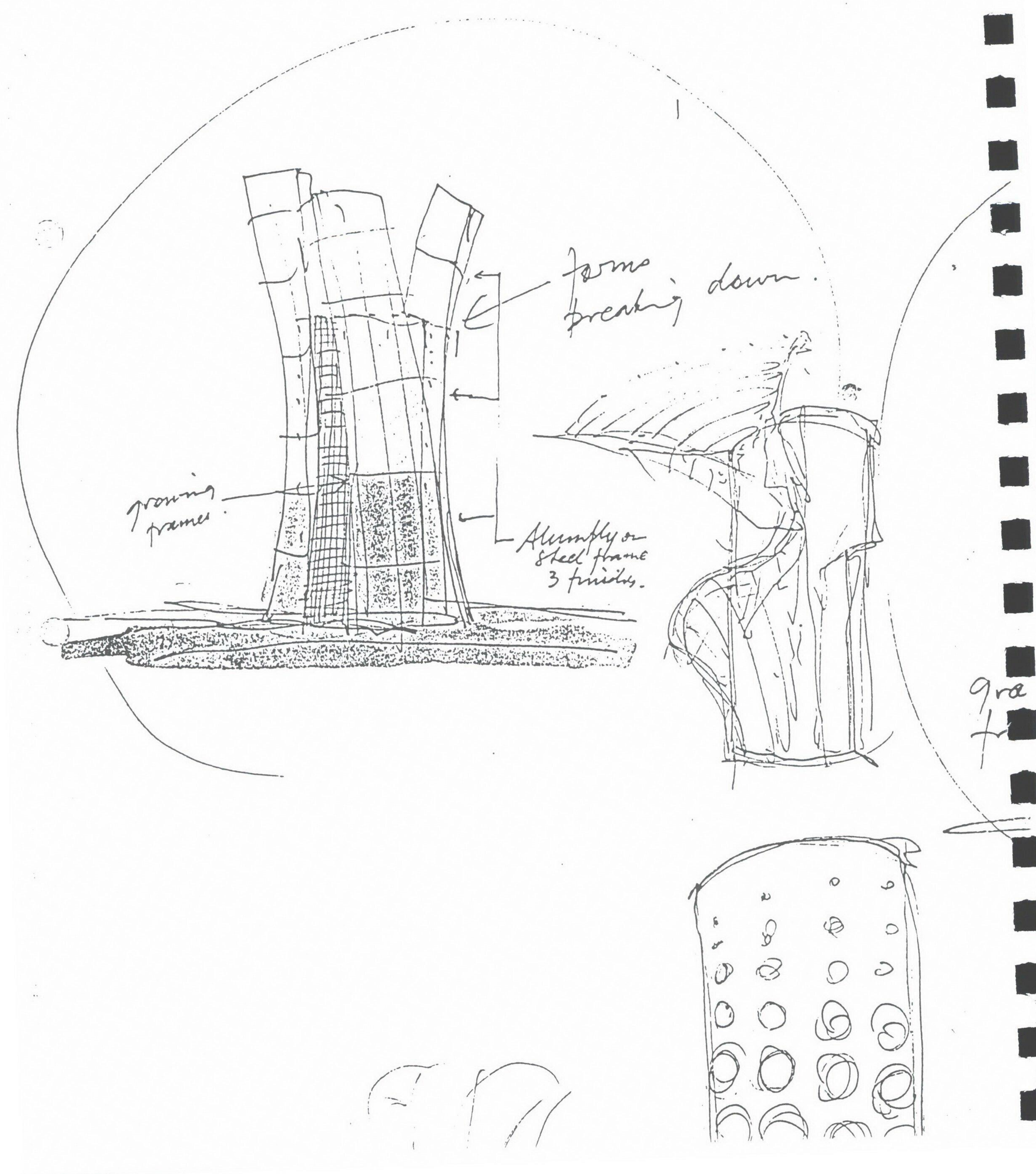
forms breaking
growing frames
Aluminum or Steel frame 3 finishes.










forms
breaking down.
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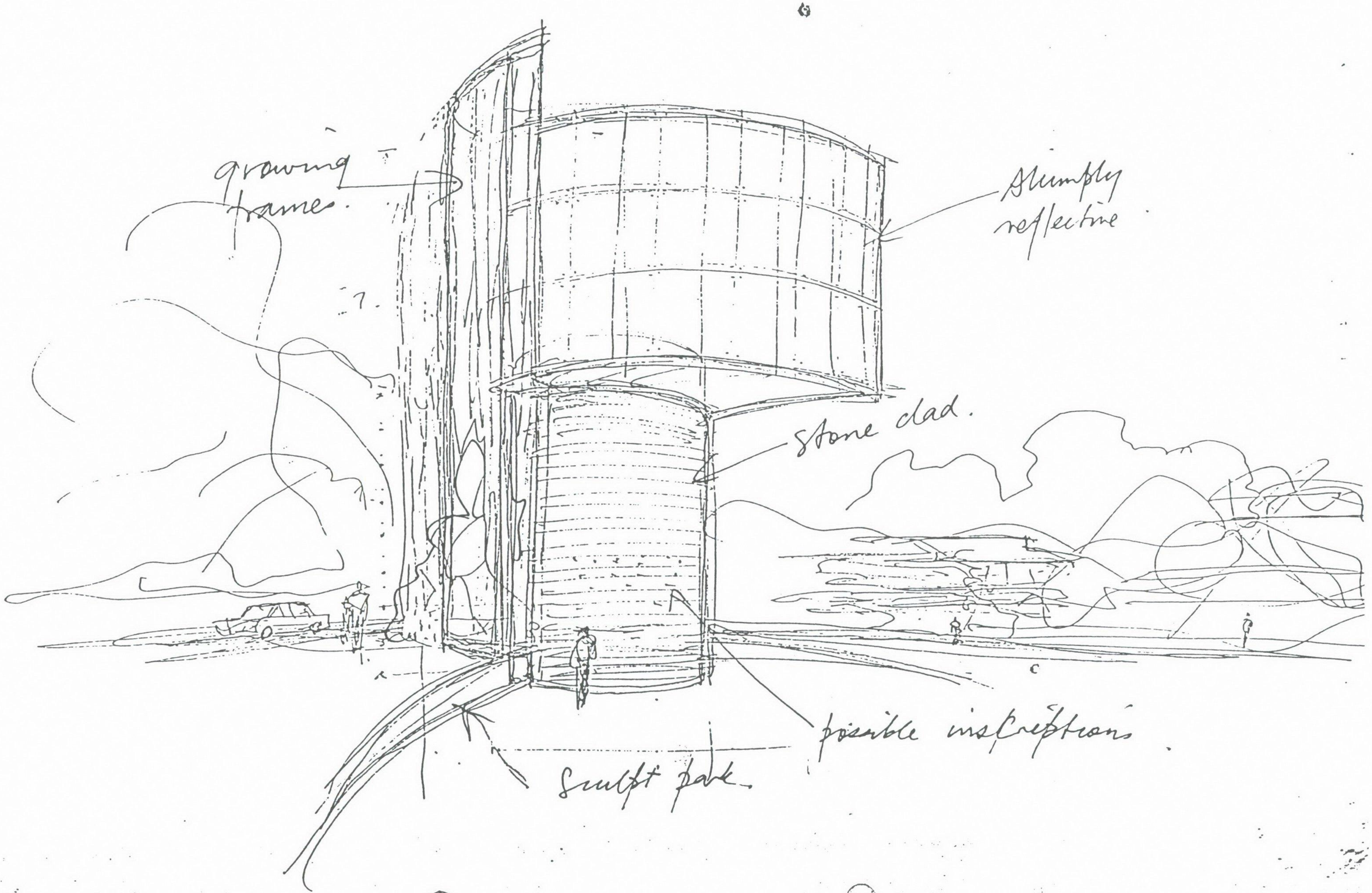
frames.
Aluminum or
Steel frame
3 finishes.



growing frame.
Glumply reflective
stone clad.
possible inscriptions
Sculpt park.

M5 EAST MOTORWAY

SUPPLEMENTARY WORKING PAPER

EUROPEAN HERITAGE ISSUES

December 1995

WENDY THORP

SECTION 1.0
EXECUTIVE SUMMARY

This work has been commissioned by Manidis Roberts Consultants as a supplement to an EIS prepared in 1995 on the possible impact of the proposed M5 East Motorway on European heritage places. The current proposal is for a direct tunnel option south of Wolli Creek with a section of road between Loftus Street and the Illawarra Railway line where it then enters a tunel to re-emerge at Marsh Street. The principal impact on potential heritage items, either physical or visual, would be through the construction of air intake/exhaust vent stacks, the road and its re-entry point at Marsh Street and a possible construction site in Coolabah Reserve. Several locations have been nominated for the vents and particular reference is made to the preferred options. As well, consideration has been given to an inter-change planned at General Holmes Drive.

The vent options generally include land that was developed from the middle to later decades of the twentieth century in response to post-war industrialisation and the construction of the East Hills Railway line in the 1930s. The two reserves, although not precisely dated, are likely to be a product of a post-1960s period of development. The vent option at the end of Moore Street is included in land that was part of an early twentieth century park that was developed during the 1930s as a golf course. Arncliffe Park has the longest history of community use being dedicated as a park in 1889.The portion of surface road would be constructed through an area of later nineteenth and twentieth century development. Its point of re-emergence at Marsh Street is in the area of a late nineteenth - early twentieth century sewerage farm. The interchange at General Holmes Drive is located on land that was part of an early nineteenth century estate.

Only one of the vent options has been identified in current heritage listings to be of European heritage value. This is Arncliffe Park (which also includes a war memorial nominated to be of heritage value). This investigation has not highlighted any of the other options to be on places of outstanding heritage value. For these reasons there are no objections on the basis of European heritage values to the selection of any option with the exception of Arncliffe Park. The lengthy association of this park with community recreation and its identification as an item of European environmental heritage in the Rockdale Heritage Study and subsequent inclusion on the Schedule of Heritage Sites attached to the Draft LEP makes this option unsuitable for selection.

The section of surface road impacts directly on one nominated item of European heritage, that is Wollongong Road. It would be close to a second item, No 22 Loftus Street, "Cairnsfoot" a late Victorian mansion now used as a school. The impact here would be visual. The portal at Marsh Street is in the area of an item of European heritage value being a line pine trees associated with the site of the former sewerage farm. There are no places known to be of heritage value on the site of the inter-change.

For the same reasons as its selection as a potential vent stack site Coolabah Reserve does not contain significant European heritage items that would be adversely impacted upon by any construction work in this area.

The principal mitigative works and actions required to be taken in the event of the surface road being constructed on the proposed alignment would be, in the case of "Cairnsfoot", screen planting appropriate to the heritage values of the site as a means of reducing the visual impact of the road. Works carried out on Wollongong Road will require a Development Application to be made to Rockdale Council. The Council is the consent authority for the work and there is a provision in the Rockdale Planning Scheme Ordinance which requires notification by Council to the Heritage Council of NSW of any demolition of a building or work that is a nominated item of environmental heritage. Consent to the Development Application cannot be granted until twenty-eight days after the Council has notified the Secretary of the Heritage Council of its intention to do so.

The pine trees at Marsh Street might also be subject to the need for a Development Application because of their inclusion within the Draft LEP. The LEP will have statutory authority when it is gazetted. They are curently protected by a tree preservation order which also requires consent from Council for any proposed work.

SECTION 2.0
PROJECT FRAMEWORK

2.1 Context of the Investigation

This work has been commissioned by Manidis Roberts Consultants on behalf of the Roads and Traffic Authority of NSW. It is a supplement to work undertaken for an EIS prepared in May 1994. This work assesses the impact of a direct tunnel option with several vent stack locations, a portion of surface road, one construction site and an inter-change at General Homes Drive.

2.2 Parameters of the Study

The direct tunnel option lies south of Wolli Creek and is on the same east-west alignment as the tunnel option considered in the EIS. The European heritage of this area has been extensively investigated as part of the 1994 EIS and earlier 1989 study. The principal impact of this option on European heritage would occur on the sites of exhaust vent stacks and/or air intake vents, the construction of a section of road between Loftus Street and the Illawarra Railway line where it then enters a tunnel to re-emerge at Marsh Street, a construction site in Coolabah Reserve and some alterations at an inter-change on General Holmes Drive.

2.3 Objectives

The principal objective of this work was to assess the possible impact on European heritage values of any of the options nominated as possible vent sites, the portion of surface road, the proposed construction site in Coolabah Reserve and the General Holmes Drive interchange and the most appropriate means of mitigating this impact.

2.4 Tasks

The tasks undertaken to achieve the objectives of the study were:

- reference to historical studies prepared for earlier reports for the purpose of identifying any potentially sensitive areas or sites
- field survey for the several options
- reference to current and updated heritage listings
- documentation of the review and assessment including recommendations, if necessary, for mitigative works.

SECTION 3.0
EVALUATION OF THE OPTIONS

3.1 The Sites

This assessment has considered all the alternative east and west vent locations with particular attention to the preferred options which are:

- Slade Road either side of the rail line outside the western gate of Bardwell Park RSL
- behind J.D.Hall's Henderson Street factory in Turella
- off the corner of Cooke and Reed Streets adjacent to No. 29 Cooke Street, Turella (back of Streets Ice Cream factory)
- alongside the railway building in rail corridor adjacent to Ron Gosling Reserve
- in Bardwell Valley Golf Course at the end of Moore Road (below the escarpment)
- Arncliffe Park
- Coolabah Reserve.
- Bardwell Road east of the Royal Place intersection
- Royal Place at the Bardwell Road intersection
- the intersection of Duff and Hill Street

The assessment has also evaluated that area of land between Loftus Street and the Illawarra Railway line as well as a portal at Marsh Street which encompasses the requirements for a surface road. The site of the inter-change on General Holmes Drive has also been assessed as part of this work.

3.2 Historical Context

The complete historical context of the area has been presented in the analysis of European heritage values discussed in the 1994 EIS. The following statements summarise the relevant facts for each of the new options considered by this supplementary work.

The Slade Road sites occur in an area that was subdivided from the later years of the nineteenth century onwards. The East Hills Railway was opened in 1931.

The factory area of Henderson Street generally represents post war industrialisation that is characteristic of large areas of Rockdale.

The Cooke Street site is located in an area that generally was developed through the influence of the railway line constructed in the 1930s.

The options at Bardwell Road, Royal Place and Duff Street are in an area that has been developed predominantly through the early decades of the twentieth century.

The option in Ron Gosling Reserve is in the East Hills Rail Corridor which was opened in 1931. The reserve appears to be a product of post- 1960s development.

The Bardwell Valley Golf Course was originally known as Kingsgrove Park and was held by Bexley Council during the early years of the twentieth century. The golf course was constructed on the site in 1937.

Arncliffe Park was proclaimed in 1889 and has had several programmes of improvements and beautification since that time.

Coolabah Reserve, like the Ron Gosling Reserve, has no precise date but is likely to be contemporary with it.

The area encompassed by the possible road between Loftus Street and the Illawarra Railway line includes land that was alienated during the early nineteenth century and principally developed from the later nineteenth century and first half of the twentieth century.

Marsh Street borders the former Rockdale Sewerage Farm which was inoperation from the later 1880s until 1916. The site has since been subsumed by Barton Park and within FAC land.

The inter-change site is within land that was part of an early nineteenth century estate belonging to a Sydney entreapeneur, Simeon Lord.

3.3 Heritage Listings

The only vent option which is located on a place of identified European heritage value is Arncliffe Park. The park (as well as a war memorial located in it) was nominated in the Rockdale Heritage Study and both have been included in the Schedule of Heritage Sites attached to the Draft LEP.

The portion of surface road would directly impact on one place of European Heritage value. This is Wollongong Road which is identified in the Rockdale Heritage Study and has been included on the Schedule of Heritage Sites attached to the Draft Rockdale LEP. The original inventory listing for this item describes it as,

"a major road route with development on both sides from Done Street to Forest Road. On both sides are a variety of buildings, mostly residential, but including some shops and Arncliffe Park - from the late nineteenth century to the 1920s. At its eastern end stone fences are common, the terrain makes the buildings on the southern side prominent in the streetscape. Remarkably free from major changes in use and retains much of its early nineteenth century character".

It was determined to be significant because,

"It contributes to amenity and character of the area, and evidence of the character of the locality from the early twentieth century".

In the immediate area of the proposed road, at 22 Loftus Street, is "Cairnsfoot", a Victorian Italianate villa built as a private residence in 1884 and now included as part of the Loftus Street School. There is likely to be some visual impact on this item which is included as an item of Environmental Heritage in the Schedule of Heritage Sites attached to the Rockdale Draft LEP.

The portal entrance at Marsh Street may impact on a site of European heritage identified in the Schedule of Heritage Sites attached to the Rockdale Draft LEP. This item is decribed as "pine trees lining the drive". They are likely to be associated with the site of the former sewerage farm.

There are no known sites of European heritage value on the site of the inter-change.

3.4 Assessment - Actions Required

With the exception of the Arncliffe Park option none of the possible vent stack sites have been identified by earlier studies or this investigation to be of European heritage significance. For this reason there are no objections on heritage grounds to the selection of any of these options. However, Arncliffe Park by reason of its lengthy association with community amenity for over one hundred years and its nomination in the Heritage Schedule attached to the Rockdale Draft LEP would not be a suitable option for selection.

The selection of Coolabah Reserve as both a possible vent stack location and construction site does not impact on any known heritage sites or places.

The construction of a surface road between Loftus Street and the Illawarra Railway line will directly impact on the heritage values expressed in the nomination of Wollongong Street as a place of European heritage value. To proceed with this work a Development Application may need to be submitted to Rockdale Council which will be the consent authority for the work. The Council is required by Clause 39C of the Rockdale Planning Scheme Ordinance to give notice to the Heritage Council of the proposed work:

"Heritage Council to be given notice of demolition consent.

39C. Where a person makes a development application to demolish building or work that is an item of environmental heritage, the responsible authority shall not grant consent to that application until 28 days after the responsible authority has notified the Secretary of the Heritage Council of its intention to do so".

The nomination of this item and those following will acquire statutory authority when the Draft LEP for Rockdale and the Schedule of Heritage Sites attached to it has been gazetted.

Development within the close vicinity of an item of environmental heritage, in this case 22 Loftus Street, is required by Clause 39B of the Rockdale Planning Scheme Ordinance to be the subject of an assessment to determine the likely impact of that work on the heritage values of the item and its setting. This work fulfils that requirement; it has been determined that some visual impact is likely. To mitigate this impact screen planting of a type and style appropriate to the heritage values of the site should be placed within the curtilage of the school site that now encompasses "Cairnsfoot".

If the pine trees at Marsh Street are impacted on they may also be subject to the need for a development Application becuase of their inclusion as heritage items within the Schedule attached to the Draft LEP. Currently the trees are protected by a Tree Preservation Order which prohibits

"cutting down, ring barking, topping, lopping, removing, injury and wilful destruction of any tree, either in excess of 300mm girth, at a height of 1 metre from the ground or exceeding a height of three metres within the Rockdale area, except with the consent of Council".

ROADS AND TRAFFIC AUTHORITY NSW

M5 East EIS

Supplementary Report to Hydrology and Hydraulics and Water Quality Study Reports

FINAL REPORT

OCTOBER 1995

WILLING & PARTNERS

CONSULTING ENGINEERS

ROADS AND TRAFFIC AUTHORITY NSW

M5 East EIS

Supplementary Report to the Hydrology and Hydraulics and Water Quality Study Reports

PROJECT Nos 3248 and 3250

OCTOBER 1995

WILLING & PARTNERS PTY LTD, CONSULTING ENGINEERS

WATER ENGINEERING DIVISION

PO Box 832, CROWS NEST NSW 2065

Telephone (02) 99595002 Facsimile (02) 99594663

TABLE OF CONTENTS

1. INTRODUCTION

This report has been undertaken on behalf of the Roads and Traffic Authority as a supplement to two previous reports prepared by Willing & Partners, namely,

1. M5 East Hydrology and Hydraulic Study (Ref 1), and

2. M5 East Water Quality Control Plan (Ref 2).

This report briefly describes the route of the "Direct Tunnel" option and compares the impact of this alternative on drainage/flooding and water quality with the predicted impacts of the preferred alignment as described in the M5 East Motorway EIS (Ref 3).

2. PROPOSED DIRECT TUNNEL ROUTE

The route and vertical alignment of the proposed motorway between Fairford Road and Bexley Road remains identical to that for the EIS option.

East of Bexley Road the "Direct Tunnel" route would diverge and follow a route averaging some 400 to 500 metres south of the EIS option. The "Direct Tunnel" route would extend under Wolli Creek east of Bexley Road before heading in an easterly direction towards the Illawarra Railway and passing beneath Bardwell Creek approximately 160m south of the Bardwell Creek - Wolli Creek confluence.

From the crossing of the Illawarra Railway the proposed "Direct Tunnel" route would merge towards the route of the EIS option near the Eve Street wetlands and continue parallel, but south of the EIS option as far as the Cooks River. East of the Cooks River the two alternatives share a common alignment.

3. FAIRFORD ROAD TO BEXLEY ROAD

The discussions relating to the frequency and extent of flooding and the mitigation options available for the EIS option remain valid for the "Direct Tunnel" option since the routes are identical.

4 BEXLEY ROAD TO BONAR STREET

4.1 Introduction

Except at the western end, the "Direct Tunnel" route between Bexley Road and Bonar Street (approximately 240m west of the Illawarra Railway) would be constructed as a bored tunnel.

The proposed alignment takes the motorway away from the Wolli Creek floodplain and is sufficiently deep at the crossings of both Wolli Creek and Bardwell Creek to avoid interfering with the drainage and flooding regime which exists in both valleys. However there is some potential for adverse impacts on Bardwell Creek arising from an option to construct an air intake vent in the Bardwell Valley at Coolabah Reserve. There are also likely to be minor localised impacts on flood behaviour if the other options to construct either an air intake vents or exhaust stacks within the Wolli Creek floodplain are adopted.

4.2 Construction Depot and Tunnel Access

One possible construction scenario involves establishing a site depot and tunnel access within the Coolabah Reserve. Based on an interpretation of CMA orthophoto mapping, the western part of Coolabah Reserve rises above the estimated 1% AEP flood level and therefore, from a floodplain management and water quality aspect, would be a suitable area for the establishment of a site depot and construction access point to the tunnel. It is recommended that the tunnel access be located at least one metre above the estimated 1% AEP flood level of RL 5.0 m AHD. Alternatively a temporary levee should be constructed to height of RL 6.0 m AHD in order to minimise the risk of the tunnel being flooded during construction. The appropriateness of these levels should be verified by a more detailed analysis during the preliminary design phase.

Owing to the close proximity of the construction depot to Bardwell Creek there is a high risk of pollutants entering the watercourse unless site specific measures are designed and implemented. The water quality control measures should form part of an integrated soil and water management plan designed to satisfy EPA criteria.

Pollutants generated from construction depots will mostly include sediment, diesel fuels, oils and lubricants all of which may be intercepted and trapped using proven techniques. A typical arrangement would require the site drainage to be designed to allow all runoff, fuel spills and the like to enter a holding basin. The holding basin would be designed to allow the polluted runoff to be treated prior to discharging to Bardwell Creek or for it to be collected for disposal at a suitable treatment facility. The size of the holding basin will depend on the anticipated life of the depot but should not be less than that required for a 10% AEP design storm.

4.3 Location of Exhaust Stack

Six possible locations have been proposed for the exhaust stack;

1. on the right bank of Wolli Creek behind JD Hall's factory and adjacent to the East Hills Railway,

2. adjacent to railway land, west of the Bardwell Park RSL building,

3. near the corner of Cook and Reede Streets, Turrella,

4. adjacent to the East Hills Railway Station approximately opposite Nelson Street,

5. in Arncliffe Park, and

6. in Girrahween Park at the end of Sutton Street, Bardwell Park.

4.3.1 Site 1

If the exhaust stack is located on the right bank of Wolli Creek at East Hills upstream of Henderson Street some modification in flood behaviour can be expected. Detailed hydraulic modelling would be required to assess the magnitude and extent of the changes in flood levels and velocites. Although the location is on the outside of the creek bend where higher flood velocities would be expected, and therefore greater changes, the impacts are likely to be small and may not be noticeable to nearby existing building development. However under high flood conditions there would be an increased risk of scouring the railway embankment due to high velocity flows occurring in the area between the stack and the embankment. The design of an exhaust stack in this location will therefore need to recognise and allow for this possibility.

The top of the exhaust stack would need to be constructed to RL 7.4 m (AHD) in order to provide the same standard of flood protection as discussed for the Coolabah Park air intake vent. The appropriateness of this level should be verified during the preliminary design phase.

Wherever construction is undertaken in or adjacent to a watercourse there are likely to be significant difficulties in ensuring water quality is not jeopardized. Construction of the exhaust stack on the Wolli Creek bank will therefore require careful planning, installation and maintenance of measures designed to minimise the risk of sediments entering the creek. The use of coffer dams or their equivalent would be the preferred measure to isolate the work site from the creek.

It would be preferable for the construction period to coincide with historically low flow periods to lessen the risk of the construction site being flooded and sediment being washed downstream.

4.3.2 Site 2A

Two alternatives have been considered west of the Bardwell Park RSL building. The southern alternative is on the opposite side of the railway to Wolli Creek and based on an interpretation of CMA orthophoto mapping, would be located where ground levels are approximately RL 10.0 m AHD. This would place the exhaust vent significantly above the estimated 1% AEP and 0.1% AEP flood levels of 5.5 m AHD and 8.2 m (AHD) respectively and would therefore have no impact on flooding. The site is considered suitable for employing standard water quality control measures during construction and is not considered to pose a risk to water quality in Wolli Creek.

Site 2B

The northern alternative would be located in the car park at an estimated surface level of RL 9.6 m AHD. This location is also significantly above the estimated 1% AEP and 0.1% AEP flood levels and would not influence flooding in Wolli Creek. Although this location is close to the creek sufficient space is available to isolate the construction site from Wolli Creek and therefore intercept and treat sediment laden runoff using standard practices which include; sediment fences, diversion channels/bunds and sediment basins (settling ponds).

4.3.3 Site 3

The third location is near the corner of Reede Street and adjacent to property at No. 29 Cook Street. The location is beyond the estimated limit of the 1% AEP flood in Wolli Creek and therefore there would be no impact on 1% AEP flood behaviour. In addition, the location would provide ample opportunities to employ standard soil and water management measures to minimise the risk of pollutants entering the drainage system. Once constructed a vent at this location would not be expected to have an impact on water quality. Therefore, this site is a preferred location with respect to flooding and water quality issues.

4.3.4 Site 4

The fourth site identified is near the eastern end of the East Hills Railway Station opposite Nelson Street. Based on existing mapping information the ground levels are at approximately RL 3 m (AHD) and the site would therefore be subjected to flooding from Wolli Creek during a 1% AEP flood. However the site is located behind existing buildings which abut the creek and is not within an area which would be categorised as floodway. Flood velocities are likely to be low and therefore flooding impacts would be expected to be insignificant.

The top of the exhaust stack should be no lower than RL 7.4 m (AHD) for the same reasons as indicated for Site 1.

The site is considered sufficiently far from Wolli Creek to allow a soil and water management plan to be implemented at the site using conventional water quality control techniques. Therefore the implications for water quality in Wolli Creek during construction are negligible. No long term adverse impacts on water quality from the presence of the exhaust vent are considered likely.

4.3.5 Sites 5 and 6

The remaining two locations, at Arncliffe Park and Girrahween Park are both out of the floodplain and therefore would have no impact on flood behaviour. In addition, each location would provide ample opportunities to employ standard soil and water management measures to minimise the risk of pollutants entering the drainage system. Therefore the Arncliffe Park and Girrahween Park sites, together with the Cook Street location (Site 3), are preferred with respect to flooding and water quality issues. Once constructed, vents at these locations would not be expected to have an impact on water quality.

Based on water quality and flooding criteria the preferred locations for the exhaust vent are Sites 3B, 4, 5 or 6.

4.4 Location of Air Intake Vent

Six potential sites for locating an air intake vent have also been identified. These are;

1. on the right bank of Wolli Creek behind JD Hall's factory and adjacent to the East Hills Railway,

2. adjacent to railway land, west of the Bardwell Park RSL building,

3. near the corner of Cook and Reede Streets, Turrella,

4. in Coolabah Reserve off Bardwell Road,

5. in Ron Gosling Reserve adjacent to the railway line at the end of May Street, and

6. in the Bardwell Valley Golf Course at the end of Moore Street below the escarpment.

4.4.1 Sites 1, 2 and 3.

The comments made for a possible exhaust vents at Sites 1, 2 and 3 apply equally to an air intake vent. Sites 1, 2 and 3A would be subjected to flooding from Wolli Creek and the risks associated with water quality during construction would be higher than for the remaining sites under consideration.

4.4.2 Site 4

Depending on the chosen location within Coolabah Reserve the vent may or may not lie within the extent of the 1% AEP floodplain. Ideally the air intake vent would be beyond the 1% AEP floodplain. However, in order to minimise the impact on localised flood levels it should at least be outside the extent of the 5% AEP flood where higher velocity flows are likely to occur.

The top of the air vent will need to be above an extreme flood level. In other locations where the proposed motorway occupies part of the Wolli Creek floodplain the suggested design flood levels are based on an approximation to the 0.1% AEP flood. However, since any water entering the tunnel would need to be pumped out, it is suggested that the air vent be either constructed above the estimated 0.02% AEP flood level and/or be provided with a reliable means of sealing the vent against the entry of floodwaters.

The preliminary estimated 0.1% AEP and 0.02% flood levels at Coolabah Reserve are RL 6.6m (AHD) and RL 7.75m (AHD) respectively. The determination of the flood levels are discussed in Appendix A at the end of this report. For concept feasibility assessments the top of the air intake vent in Coolabah Reserve should be no lower than RL 7.75m (AHD).

The Bardwell Valley Management Plan (Ref 6) identifies Coolabah Reserve as open parkland with potential for emphasising the marshland character by wetland planting. The marshland area, although presently poorly maintained, benefits water quality in Wolli Creek by providing an area of deposition for sediments and other particulates. The construction of a large diameter air vent close to the marshland may destroy the integrity of the marshland and pose a high risk to water quality during the construction period. Furthermore, the proposed location is in an active floodway area and is likely to lead to localised increases in flood levels for a range of flows in Bardwell Creek.

In order to minimise the risks associated with flooding and water quality during construction it is recommended that the construction period for works at this location be chosen to coincide with historically annual low flow periods.

4.4.3 Site 5

The suggested location in Ron Gosling Reserve would place the vent stack beyond the extent of the 1% AEP flood and is therefore a preferred location when considering flooding and water quality aspects. Where there is negligible risk of flooding the risks associated with water quality during construction are also able to minimised since there is ample scope for implementing the necessary soil and water management controls to limit pollutants entering the waterways. Once constructed a vent at this location would not be expected to have an impact on water quality.

4.4.4 Site 6

Similarly, the sixth alternative site, which is in the Bardwell Valley Golf Course, is well above both the estimated 1% AEP and extreme flood levels and as a consequence there will be no impact on flooding. Furthermore, there is sufficient space between the proposed site and Bardwell Creek to implement water quality controls to minimise pollution of the waterways during construction. Once constructed a vent at this location would not be expected to have an impact on water quality.

5. BONAR STREET TO COOKS RIVER

The eastern portal of the "Direct Tunnel" alternative would be located east of Bonar Street with a further portal east of Marsh Street. Tunnel construction would be either by boring or "cut and cover". In either case there is not expected to be any long term adverse impacts on either flooding or water quality other than the impacts previously identified for the EIS option (Refs 1, 2).

Where the tunnel is to be constructed using a "cut and cover" method measures widely used in the building and construction industry would be sufficient to guard against surface runoff entering and flooding the open cut providing they were properly maintained. The measures normally used and recommended here would be low level bunding and the provision of pumps. Any bunding should be of a stabilised material which will not erode and wash into the drainage system.

Discharge from pumps should be directed to sedimentation basins to allow the medium to coarse sediments to settle by gravity. Where high percentages of fine sediments and colloids are present the water should be flocculated and filtered prior to discharging to the drainage system. The location and size of the water quality controls, including sedimentation basins, will need to be identified during the preliminary design phase.

The nominated alignment of the motorway along the "Direct Tunnel" route will necessitate permanent alterations to both local and trunk drainage infrastructure as the tunnel approaches the surface. In particular, care will be required for the section of proposed motorway between the Illawarra Railway and the Princes Highway where the tunnel cover below a major underground trunk drainage system may require special attention to support the pipes and measures to prevent stormwater infiltration into the tunnel. It is not considered feasible to re-route the system which connects with an open stormwater channel located north east of the sewerage outfall pipeline. Therefore, where construction using a cut and cover method is proposed, a bridge will be required to support the stormwater pipelines which will need to be replaced and/or sealed. Bypass pumping for the full pipe capacity is technically feasible but is unlikely to be practical. Where the motorway would remain in an open slot it will also be necessary to ensure that overland flow paths are maintained or that the stormwater pipeline has sufficient capacity for at least the 1% AEP storm runoff. Bunding would also be required to ensure that both local runoff and flows in excess of the underground system capacity do not enter the slot and or tunnel.

The height of the ground where the tunnel emerges will be important. Substantial areas of land east of Marsh Street are flood liable and the eastern tunnel portal should be located above the extreme flood height consistent with the adopted standard for the western portions of the tunnel, ie protection at least against the 0.02% AEP flood. The maximum flood height for much of this area will be governed by the sea level and should include an allowance for potential rises in sea level due to the "greenhouse" effect. Estimates of the 1% AEP sea level vary but are usually no lower than approximately RL 2.3m (AHD). Estimates of sea levels for extreme events vary considerably and should be the subject of a separate detailed report where any doubt exists. For initial feasibility studies, the adoption of an extreme flood level no lower than RL4.0m (AHD) is recommended.

A significant adverse impact of the "Direct Tunnel" route compared with the Preferred Option outlined in the EIS (Ref 3) is in respect to water quality in and near the Barton Park wetlands.

The Barton Park wetlands comprise 3 wetlands; the Eve Street wetlands and two much smaller degraded wetlands on the edge of the Kogarah Golf Course near Marsh Street.

The "Direct Tunnel " route would take the proposed motorway to the south of the SWOOS in close proximity to the Barton Park wetlands and would interfere either directly or indirectly with at least two of the wetlands.

Two possible alignments for the proposed motorway south of Marsh Street have been considered.

One possible alignment would require the motorway to straddle the SWOOS with supporting piers located on the edge of both the Eve Street wetland and the smaller wetland on the opposite side of the sewer outfall. The alternative alignment would direct the motorway over the centre of the Eve Street wetlands and would require a bridge with supporting piers located beyond the wetland in order to minimise adverse impacts on water quality during construction. In the former case, once construction has been completed and the area stabilised and restored no long term adverse impacts on water quality or flood behaviour would be expected. However in the latter case, although there will be no direct physical disturbance to the environment once the motorway has been completed, other issues, including increased shade due to the motorway superstructure, may affect water quality and therefore the health of the wetlands.

In order to protect the larger Eve Street wetland it is recommended that, where possible all motorway drainage be directed to the northern side of the SWOOS to connect with an upgraded drainage system located within the golf course as previously described by Willing & Partners (Ref 2). Local runoff currently entering the wetlands would continue to do so. This will avoid any long term change in water quality entering the Eve Street wetland and provide the opportunity to intercept and treat polluted runoff before it enters Cooks River. A typical treatment process would include either a small gross pollutant trap (GPT) or a Continuous Separation Deflector Trap (CSDT) at the head of a grassed swale drain which could incorporate reed beds. The GPT or CSDT would remove litter and particulates and the grassed swale drain and reed beds would reduce nutrient levels.

If the proposed motorway straddles the SWOOS, drainage to the northern side of the SWOOS may be via drains located beneath the motorway but above the top of the SWOOS. It is unlikely that approval would be given to locate new drains beneath the SWOOS due to its age and high risk of effecting its structural integrity. Therefore, if the motorway is located along the alternative alignment which would take it across the centre of the wetlands, drainage from the motorway should be contained within a sealed system until it can be safely discharged beyond the limits of the Eve Street wetlands. A welded high density polyethylene (HDPE) pipe system or equivalent would be considered suitable for isolating the motorway runoff from the wetlands. Such a system could be laid within the wetlands with minimal disturbance to the its environment.

It is possible that, in aligning the motorway to minimise the impact on the Eve Street wetland, the smaller wetlands would be destroyed either by the motorway structure occupying the wetland area and/or by cutting off existing drainage paths and starving the wetlands of water. If avoidance of the wetlands is not possible, further consideration should be given to re-establishing the smaller northern wetlands as an extension of the reed beds identified previously as part of the storm runoff treatment system.

Particular attention will also need to be given to maintaining either the existing or an equivalent channel connecting the Eve Street wetland with the Cooks River. Where a change in the drainage pattern occurs the extent and/or character of the wetland will be affected. Although the existing channel occupies a narrow space between the SWOOS embankment and natural high ground between the wetland and the river it should be possible to align, and/or modify, the motorway structure to allow the drainage pattern to remain. At worst this may require approximately 250 metres of pipeline to maintain the connection between the wetland and the river.

Providing drainage from the proposed motorway is directed away from the Eve Street wetland and the embankment does not isolate the area from the Cooks River then the existing flooding regime would be expected to remain largely unaltered. The existing sewer outfall is above the estimated extreme flood height for the Cooks River and has therefore already caused a modification to river flood behaviour in the area. This situation would not be expected to alter with the presence of the proposed motorway.

The construction phase would pose significant water quality problems with respect to the wetlands. The pollutants are expected to be primarily limited to sediments and petroleum products from construction machinery and because of the close proximity of the works to the wetlands, it is likely to be very difficult to avoid causing some adverse impacts on water quality. The provision of carefully installed and maintained geotextile fences between the works site and the wetlands together with a bund, made of sand or other material capable of absorbing polluting fluids, behind the geotextile fence, is considered the minimum protection required. Any bund material which has absorbed pollutants would need to be promptly removed and replaced with clean material. Depending on the final design and construction technique adopted, other more elaborate arrangements may be required. The protection measures adopted in this area should be re-evaluated as part of the preliminary and detail design phases.

Due to the importance of the wetlands it would be desirable to establish a water quality monitoring station and regime to check the effectiveness of water quality control measures established for both the construction and "in service" phases.

6. COOKS RIVER TO GENERAL HOLMES DRIVE

From the Cooks River to General Holmes Drive the "Direct Tunnel" motorway option would follow an identical alignment to the EIS option as discussed in the EIS (Ref 3) and therefore the comments made in the EIS apply equally to this option.

7. CONCLUSION

The problems highlighted with the EIS option where it emerges in the Wolli Creek valley at Turrella in respect to both flooding and water quality and the difficulties associated with the mitigation measures such as the flood cut are avoided by the "Direct Tunnel" alternative. Wolli Creek will remain intact with no changes of either a short term or long term nature in flow regime or water quality as a result of the proposed motorway.

The impacts of the "Direct Tunnel" route on flooding and water quality between Bexley Road and the Illawarra Railway relate to local drainage issues only and would occur primarily during the construction phase. During construction, the adoption of practices as discussed by Willing & Partners (Ref 2) would be considered sufficient to reduce, to an acceptable level, the risk of water pollution. Water pollutants would be primarily sediments and petroleum products used by construction machinery.

Long term adverse impacts on water quality may be reduced to negligible proportions because the route is remote from Wolli Creek and their are ample opportunities to provide permanent facilities to intercept and retain sediments and other water borne particulate pollutants washed from the motorway. There would be no adverse impacts on flooding in Wolli Creek except for localised effects associated with some of the vent locations.

However potential major impacts on the Barton Park wetlands and the Eve Street wetland in particular, are possible. The potential impact on the wetlands is considered to be the major difference between the "Direct Tunnel" option and the EIS option. There is potential for significant damage to the wetlands to occur during the construction period and any opportunities to lower the risk must be carefully examined. Should the "Direct Tunnel" option be adopted any opportunities to align the motorway so as to avoid any direct impact on the wetlands would be regarded as worthwhile.

Both the EIS option and the "Direct Tunnel" option would be expected to have similar problems with the management of acid-sulphate soils. Although these problems would be largely avoided in the Wolli Creek valley for the "Direct Tunnel" option the benefits may be countered by potential problems if vents are constructed alongside Bardwell Creek and Wolli Creek. Where acid-sulphate soils are encountered they should be managed in accordance with accepted practice as documented in the EPA guidelines *Assessing and Managing Acid-Sulphate Soils*.

Notwithstanding the concern for the integrity of the Barton Park wetlands, the "Direct Tunnel" option is considered likely to present fewer problems overall with respect to water quality, drainage and flooding compared to the EIS option.

REFERENCES

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5. WONG H.T., (1986), *Wolli Creek and Bardwell Creek Flood Study*, Rockdale Municipal Council.

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GLOSSARY

Annual Exceedance Probability (AEP)	refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be relatively large.
Average Recurrence Interval (ARI)	refers to the average time interval between floods of a given peak flow occurring over an infinitely long period. A 20 Year ARI flood would be expected to occur on average every 20 years during the infinitely long period. It does not infer that a 20 Year ARI flood for example could not occur in either the same or successive years.
Australian Height Datum (AHD)	a common national plane of level corresponding approximately to mean sea level.
catchment	the area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
critical duration	the duration of rainfall over a catchment which produces the maximum design flood discharge.
discretised	the process whereby a catchment is divided into subcatchments for use in the hydrological (rainfall-runoff) numerical model used to determine maximum discharge at a specified point along a drainage line or waterway.
design flood	a flood of known magnitude or probability of exceedance used for engineering design and planning purposes.
designated flood	(See flood standard)
development	the erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
discharge	the rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow which is a measure of how fast the water is moving rather than how much is moving.
extreme flood	a rare flood which is usually assumed to have a probability of occurrence significantly less than a 1% AEP (100 Year ARI) flood. The peak

	discharge may not necessarily equal the peak discharge for a probable maximum flood (PMF).
flood	relatively high streamflow which overtops the natural or artificial banks in any part of a stream or river.
flood hazard	potential for damage to property or persons due to flooding.
flood liable land	land which would be inundated as a result of the standard flood.
flood prone land	see flood liable land
floodplain	the portion of a river valley, adjacent to the river channel, which is covered with water when the river overflows during floods.
flood mitigation measures	the full range of techniques available to floodplain managers.
flood standard (or designated flood)	the flood selected for planning purposes. The selection should be based on an understanding of flood behaviour and the associated flood risk. It should also take into account social, economic and ecological considerations.
flood storages	those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
floodways	those areas where a significant volume of water flows during floods. They are often aligned with obvious naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, the areas of deeper flow or the areas where higher velocities occur.
gross pollutant trap (GPT)	a structure consisting of a vertical rack placed across the waterway and a sump immediately behind the rack for the purposes of intercepting and retaining water borne pollutants such as litter, flotsam and medium to coarse sediments. There are many variations ranging from small underground installations on piped drains to structures located on major waterways occupying areas of 400m^2 or more.
high hazard	possible danger to life and limb; evacuation by trucks difficult; potential for structural damage; social disruption and financial losses could be high.

hydraulics	the study of water flow; in particular the evaluation of flow parameters such as stage and velocity in a river or stream.
hydrograph	a graph which shows how the discharge changes with time at any particular location.
hydrology	the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
invert	the lowest point in a pipe or channel. For a channel this is equivalent to the exposed surface of the bed or base of the channel.
mathematical/computer models	the mathematical representation of the physical processes involved in runoff and streamflow. These models are usually run on computers due to the complexity of the mathematical relationships.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood (PMF)	the flood calculated to be the maximum which is likely to occur.
probability	a statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
runoff	the portion of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	equivalent to 'water level'. Both are measured with reference to a particular datum and location.
stage hydrograph	a graph which shows the variation in stage with respect to time. It must be referenced to a particular location and datum.
thalweg	the line representing the lowest point along the valley.

ABBREVIATIONS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
AHD	Australian Height Datum
ARR	Australian Rainfall and Runoff (1987 edition)
BOM	Bureau of Meteorology
CMA	Central Mapping Authority, New South Wales
DWR	NSW Department of Water Resources
EIS	Environmental Effects Statement
GPT	Gross pollutant trap
HEC-2	Computer program for determining water surface profiles.
PWD	Public Works Department, New South Wales
RORB	Rainfall/runoff routing program
RAFTS	Rainfall/runoff routing program
RTA	Roads and Traffic Authority, NSW
SWOOS	South Western Ocean Outfall Sewer.

APPENDIX A

A.1 Bardwell Creek Flood Levels

The location of the proposed motorway crossing of Bardwell Creek is under Coolabah Reserve, approximately 120m north of Bardwell Road and approximately 200m south of the East Hills Railway bridge and the confluence with Wolli Creek.

The 1% AEP flood level in Bardwell Creek at Coolabah Reserve has been estimated by Wong (Ref 5) as approximately RL 4.9m (AHD) which corresponds closely to the estimated 1% AEP flood level in Wolli Creek of RL 5.0m (Ref 1). Owing to the flat hydraulic grade under extreme flooding conditions and known overtopping of the railway embankment, the lower reaches of Bardwell Creek through Coolabah Reserve will be influenced by flooding levels in Wolli Creek and may be expected to give a reasonably good estimate of the flood levels at the location of the proposed air intake vent.

The previously suggested minimum standard for the proposed motorway (Ref 1) was based on the estimated 01.% AEP flood which was assumed to have a peak flow equivalent to twice the peak 1% AEP flow. Based on this assumption the estimated 0.1% AEP flood level at the confluence of Wolli Creek and Bardwell Creek is RL6.6m (AHD). It is normal practice in floodplain management to add freeboard to the design flood height in order to provide for hydrologic and modelling uncertainties and to provide some protection for more extreme events. A freeboard allowance of 1 metre is the currently accepted standard for flood protection levees and a similar allowance is considered appropriate for the proposed motorway.

To estimate the additional protection afforded by 1 metre of freeboard, the freeboard level was compared with the estimated flood height for a flood with a peak flow rate equivalent to three times the estimated peak 1% AEP flow. The flood height estimate was made using the hydraulic model, previously assembled for the EIS by Willing & Partners (Ref 1). The estimated flood height at the confluence of Wolli Creek and Bardwell Creek for a flood 3 times larger than the 1% AEP flood was estimated as RL 7.75m (AHD) or 1.15m above the estimated 0.1% AEP flood level.

Analyses for a large number of catchments in south -eastern Australia suggests that a peak flow 3 times larger than the peak 1% AEP flow may be expected to have an 0.02% annual exceedance probability. This is equivalent to the flood having a 1 in 5000 chance of occurring in any one year.

Therefore the Wolli Creek flood level is considered an appropriate level to adopt for initial planning and feasibility studies and it is recommended that, in the absence of detailed investigations and modelling, the top of the air vent should be constructed to a level no lower than RL 7.75m (AHD). The appropriateness of this value should be verified during the preliminary design phase.