HONG KONG GOVERNMENT
ENVIRONMENTAL PROTECTION DEPARTMENT

SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES

FINAL REPORT
(Volume 1 : Main Report)

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RETROACTIVE ROAD TRAFFIC

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ENPAC Limited

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1. INTRODUCTION

1.1 Background

Hong Kong has a very unique noise problem. High-rise, high density development and close proximity of dwellings, hospitals and other noise sensitive developments to major roadways have rendered traffic noise very difficult to ameliorate. While direct technical remedies such as erecting noise barriers and totally enclosing the roads are desirable, their applicability is very limited because of past neglect.

The Second Review of the 1989 "White Paper: Pollution in Hong Kong - A time to act", has identified the need for a study to review the practicability of reducing the adverse impacts brought about by existing roads in Hong Kong. Given the scope of the study required, the review is carried out in two phases. The Phase I review (this study) is a scoping study examining all roads on the feasibility of providing retroactive road traffic noise mitigation measures while the Phase 2 review will focus on the detailed engineering and design aspects of the recommended technical remedies for the roads identified in Phase 1 review. ENPAC Limited (ENPAC) was commissioned by the Environmental Protection Department (EPD) of the Hong Kong Government (Government) on 1 September 1994 to undertake the Phase 1 Study.

1.2 Terms of Reference

The Study has been conducted under the following terms of reference:

- To conduct a scoping study to examine all existing roads with a view to providing retroactive road traffic noise mitigation measures.
- To consult relevant Government Departments for their views and concerns on the development of direct technical remedies for existing roads.
- To recommend a list of existing roads with potential for providing retroactive direct technical remedies for the subsequent Phase 2 assessment. The recommendation will include appropriate form(s) of direct technical remedies, cost estimates of the measures as well as the likely noise reduction and number of dwellings to be benefitted from measures in place.
- To prepare a time table for incorporation of the recommended measures.

1.3 Structure of the Report

This report is contained in two volumes. Volume 1 (this text) contains Chapters 1 to 10, including all tables and figures, and Volume 2 contains all Appendices.

2. STUDY METHODOLOGY

2.1 General Approach

This study is much-needed to identify the extent of the noise impacts by existing roads in Hong Kong. However, given the scope of the study and the limited study period (4 months), it was considered necessary to adopt a reasonable and practical approach for this scoping study. To this end, a set of pre-determined screening criteria has been established to select these roads using the constraint mapping technique. Development of the screening criteria are described in Section 5.

The selected roads have been investigated in turn for possible direct technical remedies, and the number of dwellings to be benefitted from the measures and the cost of implementing the measures have been estimated.

This study has therefore comprised the following main tasks :

(a) development and establishment of screening criteria for the selection of noisy roads,
(b) initial noise impact assessment,
(c) compilation and appraisal of selected roads with potential for practicable direct technical remedies,
(d) evaluation of the effectiveness of available direct technical remedies for the selected roads, and
(e) compilation of a broad priority list for further investigation.

For the purpose of this study, all existing roads are classified into four broad types, namely highways (i.e. expressways and trunk roads), primary roads (i.e. primary distributors), district roads (i.e. district distributors) and local access roads (i.e. local distributors and rural roads). Noise sensitive receivers (NSRs) include those defined in the Hong Kong Planning Standards and Guidelines. However, at the First Study Management Group Meeting held on 12 September 1994 to discuss the approach and methodology for this Study, it was agreed that:

- Courts of law would not be regarded as noise sensitive buildings as they had been centrally air-conditioned.

- Educational institutions would be covered by a separate program, "Noise Abatement Measures in Schools", and they should be excluded from this study.

The application of friction course and other low noise road surfaces would not be considered as a direct technical remedy under this study since:

- EPD is currently implementing "Quiet Road Surface Programme" project to reduce traffic noise by applying low noise road surfacing material on high speed roads.

- EPD and the Highways Department (HyD) are currently studying the feasibility of applying low noise road surfacing material on local roads.

To avoid duplicating efforts, existing roads or road sections have been excluded from the identification process and noise assessment if any one of the following circumstances arises:

- The road/road section is under a concurrent noise impact or abatement study. This includes situations where the road/road section is being improved or widened to significantly impact on the NSRs around. According to the standing environmental policy, direct mitigation measures will be provided wherever practicable to reduce noise impact on nearby existing dwellings.

- Noise mitigation measures have already been provided or will be provided in accordance with previous EIA studies, except where serious complaints have been lodged.

- No existing/committed NSRs can be identified in close proximity to the road/road section. This includes situations where NSRs are recently demolished/removed; housing estates are being redeveloped; roads run in industrial estates or commercial centres.

- The road/road section runs in tunnel or underpass because the noise impact is unlikely to be significant due to the enclosed road environment.

2.2 Noise Assessment Criteria

At present, there is no policy or standard to address the noise problem arising from existing roads. Whilst road traffic noise problem is more amendable through planning process, for the purpose of identifying "noisy" roads for a retroactive noise mitigation feasibility study, it is considered reasonable to adopt similar criteria as for planning new roads or siting new NSRs. These criteria, according to the Hong Kong Planning Standards and Guidelines (HKPSG), require that the maximum permissible noise levels, L_{10}(1-hour), at the external facade due to road traffic should not exceed 70 dB(A) for domestic premises, 65 dB(A) for places of worship and 55 dB(A) for medical establishments. These noise criteria have also formed the basis for noise mitigation, i.e. the identified noise mitigation must aim to achieve the above noise criteria.

2.3 Initial Assessment of Noise Impacts

An initial noise assessment has been conducted to determine the extent of the noise impacts from existing roads on existing/committed NSRs in Hong Kong. The noise calculations have been based on the UK Department of Transportation (DOT) procedure "*Calculation of Road Traffic Noise*", 1988. In order to manage the large volume of calculations and data which would have been involved, the assessment has been based on the calculated noise levels at the nominal facade of each road which is defined as a fictitious facade located at the average distance from the road, 5m above the road surface and having a 160-degree angle of view of the road. In addition, several simplifying assumptions as described below have been used to estimate the input data for the calculations.

The traffic flows and percentages of heavy vehicles during peak hours have been obtained from "The Annual Traffic Census" 1993 published by Transport Department. For those traffic counting stations (i.e. coverage stations) where only Annual Average Daily Traffic (AADT) data are available, the following method has been adopted to estimate the traffic data at the station:

$$Q = AADT \times K_{av} \quad \ldots\ldots\ldots\ldots (1)$$

$$P = P_{av} \quad \ldots\ldots\ldots\ldots (2)$$

where

Q = Nominal peak hour traffic flow at coverage station

AADT = Annual Average Daily Traffic at coverage station

K_{av} = Average proportion of daily traffic in the peak hour of the core stations within the same traffic counting station group

P = Percentage of heavy vehicles at coverage station

P_{av} = Average percentage of heavy vehicles of the core stations within the same traffic counting station group

The vehicle speed is taken as the speed limit of each type of roads (i.e. 50 km/h for urban roads, 70/80 km/h for expressways) and the road gradient is taken as either 0, 3, 6, 9, 12 or 15% as estimated from 1:5000 survey maps.

For roads where no traffic data is available, it has been found by analyzing the traffic noise complaints data that seldom noise complaints arise from these roads. Appendix B summarizes the noise complaint records supplied by EPD, and an analysis of the complaint statistics is given in Table 1.

Table 1 Analysis of Traffic Noise Complaints Statistics

Road Type	Roads with L_{10} > 70 dB(A)[1]		Roads with Traffic Data	
	No.[2]	Percentage based on All Road Types (%)	No.[2]	Percentage based on Each Road Type (%)
EX	14	16.9	14	100
UT	5	6.0	5	100
PD	24	28.9	24	100
DD	30	36.1	29	96.7
RA	1	1.2	1	100
LD[3]	9	10.8	8	88.9
Total	83	100	81	97.6

Notes:
1 Noise level dominated by road traffic noise only.
2 Roads are counted separately if they appear in different records.
3 Including 1 local street.

Legends:
EX Expressway
UT Urban Trunk
PD Primary Distributor
DD District Distributor
RA Rural Road
LD Local Distributor (including local street)

According to these records, traffic noise complaints were lodged against 83 roads (the roads are counted separately if they appear in different complaint records) where noise levels L_{10} of over 70 dB(A), mainly due to road traffic, were recorded. However, of these 83 roads only one is a local street; the rest (82 roads) are highways, distributors and rural road, for which the majority of the traffic information can be readily obtained from *"The Annual Traffic Census"* published by Transport Department. Statistically, it is apparent that local streets only receive occasional traffic noise complaints, probably because of the lower traffic volumes and the associated insignificant noise impacts. As such, exclusion of the local streets is unlikely to degrade the quality of this study. Also on a collective basis, over 97% of the roads analyzed have published traffic flow data. Therefore, for the purpose of this study, it is considered reasonable to conduct this initial noise impact assessment based on roads with published traffic data.

In addition, facade noise levels have also been obtained from traffic noise complaint records/statistics, and school survey reports supplied by the EPD where the noise sources were identified to be road traffic.

2.4 Assessment of Potential for Noise Mitigation

Following the selection of roads with potential for provision of retroactive noise mitigation, each section of the selected roads has been subject to a more detailed, site specific noise assessment to identify the need for and the most appropriate form of noise mitigation. The effectiveness of implementing the identified measures, in terms of the noise reduction which may be achieved and the number of dwellings to be benefitted has also been evaluated.

The assessment is based on the calculated noise levels using the DOT procedure at representative noise sensitive facades selected from the particular road section where the need for noise mitigation has been identified. Noise calculations are made for the first floor mid-window level (which is at 5m AG unless otherwise indicated), the mid-floor level and the top-floor level (based on 2.8m per floor level). Only those storeys above the road level have been taken into account. Site-specific conditions, e.g. angle of view, road gradient, screening by adjoining structures, etc. are used as much as practicable. All roads likely to affect the NSR have been included to determine the overall noise levels.

While the form of noise mitigation has been established (see Section 3.2), the horizontal extent of coverage e.g. length of barriers, has not been determined. For the purpose of the noise assessment, it has been assumed that the proposed barrier/enclosure must screen at least 135 degrees of the angle of view of the road at each exposed NSR. The exact configuration will be subject to detailed design to be conducted in Phase 2. To better utilize the limited resources, there is a need to give priority to measures which could protect higher percentage of dwellings. As such, it was decided that the identified form of the noise mitigation measure must aim to achieve the HKPSG noise criteria at 50% or more of the exposed population over a vertical section for high-rise buildings or over a horizontal section for low-rise buildings such as village houses.

3. IDENTIFICATION OF PRACTICABLE DIRECT TECHNICAL REMEDIES

3.1 Representative Road-Receiver Configurations

The feasibility of providing direct technical remedies to existing roads depends to a large extent on the presence and arrangement of the following road and roadside features:

- Road level
- Number of carriageways
- Transportational mode other than vehicular traffic
- Verge, marginal strip and/or hard shoulder
- Central reserve
- Footway
- Embankment
- Bicycle track
- Retaining wall

A review of the spatial relationship between existing roads and the adjoining sensitive uses in Hong Kong has identified 11 road-receiver configurations. Table 2 summarizes these 11 categories and Figures 1 to 11 illustrate conceptually these relationships.

Type A: Type A configuration represents typical rural roads found in the New Territories. Noise sensitive receivers (NSRs) usually consist of isolated or clustered low-rise buildings which are distributed at some distance from either sides of the road. (e.g. Castle Peak Road near San Wai Tsuen, Yuen Long; Fan Kam Road, Pat Heung)

Type B: Type B configuration is usually found along expressways or trunk roads in both rural and urban areas. NSRs, which are normally clustered low- or high-rise buildings, are separated from either sides of the road at a moderate distance. (e.g. Lung Cheung Road, Wong Tai Sin)

Type C: Type C configuration delineates those roads with separate carriageways. NSRs are usually isolated or clustered high-rise buildings located at some distance from one side of the road. (e.g. Tuen Mun Road near Tsuen Wan)

Type D: Type D configuration denotes roads with isolated or clustered NSRs distributed at a moderate distance from one or both sides of the road. The NSRs could be low- or high-rise buildings. (e.g. Jockey Club Road, Sheng Shiu; Fung Shue Wo Road, Tsing Yi Estate)

Type E: This type of road-receiver relationship is often found in urban areas or new towns. High-rise NSRs are grouped in clusters or continuously on one or both sides of the road. Separation between the NSR and the road could range from small to moderate. (e.g. Wai Tsuen Road, Tsuen Wan; Sheung Fung Street, Wong Tai Sin; Ting Hau Temple Road, North Point)

Type F: Type F configuration represents typical road conditions in densely populated urban areas. NSRs are continuous or clustered high-rise buildings usually mushrooming at both sides of the road. There is limited building set back from the carriageway and the ground floors of the NSRs are very often occupied by commercial development. (e.g. Whitfield Road, North Point; Yen Chow Street, Sham Shui Po; Cheung Sha Wan Road, Sham Shui Po)

Type G: For this type of road-receiver configuration, NSRs are located at a moderate distance from an elevated road (or the elevated section of a road), either on one side or both sides. NSRs are usually high-rise buildings; however, they could also be low-rise buildings, particularly for those located in new towns. (e.g. Tsing Tsuen Road, Tsuen Wan; Tai Wo Road, Tai Po; Island Eastern Corridor, North Point)

Table 2 Representative Road-Receiver Configurations (Road Sections)

Section	Typical Road Type	Road Level	Carriageway	Other Traffic	Road Features		Roadside Features			
					Verge/Marginal Strip/Hard Shoulder	Central Reserve	Footway	Embankment	Bicycle Track	Retaining Wall
A	RT/RA	At Grade	Single	Nil	Yes/No	No	Yes/No	No	No	No
B	EX/UT/RT	At Grade	Dual	Nil	Yes	Yes	No	No	Yes/No	No
C	EX/UT/RT	At Grade	Dual	Nil	Yes	No	No	No	No	No
D	PD/DD	At Grade	Single/Dual	Nil	Yes/No	Yes/No	Yes/No	No	Yes/No	No
E	DD/LD	At Grade	Single/Dual	Nil	No	Yes/No	Yes	No	No	No
F	PD/DD/LD	At Grade	Single/Dual	Nil	Yes/No	Yes/No	Yes	No	No	No
G	UT/PD/DD	Elevated	Single/Dual	Nil	Yes	Yes/No	No	Yes	Yes/No	No
H	UT/PD	Elevated[a]	Single/Dual	Nil	Yes	Yes/No	Yes	No	No	No
I	DD/LD	At Grade[b]	Single	Nil	No	No	Yes	No	No	No
J	All Types	At Grade[c]	Single/Dual	Nil	Yes/No	Yes/No	Yes/No	Yes	No	Yes
K	PD/DD/LD	At Grade	Single/Dual	Tram / LRT	Yes/No	No	Yes	No	No	No

LEGENDS:

EX	Expressway
PD	Primary Distributor
DD	District Distributor
RA	Rural Road
MTR	Mass Transit Railway
RT	Rural Trunk Road
LD	Local Distributor
UT	Urban Trunk Road
LRT	Light Rail Transit

NOTES:

a	With road(s) under elevated road.
b	Adjacent to elevated MTR line or flyover.
c	With embankment/retaining wall at one or both sides.

Type H: Type H configuration is similar to Type G except the NSRs encountered are usually high-rise buildings and there is limited separation between the NSR and the elevated road. (e.g. Tsing Fung Street Flyover, North Point; Canal Road Flyover, Wanchai)

Type I: For Type I configuration, the road(s) is running adjacent to a flyover or an elevated MTR line. Continuous high-rise NSRs spread along either sides of the road(s). Buffer distance between the road and the NSR could vary from a few meters to over tens of meters. (e.g. Kwun Tong Road, Ngau Tau Kok; Boundary Street at Cheung Sha Wan Road, Mong Kok)

Type J: Type J configuration represents those sections of roads with embankments or retaining walls on either sides. High- or low-rise NSRs are usually situated at some distance from the roads. (e.g. slip roads at Tai Po Road/So Kwun Po Road, Fanling)

Type K: This type of configuration is similar to Type F except there is a tram line or Light Rail Transit (LRT) line running on the road. (e.g. Shau Kei Wan Road , Shau Kei Wan; Tuen Mun Heung Sze Wui Road, Tuen Mun)

3.2 Available Forms of Practicable Noise Mitigation

A wide variety of direct technical remedies are available to abate road traffic noise. Experience with the application abroad has shown that the following forms, when suitably implemented, are effective :

- Roadside barriers (conventional, inverted, curved, landscaped, absorptive panel, etc.)
- Noise enclosures (semi-enclosed, fully enclosed and noise control shelter)
- Topographical features (earth mound, earth bank, road cutting, etc.)
- Road decking
- Low noise road surfaces (e.g. friction course).

However, Hong Kong has a unique road-receiver environment which differs considerably from that in other countries. The high-rise, high density nature of developments, compounded by close proximity of noise sensitive receivers to noisy roadways, have rendered traffic noise very difficult to ameliorate. The situation is even worse for existing roads due to past neglect.

While the potential application of noise mitigation measures on existing roads is subject to a wide range of factors (e.g. safety, structural considerations, ventilation requirements, maintenance considerations and public disturbance, etc. as detailed in Section 4.1 below), the forms of mitigation measures are, to a large extent, dictated by the road-receiver configurations.

For instance, Types E, F, G, H, I and K are the most common road-receiver configurations in Hong Kong. In order to provide adequate protection of the sensitive receivers in these cases, semi-enclosure, enclosures and, to a lesser extent, barriers stand out as the more rational choices. Low noise road surfacing is also applicable where maintenance would not totally prelude its use. On the other hand, topographical features such as earth mounds or earth banks have a very limited application here because of the severe land intake requirements. Road decking is seldom applicable because of the need to integrate building development with road construction and maintenance. For those road-receiver configurations involving low-rise buildings and/or with large buffer distance like Types A and B configurations, roadside barriers or semi-enclosures are appropriate.

Therefore, it is unlikely that all the above-mentioned noise reduction measures can be practically applied in Hong Kong. Consequently and given that low noise road surface is under other concurrent study/program by EPD and HyD, four different forms of noise mitigation measures have been identified for further discussion. All of these mitigation options have been successfully adopted in Hong Kong and broad local experience has been gained:

- Plain barrier (maximum 3.5 m high)
- Plain barrier (maximum 7 m high)
- Semi-enclosure
- Full enclosure

Figures 12, 13, 14 and 14A illustrate the conceptual arrangement of the identified forms of direct mitigation options. All these noise barriers and enclosures are free-standing structures supported on spread or piled foundations. In addition, the noise structures are either located at the back of the footpath or, in the absence of any footpath, at minimum 1m from the carriageway slab. For the purpose of this study, it has been assumed that a semi-enclosure could be erected to cover the entire kerbside lane while a full enclosure could have a single span up to 25m.

Noise barriers and enclosures can be constructed of various materials. Common materials used for noise screening structures include steel, aluminium, polycarbonate or acrylic sheets, concrete, masonry, brick, glassfibre reinforced concrete (GRC), wood and proprietary acoustic panels. Each material has its specific merits and dismerits, both acoustically and non-acoustically. To achieve a more satisfactory result, a combination of different materials may sometimes be needed. The ultimate choice of materials will, however, depend on the noise environment of the existing roads, as well as spacial relationships between roads and receivers.

4. APPLICATION OF NOISE MITIGATION MEASURES TO EXISTING ROADS IN HONG KONG

4.1 Considerations in Application to Existing Roads

The feasibility of implementing suitable direct technical remedies on existing roads is largely controlled by the existing road-receiver configuration and the road design. Conventional plain barriers are the simplest noise abatement structure to use. Among the basic forms of mitigation measures identified, this noise screening method requires minimal space. However, the applicability of plain barriers may be fairly limited. Their uses are very often confined to where low-rise buildings are to be protected, or where there is an adequate set back of sensitive receivers. Besides, the effectiveness of plain barriers should be assessed on individual merit as the successful application of barriers will depend on many factors such as traffic flow, topographic conditions and source-receiver separation distance.

Generally, semi-enclosures provide a more effective noise protection to affected receivers than that offered by plain barriers. Subject to the availability of space and compliance with the safety requirements such as sightline distance, semi-enclosures could be built against the edge of road. Should existing infrastructure permit, a properly located semi-enclosure may protect high-rise buildings close to a road.

In terms of acoustical performance, complete enclosures can reduce road traffic noise by a substantial amount. Without the safety constraints imposed by existing road conditions (e.g. sightline problem), they are one of the most effective means in shielding traffic noise from reaching high-rise receivers in the vicinity of noisy roads. Despite their effectiveness on noise reduction, factors such as road structure, visual impacts, maintenance problems and ventilation requirements should be considered carefully when conducting the detailed design.

Among the many factors,which may influence the determination of form, location and material of noise abatement structure, safety, structural consideration, ventilation and sunlight, maintenance, public disturbance and visual impact stand out as the critical determinants for providing noise mitigation measures on existing roads. With the exception of safety, problems brought about by other factors could very often be overcome by careful design, according to previous implementation experience. While safety constraint could often render the erection of noise mitigation measures on existing roads impractical, recent EIA studies such as Route 5 Extension in Tsuen Wan provide workable solutions to incorporate this concern into the noise barrier/enclosure design.

Safety

From a safety standpoint, noise barriers and enclosures should not be installed where they will present a hazard to road safety. Wherever existing conditions allow, it is desirable to locate a noise barrier beyond the recovery zone of a carriageway, though the actual placement will vary with the width of verge, marginal strip and/or hard shoulder. Set back requirements of noise reduction measures should be evaluated for traffic safety with special emphasis on road alignment, sight distance and line-of-sight, which in turn are functions of vehicle speed, deceleration rate, radius of road/ramp curvature and driver reaction time. Due considerations should be given to situations like on- and off-ramps, ramp intersections, and intersecting roadways.

In densely developed areas, maintenance of adequate emergency access becomes a crucial safety factor. The noise screening structure should not obstruct the egress of public in crisis situations, and operation of fire engines, ambulances, police vehicles, cranes and other emergency vehicles, equipment or plant. In this respect, restrictions on the setting out and dimensions of noise barriers or enclosures should be observed to minimize the safety

implications. On the other hand, obstruction to pedestrian flows and creation of criminal black spots should also be prevented as far as possible.

Proper selection of barrier and enclosure materials constitutes another important safety aspect. Metallic and transparent materials can produce head-light glare at certain incident angles. Materials that have low fire rating or produce toxic fumes in a fire should be avoided. Additionally, the screening structure should be carefully designed such that it will not be easily broken into splinters in a crash situation. Under certain circumstances, addition of a safety barrier may be desirable.

Structural Considerations

As noise screening structures are to be erected on existing roads, the structural integrity of noise barriers and enclosures should be assessed in relation to the infrastructure setting. For situations involving elevated roads, embankments, retaining walls, steep slopes, services mains and/or foundations, structural impacts should be thoroughly investigated, and appropriate installation restrictions, design standards and guidelines should be strictly followed. For instance, HyD advise that installation of barriers or enclosures would be impractical on existing roads and flyovers because of the additional loading. To reduce the extra loading imposed on the infrastructure, self-supported noise screening structures with independent foundation should be employed where adequate space is available.

Other structural considerations such as wind loading should also be taken into account when evaluating the potential of erecting direct technical remedies on existing roads.

Ventilation and Sunlight

To prevent accumulation of vehicle exhaust gases, adequate natural or forced ventilation should be provided for full noise enclosures. Special circumstances such as where extremely high traffic volume and negligible road-receiver separation occur may warrant the verification of ventilation requirements even in the case of semi-enclosures. Enclosure headroom and length are important considerations when it comes to ventilation needs.

A high noise barrier or enclosure placed close to residents or other sensitive receivers may block the incoming sunlight, reduce the amount of natural ventilation and create turbulence, which would alter the micro-climate ultimately. The noise screening structure shall therefore be erected in such a way to minimize these adverse effects on buildings.

Maintenance Considerations

Maintenance issues pertaining to the addition of a noise screening structure to an existing roadway consist of two major aspects: maintenance of the noise barrier or enclosure itself, and maintenance associated with the existing road and roadside facilities.

In general, maintenance of barriers or enclosures may be relatively less problematic, as the choice of materials and cleaning arrangement (and to a lesser extent, forms and layout of mitigation measures) are basically controllable. However, the proposed mitigation structure may obstruct the original maintenance access and cause inconvenience for the servicing of existing roads and related facilities. Potential maintenance difficulties may further limit the options of suitable mitigation measures to busy or heavily serviced roads.

For the maintenance of noise abatement structure, the following points should be considered:

- Noise screening structures made up of acrylic and polycarbonate panels may subject to discolouration, ultraviolet attack and/or dust buildup, which may lead to consequent loss of transparency.

- Accumulation of rubbish on the roof of noise enclosures could create significant maintenance and hygiene problems, particularly where the enclosures are located right adjacent to domestic premises. In addition, the cover of the enclosures could also be damaged by objects dropped from nearby high-rise buildings.

- Artificial lighting is usually required in both full enclosures and semi-enclosures. Special maintenance arrangement such as temporary closure of traffic lane may be required when servicing the luminaries. Nevertheless, this problem could be resolved if provision for maintenance access is made in the noise mitigation structure.

Public Disturbance

Potential disturbance to the public is another concern for the selection, design and construction of direct technical remedies on existing roads. For example, erecting noise reduction structures on major routes and in busy commercial areas could cause significant public inconvenience. As an extreme example, the installation of noise enclosures or barriers along Nathan Road will obviously bring about intolerable disruption or interruption to the roadside commercial activities, which in turn would not only limit the choice of mitigation measures, but also render the provision of practicable noise mitigation solution impracticable. Despite the potential impacts of erecting noise screening structures on adjacent shops, it is yet possible to build noise barriers/enclosures in urban areas (e.g. Road 3/2 in Tsuen Wan).

Visual Impacts

The noise screening structures should preferably be planned to match the visual characters of the transportational and adjoining environmental elements. However, the design and placement of direct technical remedies are often governed by the existing road-receiver conditions. Despite this, various visual concepts should be employed as far as possible to avoid excessive visual impacts such as shading and tunnel effects. These two effects will not only increase the visual dominance of the screening structure, but they will also impair the visual and psychological perception of the drivers. Adverse visual impacts of noise barriers/enclosures, however, could be ameliorated through careful design such as proper selection of materials and colours, and mindful layout planning and landscaping.

4.2 Examples of Successful Application of Noise Mitigation Measures in Hong Kong

Despite the considerable limitations in implementing direct technical remedies on existing roads in Hong Kong, there are successful examples where noise mitigation measures work. Table 3 illustrates examples of noise barriers and enclosures installed in Hong Kong.

Table 3 Noise Barriers and Enclosures in Hong Kong

Location	Barrier Form	Materials	Size (H x L, m)	NSR Protected
Fenwick Pier Street Flyover	Plain Barrier	Concrete	1.8 x 50	Hong Kong Academy for Performing Arts
Flyover at Hing Wah Estate	Plain Barrier	Acrylic Sheets	3 x 100	Rotary Club of Hong Kong Island West Morninghope School
Tolo Highway and Slip Road	Plain Barrier	Precast Concrete	1.8 x 140 1.8 x 309	Wan Tau Tong Estate
Shatin Road near Pok Hong Estate	Plain Barrier	Acrylic Sheets	4 x 185	Schools in Pok Hong Estate
Tate's Cairn Tunnel Approaches at Choi Hung Estate	Enclosure	GRC and Acrylic Panels	5.5 x 119	Choi Hung Estate
Tate's Cairn Tunnel Approaches at Richland Gardens	Enclosure	GRC and Acrylic Panels	5.5 x 166	Richland Gardens
Route 5 - Shatin Approach	Plain Barrier	Acrylic Sheets	1.5-4 x 991	Mei Lam Estate
Lei Yue Mun Road	Deck	Concrete Decking	261 L x 45.5 W	Sceneway Garden
Route 5- Tsuen Wan Approach Cheung Pei Shan Road	Plain Barrier	Crib Wall	2-3 x 340	Sam Tung Uk Village and Hoi Pa Resite Village
Yuen Long - Tuen Mun Eastern Corridor	Plain Barrier	Acrylic Sheets	3 x 32	To Yuen Wai
A Kung Kok Road	Plain Barrier	Concrete Wall with Transparent Panels	3 x 645	A Kung Kok Village
Smithfield Extension	Plain Barrier	**	**	Mei Wah House and Wah Fai Mansion
Road 3/2 in Tsuen Wan	Enclosure	**	**	Kam fung Garden, Tsuen Tak Gardens and Joyful Buildings

Notes: ** Subject to detailed design

Source: Noise Policy Group, EPD, "Application of Screening Structures to Abate Noise from Surface Transportation"

5. DEVELOPMENT OF SCREENING CRITERIA FOR PROVIDING RETROACTIVE NOISE MITIGATION

The constraint mapping technique has been employed to select a manageable number of roads for detailed engineering studies. In essence, this comprises establishing a set of screening criteria which are applied systematically to screen all existing roads.

Given that there are tens of thousands of roads over the territory, it is prudent to apply screening criteria without compromising the study result. The following 3-level screening procedure aims to provide a pragmatic system to select these roads for further investigation :

Level 1 - Policy Consideration

Selection Criterion: That the road must be "noisy".

For the purpose of this study, roads are defined as "noisy" if any one of the following conditions is met :

(a) Peak-hour L_{10}(1-hour) at a nominal facade from the edge of the carriage exceeds the HKPSG noise criteria, i.e. 70 dB(A) for domestic premises, 65 dB(A) for places of public worship and 55 dB(A) for medical establishments; or

(b) Noise complaints have been received by EPD and the measured noise level due to road traffic at the facade of the complainant exceeded L_{10}(1-hour) 70 dB(A);

(c) Measured noise levels reported in a school survey report supplied by the EPD and normalized at residential facade exceeded L_{10}(1-hour) 70 dB(A).

The above criteria follow directly from an analogy of the HKPSG criteria.

Level 2 - Macroscopic Consideration

Selection Criterion: That the road is amendable to retroactive treatment without adverse effects on safety, structural integrity and public/business activities.

A Consultation Paper has been sent to all concerned Government departments in November 1994 to consult their views and concerns on the implementation of retroactive noise mitigation of existing roads and comments have been received. Responses to comments from these departments are included in Appendix J.

For example, the Fire Services Department (FSD) have expressed grave concerns about the likely adverse effects of barriers or enclosures on rescue and fire fighting operation. FSD comment that operations will be severely impaired if noise screening structures are erected at positions such that: (1) external rescue and fire fighting operation by means of ladders is rendered impossible; (2) vehicular access to areas on both sides of a road is blocked; or (3) emergency crossing to the opposite lane of a road is blocked.

HyD, on the other hand, have requested that the foundation of a noise screening structure should be kept clear from the road infrastructure (i.e. the foundation slab should be wholly outside the footway, or if there is no footway, at least 1m from the carriageway slab). This space requirement may not be met for roads running through urban areas because of the often limited roadside space. HyD dismiss as impractical any proposals to fix barriers or enclosures on existing highway structures, unless separate or independent structures could be provided. HyD also point out that improper location of noise screening structures could cause severe public and business disturbance (e.g. disruptions to kerbside parking, loading/unloading,

vehicular access to buildings and commercial activities).

The above comments have formed the basis for the development of this Level 2 criterion and can be summarized as :

(a) Blockage or obstruction to fire fighting or emergency access.
(b) Insufficient space for installation.
(c) Significant impact on public/business activities.
(d) Significant impact on existing road structures, i.e. existing flyovers, central dividers, etc.

Level 2 has therefore aimed to select those "noisy" roads which may have provisions along some sections to avoid creating these adverse impacts. These selected roads have been subject to a more detailed investigation on site at Level 3 based on other concerns of these departments.

Level 3 - Local Consideration

Selection Criterion: That the section or subsection is amendable to retroactive treatment in a practical and effective manner.

Level 3 has aimed to focus on one or more sections or subsection of a "noisy road" with a view to identifying one or more for treatment and thereafter to identify the form, practicability and effectiveness of the treatment.

In order to select the sections or subsections for noise treatment, it has been necessary to evaluate the effectiveness of providing the treatment. As agreed with the EPD, due to resources constraint, higher priority has been allotted to those road segments where 50 % or more of the exposed population may be practically protected or where the exposed population is sufficiently clustered together for a mass protection.

For a given barrier or enclosure configuration, the following factors may degrade the performance of the noise treatment and hence whether 50 % or more of the exposed population may be practically protected :

(a) Presence of multiple vehicular/pedestrian access in the close vicinity.
(b) Presence of sightline problem which dictates that the barriers or partial enclosures must be setback further from the edge of the road.

For example, in well-developed areas like the urban districts, the presence of multiple road junctions, bus lay-bys, pedestrian crossings, MTRC entrances and private driveways, etc. over a short length of road section tends to degrade the acoustic performance of any noise screening structure and very often may render the structure ineffective to protect the target NSRs. This is because openings are needed in the structure to maintain the flow of pedestrian and traffic.

In general, barriers and partial enclosures may be placed at 3m from the road edge of the straight section of a road without impairment of the sightline. However, for a curved section with a speed limit of 70 km/h, it is a requirement of the Transport Department that the barriers/partial enclosures must be so located to give a clear visibility of 125m ahead. Similarly, a 70m visibility line must be maintained for a curve with a speed limit of 50 km/h. As a result, additional setback would be required to maintain the required visibility.

Another practical consideration is to determine whether the exposed population is sufficiently clustered together. A desk-top survey of the village settlements along rural roads shows there are a large number of isolated, low-rise settlements which are potentially amendable to retroactive road traffic noise mitigation measures. However, given the limited resources

available, it is unlikely that all can be equitably protected. Apparently, it is more effective to protect clustered settlements such as villages with a noise barrier than isolated houses with a number of shorter barriers. A "linear density", which is defined as the total number of dwellings protected per unit length along the road, has been employed to screen these rural roads. Mitigation works which result in more dwellings to be protected per unit length have higher linear densities.

Typically, the length of clustered rural developments ranges from approximately 70 to 200 m, with the total number of dwellings varying between 30 and 90 units. The linear densities of the developments have been calculated to be in the range of 0.24 and 0.6 dwelling/m. Based on the shortest length (i.e. 70 m) and the lowest linear density (i.e. 0.24), the linear density of 17 dwellings per 70m has been adopted as a screening criterion. Rural developments with a linear density lower than the criterion will not be recommended for Phase 2 study because of the ineffectiveness of the noise mitigation.

Figure 15 shows a flow chart summarizing the screening procedures of noisy roads with potential for retroactive noise mitigation.

6. SELECTION OF EXISTING ROADS FOR RETROACTIVE NOISE MITIGATION

6.1 Level 1 Selection

Appendix A gives the calculated noise levels at the nominal facades of all roads with traffic data. All noise complaint reports and school survey reports supplied by the EPD have been analyzed and the results are summarized in Appendix B and Appendix C respectively. Based on these results, all roads with noise levels exceeding 70 dB(A) at the nominal facade have been selected and are contained in Appendix D for further screening.

While Appendix A covers mainly all major roads, Appendices B and C cover major and some minor roads and hence supplement the results in Appendix A. It should be noted that results for major roads in Appendix A are found to be consistent with the results in Appendices B and C.

The identified "noisy roads" are summarized in Appendix D. As shown in this Appendix, 665 roads out of 740 roads included (or 90%) in the study are considered "noisy" by the Level 1 criterion.

6.2 Level 2 Selection

Level 2 selection has resulted in only 34 of all "noisy roads" which may be considered for further investigation. These roads include mainly the expressways and primary distributors, and to a lesser extent, district distributors in new towns and fringe areas in developed districts. An appraisal of these roads is given in Appendix E. The short-listed roads are:

(1) Island Eastern Corridor (Tai Koo Shing)
(2) Pokfulam Road
(3) Victoria road
(4) Aberdeen Praya Road
(5) Ching Cheung Road
(6) Lung Cheung Road
(7) Cornwall Street
(8) Tung Tau Tsuen Road
(9) Po Kong Village Road
(10) Hong Ning Road
(11) Hip Wo Street
(12) Sau Mau Ping Road
(13) New Clear Water Bay Road
(14) Cha Kwo Ling Road
(15) Che Kung Miu Road
(16) Hung Mui Kuk Road
(17) Tin Sam Street
(18) Tai Chung Kiu Road
(19) Yuen Wo Road
(20) Chap Wai Kong Street
(21) Ma On Shan Road
(22) Ting Kok Road (Sections in rural areas)
(23) Po Lam Road
(24) Po Lam Road North
(25) Po Hong Road
(26) Fung Shue Wo Road
(27) Lung Mun Road
(28) Tai Po Road (Sections in rural areas)

(29) Tuen Mun Road (Tsuen Wan, Tsing Lung Tau and Castle Peak Bay)
(30) Castle Peak Road (Sections in rural areas)
(31) Hiram's Highway (Sections in rural areas)
(32) Tolo Highway (Ma Liu Shui and Tai Po Kau)
(33) Cheung Pei Shan Road
(34) Junk Bay Road (Lam Tin section)

6.3 Level 3 Selection

On-site investigation has confirmed that about 19 out of the 34 "noisy roads" may be provided with retroactive treatment along some sections or subsections of the roads. A list of the identified road sections is shown in Table 4 and an appraisal of these roads is given in Appendix F. Figures 16-34 show the conceptual design/arrangement of retroactive noise barriers, partial enclosures and full enclosures identified for these road sections based on the concerns of the relevant departments.

About half of the identified roads are highways or primary roads with a Type B/C road-receiver configuration (see Section 3.1). Adequate roadside reserves and moderate to ample road-receiver buffer distance provided by these roads greatly enhance the possibility of the installation of direct technical remedies. A number of district distributors in the new towns (e.g. Sha Tin, Tai Po, Tuen Mun and Tseung Kwan O), mostly of Type D configuration, have also been selected for a more detailed evaluation. Cramped road environment has been avoided in these new towns because of the orderly developed infrastructure and the well planned town layout. Roadside space may be available for the accommodation of the noise screening structures without adversely impairing emergency operations, road safety and commercial activities.

None of the short-listed roads is located in the old urban areas. The only exception to this is Tung Tau Tsuen Road, where the adjoining housing estates have recently been redeveloped. In view of the set back of the new residential towers and the provision of open space along the frontage, it is feasible to erect noise barriers or enclosures in this road.

Certain roads in the rural areas with a Type C road-receiver relationship (e.g. Castle Peak Road) have also been identified for retroactive treatment assessment. The rationale for the inclusion of these roads is obvious: low noise barriers, which require only minimal installation space, are effective enough to protect the village houses distributed at some distances from the roads. By the same token, if the targeted NSRs are low-rise buildings such as temporary housing areas (also subject to further consideration of the programmed demolition dates), provision of noise mitigation measures is often possible even the roads are located in the urban areas. Che Kung Miu Road, Ma On Shan Road and Fung Shue Wo Road are examples of those roads selected with such road-receiver environment.

Table 4 **Roads with Potential for Retroactive Noise Mitigation**

Road	Section	Road Type	Location
Island Eastern Corridor	Tai Koo Shing	EX	Tai Koo Shing
Tung Tau Tsuen Road	-	DD	Kowloon City / Wong Tai Sin
Che Kung Miu Road	-	PD/DD	Sha Tin
Tin Sam Street	-	DD	Sha Tin
Hung Mui Kuk Road	-	PD	Sha Tin
Tai Chung Kiu Road	-	PD	Sha Tin
Yuen Wo Road	-	PD	Sha Tin
Ma On Shan Road	-	PD	Sha Tin / Ma On Shan
Ting Kok Road	Yuen Sin Road to Brides Pool	DD/LD/RA	Tai Po
Po Lam Road North	-	PD/DD	Tseung Kwan O
Po Hong Road	-	PD/DD	Tseung Kwan O
Fung Shue Wo Road	-	LD	Tsing Yi
Tai Po Road	Fanling	EX	Fan Ling
Tuen Mun Road	Tsuen Wan Tsing Lung Tau Castle Peak Bay	EX EX EX	Tsuen Wan Tsing Lung Tau Castle Peak Bay
Castle Peak Road	Hung Sui Kiu Ping Shan	RT RT/DD	Yuen Long
Hiram's Highway	Marina Cove	RA	Sai Kung
Tolo Highway	Ma Liu Shui Tai Po Kau	EX EX	Ma Liu Shui Tai Po Kau
Cheung Pei Shan Road	-	PD/DD	Kwai Chung
Junk Bay Road	Lam Tin	PD	Kwun Tong

Legends: EX Expressway; DD District Distributor; LD Local Distributor; PD Primary Distributor; RA Rural Road; RT Rural Trunk

7. PRELIMINARY APPRAISAL AND COST ESTIMATION FOR NOISE MITIGATION

The selected roads have been subject to a more detailed investigation, including site survey to identify the feasibility of providing noise treatment in the light of the concerns of the Government, the number of dwellings likely to be protected and a site-specific noise calculation to determine the noise reduction and the effectiveness of the identified measures.

Appendix G gives the predicted noise levels at the first floor (above road level), mid-floor and top-floor, together with the input data without noise mitigation. Appendix H gives the corresponding predicted noise levels with the form(s) of mitigation measures identified, together with the number of dwellings protected.

The cost-effectiveness of the identified treatment has been estimated in terms of the number of dwellings to be protected and the noise reduction as measured at the mid-floor level (top-floor level for 2-storey buildings).

The cost has been based on the results of similar studies by ENPAC and the unit costs are listed in Table 5 below. These costs include capital and maintenance costs. A cost-effective analysis is given in Appendix I. Typical construction of barriers and enclosures adopted for the preliminary cost appraisal are:

3.5m high plain barrier: The barrier may be designed as free standing wall on reinforced concrete pads or shallow spread foundation. A simple, cost effective form of construction would be steel post with glassfibre reinforced concrete (GRC) panels.

7m high plain barrier: Where a barrier much in excess of 5m is required, it is found that comprehensive foundation works like extensive continuous footings and piled foundations are required for a free standing structure to resist the high wind load force generated on it, resulting in a substantial increase in construction cost. Typically, the 7m high barrier can be constructed of a steel portal frame with concrete planks and top 2m Paraglass.

Partial enclosure: A free standing partial enclosure would require piled foundations and would also need large structural frame members at close spacing to support the overhanging roof section of the partial enclosure. To minimize the loading of the structure, Paraglass wall and roof could be used.

Full enclosure: Full noise enclosure would consist of steel portal framework spanning both carriageways, supporting walls and roof made of Paraglass, and resting on piled foundations.

Table 5 Unit Costs for Noise Mitigation Measures

Type/Form	Description	Cost/linear meter (HK$/m)
Plain Barrier 3.5m	Steel post with GRC panels	6,000
Plain Barrier 7.0m	Steel portal with concrete planks and top 2m Paraglass	50,000
Partial Enclosure	Enclosure over one lane, Paraglass wall and roof	71,000
Full Enclosure	Enclosure over up to four lanes, Paraglass walls and roof	180,000

8. PRIORITIZATION OF NOISE MITIGATION WORKS PROGRAMME

In order to prioritize the implementation works, a cost-effectiveness factor, defined as :

F = number of dwellings protected x dB(A) noise reduction / cost of implementation

has been used to sort the noise mitigation works in order of increasing F. Works which result in more dwellings to be protected and larger noise reduction per unit cost have higher F values.

Table 6 gives a priority list based on the overall F values of the roads. These overall F values are calculated based on the total number of dwellings to be protected and the average noise reduction over the different road sections divided by the total cost of implementation. On an individual section, the F value is calculated based on the number of dwellings, the average noise reduction and the cost of implementation for that section.

Table 6 Prioritization of Noise Mitigation Works

Priority	Road Name	Section	Effectiveness Factor (Dwelling dB(A)/HK$) ($x10^{-5}$)		
			Sectional		Overall
1	Ma On Shan Road	-	I	1.5	49.0
			II	51.8	
			III	83.9	
2	Tung Chau Tsuen Road	-	I	31.8	31.8
3	Po Lam Road North	-	I	14.7	25.6
			II	61.8	
			III	5.5	
			IV	20.4	
4	Tin Sum Street	-	IV	24.9	24.9
5	Hung Mui Kuk Road	-	III	22.4	22.4
6	Junk Bay Road	-	I	14.1	20.9
			II	27.7	
7	Tuen Mun Road	Tsuen Wan	I	14.6	18.8
		Tsing Lung Tau	II	21.3	
		Castle Peak Road	III	21.0	
8	Yuen Wo Road	-	II	16.6	15.0
			III	13.6	
9	Fung Shue Wo Road	-	I	12.3	14.0
			II	15.6	
10	Tai Chung Kiu Road	-	I	10.2	10.2
11	Po Hong Road	-	V	6.8	6.8
12	Cheung Pei Shan Road	-	I	3.5	6.1
			II	9.6	
			III	6.4	
			IV	5.8	
			V	6.1	
			VI	5.1	
13	Island Eastern Corridor	Tai Koo Shing	I	5.9	5.9
14	Ting Kok Road	-	I	5.0	5.0
15	Che Kung Miu Road	-	I	0.4	4.7
			II	8.7	
16	Tolo Highway	Ma Liu Shui	I	5.4	3.4
		Tai Po Kau	II	0.6	
17	Hiram's Highway	-	I	1.6	1.6
18	Castle Peak Road	Hung Shui Kiu	I	1.6	1.6
		Ping Shan	I	3.6	1.2
			II	0.5	

9. DISCUSSION

A closer examination of potential roads for retroactive noise mitigation in Table 4 suggests that they share some common features as below :

- The roads are mostly major roadways (i.e. highways and primary distributors), or main roads (i.e. district distributors) in new towns.
- The roads are located either in new towns, rural areas or recently redeveloped urban areas.
- The roads are outside old or heavily developed urban areas.
- The roads are not of a flyover type.

The last bulletin point has causes for concern because existing flyovers are notorious for being "noisy" but on the other hand HyD's require that noise screening structures must be supported on independent and separate structures. Given that existing flyovers are usually interspersed between congested urban environments, it is very unlikely that enough space is available to accommodate separate structure supports. Even if it is feasible in extreme cases, the enormous cost would penalize these road sections to the effect that they are highly ineffective on cost terms. Alternatively, the existing structures of the flyovers could be reinforced to accommodate the structural loadings of the noise screening structures. As it is beyond the scope of the present study to consider this issue, it is considered prudent for the Government to commission a separate study to review the structural loadings of the existing flyovers and to recommend the most appropriate forms of mitigation for flyovers.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

This scoping study has examined the feasibility of providing retroactive road traffic noise mitigation for over 740 existing roads across the territory. Among the roads examined, 90% of them or 663 roads have been identified as "noisy" roads. However, only 18 of the identified roads have the potential for retroactive noise mitigation because of six crucial factors which are likely to limit the practical and effective application of direct technical remedies to these roads. All these factors are related to safety, structural integrity or public disruption. They are: (1) obstruction to access for fire fighting or rescue operations; (2) inadequacy of installation space; (3) severe disturbance to public or business activities; (4) significant structural impacts on existing road infrastructure; (5) presence of multiple vehicular or pedestrian access; and (6) sightline problems.

Feasible forms of mitigation measures identified include plain barriers (3.5m or 7m high) and semi-enclosures. In general, noise barriers could be applied where the targeted NSRs are low-rise buildings. They are also applicable where high-rise NSRs are situated well away from the road, or the buildings are below the road level. Semi-enclosures may be used where high-rise buildings are clustered on one side of the road. The estimated unit costs of the mitigation options are summarized in Table 5, and the estimated implementation costs for each road section are presented in Appendix I.

While full enclosures are effective and often desirable in mitigating traffic noise at high-rise NSRs on both sides of a road, site-specific concerns, particularly those raised by HyD such as potential structural impacts on existing roadwork and lack of roadside space, have limited the application of this option to NSRs along the identified roads. As such, no full enclosure has been included in the list of recommended mitigation measures.

Altogether 37 subsections in these 18 noisy roads have been selected for detailed noise assessment and mitigation investigation. The total number of exposed units which can expect to be benefitted (i.e. having noise reduction by 1 dB(A) or more) is estimated to be 27,000, of which 21,000 units are expected to meet the HKPSG noise criterion as a result of implementing the noise mitigation scheme. An effectiveness factor (F) has been derived to take into account the number of dwellings protected, anticipated noise reduction and the approximate cost of implementing the retroactive treatment and this has been used to prioritize the noise mitigation works programme. Mitigation works with larger F values denote that they are more cost-effective and should receive higher implementation priority.

10.2 Recommendations

10.2.1 Roads for Further Review

It is recommended that the following roads should be investigated in greater details during the Phase 2 assessment for possible retroactive treatment :

(1) Island Eastern Corridor (Tai Koo Shing)
(2) Tung Tau Tsuen Road
(3) Che Kung Miu Road
(4) Tin Sam Street
(5) Hung Mui Kuk Road
(6) Tai Chung Kiu Road
(7) Yuen Wo Road
(8) Ma On Shan Road
(9) Ting Kok Road (Yuen Sin Road to Brides Pool)
(10) Po Lam Road North
(11) Po Hong Road
(12) Fung Shue Wo Road
(13) Tuen Mun Road (Tsuen Wan, Tsing Lung Tau and Castle Peak Bay)
(14) Castle Peak Road (Hung Sui Kiu and Ping Shan)
(15) Hiram's Highway (Marina Cove)
(16) Tolo Highway (Ma Liu Shui and Tai Po Kau)
(17) Cheung Pei Shan Road
(18) Junk Bay Road

The appropriate form of direct technical remedies, cost estimates of the measures, likely noise reduction and number of benefitted dwellings associated with each identified road are indicated in Appendices H and I.

10.2.2 Implementation Programme

On the basis of the above cost-effectiveness analysis, it is recommended that the mitigation works be implemented in three stages. Roads to be included in each stage are indicated in Table 7.

Table 7 Implementation Programme for Retroactive Noise Mitigation Measures

Implementation Programme	Roads
Stage 1	Ma On Shan Road, Tung Tau Tsuen Road, Po Lam Road North, Tin Sum Street, Hung Miu Kuk Road, Junk Bay Road
Stage 2	Tuen Mun Road, Yuen Wo Road, Fung Shue Wo, Tai Chung Kiu Road, Po Hong Road, Cheung Pei Shan Road
Stage 3	Island Eastern Corridor, Ting Kok Road, Che Kung Miu Road, Tolo Highway, Hiram's Highway, Castle Peak Road

10.2.3 Further Implementation Considerations

In the light of the concerns of various Government Departments, it is recommended that further considerations (other than those discussed in Section 5) should be given to safety and visibility, structural impacts, public disruption, obstruction to facilities and services, air quality and ventilation, lighting, maintenance, and visual impacts and amenity during the detailed engineering design of mitigation measures in the Phase 2 Study. The following are relevant:

Safety and Visibility

- Proper location of noise screening structures to avoid obstruction to emergency facilities such as fire hydrants.
- Use of barrier/enclosure materials with adequate fire resistance ratings.
- Provision of smoke extraction fans for full enclosures longer than 230m.
- Provision of adequate fire fighting installations for full enclosures longer than 450m.
- Possible impacts on the radio communication between fire appliances and the Fire Services Mobilizating and Communication Centre.
- Proper siting of noise barriers and enclosures to prevent the creation of criminal black spots (e.g. not placing noise barriers/enclosures between footway and carriageway).

Structural Impacts

- Wind loading on noise mitigation structures.

Public Disruption

- Possible objections from the commercial operators and other frontage users.

Obstruction to facilities and Services

- Avoid placing the foundations of noise screening structures on underground services.
- Design provisions for temporary removal and subsequent reinstatement of noise screening components (e.g. removable screening panels, simple panel to foundation joints) to facilitate easy operation and maintenance of services and utilities.
- Proper design and location of noise barriers and enclosures to prevent substantial utility and roadside facility diversions (e.g. cables, water mains, telephone mains, gas mains, drains, surface channel, kerbside carparks, loading/unloading bays, bus stops, footpaths, bicycle tracks, lamp posts, traffic signs, etc.).
- Provision of alternative access behind noise screening structures to facilitate slope maintenance work.

Air Quality and Ventilation

- Adverse air quality impacts on the adjacent buildings.
- Possible degradation of air quality inside noise enclosures.
- Use of modelling techniques (e.g. Computational Fluid Dynamics) for air quality assessment for enclosures.

Lighting

- Effect of the erection of high noise barriers or enclosures on the quantity of natural lighting available to the adjacent building.
- Prevention of tunnel effects due to sudden changes in light conditions in full enclosures.

Maintenance

- Availability of replacement parts for proprietary noise mitigating products.

Visual Impacts and Amenity

- Submission of the noise screening structures to the Advisory Committee on the Appearance of Bridges and Associated Structures for approval.
- Use of landscaping and roadside planting to ameliorate visual impacts.
- Preservation of existing trees and vegetation.

10.2.4 Other Recommendations

(1) A detailed survey of all sensitive receivers potentially benefitted from the noise mitigation scheme should be commissioned.

(2) A detailed site survey of soil and roadside features should be commissioned to provide information for foundation design of noise screening structures.

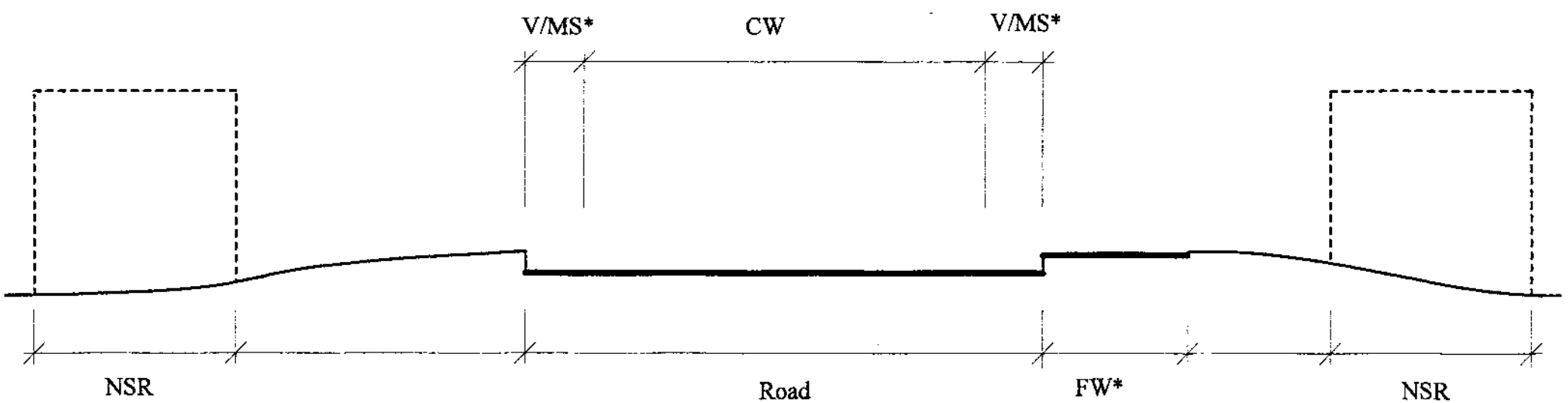
(3) Information on underground utilities should be obtained from all relevant Government departments and utility companies for design of noise screening structures.

(4) A focused feasibility study of retrofitting existing flyovers should be commissioned.

FIGURES

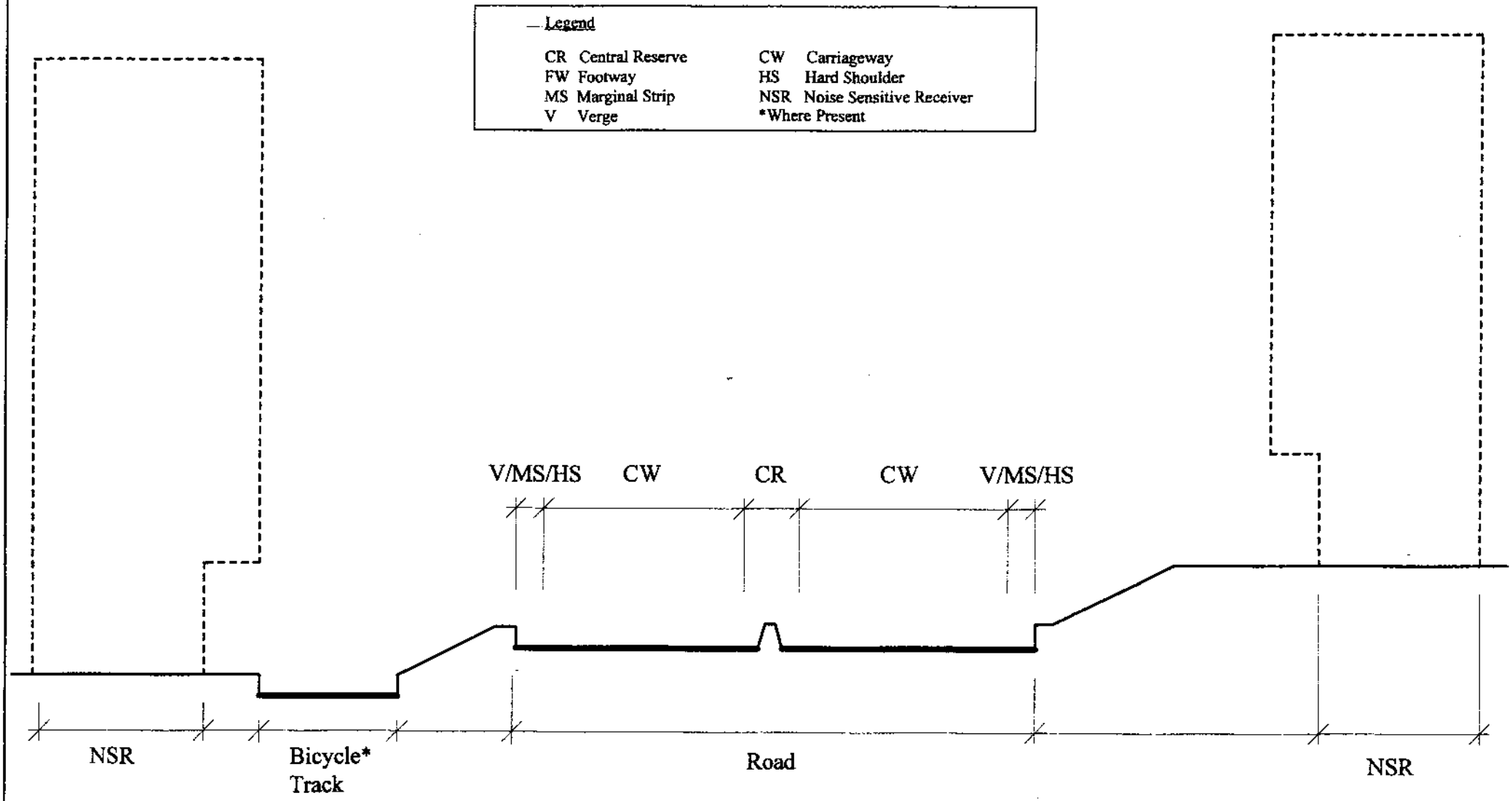
Legend

CR	Central Reserve	CW	Carriageway
FW	Footway	HS	Hard Shoulder
MS	Marginal Strip	NSR	Noise Sensitive Receiver
V	Verge	*Where Present	



Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	1
		Scale	N.T.S.
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type'A')	**Date**	Nov. 1994

Environmental Assessment & Pollution Control

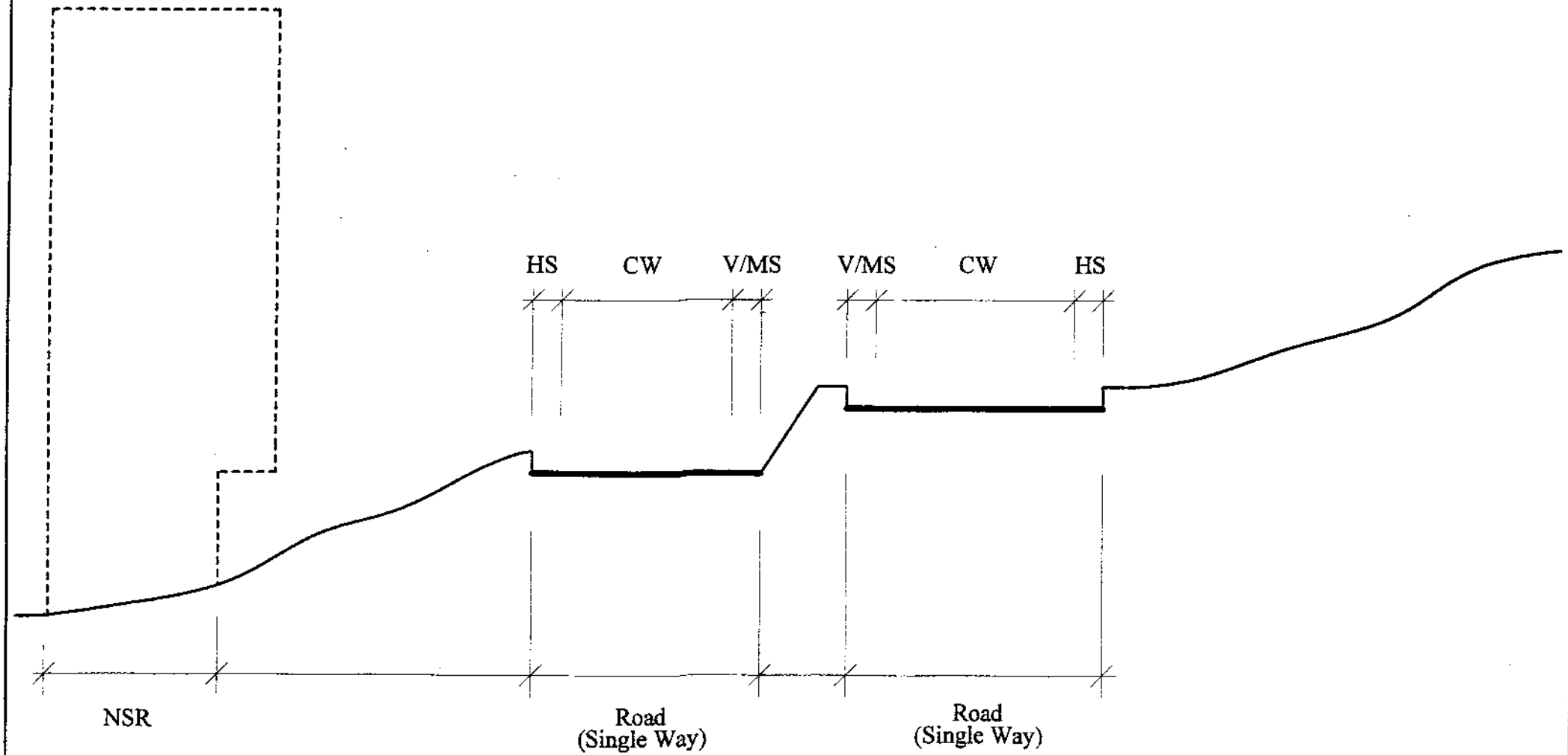


Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'B')
Figure	2
Scale	N.T.S.
Date	Nov. 1994

Environmental Assessment & Pollution Control

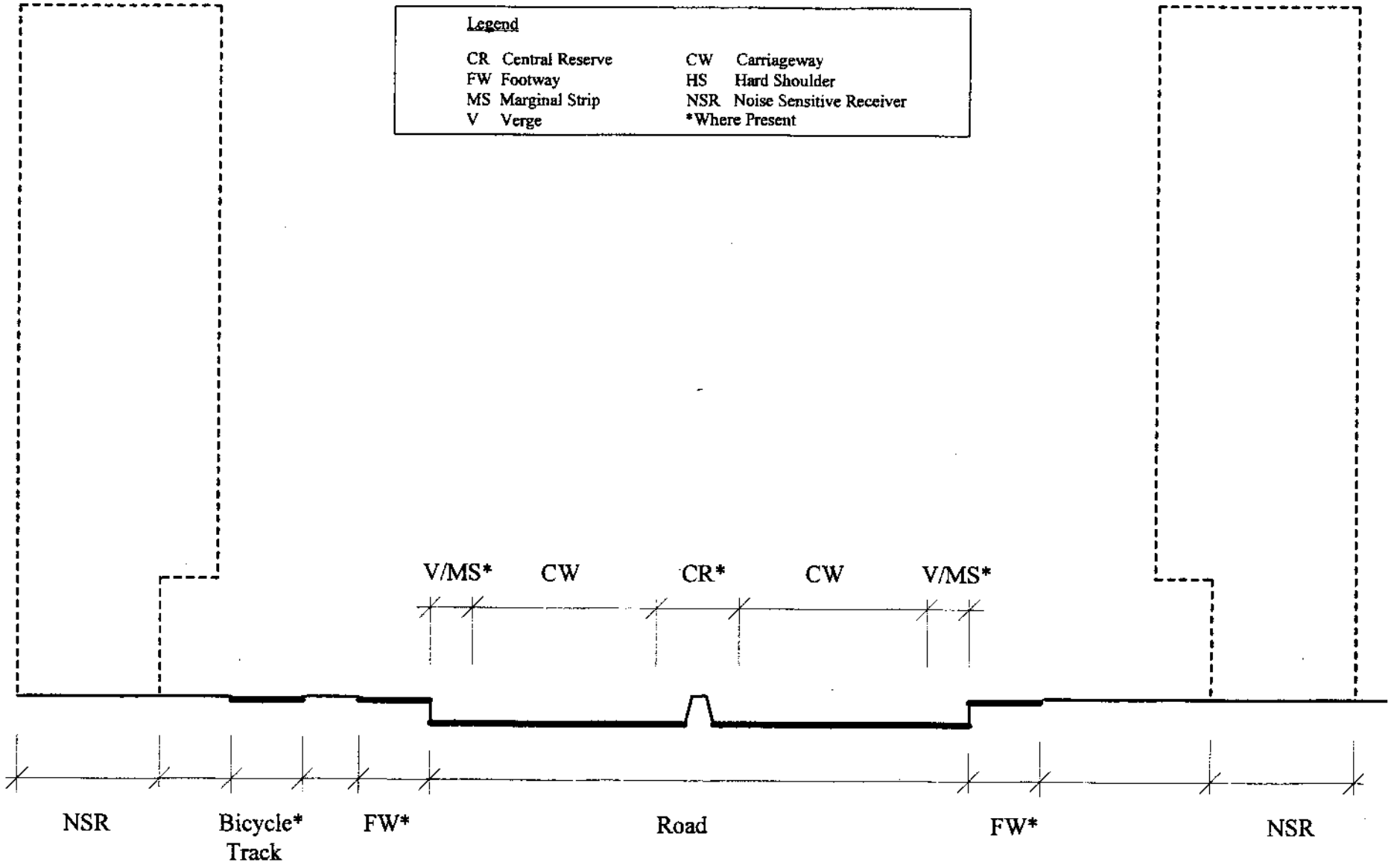
Legend

CR Central Reserve	CW Carriageway
FW Footway	HS Hard Shoulder
MS Marginal Strip	NSR Noise Sensitive Receiver
V Verge	*Where Present



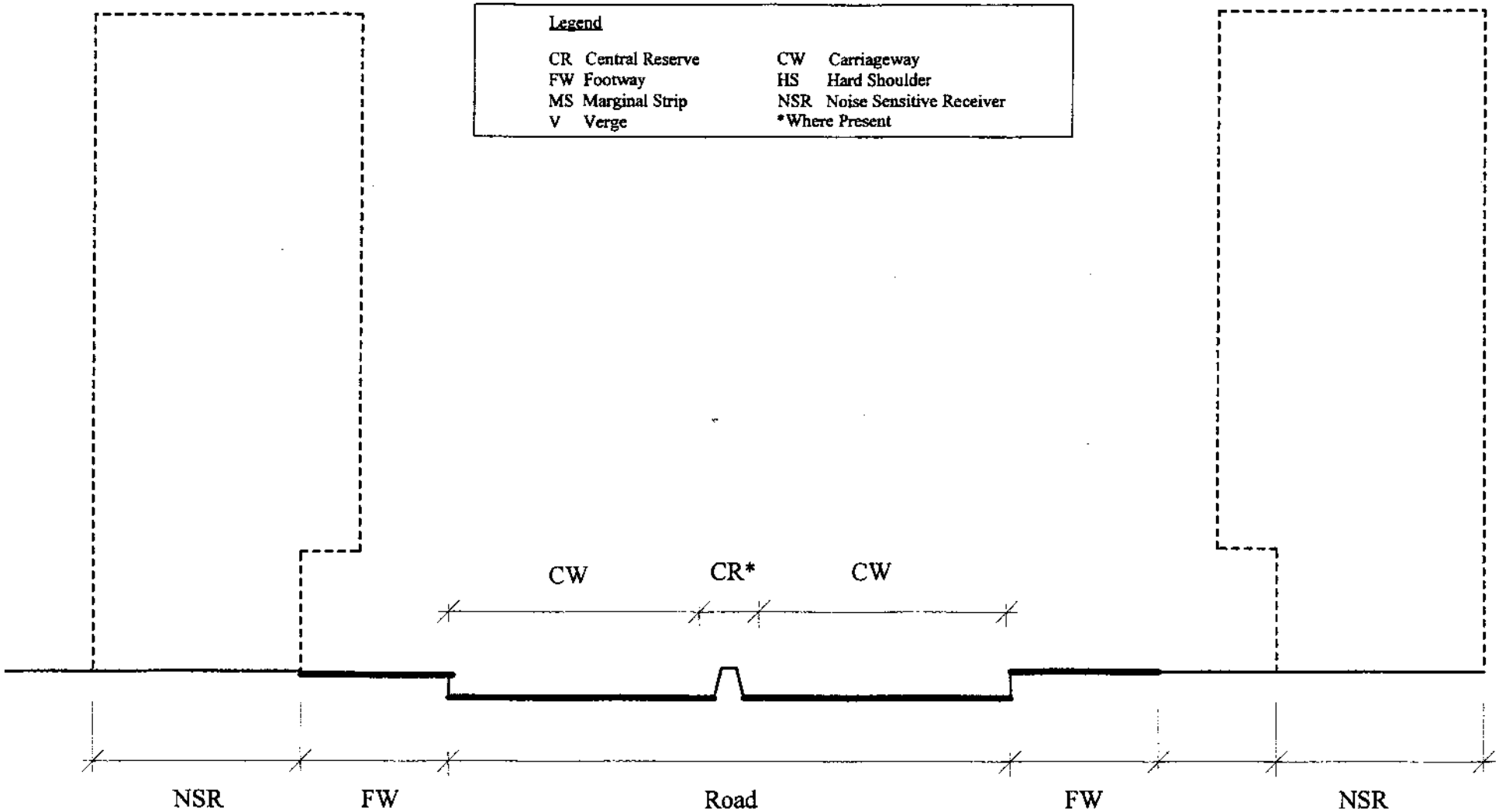
Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	3
		Scale	N.T.S.
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'C')	**Date**	Nov. 1994

Environmental Assessment & Pollution Control



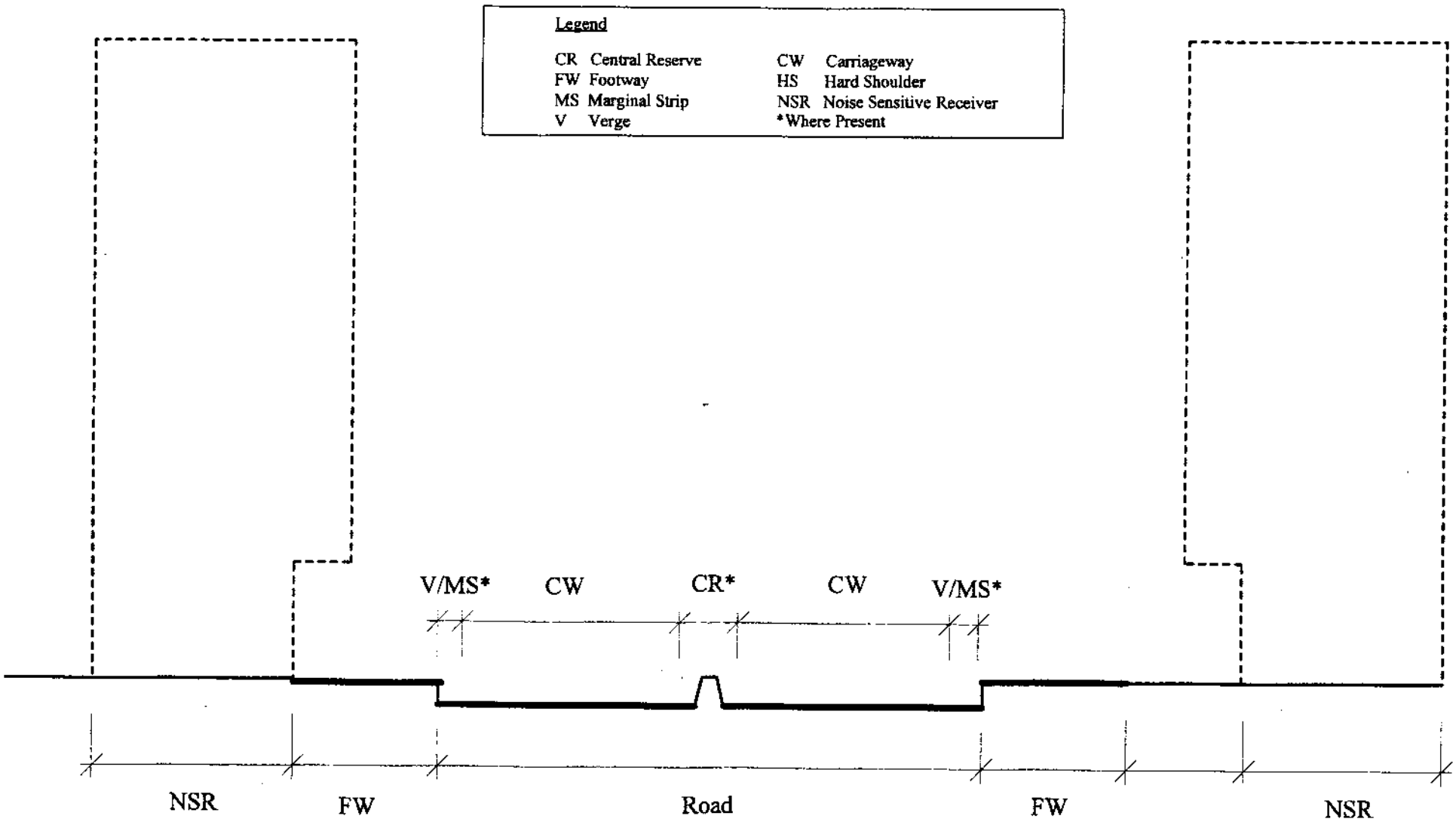
Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	4
		Scale	N.T.S.
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'D')	**Date**	Nov. 1994

Environmental Assessment & Pollution Control



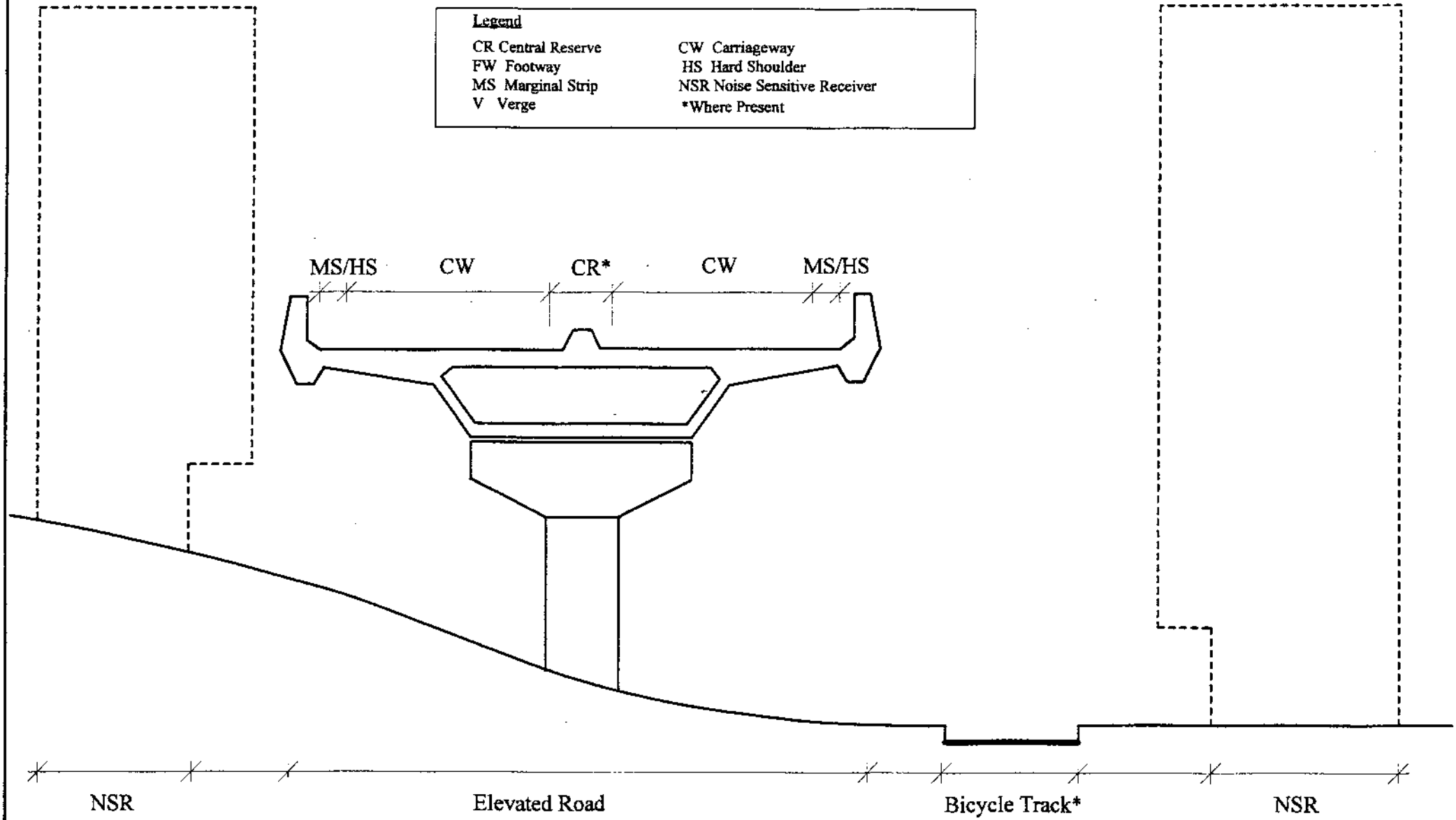
Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	5
		Scale	N.T.S.
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'E')	**Date**	Nov. 1994

Environmental Assessment & Pollution Control



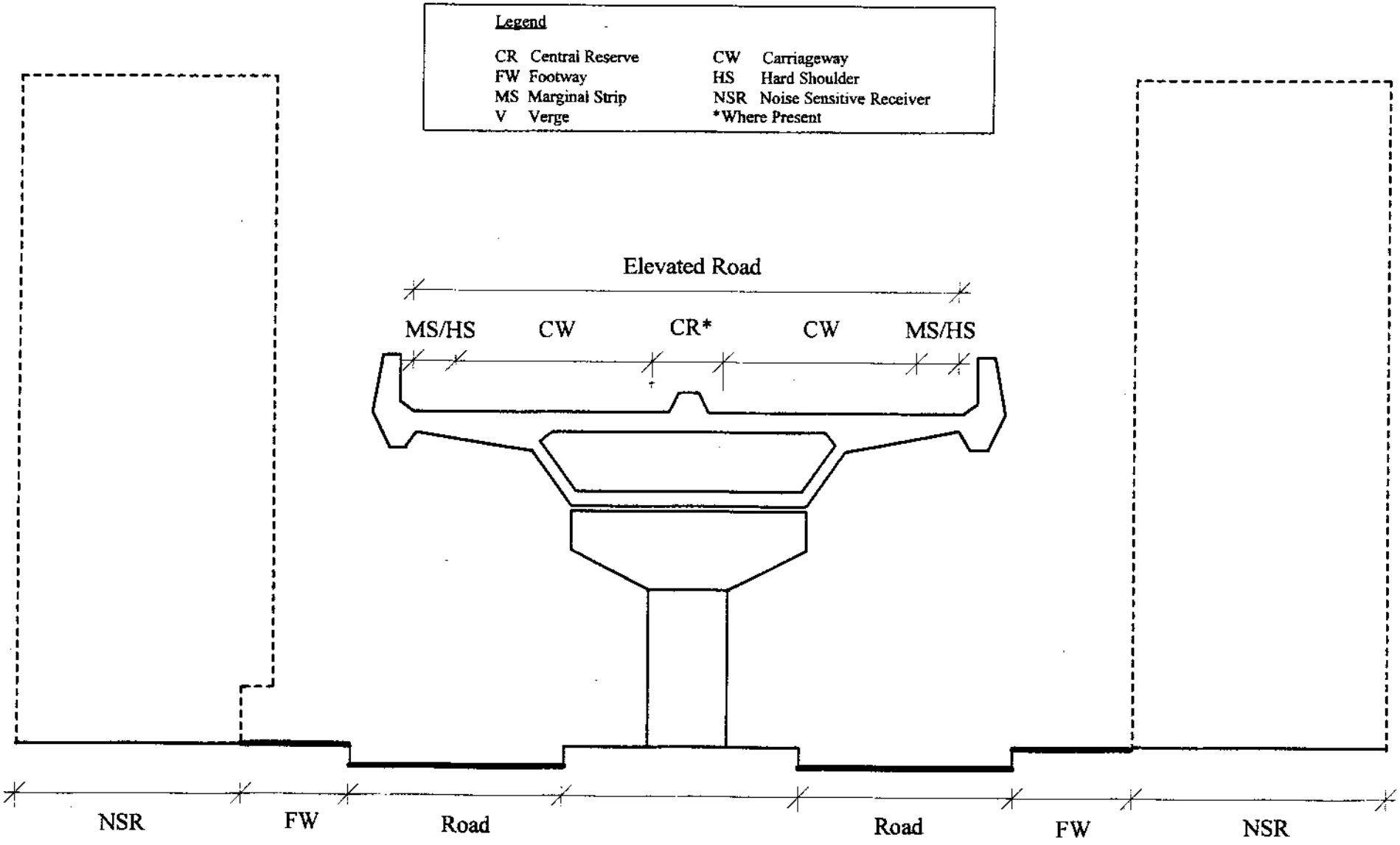
Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	6
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'F')	**Scale**	N.T.S.
		Date	Nov. 1994

Environmental Assessment & Pollution Control



Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	7
		Scale	N.T.S.
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'G)	**Date**	Nov. 1994

Environmental Assessment & Pollution Control



Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	8
		Scale	N.T.S.
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'H')	**Date**	Nov. 1994

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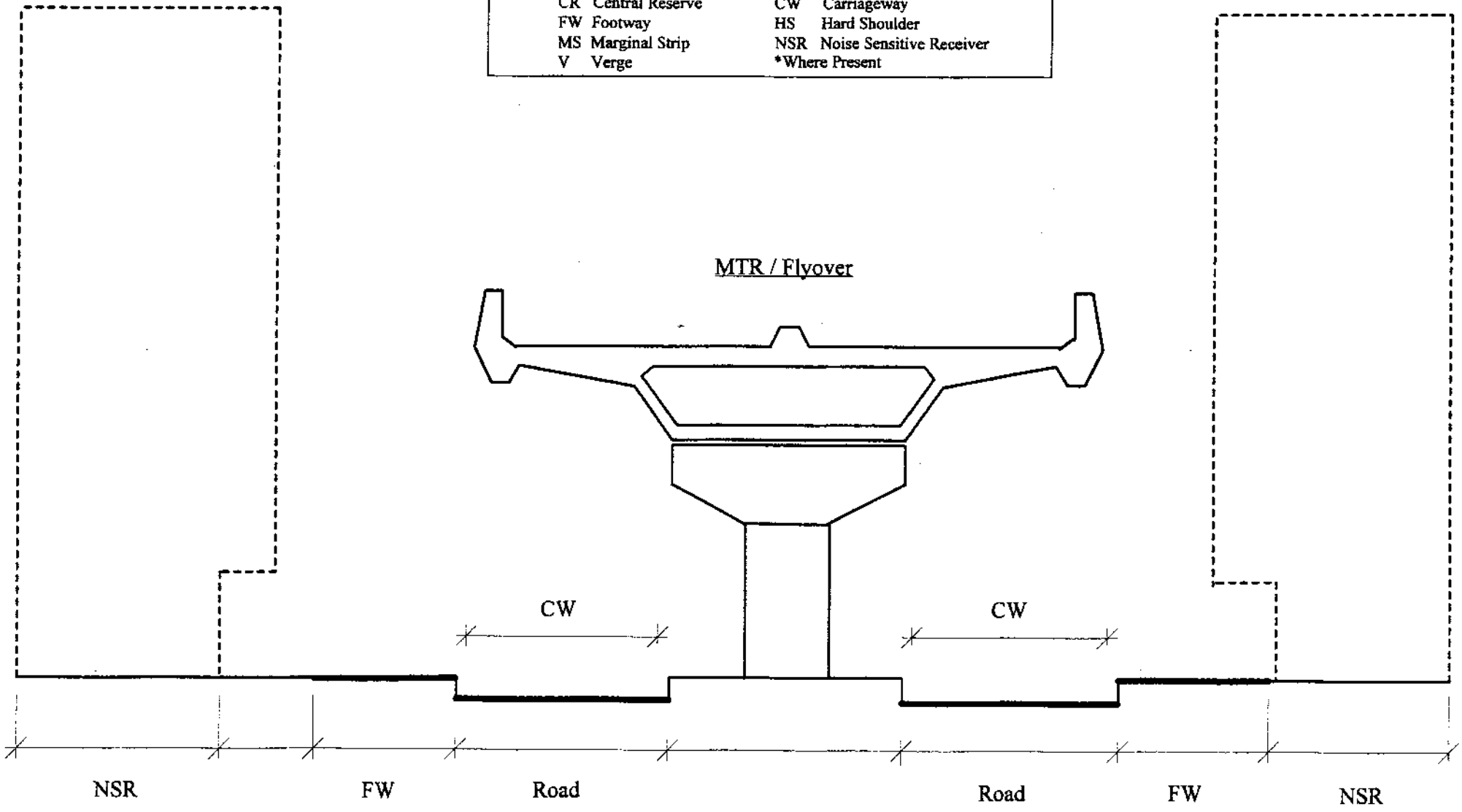
Legend

CR Central Reserve	CW Carriageway
FW Footway	HS Hard Shoulder
MS Marginal Strip	NSR Noise Sensitive Receiver
V Verge	*Where Present



Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	9
		Scale	N.T.S.
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'I')	**Date**	Nov. 1994

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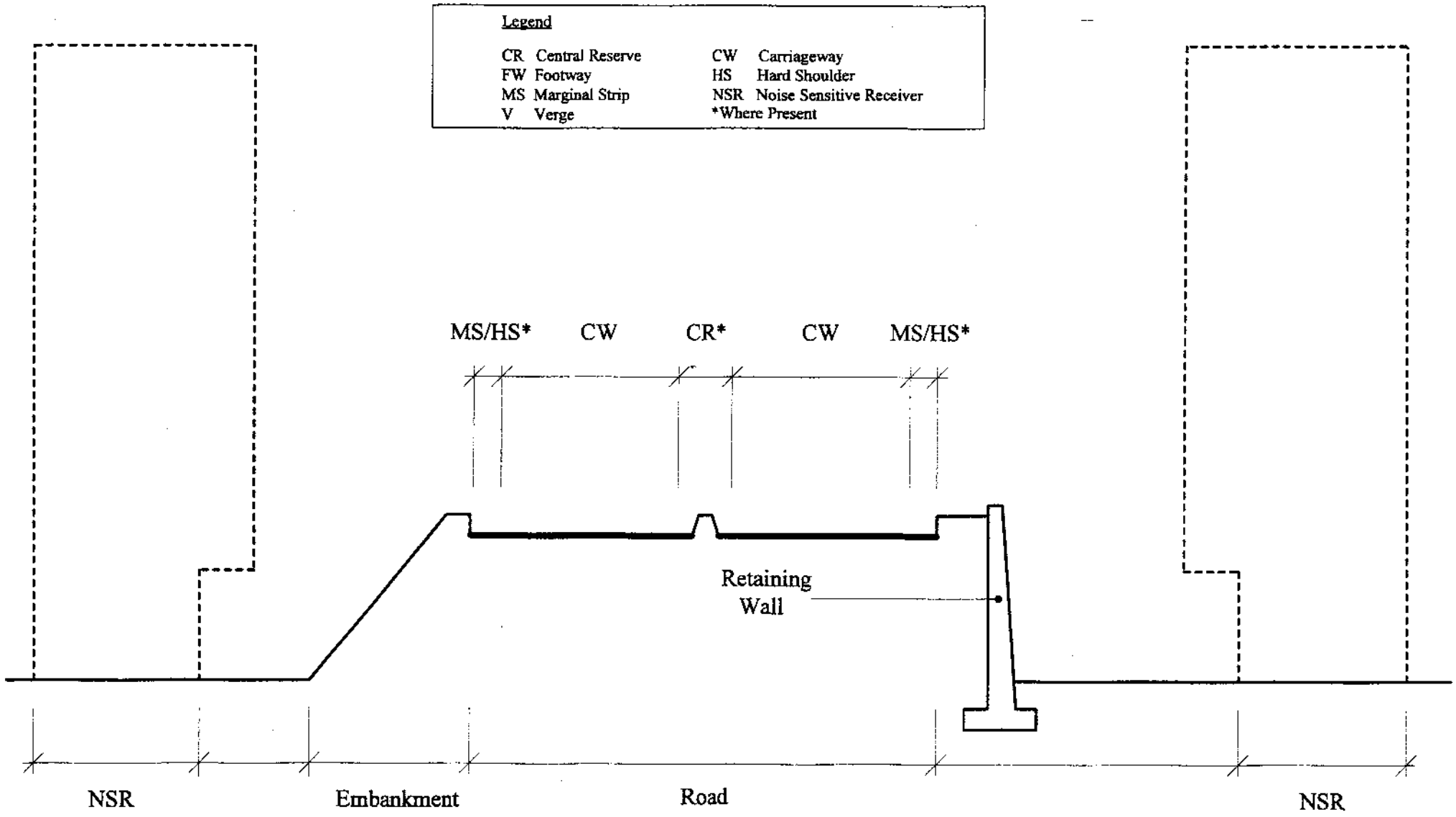

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'J')

Figure	10
Scale	N.T.S.
Date	Nov. 1994

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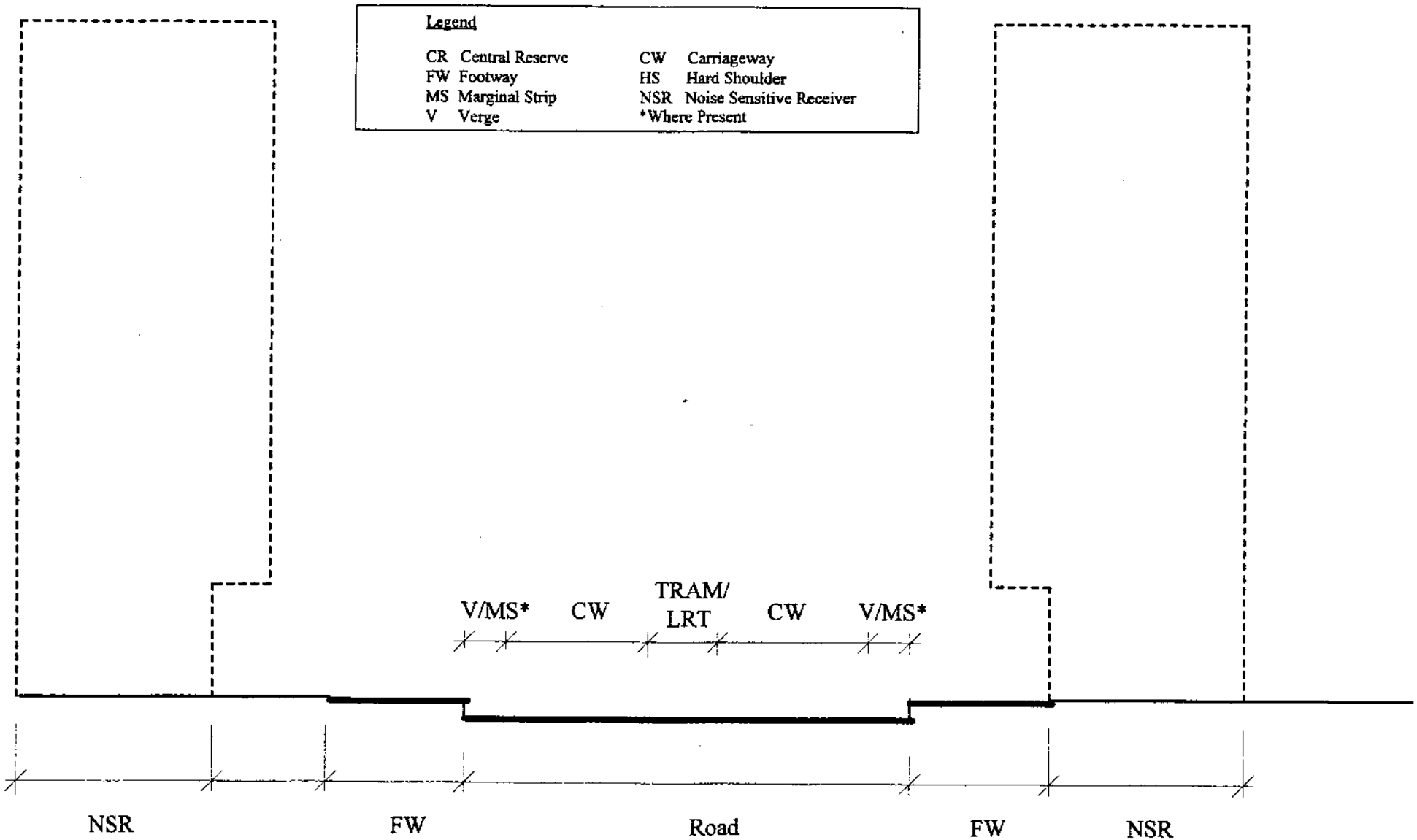

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	11
		Scale	N.T.S.
Title	TYPICAL ROAD - RECEIVER CONFIGURATION (Type 'K')	**Date**	Nov. 1994

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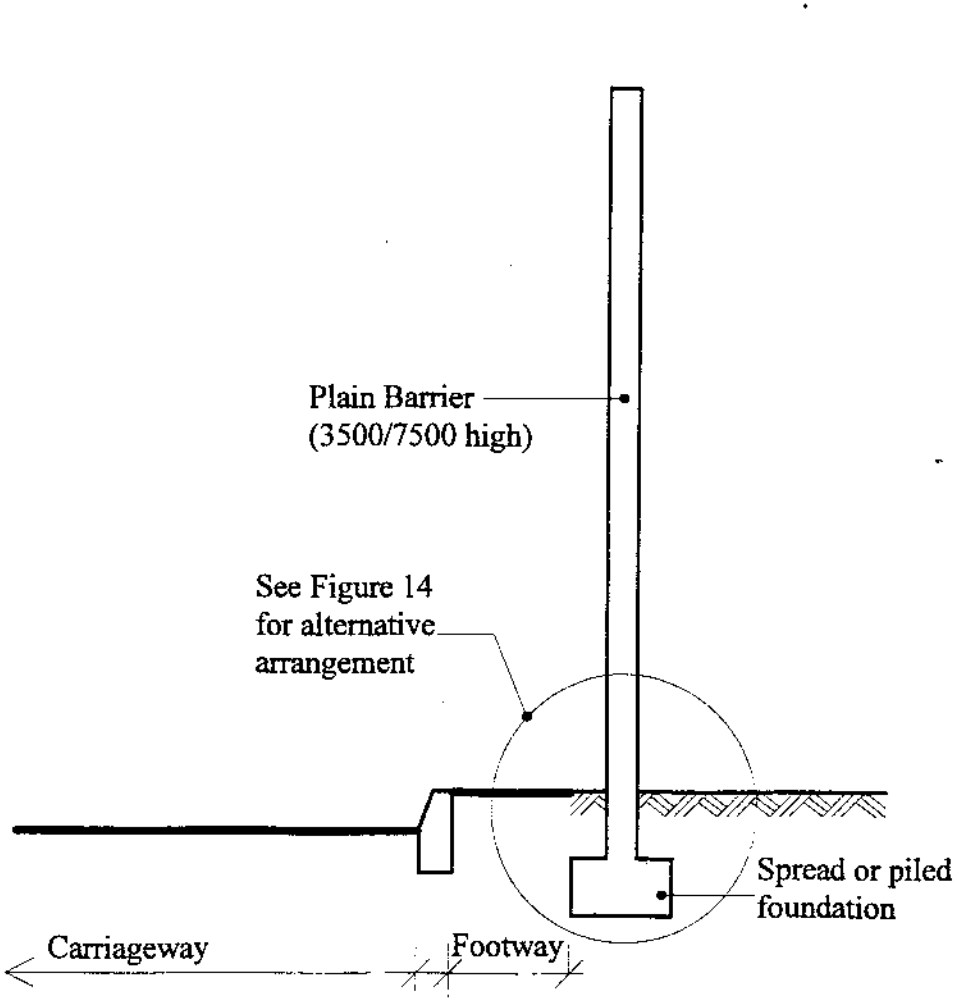
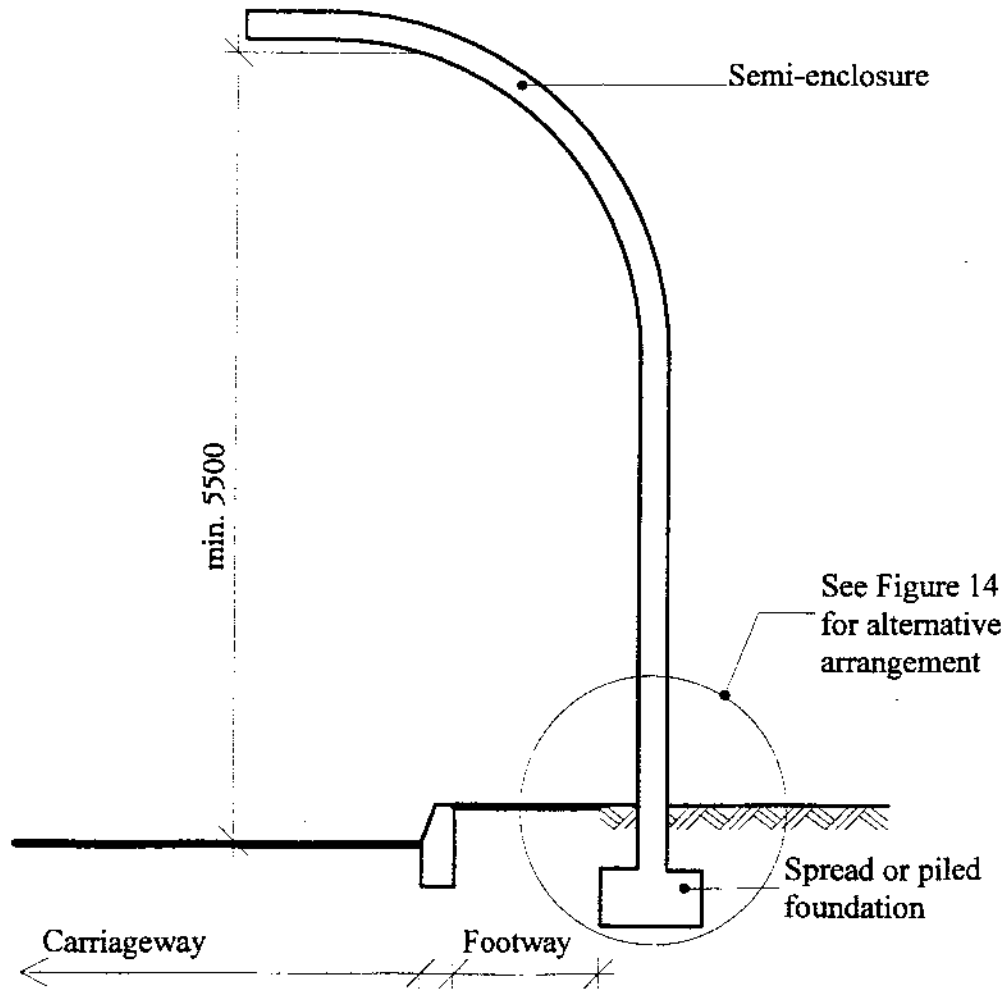


Plain Barrier



Semi - enclosure

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	12
		Scale	N.T.S.
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES (SHEET 1 OF 4)	**Date**	FEB 1995

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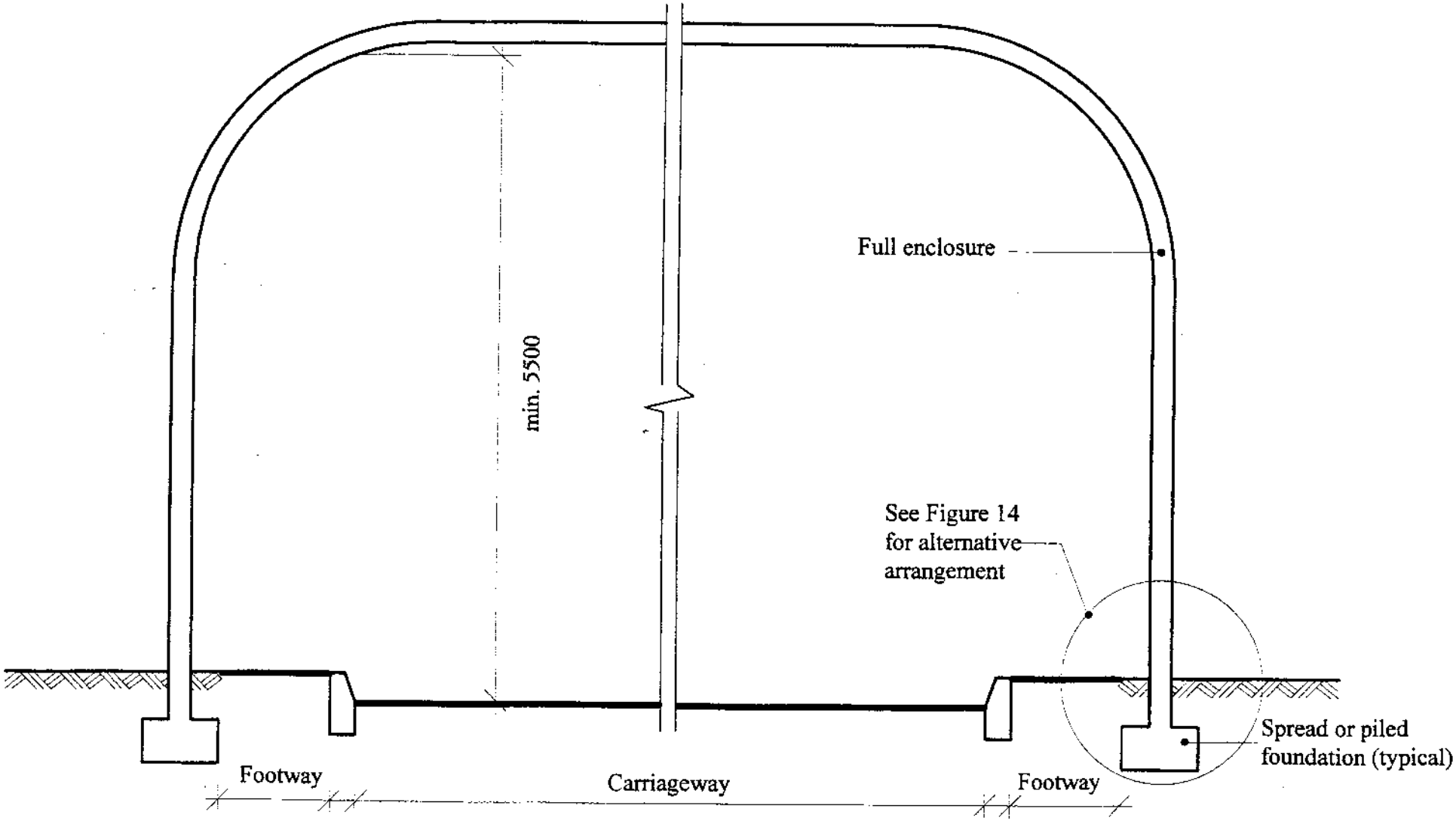

Full Enclosure

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	13
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES (SHEET 2 OF 4)	**Scale**	N.T.S.
		Date	FEB 1995

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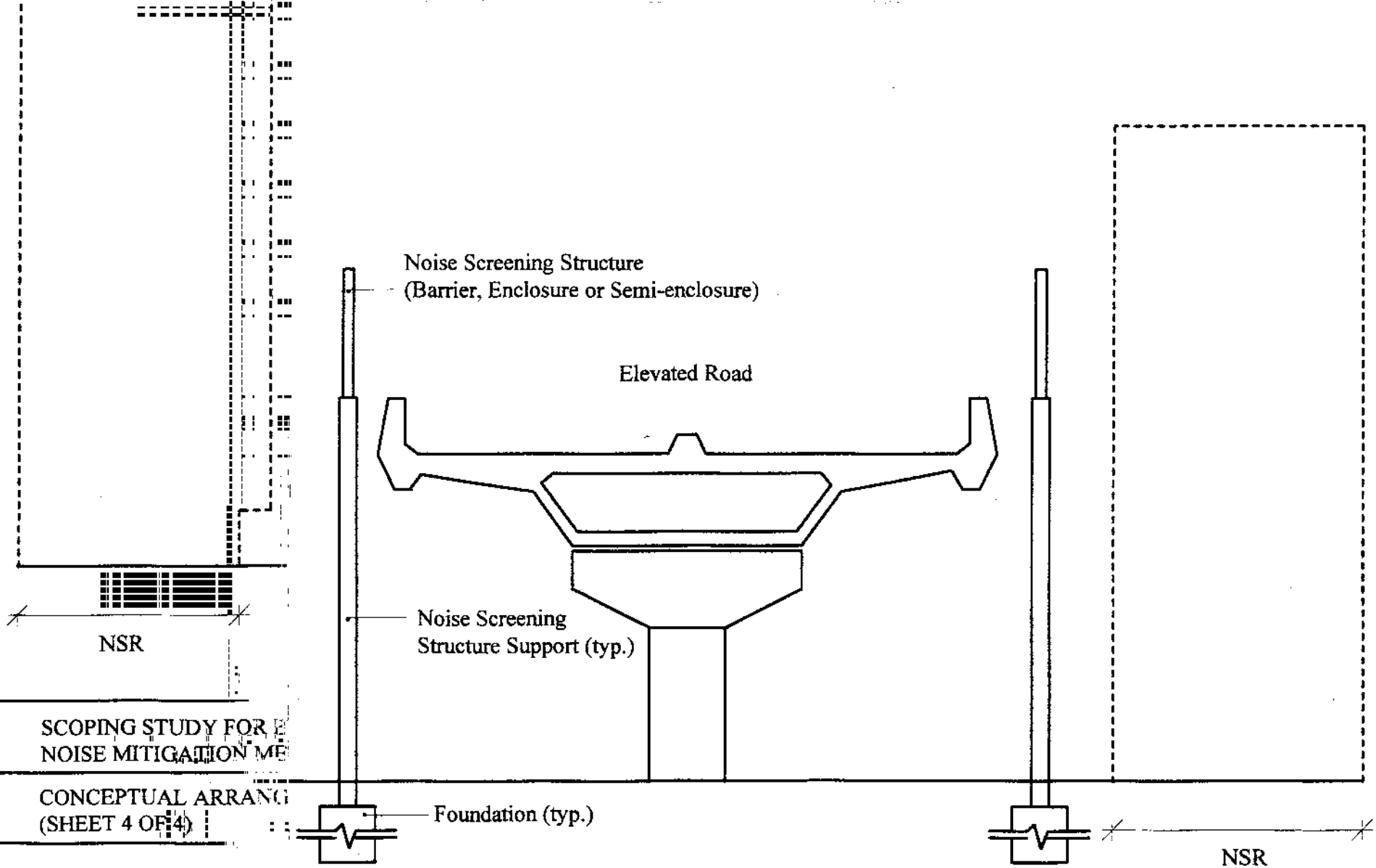

Self-Supported Noise Screening Structure for Elevated Road

Project	SCOPING STUDY FOR E NOISE MITIGATION ME
Title	CONCEPTUAL ARRANG (SHEET 4 OF 4)

ROVIDING RETROACTIVE ROAD TRAFFIC
ASURES

MENT OF NOISE MITIGATION MEASURES

Figure	14A
Scale	N.T.S.
Date	FEB 1995

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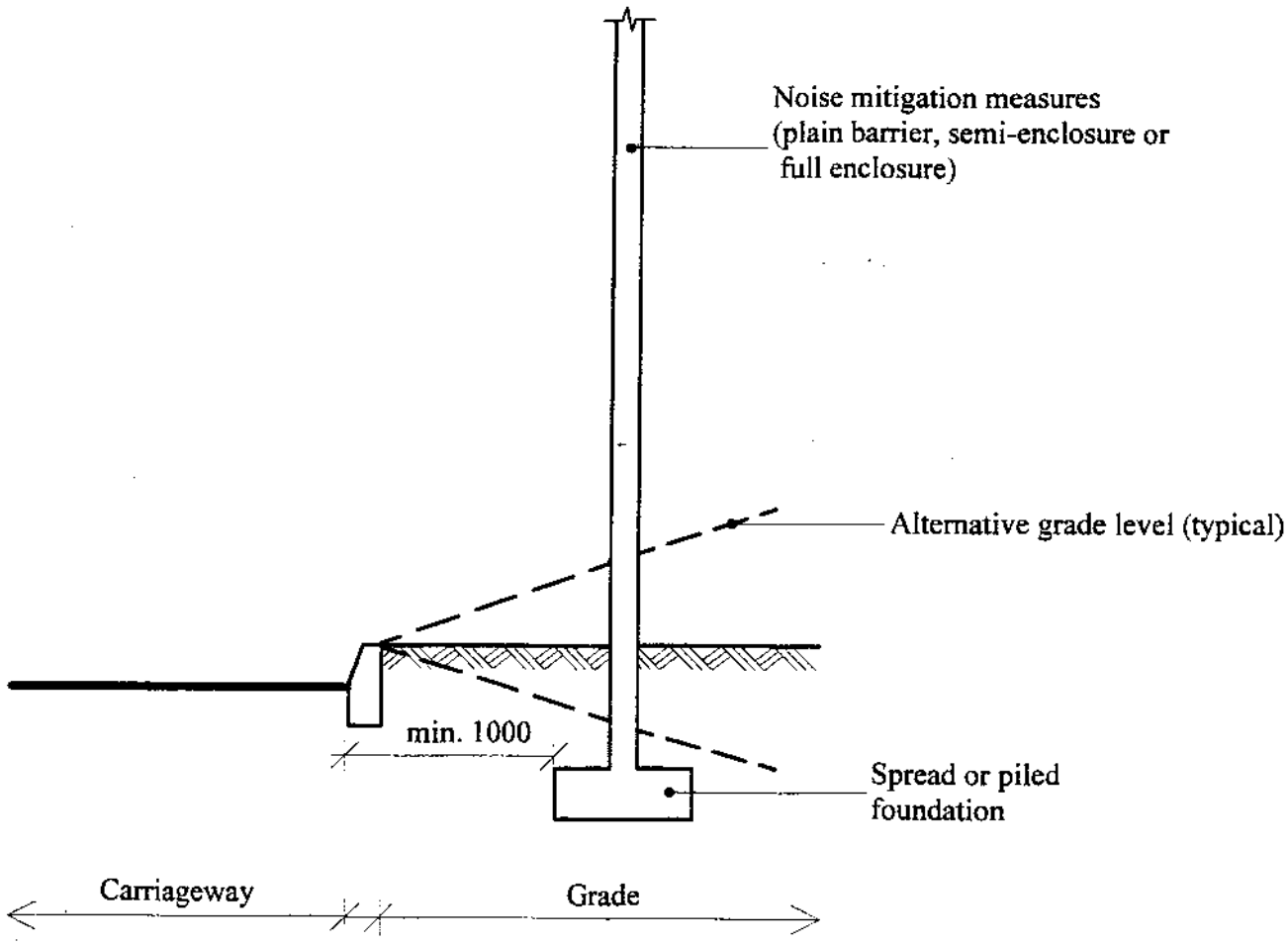

Alternative Arrangement of Noise mitigation Measures

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	14
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES (SHEET 3 OF 4)	**Scale**	N.T.S.
		Date	FEB 1995

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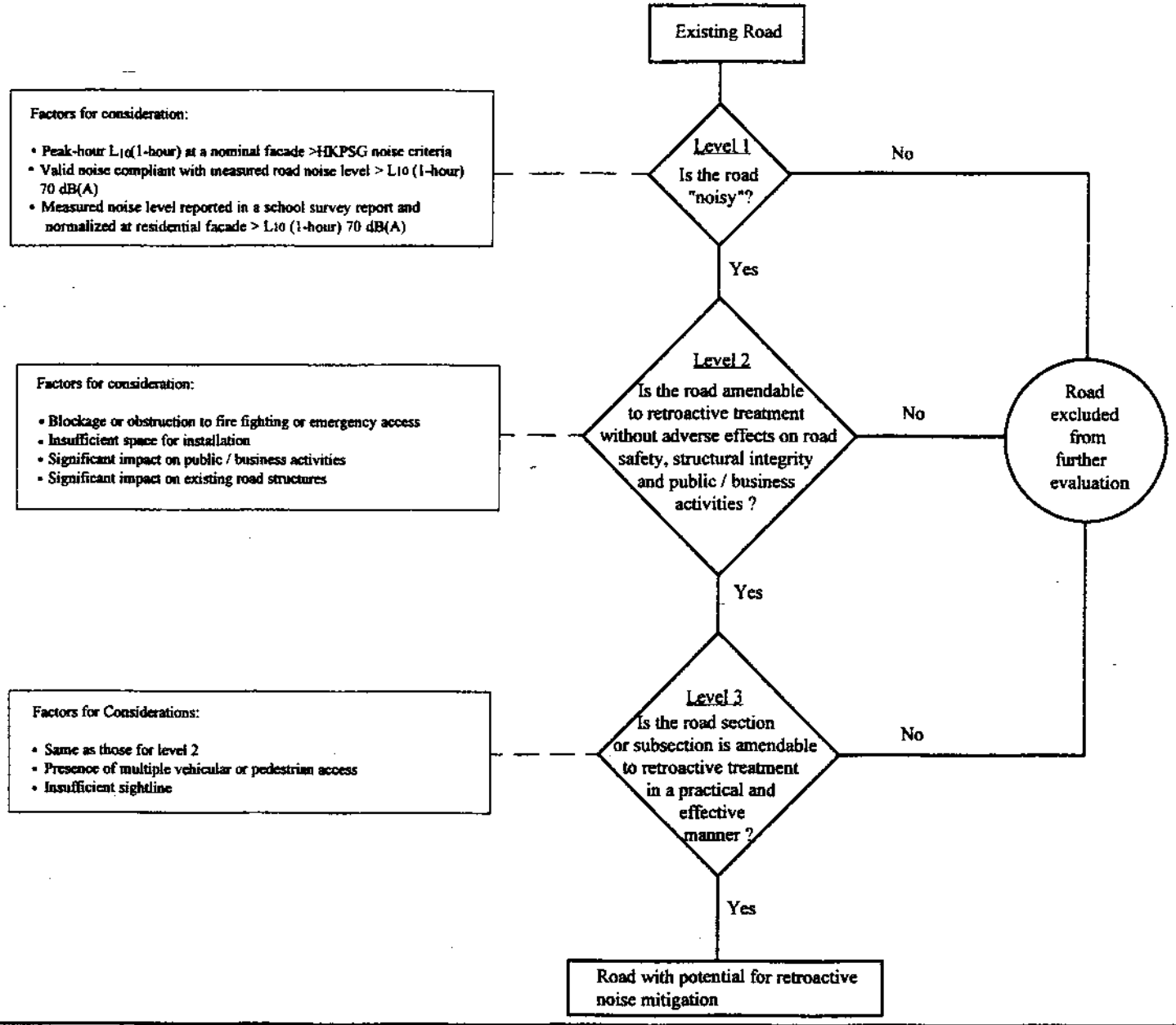
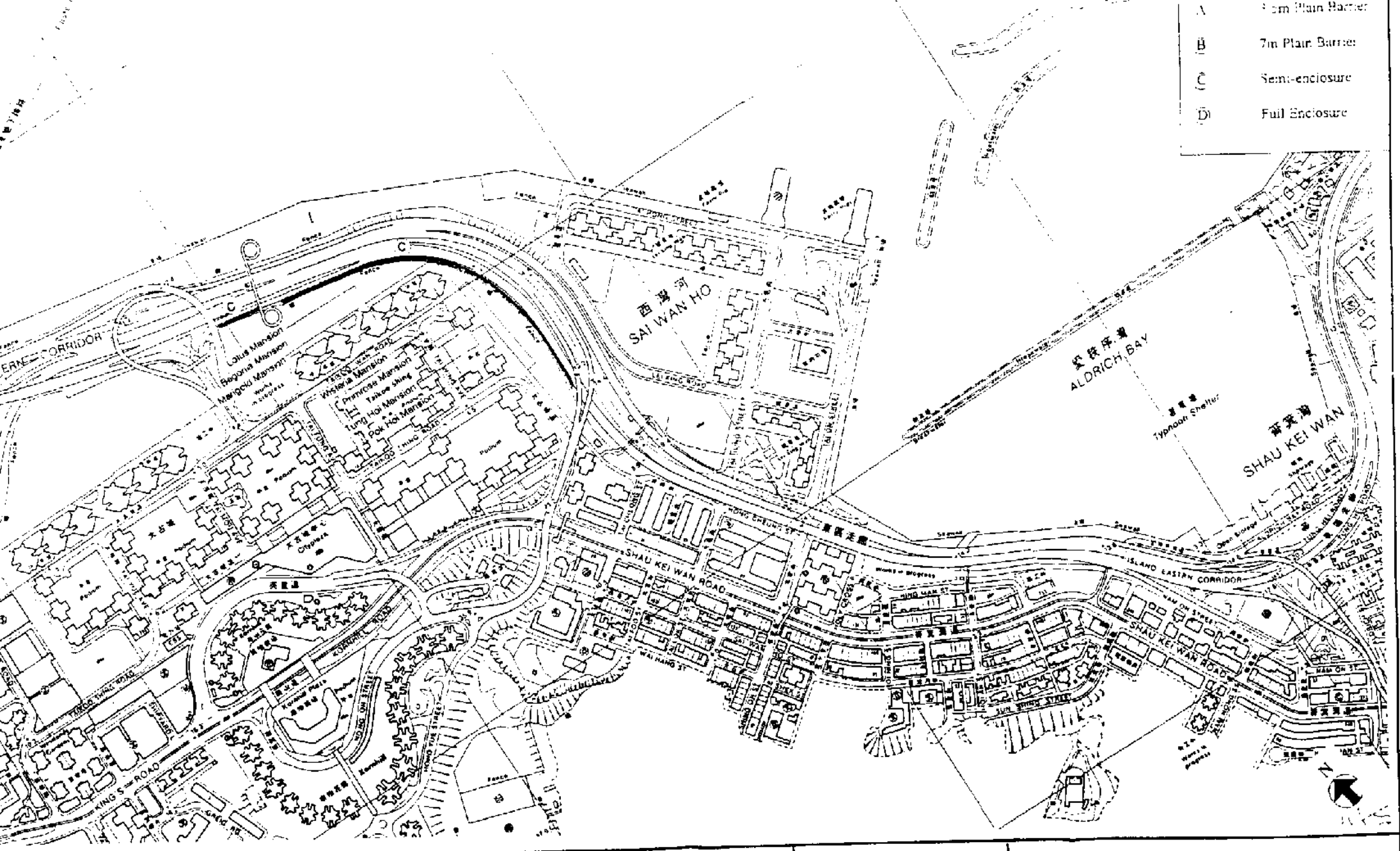


Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	15
Title	FLOW CHART FOR SELECTION OF NOISY ROADS WITH POTENTIAL FOR RETROACTIVE NOISE MITIGATION	**Scale**	N.T.S.
		Date	FEB 1995

Environment Assessment & Pollution control



Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	16
		Scale	1:5000
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES ISLAND EASTERN CORRIDOR - TAI KOO SHING (SHEET 1 OF 1)	**Date**	FEB 1995

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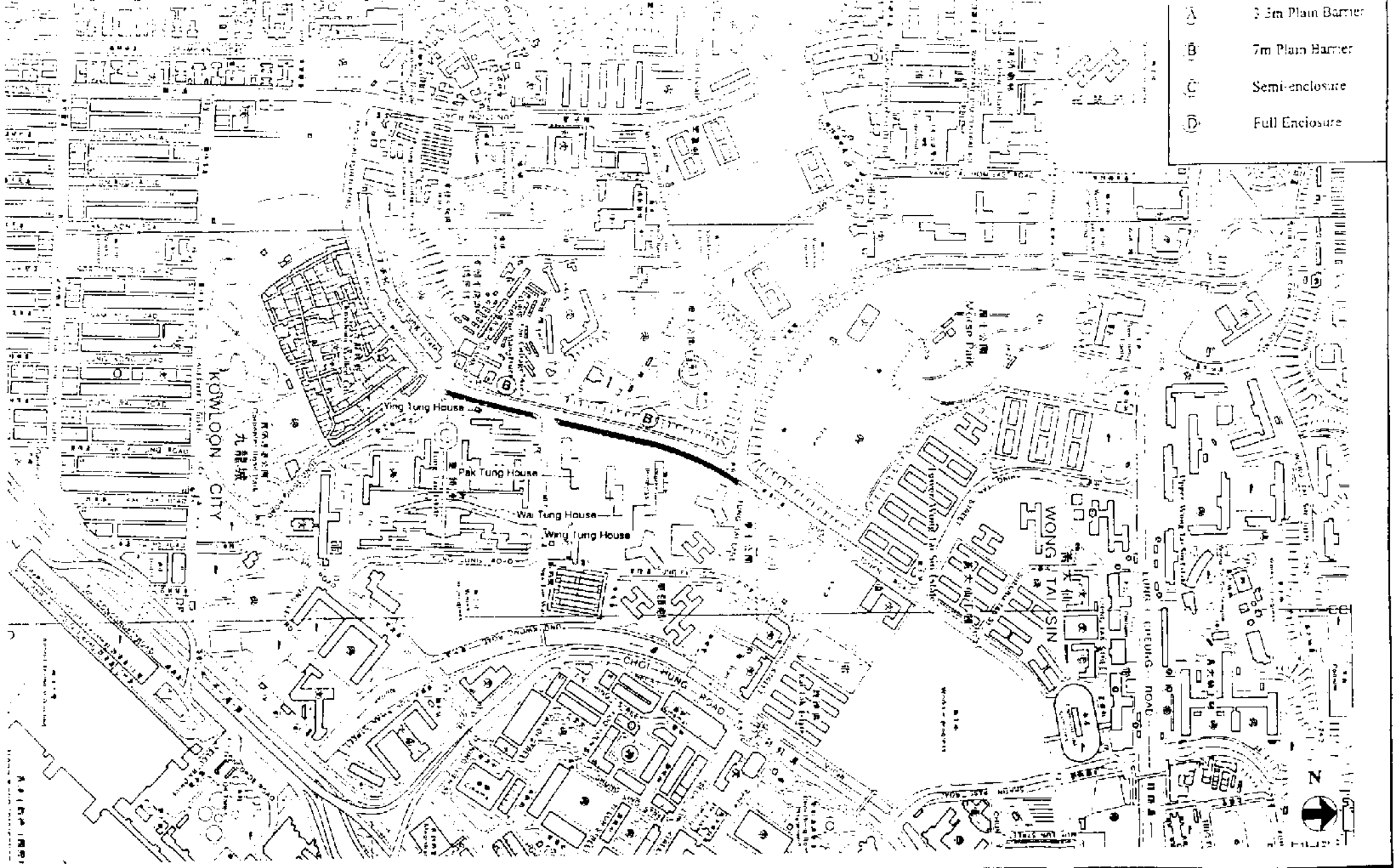

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	17
		Scale	1:5000
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES TUNG TAU TSUEN ROAD (SHEET 1 OF 1)	**Date**	FEB 1995

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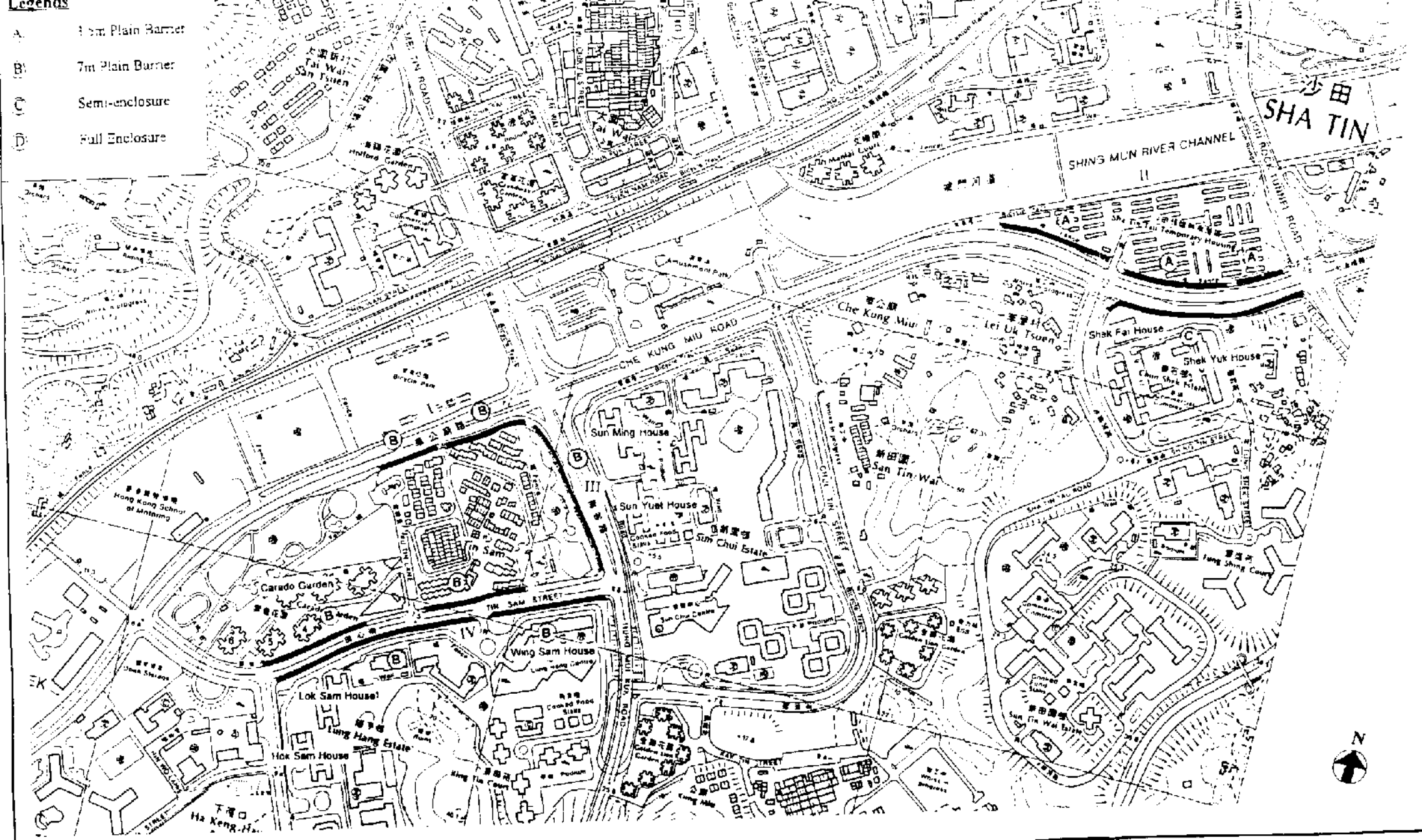

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	18
		Scale	1:5000
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES CHE KUNG MIU ROAD (SHEET 1 OF 1)	**Date**	FEB 1995

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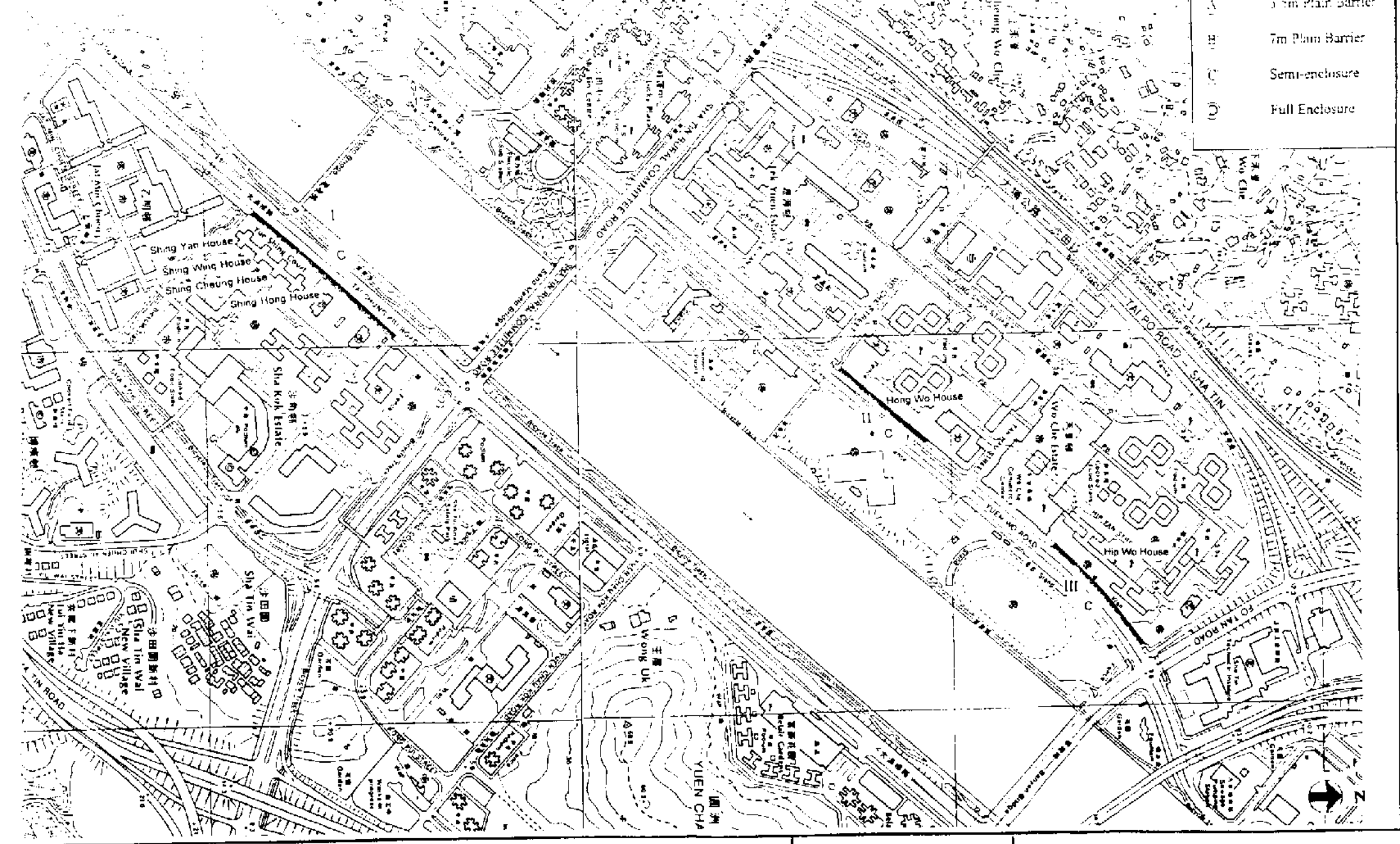

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	19
		Scale	1:5000
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES TAI CHUNG KIU ROAD (SHEET 1 OF 1)	**Date**	FEB 1995

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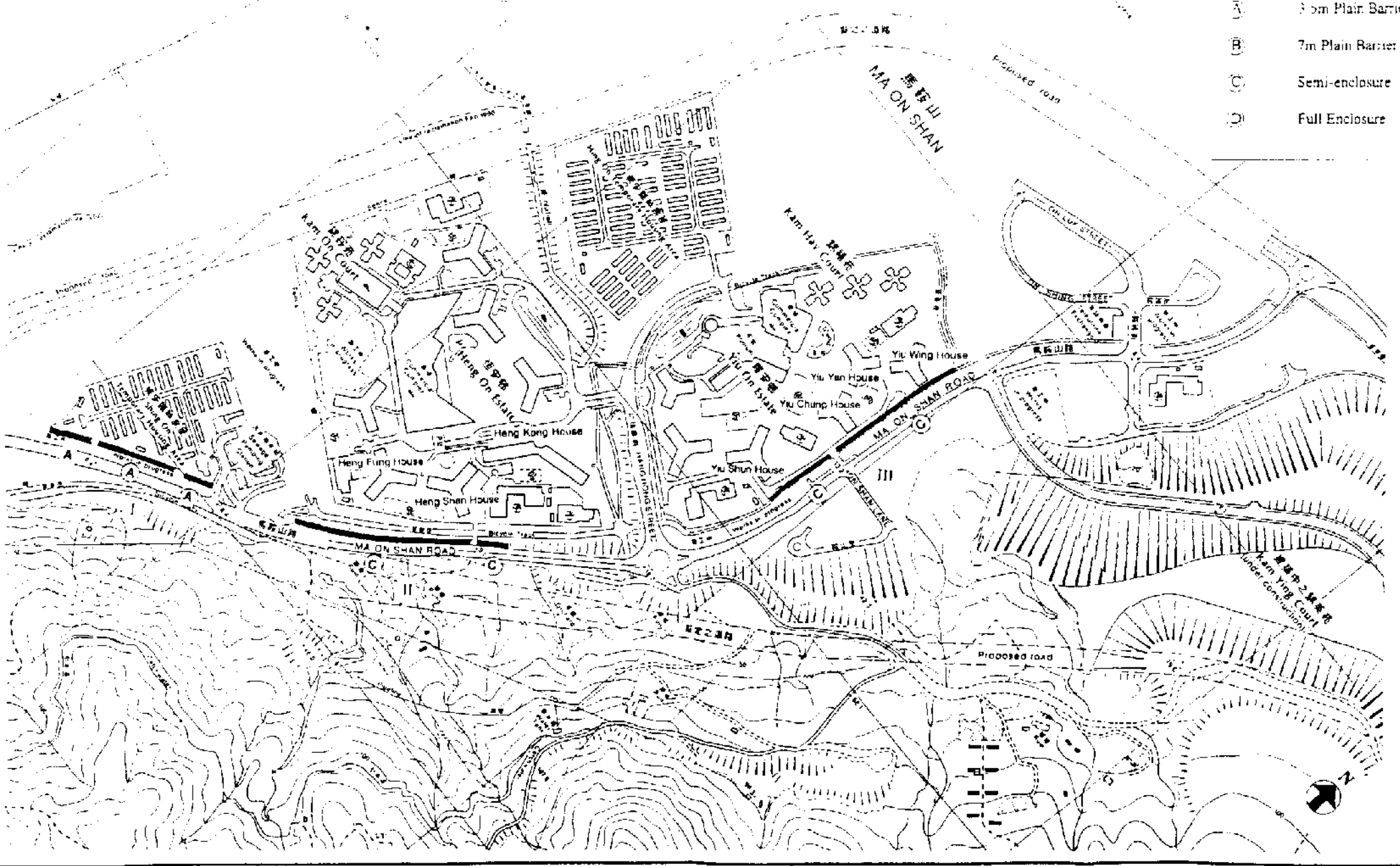

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	20
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES MA ON SHAN ROAD (SHEET 1 OF 1)	**Scale**	1:5000
		Date	FEB 1995

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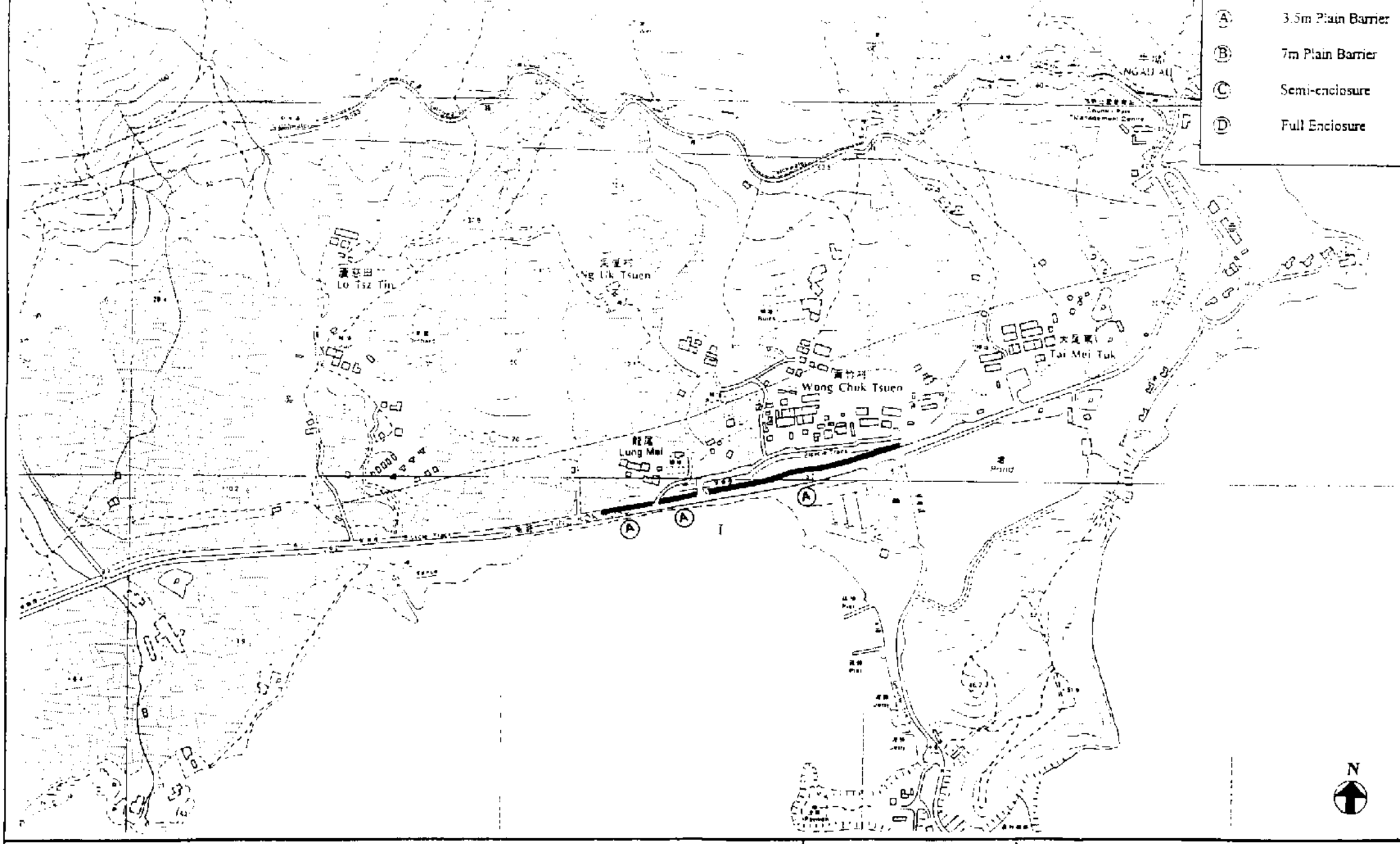

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	21
		Scale	1:5000
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES TING KOK ROAD (SHEET 1 OF 1)	**Date**	FEB 1995

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Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	22
		Scale	1:5000
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES PO LAM ROAD NORTH (SHEET 1 OF 1)	**Date**	FEB 1995

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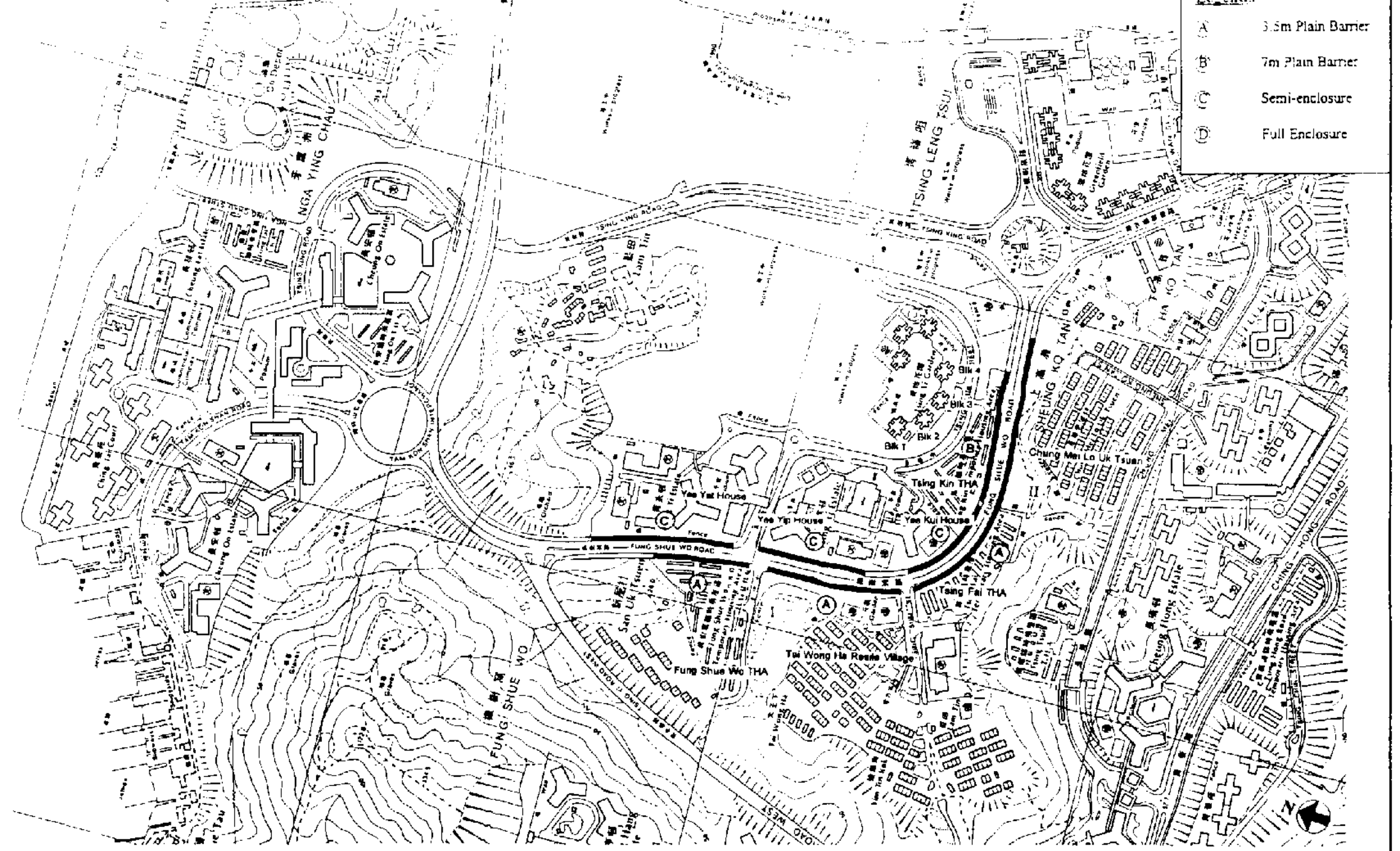

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES FUNG SHUE WO ROAD (SHEET 1 OF 1)
Figure	23
Scale	1:5000
Date	FEB 1995

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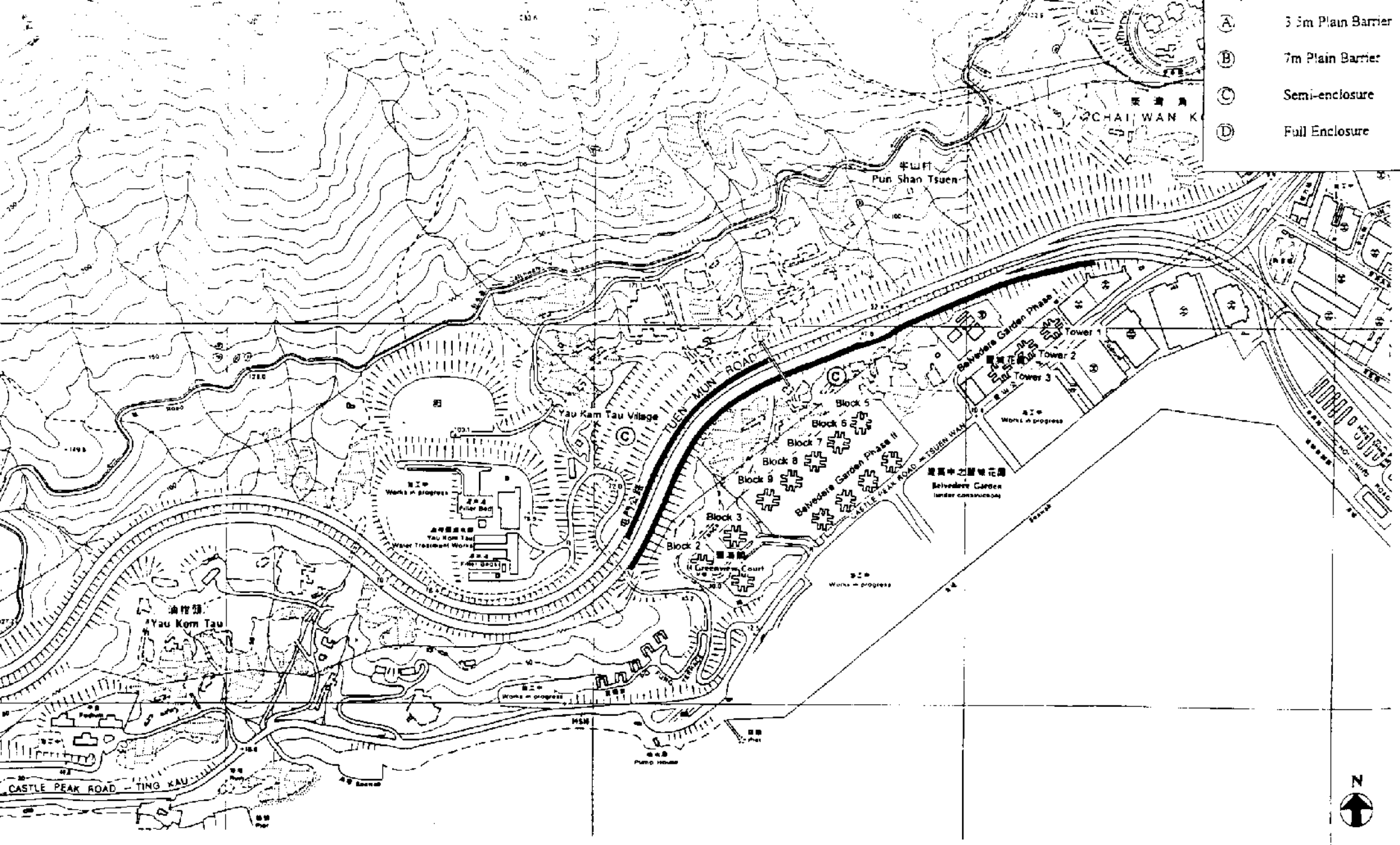

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES TUEN MUN ROAD (SHEET 1 OF 3)
Figure	24
Scale	1:5000
Date	FEB 1995

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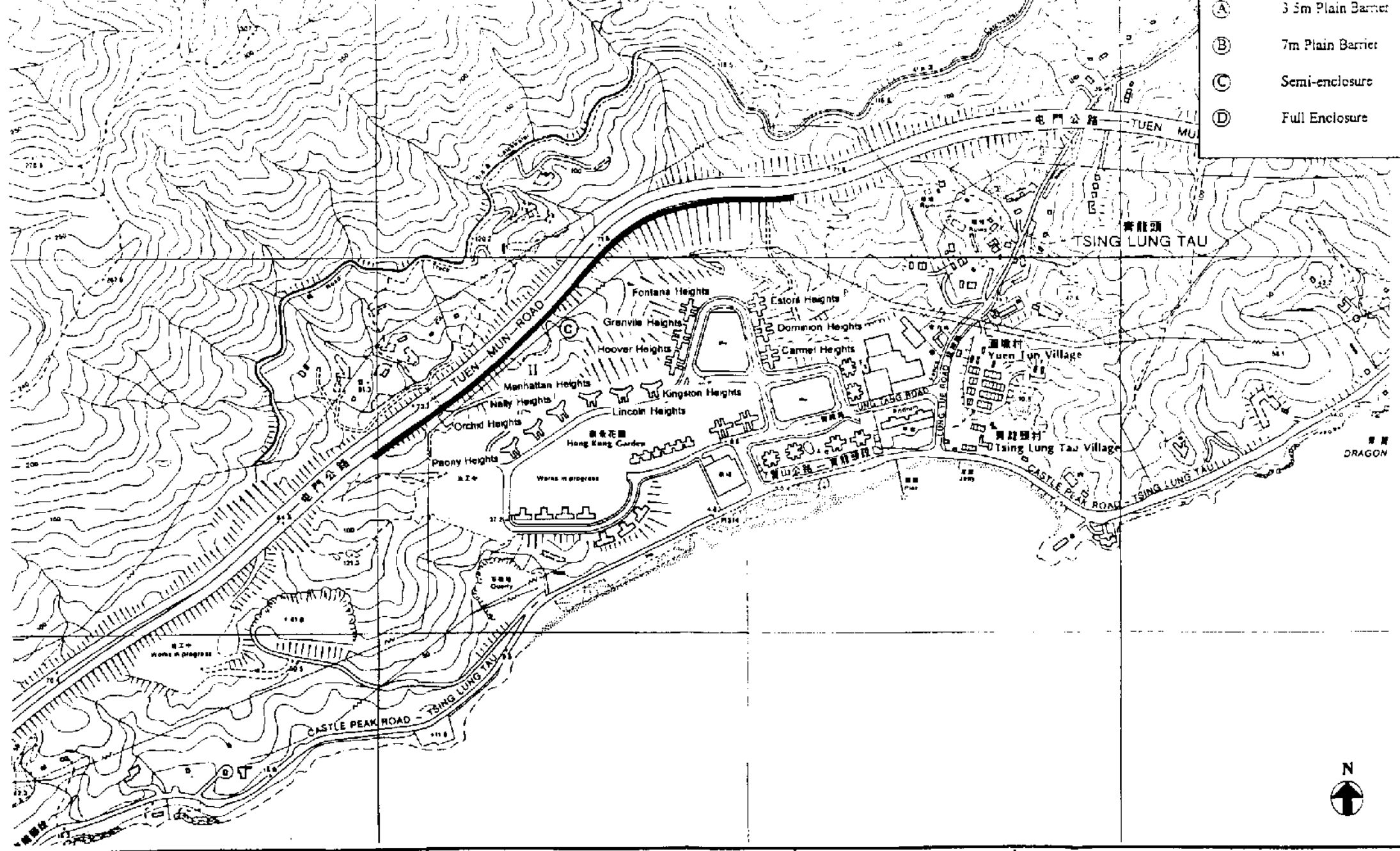

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES TUEN MUN ROAD (SHEET 2 OF 3)
Figure	25
Scale	1:5000
Date	FEB 1995

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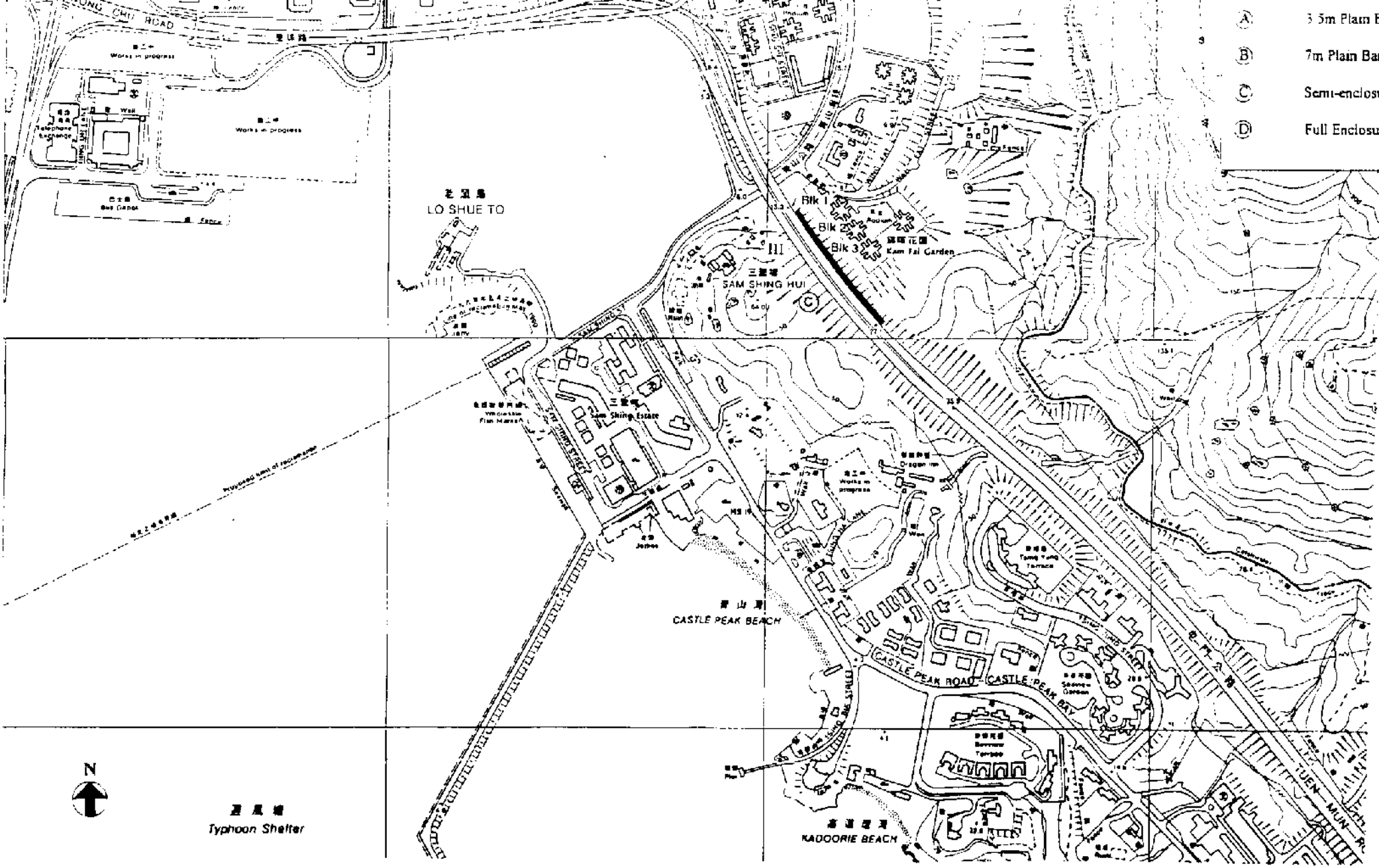

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	Figure	26
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES TUEN MUN ROAD (SHEET 3 OF 3)	Scale	1:5000
		Date	FEB 1995

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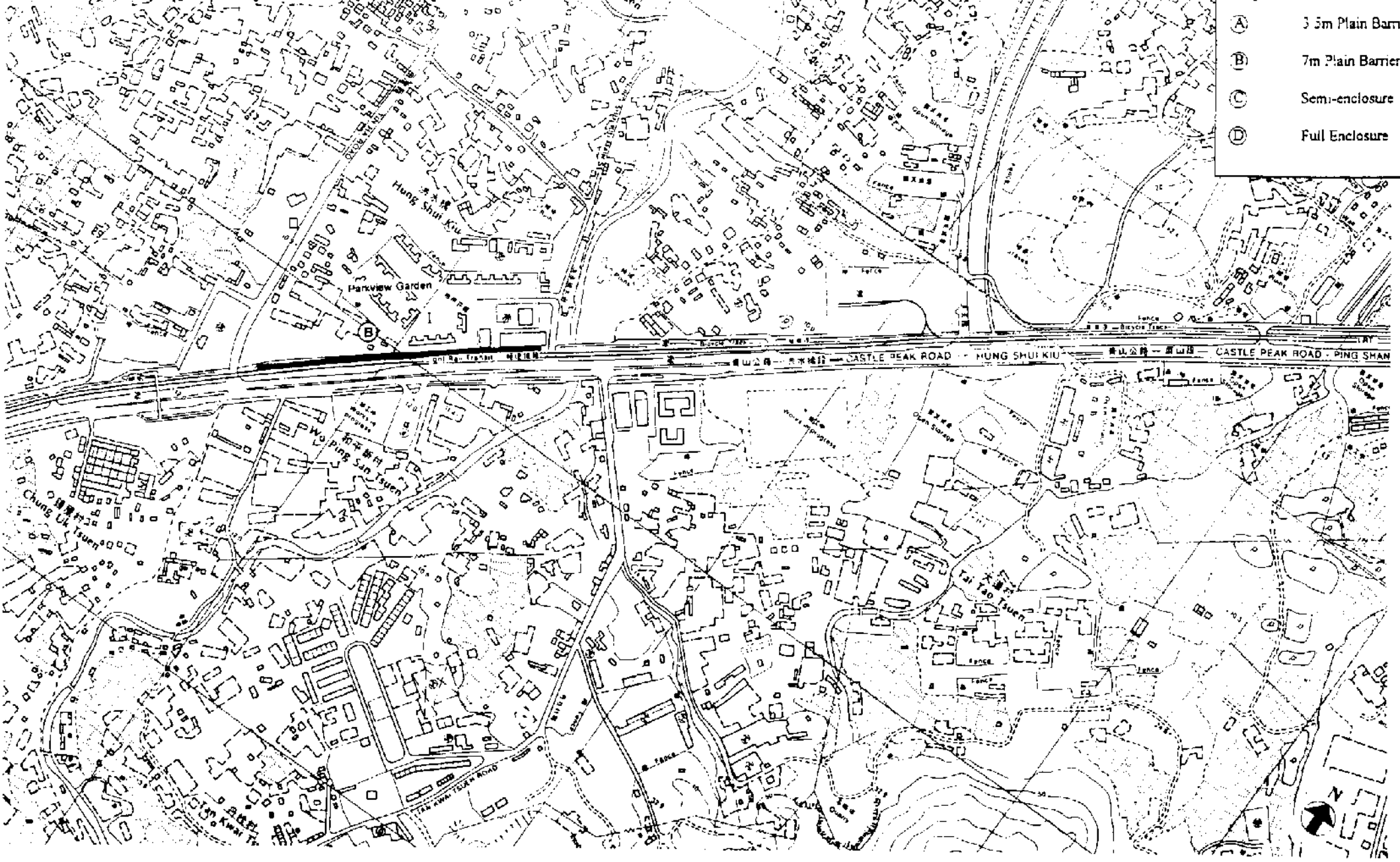

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	27
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES CASTLE PEAK ROAD - HUNG SHUI KIU (SHEET 1 OF 1)	**Scale**	1:5000
		Date	FEB 1995

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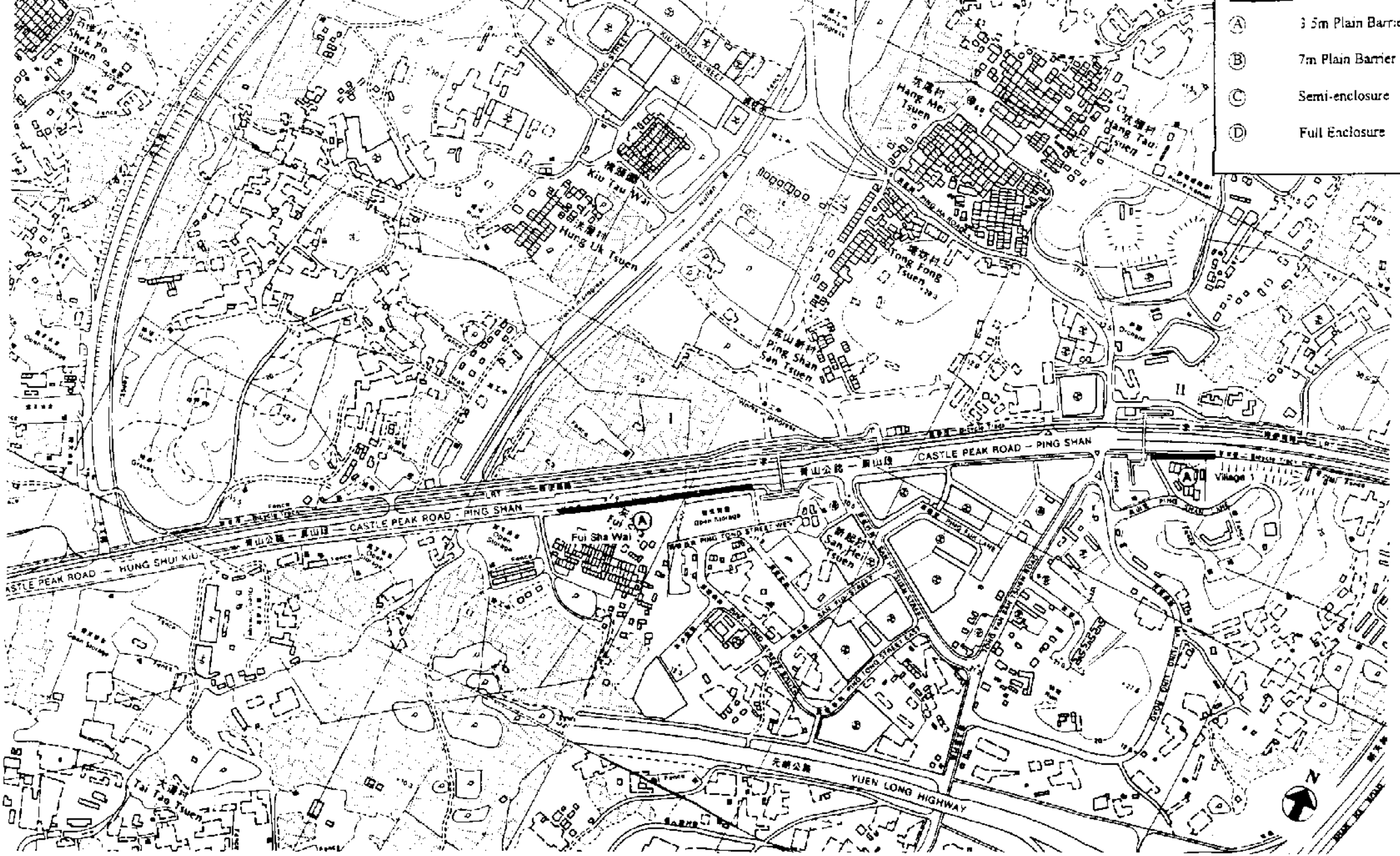

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES CASTLE PEAK ROAD - PING SHAN (SHEET 1 OF 1)
Figure	28
Scale	1:5000
Date	FEB 1995

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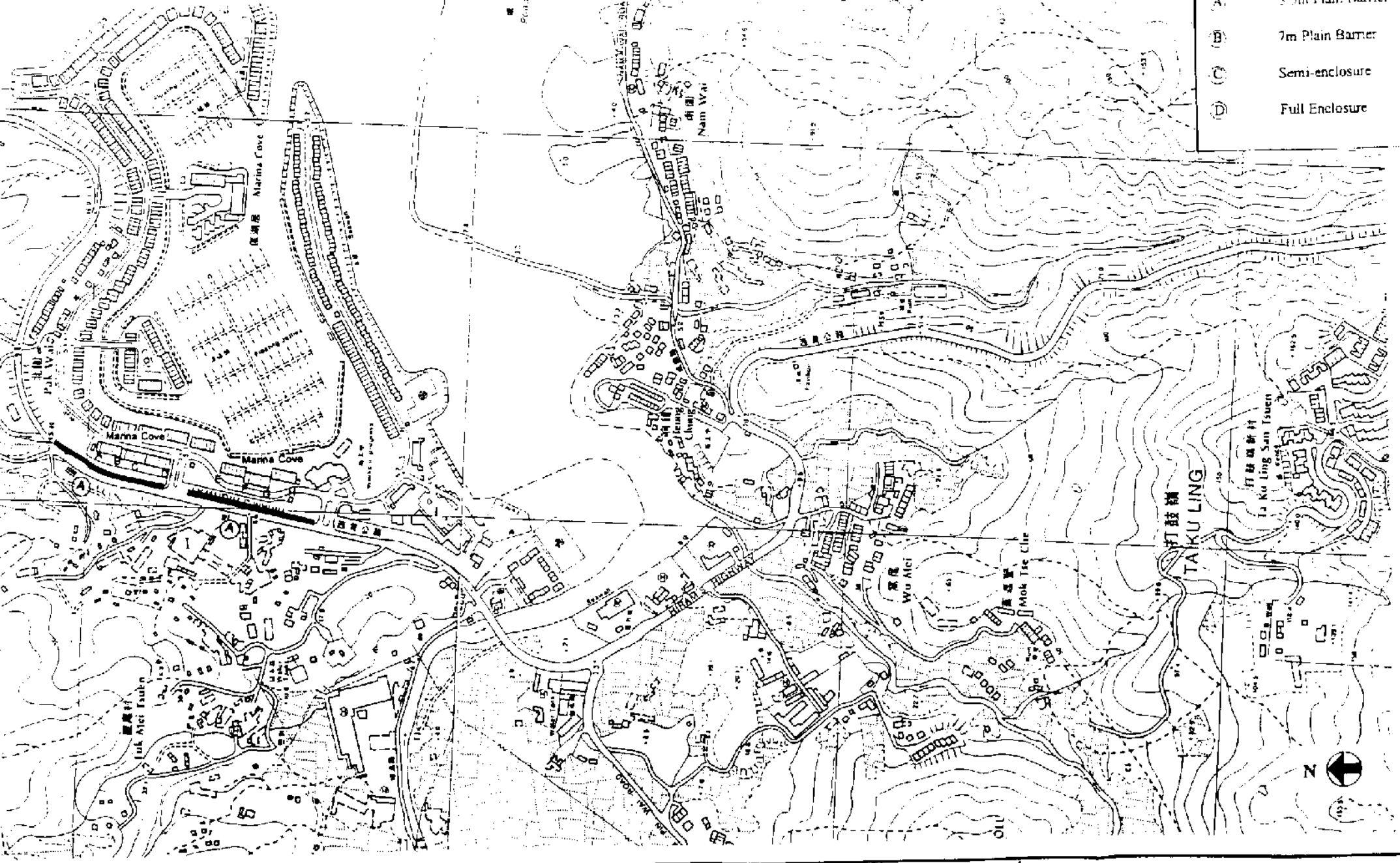

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES HIRAM'S HIGHWAY (SHEET 1 OF 1)
Figure	29
Scale	1:5000
Date	FEB 1995

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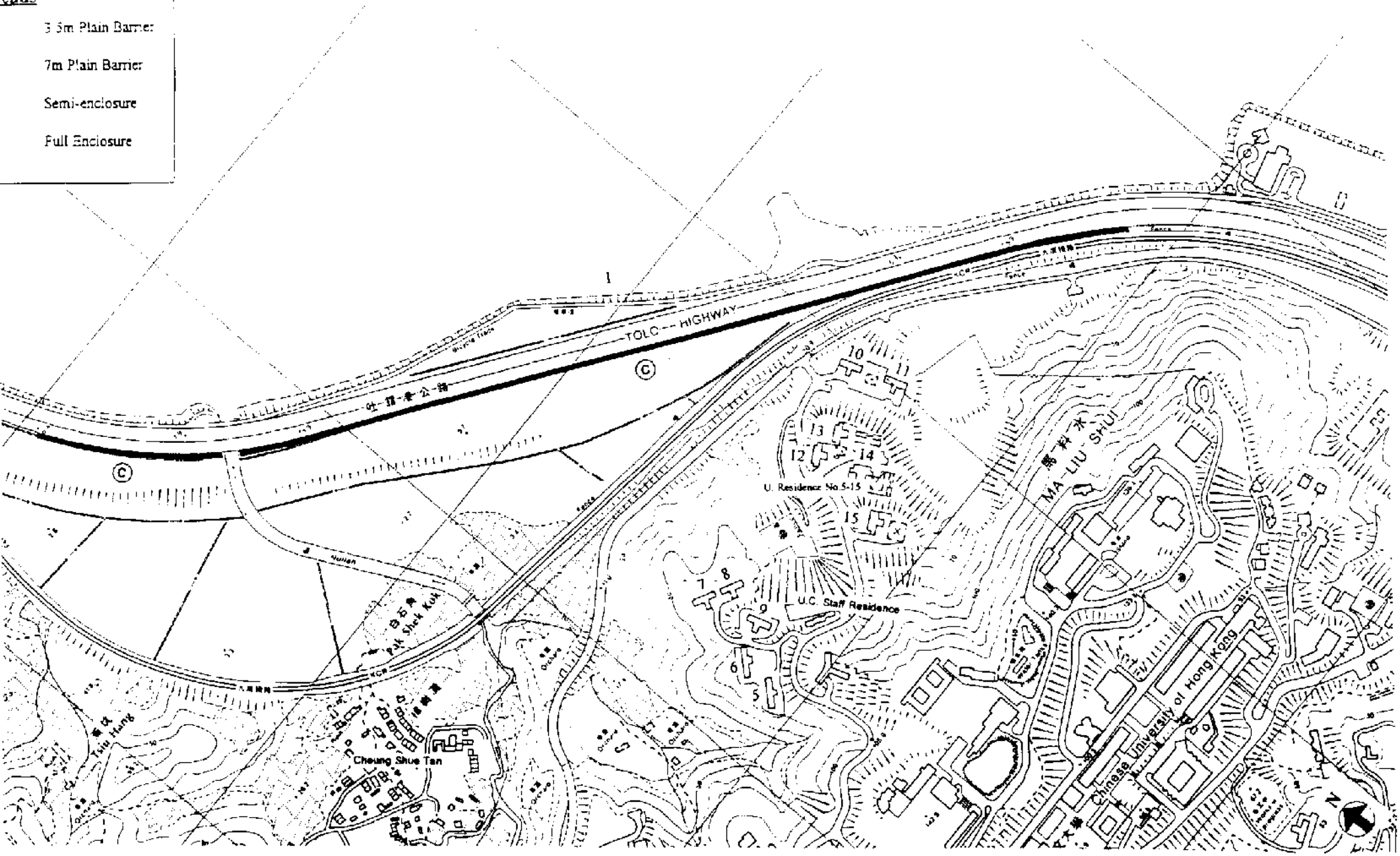

ject	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
e	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES TOLO HIGHWAY (SHEET 1 OF 2)

Figure	30
Scale	1:5000
Date	FEB 1995

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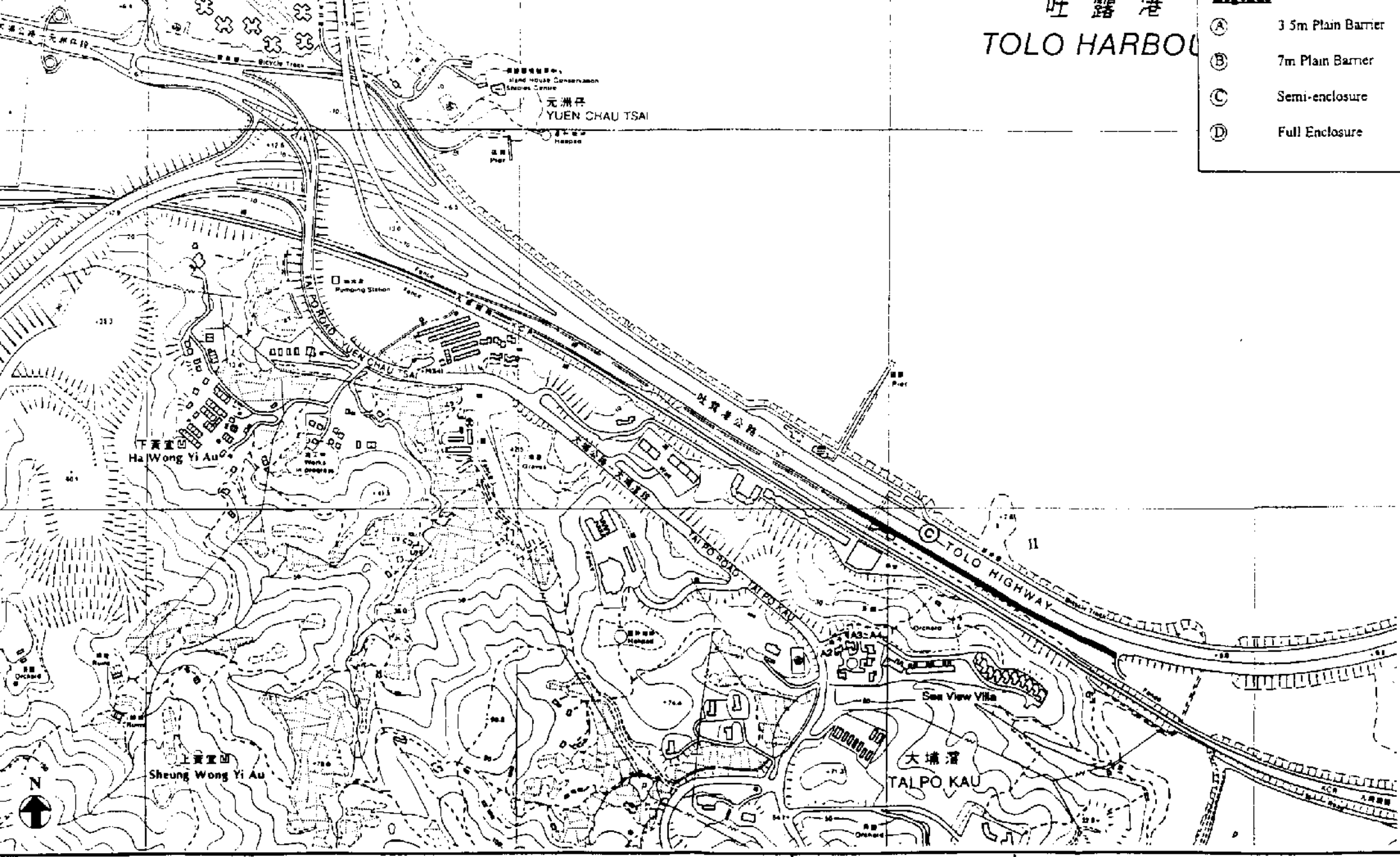

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES TOLO HIGHWAY (SHEET 2 OF 2)
Figure	31
Scale	1:5000
Date	FEB 1995

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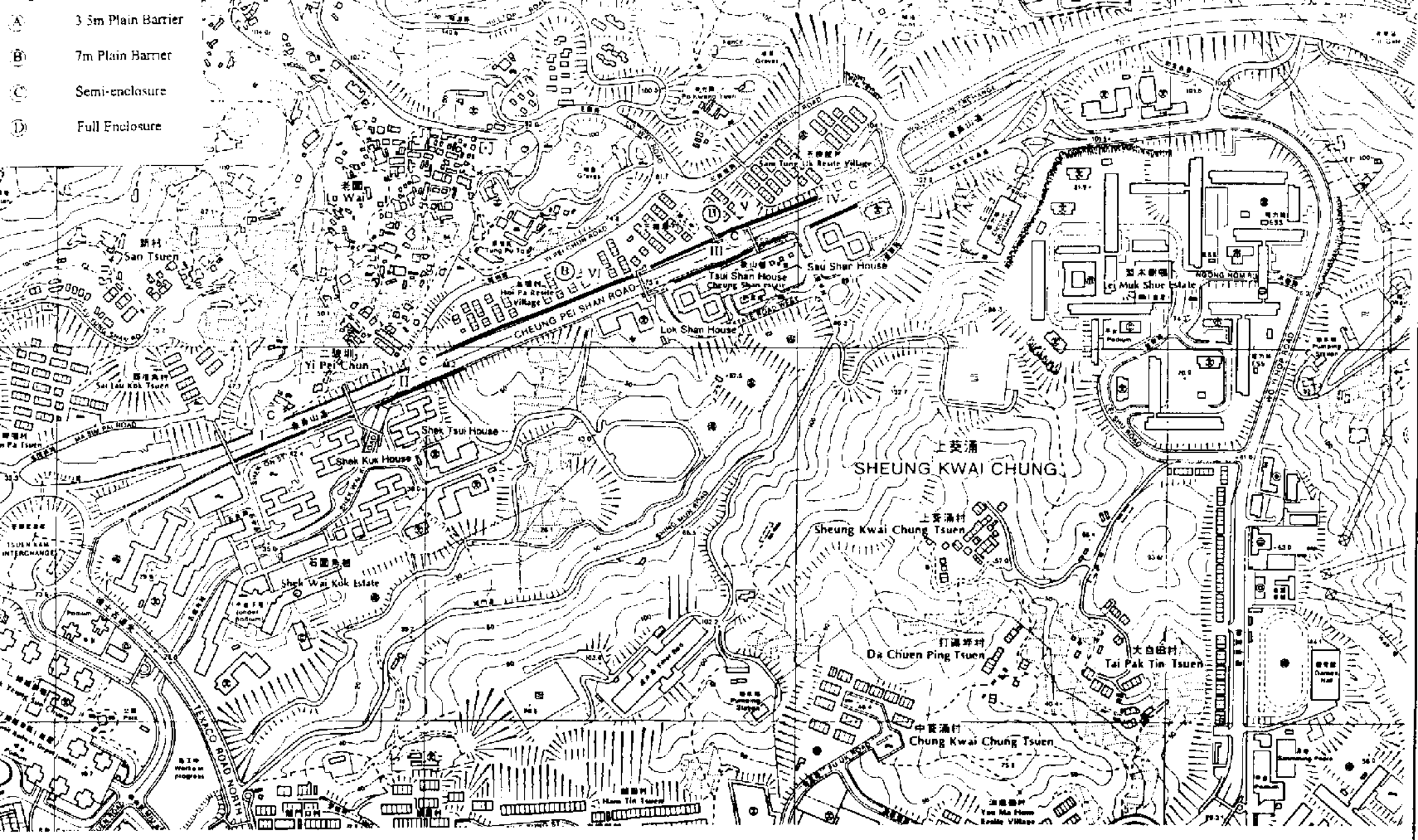

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES	**Figure**	32
		Scale	1:5000
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES CHEUNG PEI SHAN ROAD (SHEET 1 OF 1)	**Date**	FEB 1995

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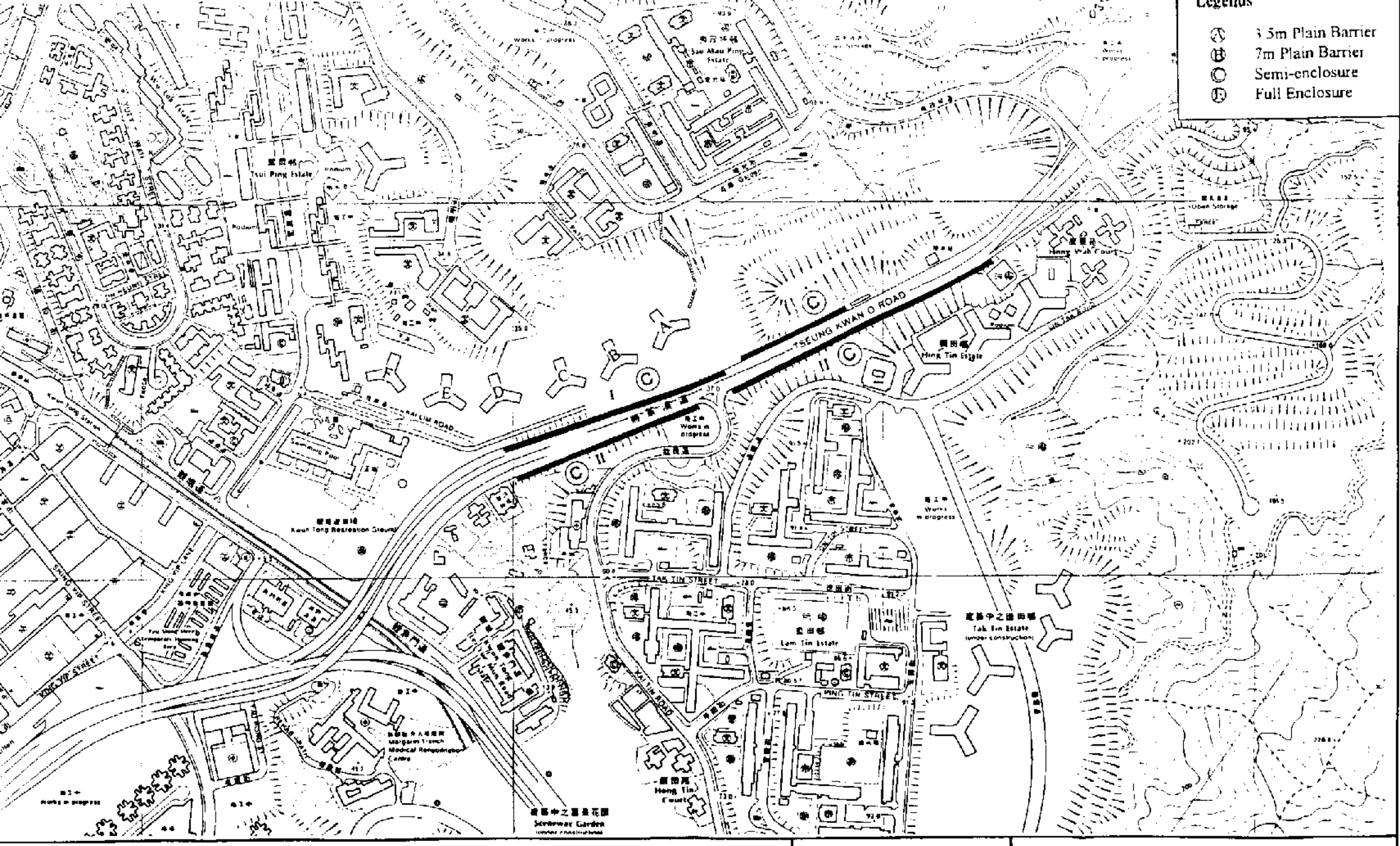

Project	SCOPING STUDY FOR PROVIDING RETROACTIVE ROAD TRAFFIC NOISE MITIGATION MEASURES
Title	CONCEPTUAL ARRANGEMENT OF NOISE MITIGATION MEASURES JUNK BAY ROAD (SHEET 1 OF 1)
Figure	33
Scale	1:5000
Date	Dec. 1995

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