Appendix V – Busway Planning and Design Manual, City of Winnipeg Transit Department, September 2004

CITY OF WINNIPEG
TRANSIT SYSTEM

CITY OF WINNIPEG
TRANSIT DEPARTMENT

BUSWAY PLANNING AND DESIGN MANUAL

September, 2004

DILLON
CONSULTING

MRC
McCormick Rankin
Corporation

Winnipeg
Embrace the Spirit • Vivez l'esprit

CITY OF WINNIPEG
TRANSIT DEPARTMENT

BUSWAY PLANNING AND DESIGN MANUAL

DILLON CONSULTING
McCORMICK RANKIN CORPORATION

September 13, 2004

Inquiries regarding acquisition, amendments, comments or suggestions should be directed to:

Owner:

City of Winnipeg
Transit Department

Manual Developed by:

McCormick Rankin Corporation

Dale Turvey, P. Eng.
Manager Transit
McCormick Rankin Corporation
2655 North Sheridan Way
Mississauga, Ontario, CANADA
L5K 2P8
Phone:(905) 823-8500
Fax:(905) 823-8503
E-mail: dturvey@mrc.ca

This manual is published without prejudice as to the application of the recommendations. This document may be reproduced for non-commercial purposes with attribution to the City of Winnipeg Transit Department.

FOREWORD

This manual was produced as part of the planning and design of the Southwestern and Eastern Corridors of Winnipeg's Bus Rapid Transit System. It is intended to provide standards, guidelines and typical applications for the use of planners and designers involved in the development of the busways.

The development of the standards and guidelines draws heavily on the design and operating experiences gained from busway systems in Pittsburgh, Ottawa and Brisbane, Australia. This experience has confirmed the importance of the station design standards to the ultimate success of busway design and the need to recognise that a busway is a legitimate rapid transit technology that happens to employ rubber-tired vehicles running on pavement instead of steel-wheeled vehicles running on track.

CONTINUING RECORD OF REVISIONS MADE
TO THE
BUSWAY PLANNING AND DESIGN MANUAL

This sheet should be retained permanently in this page sequence in the Manual. All revised material should be inserted as soon as received and the relevant entries made by hand in the spaces provided.

Manual Revision		**Entered By:**	**Date of Entry:**
No.	**Date**		
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			

TABLE OF CONTENTS

Page No.

LIST OF DRAWINGS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF TERMS

All Station service:	Bus service mode in which buses stop for passengers at each and every station.
Articulated Bus:	A flexible two-section, three-axle bus of up to 18 m length which bends when turning corners to reduce the turning radius that would otherwise be required. Rear wheels may be steerable.

Bikeway:	A pathway intended for the use of bicyclists and signed for their exclusive use.
Busway Underpass:	A structure or structures which permit a road or pathway to pass under the Busway.
Busway Overpass:	A structure or structures which permit a road or pathway to pass over the Busway.
Deadhead:	The term used to describe a bus or part of a bus trip when the bus is travelling out of service from one point on a route to another.
Dynamic Sign:	A changeable or variable message sign, sometimes used in the "travelling message" mode or in the static but changeable mode. Normally used as "arrivals" and "departures" boards at stations.
Feeder/line haul service:	A bus route, which performs initially as a feeder service, but then continues in service on the Busway thus eliminating its need for passengers to transfer.
Feeder service:	A bus route which gathers passengers from local collector or arterial roads and delivers them to the busway station for transfer to the rapid transit system; sometimes used as the term for any local route bus.
Hunting Force:	A horizontal live load caused by lateral interaction of the rail vehicle and the guideway. Referred to as a nosing force by the rail industry.
Interlining:	An operational mode whereby a bus makes sequential trips on several different routes rather than the same route.
Kiss and Ride:	A stopping zone or short term parking zone adjacent to or near a station which is meant for the prime purpose of dropping off or picking up passengers by private vehicles.
Line haul service:	A bus route that shuttles back and forth along the Busway.
Link:	A covered walkway (roof only) between two shelters.
Park and Ride:	A parking lot provided adjacent to or near a busway station for the purpose of providing parking for passengers. Park and Ride lots may also be remote from the Busway where they are directly served by feeder/line haul routes.

Rail-Structure Interaction Forces:	Forces created by differential movement of continuous welded rails with respect to the structure when the rails are directly fastened to the structure.
Railings:	A barrier consisting of rails and supports; a barrier wall.
Recreational Pathway:	A joint use pathway for pedestrians and bicyclists.
Route Tab:	A sign at a bus stop showing the route numbers of all buses which will stop there.
Through Routing:	An operational mode in which two routes that would normally terminate in the same general area are linked so that passengers can travel from one route to the other without changing buses.

END OF SECTION

CHAPTER 1

INTRODUCTION

CHAPTER 1 - INTRODUCTION

1.1 GENERAL INFORMATION FOR USE OF THE MANUAL

1.1.1 General

This manual, together with the Standard and Directive Drawings, constitute the Design Criteria set forth and adopted by the City of Winnipeg Transit Department for the planning and design of the *Bus Rapid Transit (BRT) system* and any departure from these criteria must receive prior approval.

The use of this manual will ensure a state-of-the-art and consistent approach to the planning and design of the bus rapid transit facilities. The standards and guidelines that it recommends have been proven in practice. ***The Planner / Designer is urged to read Chapters 1 and 2, which provide an introduction to the subject of Busways and Bus Rapid Transit planning and design, so as to properly understand the manual's design approach.***

Chapters 3 through 14 cover the standards and guidelines for specific elements of Busway and Bus Rapid Transit design. This is a standards manual and does not include engineering design calculations or methodologies with which the Planner / Designer is assumed to be familiar. To reduce the need for updating and re-printing, rather than providing excerpts, references are made to other standards, codes and design manuals, which must be used in conjunction with this manual. A listing of these reference documents is contained at the beginning of each chapter.

Also included is a Glossary of standard Bus Rapid Transit terms. The Standard and Directive Drawings are grouped in the following manner:

Series A-Design Vehicle

Series B-Busway Sections

Series C-Busway Details

Series D-Access Ramps

Series E-Busway Stations

Series F-Busway Structures

1.1.2 Manual Updates

It is intended that this manual will be edited to conform to current Winnipeg Transit standards where appropriate. Winnipeg Transit also maintains a listing of all revisions made to the final version of this manual. The Planner / Designer must consult Winnipeg Transit to ensure that he / she is in possession of all such revisions. It is the responsibility of the user to ensure that the "Record of Revisions" (found inside the title sheet) is complete and up to date. It is recommended that the user retain each edition of the Transmittal Letter for revisions, as it is issued, in the last section of this manual under "Revisions".

1.2 THE BUS RAPID TRANSIT CONCEPT

1.2.1 Introduction

Bus Rapid Transit (BRT) is defined as the operation of buses in an exclusive or semi-exclusive right-of-way with on-line stations. It provides benefits similar to train travel in rail corridors but, in many cases, without the need for passengers to transfer from a feeder bus or other access mode to the rapid transit line haul service because the same vehicle can perform both functions.

Busway rapid transit provides unlimited flexibility to tailor the public transport operation to suit the corridor and regional needs because the rapid transit vehicle, the bus, can operate on and off the rapid transit right-of-way. Busway station design allows buses to pass other buses that are picking up and dropping off passengers. This means that skip stop and express services can be combined with local stopping services in the same right-of-way.

The planning and design of Bus Rapid Transit, or BRT, involves a total systems approach to the supply and operation of a bus based rapid transit service. The flexibility of the bus to operate on different types of right-of-way and under different operating conditions means that BRT encompasses significant variations in guideways, stations, vehicles, Intelligent Transportation Systems (ITS) technologies and operating strategies.

In planning and designing a specific BRT application, the guiding principle when selecting from among the range of BRT options must be to deliver a superior level of service and a high quality public transit image.

Clearly, transit use will only increase as a result of BRT implementation if its design and operation result in a public transit service that meets the rising expectations of a sizeable proportion of a population who now commute by car.

Satisfying this passenger expectation should be the guiding principle that underlies any implementation strategy for BRT. It will require that BRT deliver a service, which is fast, frequent, convenient and simple and easy to understand. Thus, the passenger facilities should be pleasant, high quality environments with a well-developed directional signage system that directs the passenger through the facility, to and from important areas and buildings in its immediate vicinity and to and from other transportation modes where applicable.

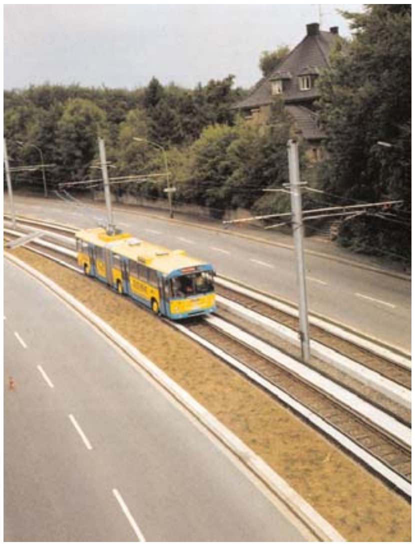
Passengers should be able to easily use real time information that informs them how to travel on BRT by a local feeder or express bus to their ultimate destination. The requirements of the fare system should be explained and be easily understood. It should be easy to pay a fare and make a trip involving the use of buses operated by different bus companies, if necessary, and other modes of transport.

Passengers will expect the bus service to be fast, frequent and reliable. This will require some form of centralized vehicle monitoring, service control and real time passenger information.

All this implies a need for customer service focus during all steps in the development of the BRT system. This customer service focus will affect the design and construction of the BRT infrastructure as well as its operating policies.

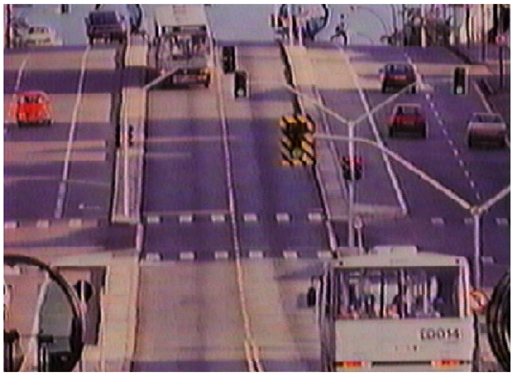
1.2.2 BRT Infrastructure

Running Ways



In its most developed form, BRT operates on a busway, which is a two-way road or guideway. Shoulders are only required where snow storage is necessary. Ramps are provided at key locations to allow buses to enter or exit the busway to and from the local streets to give passengers a transfer-free ride. Ramps connecting to arterials are normally two-way and located so that buses using the ramp can also serve the station before continuing on the busway. The connection to the local streets is designed through signing, pavement markings and curbs to discourage unauthorized access to the busway. For most ramps the predominant direction of travel is to and from the Central Business District (CBD). Where possible, however, all turning movements on and off the busway should be accommodated to allow for future flexibility in bus service design.

Guided busways are used to minimize the right-of-way required and to improve ride comfort at high speeds. They also give the busway more of a “rail-like-feel”.



Where a fully grade separated right-of-way cannot be justified, BRT can operate in a bus lane or even a mixed flow lane on an arterial street or controlled access highway. The bus lane may be a conventional curb lane, median lane, or controlled access highway shoulder lane. Intersection priority may be provided through various forms of signal priority with or without queue jump lanes or by limited grade separation. There are numerous examples of different bus lanes and intersection treatments. Because the BRT bus can operate both on and off a busway, the use of a bus lane or mixed flow lane can be combined with short discontinuous sections of busway. This means that a region-wide BRT system can be put in place initially with only a small amount of new infrastructure in areas of high congestion.

Where it is judged to be cost effective, the running way line, grade and vertical and horizontal clearances can be designed to be compatible with LRT requirements to protect the option for long term conversion to rail should this ever be necessary.

Stations

The normal station layout consists of two parallel side loading platforms preferably offset head-to-head on either side of a grade separated pedestrian crossing. In major stations with planned one-way hourly bus volumes of greater than about 150, the busway is widened to four lanes with a central fenced median to allow buses to pull out around stopped buses and express buses to bypass the station. Where hourly one-way bus volumes are less than about 100 per hour, an at-grade pedestrian crossing may be employed.

Parallel platforms are used because conventional transit buses only have doors on the right hand side. Island platforms that are often used on rail systems can only be used if buses can cross from one lane to the opposing lane at either end of the platform. There is, however, growing interest in new BRT buses with doors on both sides that could accommodate island platform layouts as this could reduce the overall station infrastructure and property costs.

BRT stations can be designed with high platforms and pre-paid areas to speed loading and facilitate access by disabled persons where some form of precision docking is employed.

The station buildings and facilities are the same as those required for rail and can be as simple as a single shelter or as complex as those found on any subway rail system. Because both stopping and express services can use the same stations, stations can be as little as 600m apart where land use reasons dictate. Properly designed stations are of paramount importance for the functioning of the BRT system as a rapid transit facility and in presenting BRT as a high quality transit technology. The stations should be designed to a common highly recognizable architectural theme. They are normally unattended and their design should stress passenger safety, convenience, comfort, low maintenance and accessibility. Station layouts follow design standards subject to the dictates of site conditions.

The recommended platform lengths for BRT stations assume low per passenger boarding times of between 1.0 and 1.5 seconds particularly at high usage stations. This is best accomplished through the use of multi ride tickets or passes and off board fare purchasing including SmartCard technology. On routes using articulated buses multi door entry using some form of honour fare is desirable.

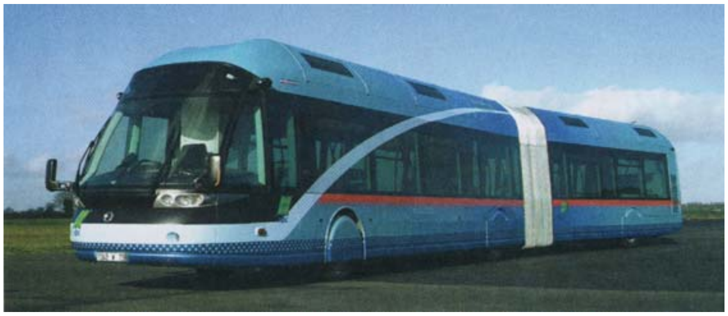
Passengers arrive and depart from most stations as pedestrians, local bus passengers, bicycle riders, park and ride or kiss and ride users. The pedestrian links to the local sidewalk system are thus very important and should accommodate pedestrian flows via the shortest practical route to and from all parts of the community. The majority of walk-in passengers walk less than 400m to and from the station but some passengers can be expected to walk up to 600m.

Experience has shown that well designed busway stations have the same ability as rail stations to act as catalysts for land use intensification. Busway station investments can influence compact, mixed use, and transit-supportive development. This in turn can stimulate increased transit ridership but transit investment alone is not sufficient to influence land use decisions. Other supportive policies are required as well. These may include transit oriented regional planning policies, urban design standards and parking policies.

Maintenance Considerations

The future maintenance demands created by the construction of the BRT facility must be considered during its design. The seven-day-a-week, eighteen to twenty hour daily operation of public transit means that most maintenance must be capable of being performed during operating hours without seriously disrupting bus service. Design of the busway and stations should stress the use of durable and vandal resistant materials and modular and easily available components, to minimize ongoing maintenance costs and reduce inventory costs.

1.2.3 Bus Types



Even with the service advantages of a grade separated alignment, there is some concern that the choice of BRT technology for a corridor somehow infers that it will be second class compared to corridors in which rail has been recommended. This concern is reinforced by the poor image of the present bus service in many communities especially among non-transit users. Much of this image problem is connected with the vehicle itself which until recently would have been a conventional diesel bus. Many European and North American bus manufactures are now developing new state-of-the-art buses specifically for the BRT market. Some of the potential attributes of these vehicles such as low-floors, doors on both sides and precision docking and guidance capabilities may need to be considered in the station design process.

Even with the introduction of new BRT buses, however, conventional buses are likely to remain in widespread use for many years to come and will thus continue to be much in evidence on BRT services, particularly on the combined feeder/line-haul routes. This means that depending upon the service design and operating plan, the station designs will still have to accommodate these vehicles as well.

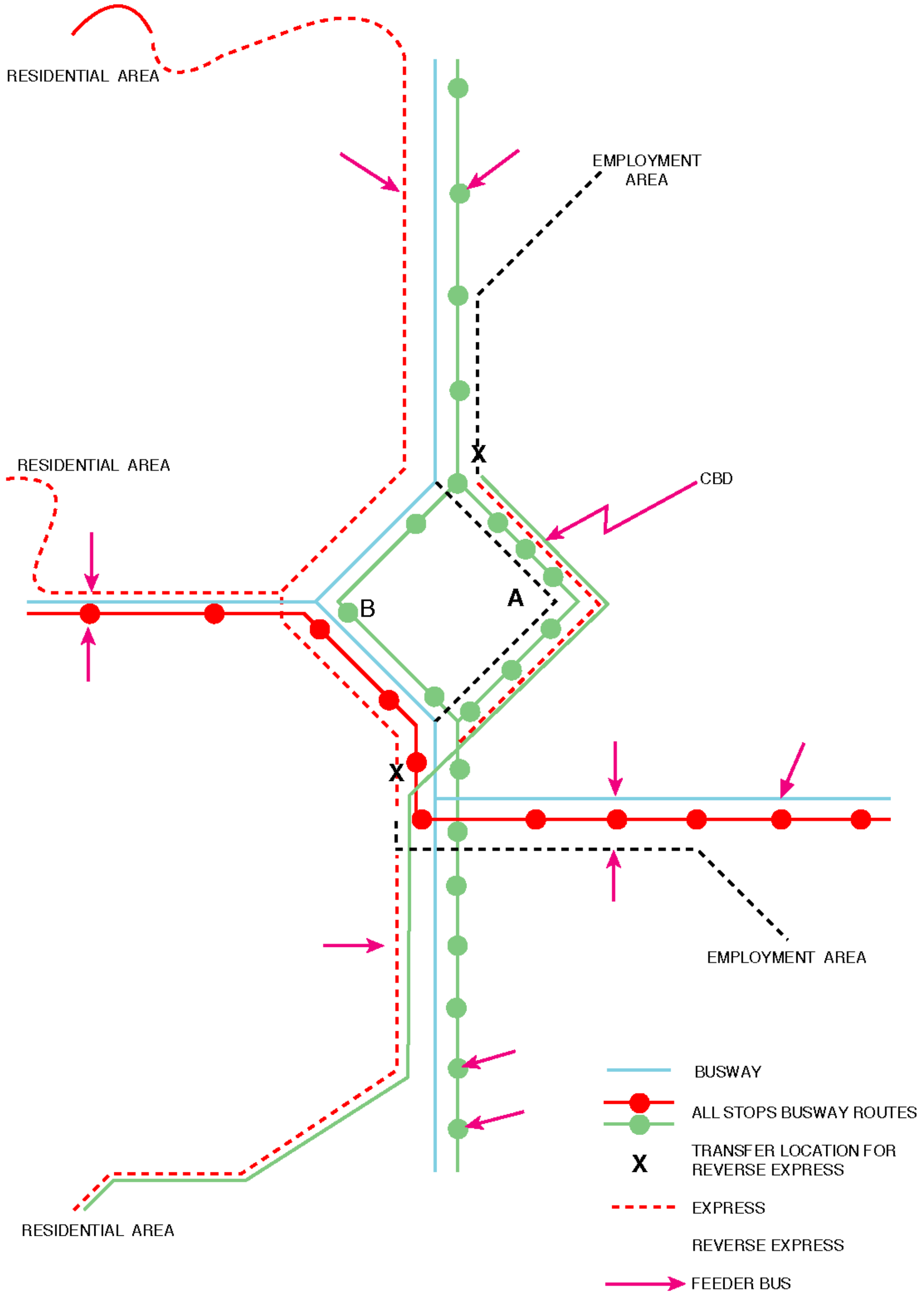
1.2.4 BRT Operations

Route Structure

BRT is an appropriate rapid transit technology for corridors with projected peak hour / peak direction passenger volumes in the 1,500 to 10,000+ range. Busway operating speeds are normally 80km/h between stations in unconstrained areas, and 50km/h in constrained areas and within stations.

The typical BRT route structure is illustrated schematically in Figure 1.2A and includes the following service types.

Figure 1.2A – BRT Route Structure



All Stops Route

This route operates just like a rail service, running over the full length of the busway and stopping at each station where it serves passengers arriving and departing at the station on foot by feeder bus, bicycle, kiss and ride and (at some locations) by park and ride. Park and ride facilities have to be carefully located so as to avoid sterilizing potentially valuable developable land adjacent to the station. The All Stops route may be extended off the busway, via a priority routing if necessary, to a remote park and ride site.

The All Stops route service frequency must be high throughout the normal operating day (5 minutes peak, 10 minutes midday at least). The base service may be supplemented by additional short-term services in the central higher demand sections and articulated and double articulated buses used where demand levels warrant.

Peak Direction Express / Limited Stop Service

A key BRT feature is the ability to offer a high frequency no-transfer service to a higher proportion of trips than is usually the case for rapid transit in suburban areas. This is achieved through the operation of a network of one-way, high frequency (every 10 minutes or better), express / limited stop services. In the a.m. peak, for example, buses pick up passengers in residential areas away from the busway, travel on the local street system to the busway, then operate on the busway in an express or limited-stop mode depending upon the demand levels and trip patterns. The intermediate station stops allow passengers to directly access developments next to the stations and to transfer to the all stops and counter peak direction express / limited stop services for travel to other locations in the corridor. In the p.m. peak, the one way service is provided in reverse.

The express/limited stop combined feeder/line haul services are a key feature of BRT, which gives it the ability to offer a high frequency no-transfer service to a higher proportion of trips than is usually the case for rapid transit in suburban areas. In the Ottawa system, for example, 70% of the passengers use this type of service and on the Adelaide guided busway 64% of passengers access their bus before it reaches the busway.

In the operating plan, it will be important to design the express / limited stop routes so that they each have a large enough catchment area and serve a sufficient number of destinations and intermediate stations to justify a service frequency of at least a bus every 10 minutes. It is usually preferable to achieve this by adding destinations rather than by increasing the size of the residential pick-up loop since this usually minimizes the running time per passenger served.

Counter Peak Direction Express / Limited Stop Service

The all stops service serves corridor destinations, but to reduce the need to transfer to major destinations away from the busway a network of counter peak direction express / limited stop routes can be operated.

Because these routes operate in the counter peak direction, they can be provided by using bus trips that would otherwise be the deadhead links for the one way peak direction express / limited stop services. The marginal cost of providing these routes is therefore usually low and a high frequency (every 10 minutes or better) service can be provided even where demand levels would not normally justify it.

Sophisticated scheduling programs allow the two express / limited stop networks to be developed in a compatible way using trip-to-trip interlining to minimize the total number of buses required. Actual operating experience has shown bus savings in the 10% to 12% range. The combination of area-wide peak and counter peak direction express / limited stop network means that all major destinations can be within a one transfer ride of virtually all residential areas. These factors translate into per passenger km operating costs that are usually less than those for an equivalent surface bus operation and a transit technology that is particularly adaptable to the dispersed trip making that occurs in modern suburban areas.

Local Arterial/Feeder Services

Arterial bus services will continue to be operated as at present with their routes modified to reflect the presence of the busway. These modifications will include:

- Route diversions to ensure that each route intersects the busway in at least one location where passengers can transfer conveniently at a busway station.
- The elimination of route sections where arterial bus service can be replaced by walk-in access to the busway.
- Route diversions where the arterial route may actually use a section of busway.
- Timing changes to provide a ‘pulse’ operation at major transfer locations (particularly late at night when service frequencies may be low).

In some cases, the BRT station stop for the arterial/feeder route may be part-way along the local route and an on-street fly stop is all that is required. Where the feeder bus service terminates at a BRT station, a local bus terminal with bus turn-around facilities will be required.

Service Control and Public Information

An important aspect of rail transit that many people cite as one of the key reasons why they would use it as opposed to bus transit is its ease of use and simplicity. Getting lost and the fear of making a fool of oneself are important reasons for not using the bus quite apart from overall level of service considerations. To help overcome this, BRT includes ITS such as vehicle location and control systems to provide a rail like level of service in terms of reliability and real time passenger information.

The use of ITS also permits a more creative approach to the whole issue of traffic control and signal priority. It is often difficult to make much use of signal priority in an integrated traffic signal network because of the limited ability to modify cycle times and phases. Also, from the BRT perspective, being able to maintain service regularity in the face of traffic congestion can be equally if not more important than simply increasing travel speeds on some buses. Giving priority to a bus that is running ahead of schedule will, for example, only exacerbate the typical bunching problem that is often associated with high frequency bus routes. By using ITS to give priority to only buses that are behind schedule, this problem can be avoided.

Bus systems are often difficult for the infrequent user to understand and use. The network simplicity of most rail systems makes them particularly attractive and is one of the reasons why infrequent transit users tend to favour rail. To be marketed successfully, BRT needs to be able to emulate a rail-like simplicity and to be identified as something different than simply an improved bus system.

Information and directional signage and services should be provided so that an infrequent transit user with limited geographic knowledge of the commuting alternatives and neighbourhoods served by each BRT station is able to use the BRT system easily and with confidence.

On entering the station, information on fare payment methods and trip planning should be clearly visible, discernable and accessible for pedestrians. Clear directional signage should be provided from this point to the stop or stops on the station platform. At each stop the basic information should be repeated to confirm the fare and trip planning decisions made by the passenger. For the passenger arriving at the station, route information about connecting local services and the immediate station vicinity within a reasonable walking distance should be provided at each station stop and the station exit.

This information should be provided using conventional static maps, schedules and written material supplemented by the installation of automated dynamic real time information systems provided as part of the BRT ITS. Real time information can be provided in a variety of formats ranging from the ability to interrogate an information service by telephone to the display of real time bus arrival information on a TV screen. Both approaches should be considered.

1.2.5 Implementation

Busways are the infrastructure component of bus rapid transit and perform the same function for bus rapid transit as the track and stations do for the rail vehicles in rail rapid transit systems. The key functional difference between the two systems is the ability to operate busway stations as stand alone entities without necessarily initially having to connect them with a busway right-of-way or track as is required for rail rapid transit. This aspect of busway infrastructure has important implications for the planning, design and operation of any busway corridor.

The separation of the busway stations and right-of-way opens up many more options for the development and implementation of a busway corridor than is usually possible with rail transit. While the end point will be the same; an exclusive right-of-way with on-line stations, the staged development of a busway corridor may include sections in which buses use existing streets and bus lanes between stations as an interim measure. This flexibility means that rather than implementing a busway corridor by building it in a conventional rapid transit manner from one end to the other, strategic infrastructure investments can be made initially at key locations throughout the whole length of the corridor to establish an early presence for the bus rapid transit service.

This provides an opportunity to influence travel behaviour and land use as new development is occurring. For example, a busway corridor might be developed by initially constructing a limited number of key stations where land use development potential exists and linking them by mixed flow traffic lanes and exclusive bus lanes and then gradually replacing these links with fully exclusive busway sections.

While BRT shares many of the characteristics of rapid transit rail systems, there are key differences that should be exploited if full advantage is to be taken of the flexibility of BRT. These differences include:

- the ability to provide stations at a closer spacing than is possible with rail;
- to directly serve land uses beyond a convenient walking distance of the guideway (busway) through the use of combined feeder/line-haul services; and
- to stage construct the guideway and provide service throughout the corridor.

BRT is also recognized as a legitimate precursor to rail rapid transit. Properly planned and designed, it can help to establish and grow patronage to levels that can eventually support frequent rail services. The early introduction of rapid transit in a corridor through the use of BRT also encourages the important link between transportation and land use.

Rail transit can be implemented in this way by ensuring that the basic infrastructure elements of the busway are also rail compatible.

END OF CHAPTER

CHAPTER 2

DESIGN APPROACH

CHAPTER 2 - DESIGN APPROACH

2.1 INTRODUCTION

This chapter summarises the Bus Rapid Transit System design philosophy contained in more detail under specific chapter headings. It also provides guidance as to the circumstances under which recommended standards may be relaxed.

2.2 DESIGN POLICIES AND PRINCIPLES

BRT is a rapid transit system designed to provide passengers with a convenient, comfortable and fast ride in a cost-effective manner. The BRT System is rapid transit with a series of stations that happen to be linked by a paved roadway rather than a rail track*.* ***It is not a two lane highway with bus stops*****.**

From the passenger's perspective the focus of the design effort must therefore be on the following factors:

- The convenience, comfort, and safety of the stations and their integration, particularly in a pedestrian sense, with the surrounding communities;

- the busway connections with crossing streets to provide the greatest possible flexibility in service design in response to changing customer needs; and

- the alignment, grade and cross-section of the busway roadway and on-street bus lanes linking the stations to provide a safe, comfortable and fast ride.

Stations may be located at much closer spacing than is the case with rail service because of BRT's flexibility to accommodate a full range of different operating strategies. Buses stopping at one station can bypass the next station and thus maintain a high average operating speed even with close station spacing. This closer station spacing allows more residential and commercial development to be within a convenient walking distance of a station. This is of obvious benefit to BRT passengers and may also produce operating cost savings through the consequent elimination of some local service because of its replacement by walk-in access to a busway station.

The quality of the pedestrian links between each station and its surrounding community are of paramount importance. They must be designed to provide convenient, comfortable and safe access. Convenience implies as short and as direct as possible links with adjacent developments. Comfort requires some weather protection from the elements and acceptable ramp grades and staircases. Safety considerations cover not only adequate protection from possible vehicle impacts but also the elimination of any circumstances (such as poor lighting) that might contribute to feelings of fear on the part of solitary passengers, particularly late at night. Urban design impacts must be addressed during the preliminary design process, keeping these objectives in the forefront throughout the process.

It is acceptable practice to adjust the busway alignment and grade to achieve these station objectives. Particular attention shall be placed on catering to the accessibility of passengers with disabilities.

Station designs shall emphasise the use of low maintenance materials and commonality of parts from one station to another to minimise the maintenance inventory.

Station designs shall also allow for the advent of Advanced Public Transit Systems (APTS) that are now revolutionising the operation of public transit. These include automatic vehicle location and control (AVLC), real time passenger information systems and remote sensing smart card technology for fare payment.

Because bus services are flexible and will be modified over time to reflect changing passenger and developmental growth patterns, where possible, connections between dedicated bus roadway and the street system shall be designed from the outset to accommodate turns in all directions.

The busway roadway design with respect to line, grade and cross-section is determined by the requirements of a low volume (200 to 300 vehicles per hour per direction), high speed roadway modified as described elsewhere to allow for possible long term conversion to light rail transit. These requirements are to be regarded as desirable rather than essential and may be varied with the approval of Winnipeg Transit. BRT provisions for on-street operations take their design cues from the characteristics of the host arterial, while aiming to insulate buses and passengers as much as possible from delays, conflicts, and congestion in the general traffic lanes.

Both the ownership boundaries and maintenance boundaries should be clarified early in the design process. A relationship diagram should be established to identify all neighbours and what they are entitled to, their wants/concerns/complaints/etc.

Possible commercial opportunities shall be assessed during the design phase to determine the opportunities and benefits available. Coffee shops, kiosks, newspaper stands, and advertising space can provide additional revenues capable of covering cleaning costs, station maintenance costs, water and electricity costs, etc.

2.3 APPLICABLE CODES AND REGULATIONS

2.3.1 General

Each chapter contains specific references to the codes, criteria and regulations that are to be followed in designing the Busway except as otherwise noted in the manual. The title of each publication is listed.

Where facilities will be owned, inspected or maintained by agencies other than Winnipeg Transit, references are made to the agency having jurisdiction over the particular work. It shall be the responsibility of the Planner/Designer to obtain such published criteria, including all applicable standard drawings, directives, manuals, specifications, together with all revisions thereto as issued by the agency involved prior to commencing any design work. Furthermore, the Planner/Designer must keep records of any revisions made while his or her work is in progress, and refer such revisions to Winnipeg Transit where planning or design work already completed is affected by these revisions.

2.3.2 Permit Requirements

When a busway is constructed within 100 metres of a natural water course permits will be required from:

- City of Winnipeg Riverbank Management Committee.
- Federal Department of Fisheries and Oceans.
- Manitoba Environment

When a busway is constructed over a navigable waterway a permit will be required from:

- Canadian Coast Guard.

2.4 DESIGN REVIEWS AND APPROVALS

All preliminary and final planning and design drawings are subject to the approval of Winnipeg Transit and City of Winnipeg Public Works.

2.5 CONVERSION TO LIGHT RAIL TRANSIT

The choice between BRT and light rail transit (LRT) for a corridor rapid transit service is normally a matter of system continuity and corridor densities. LRT may be favoured if it is already part of the municipal system and corridor densities are high. BRT operating experience in Ottawa, Pittsburgh and elsewhere in North America demonstrates that busways usually have lower operating and capital costs than light rail transit (LRT) but similar passenger carrying capacities. Cost considerations therefore usually favour the selection of BRT. Despite an initial decision to adopt BRT technology, however, corridor land uses and the system wide rapid transit strategy can be expected to change over the long term and conversion to or colocation with rail technology might be appropriate at some future point.

Winnipeg Transit therefore wishes to provide as much flexibility as is reasonable in the design of the BRT System to allow for a possible future conversion to LRT. Since such a technology conversion is uncertain and unlikely to occur, except in the long term, it is only cost-effective to protect this option if it can be done at little real cost. Over a 30 year period at a real interest rate of between 3 and 5% for example, the saving of a future cost of say $ 10,000,000 would justify an investment of no more than $ 500,000 to $ 650,000 today.

Provision for future LRT conversion shall be limited to the main Busway right-of-way only and shall not apply to connecting roads. On the Busway proper, the accommodation of a possible future LRT conversion shall be limited to the use of current light rail vehicle standards for:

- Vertical clearances/track integration.
- Right-of-way geometry and grades.
- Structural loading.

- Trunk storm sewers.
- Utility accommodations (power and communications conduit).

These standards shall apply only where the marginal cost to meet them is likely to be less than about 5% of the future cost to replace the item in question. Where the additional cost to meet the LRT standard can be easily deferred this shall be done. An example of this might be a retaining wall required only to accommodate the horizontal or vertical alignment of LRT as compared to a busway. Similarly, where the additional bridge loading of an LRT vehicle can be feasibly accommodated by the future addition of beams or cross-bracing, this shall be done. In such instances the addition of phantom details to a limited number of drawings to show how the conversion can be accommodated is desirable. Another element normally considered is barrier walls on bridges. Accommodations for future catenary support foundations may not be feasible, however, ground returns for electrolysis cable connections should be provided at all underground utility crossings.

Careful consideration shall be given to defining property (right-of-way) requirements in the design stage, with respect to existing or future adjacent structures which may interfere with the ability to develop an LRT option.

Station buildings and platforms are generally regarded as replaceable within the time frame in question and shall not be designed for LRT operation.

During any conversion from busway to LRT operations, the diversion onto adjacent local streets of one or both directions of bus travel is a likely option although not desirable. The protection of the extra right-of-way to allow for detours for this purpose is not cost-effective. If conversion is anticipated within an early timeframe then integration of tracks or track forms in concrete may be desirable.

The occasion may also arise in the future for buses and LRT vehicles to co-locate and operate together in the same roadbed. Design issues are likely to arise relating to pavement strength, road crossfall and vehicle tracking, station platform length and height, station shelter configuration, and signalling. This Design Manual does not address this situation. Any design issues will need to be resolved with reference to the particular circumstances at the time, and with reference to applicable standards and practices.

For details on specific LRT future requirements, Winnipeg Transit shall be consulted for direction on which North American LRT operation should be used as a guide.

2.6 RAILWAY CLEARANCES

The BRT facilities to which this Design Manual applies are expected to have exposure to active freight or passenger rail facilities. Where a Busway crosses an active railway track, minimum railway clearances shall be maintained in accordance with rail requirements. The following clearances are typical only and are provided for functional planning purposes. The designer must check with the appropriate railway authority for specific requirements and the necessary approvals.

2.6.1 Permanent Clearances

- The minimum horizontal clearance from centerline of any rail track to the edge of the Busway right-of-way is 5.50 m
- The minimum vertical clearance from top of rail to the underside of any overgrade bridge or any barrier or signage pole or structure is 7.0m.

2.6.2 Construction (Temporary) Clearances

- The minimum horizontal clearance from centreline of track to the edge of the Busway pavement or any barrier or signage pole or structure is 2.6m.
- The minimum vertical clearance from top of rail to the underside of any overgrade bridge is 6.7m.

2.7 ENVIRONMENTAL IMPACTS

Minimizing impacts is an important consideration in the selection of the preferred busway concept and alignment. Concern for neighbourhood impacts, social and economic impacts, local street impacts, heritage and cultural impacts, traffic diversion impacts, visual aesthetic impacts and environmental impacts and their mitigation therefore shall be a requirement of the busway planning and design process.

Key design considerations include visual and aesthetic impacts, air quality, noise pollution, vibration, drainage, shading provided by structures and trees and the legal and regulatory requirements concerning historic and archaeological resources. References to the various standards and regulations that pertain are to be found in the pertinent chapters of this manual.

2.8 ACCESSIBILITY REQUIREMENTS

It is the policy of Winnipeg Transit that all BRT stations shall be designed to be fully accessible by persons with disabilities who are capable of boarding and riding unassisted in a low floor public transit bus.

This means that all stations must be equipped with appropriate audio, visual and tactile cues to enable their use by passengers with audio and visual impairments. It also means that all grade changes within the station and between the station and the adjacent sidewalk system must be accessible by persons in wheelchairs either through the use of ramps or elevators. All accessibility facilities must meet the latest requirements of the applicable disabilities act.

END OF CHAPTER

CHAPTER 3

BUS CLEARANCES AND PERFORMANCE

CHAPTER 3 - CLEARANCES AND PERFORMANCE

3.1 INTRODUCTION

Basic criteria regarding the operating bus fleet are provided herein. However, the fleet mix and types of buses operated can be expected to change over time. The Planner / Designer shall ensure that the Busway can easily accommodate such changes where this can be readily included at little additional cost. Areas where changes could occur include the following:

- Axle load increase.
- Vehicle height due to operation of non-diesel coaches.
- Vehicle height due to the operation of double deck coaches.
- Vehicle length due to operation of single and double articulated coaches.
- Ground clearance due to operation of low floor coaches.
- Turning radius increase.

3.2 CLEARANCES

The dimensions of the proposed standard and articulated design bus are provided on Drawings A-1 and A-2 and in Table 3.2A.

Table 3.2.A – Dimensions of Proposed Design Bus (Millimetres)

Variable	Standard	Articulated
Length	12470	18510
Width (excluding mirrors)	2590	2590
Height - Front	3010	3350
Wheelbase	7240	5800 Front/7690 Rear
Overhang: Front / Rear	2130/ 2940	2130/2900
Floor Height	370	410
Turning Radius	12790	13760

To ensure the operational flexibility of the busway and its facilities to accommodate potential future changes in bus dimensions, the Planner / Designer shall also take account of the maximum dimensions for each class of bus shown in Table 3.2B where this can be done without adding significant current cost to the busway and its facilities.

Table 3.2.B – Maximum Existing Bus Dimensions (Millimetres)

Bus Type	Length	Width	Height	Wheel Base	Turning Radius
12-Metre					
Diesel	12570	2590	3120	7440	13410
CNG	12460	2590	3350	7440	13410
Diesel-Electric	12460	2590	3350	7440	13720
Fuel Cell	12570	2590	3680	7440	13410
All 12-Metre	**12570**	**2590**	**3680**	**7440**	**13720**
14-Metre	**13870**	**2590**	**3450**	**8430**	**14630**
18-Metre					
Diesel	18500	2590	3430	5790/7700	14020
CNG-Electric	18510	2590	3350	5800/7690	13760
All 18-Metre	**18510**	**2590**	**3430**	**5800/7700**	**14020**
12-Metre Double Deck	**11990**	**2490**	**4290**	**-**	**10060**

Table 3.2.C shows typical standard minimum horizontal and vertical clearances for buses. The buses using Winnipeg Transit facilities are assumed to have a horizontal width of 2590mm maximum, excluding mirrors. Reference should also be made to Drawings F-2 and F-3.

The use of busway minimum vertical clearances under roadways that will not necessarily accommodate large trucks should be used only with prior approval of Winnipeg Transit.

Table 3.2.C – Bus Clearances *

Variable	Unobstructed Clearance
Construction Clearance – Overhead	4.42
Construction Clearance - from edge of lane	500mm
Clearance - Overhead (buses only)	5.0m (desirable) 4.7m (minimum)*
Clearance - Overhead Pedestrian Crossing	5.0m (desirable) 4.7m (minimum)*
Side Clearance - from edge of lane	600mm

** Use of less than desirable clearances shall require the approval of Winnipeg Transit.*

3.3 AXLE LOADINGS

The axle ratings in Table 3.3.A are based on existing bus fleets and the proposed specifications for the design vehicles. The maximum axle loading shown assumes crush loaded buses with 80 passengers on 12 metre buses, 100 passengers on double deck buses, 110 passengers on 18-metre articulated buses and 150 passengers on 24-metre double articulated buses. The average passenger is assumed to weigh 75kg and the live load is distributed equally to each axle.

Table 3.3.A – Typical Bus Weights and Axle Loadings (Kilograms)

Bus Type	Total	Front	Centre	Rear
12-Metre				
Diesel	13725	3735	–	9990
CNG	14060	4230	–	9830
Diesel-Electric	14880	5010	–	9870
Fuel Cell	16100	4475	–	11635
Design Bus	12395	4025	–	8370
18-Metre				
Diesel	18850	3900	5050	9900
Design Bus	19740	4183	5179	10377
12-Metre Double Deck	16055	3985	12070	15820

3.4 PERFORMANCE

The acceleration performance of individual buses varies. Testing carried out in Ottawa, Canada, with different standard 12-metre bus types established the busway dimensions as far as acceleration and deceleration are concerned that were used for the Ottawa design. These performance measurements were confirmed by similar tests carried out by General Motors. This is considered to provide representative data on the likely performance of existing and future loaded conventional buses.

Table 3.4.A shows 1990 Ottawa acceleration data on flat ground for two types of 12-metre buses. The buses were tested unladen and also with a payload of 1360 kg. Table 3.4.B shows the generalized bus performance data that shall be used for busway design.

Based on these data, the initial design standards adopted in Ottawa required busway stations to be designed with deceleration and acceleration lanes and tapers of sufficient length to allow a bus to decelerate to a stop at a station platform and then accelerate back into the busway flow on the station through lane without disrupting the operation of non-stop buses with a posted speed limit of 50 km/h (13.8 m/sec) in station areas. This resulted in a requirement for a 90 m long acceleration lane.

In practice, buses rarely use this acceleration lane because there are usually gaps in the traffic flow that allow drivers to pull out around stopped buses directly into the through lane. For this reason, the recommended standard has been reduced to a 20m acceleration lane with a 21m long taper.

Table 3.4.A – Acceleration Performance of 12-Metre Ottawa Buses

Bus Model	**1989 MCI - Classic**		**1990 Flyer D-40**	
BHP	253		220	
Test Weight – kg.	11260	12620	12650	14010
Distance in feet	**Accel. Time (sec.)**	**Accel. Time (sec.)**	**Accel. Time (sec.)**	**Accel. Time (sec.)**
15.2	4.9	5.1	5.4	5.7
30.5	6.7	7.7	7.6	7.8
61.0	9.8	10.6	11.1	11.4
Distance	**Speed (m/s)**	**Speed (m/s)**	**Speed (m/s)**	**Speed (m/s)**
15.2	6.2	6.0	5.6	5.4
30.5	9.1	7.9	8.0	7.8
61.0	12.4	11.5	11.0	10.7

Similarly, deceleration figures were developed on the principle that the maximum comfortable deceleration rate for a standing passenger not using stationary handholds is 1.5 m/sec^2. The speed limit for buses through stations is typically 50 km/h. To decelerate from 50 km/h to a stop therefore requires 60m. Accordingly, for the bus to decelerate in heavy traffic without affecting the flow of through buses, a deceleration lane approximately 60m in length would be required.

However, operational experience with the relatively low hourly volumes on a busway suggests that deceleration lanes may be reduced to 20m in length and deceleration tapers to 20m. In constrained conditions, these dimensions may be further reduced as required, with the understanding that the operating speeds will be reduced in that situation.

Table 3.4.B – General Bus Performance

End Speed	**Acceleration** (m/s^2)	**Time (cumulative)** (seconds)	**Distance (cumulative)** (m)
to 50 km/h (13.9 m/s)	0.926	15	104
to 80 km/h (22.2 m/s)	0.333	40	555
to 100 km/h (27.8 m/s)*	0.333	57	980

- based on acceleration of 0.333 m/s^2 from 50 to 80 km/h

Start Speed	**Deceleration** (m/s^2)	**Time (cumulative)** (seconds)	**Distance (cumulative)** (m)
from 50 km/h (13.9 m/s)	1.543	9	60
to 80 km/h (22.2 m/s)	1.389	15	170
to 100 km/h (27.8 m/s)*	1.389	19	270

- based on deceleration of 1.389 m/s^2 from 80 to 50 km/h
- formulae: $a = (v_2 – v_1) / (t_2 – t_1)$; $S = v_2 t + ½ a t^2$

Lack of operating experience with the proposed design vehicles precludes the provision of similar data for these buses at present. For design purposes, however, it is expected that their performance will be equal or superior to that shown in the above tables for acceleration characteristics.

END OF CHAPTER

CHAPTER 4

BUSWAY GEOMETRY

CHAPTER 4 - BUSWAY GEOMETRY

4.1 INTRODUCTION

The various elements outlined in this section are applicable to the geometric design of a Busway Rapid Transit System (BRT) and include consideration of possible future conversion to light rail transit.

For busway rapid transit design, the general principles governing geometric design are contained in the Transportation Association of Canada (TAC) Geometric Design Guide for Canadian Roads, 1999.

The geometric design principles are augmented by empirical standards arising from busway operating experience in Ottawa, Pittsburgh, Brisbane and ongoing design in Auckland, New Zealand.

Geometry will influence the transit riding quality, especially for standing passengers. The Planner/Designer shall consider alignments that reduce sags, crests and directional changes to a minimum, consistent with reasonable economy.

The desirable minimum standards set for passenger comfort are to be used wherever economics and geometrics permit, with absolute minimums to be referenced to the current Winnipeg Transit standards.

4.2 GENERAL

4.2.1 Alignment Considerations

In developing the busway alignment, consideration shall be given to:

- Safety
- Sight Distance and Visibility
- Passenger Comfort
- Operator Capabilities
- Intended Operation
- Vehicle Performance
- Underground Utilities
- Horizontal and Vertical Clearances
- Alignment Standards
- General Appearance
- Impact on At-grade Crossings
- Adjacent Roadways and Railways
- Impact on Adjacent Property
- Economics
- Type of Construction
- Protection for LRT Horizontal and Vertical Alignment

- Protection for LRT Horizontal and Vertical Clearances

4.2.2 Design Speeds

Design speeds on the busway system shall be as shown on Table 4.2.A. Operational busway experience, with the transit buses that will normally use the busway, has shown that design speeds greater than those shown are not required. The busway operating rules do not permit passing on the busway except in station areas.

The posted busway operating speeds are 40km/h in station areas with at-grade pedestrian crossings, 50km/h in station areas with grade separated pedestrian crossings and 80km/h elsewhere. Where necessary due to the geometric constraints of the right-of-way, the design speed may be reduced to that of the posted speed.

Table 4.2.A – Design Speeds

Location	Design Speed (km/h)
Main Busway	90
Arterial on-street operation	60 or the design speed of the arterial
Station Areas	60
Absolute Minimum - Main Busway	50
Arterial Busway Ramps and Access Roads	40

Lower design speeds may be used where station spacing effectively precludes the achievement of the maximum inter-station busway operating speed of 80km/h. Greater design speeds may be used wherever such higher standards do not result in significant increases in construction costs or property requirements. Transition areas should respect the design speed of the connecting facility.

4.3 HORIZONTAL ALIGNMENT

4.3.1 General

The horizontal control for all alignments and the vertical control shall be based on the latest local publications. All alignment and control line setting out standards shall be based on City of Winnipeg requirements.

All alignment distances given, which relate to the engineering control line shall be ground distances. The local Combined Scale Factor (CSF) used shall be stated correct to seven decimal places and shall be based on the mean easting co-ordinate and the mean elevation for major sections of the project. To avoid confusion, point co-ordinate values shall not be shown except on alignment and geometry sheets.

A statement declaring that all distances shown are horizontal ground distances along with the value of the local CSF shall appear adjacent to any horizontal alignment details.

4.3.2 The Engineering Control Line

The engineering control lines (baseline, centre line, etc.) shall be capable of being co-ordinated from two independent pairs of co-ordinated permanent survey marks (PSMs) and property corner recovery marks which will be protected from any proposed construction. Winnipeg Transit standards for design presentation and setting out details shall apply.

The engineering control line shall consist of tangent lines joined by circular and spiral transition curves and shall be stationed with an independent stationing system. Changes in direction of the engineering control line shall be noted at all intersection points showing the full curve setting out data.

Engineering control line stationing equations shall be avoided wherever possible. When stationing equations are unavoidable, they shall be located on portions of the Busway which are horizontally tangent; preferably at the end of a curve and away from geometry details.

All construction details shall be related to, or dimensioned from, the engineering control line (centreline or baseline) by dimensioning. In some instances the engineering control line may not necessarily be the centre of the busway or station.

Secondary control lines for ramps and access roads shall be subject to the above criteria and shall each be stationed with an independent chainage system on a centreline or baseline.

4.3.3 Sight Distance

General

The ability of a driver to see ahead is of fundamental importance in the safe and efficient operation of the busway. The Planner/Designer must provide sufficient sight distance so that drivers can control the speed of their vehicles to avoid striking an unexpected obstacle in the travelled way. Since the eye ellipsoid of bus drivers is greater than 2.1m above grade; bus passing between stations is not permitted and since the drivers are professional drivers with better than average reaction time, normal sight distance practices for highways may be modified.

Stopping Sight Distance

Minimum stopping sight distance must be provided along the busway, ramps, access roads and intersecting roadways.

A combined perception-reaction time of 1.75 seconds is suggested as being suitable for busways (rather than the 2.5 seconds normally used for general traffic). As well, the maximum acceptable deceleration rate for a bus so that standing passengers do not lose their balance, is 1.5 m/s^2. When this deceleration rate is taken into account, the stopping sight distances are as noted in Table 4.3.A. These are the desirable and minimum stopping sight distances for BRT design.

Table 4.3.A – Stopping Sight Distances

Design Speed (km/h)	**Desirable Stopping Sight Distance** (m)
50	60
60	122
80	170
90	236

Passing Sight Distance

Passing on the busways between stations shall not be permitted, except for the passing of stalled or immobile vehicles. Passing sight distance criteria are therefore not used in BRT applications.

Horizontal Sight Distance

Safe horizontal sight distances are required and shall conform to desirable TAC standards where feasible.

4.3.4 Curves

Horizontal Curves

The application of horizontal curves shall be carried out in general accordance with the requirements of the TAC *Geometric Design Guide for Canadian Roads, 1999*, Chapter 2.1: Alignment and Lane Configuration. Table 4.3.B shows the desirable minimum circular curve radii for the main busway.

Table 4.3.B – Recommended Minimum Horizontal Curves

Design Speed (km/h)	**Minimum Radius** (m)
90 (main Busway)	330*
60 (vicinity of stations and on arterials)	120
50 (absolute minimum)	80
40 (ramps and access routes)	45

* Radius of 330m is suitable for the future LRT with a design speed of 70km/h.

Radii of 330m shall be considered as the desirable minimum for busway roadways. It is desirable however to develop radii as large as possible taking into account constraints on horizontal alignment such as topography and existing development. The 330m radii will allow LRT design speeds up to approximately 70 km/h (with 100mm track elevation difference) whereas the desirable minimum radii for LRT to achieve a 80 km/h design speed is 400 m. Radii shall be decreased below 330m only in the vicinity of stations or where existing road alignment, topographical or property problems cannot otherwise be overcome. The absolute minimum radius in the vicinity of stations or speed-reduced areas shall be 80m. Section 5.2.3 discusses pavement widening through curves less than 330m.

Spiral transition curves shall be used on all main busway curves, 870m radius or less, and are desirable on all other main busway curves, to connect the circular curves to their tangents. Graceful transitions are important for passenger comfort.

Circular Curves

Circular curves shall be specified by their radii in metres to two decimal places. Simple radii shall be considered where appropriate to simplify calculations.

Superelevation

The maximum desirable superelevation for all sections of the busway, ramps and access roads shall be 3.0% and no greater than 4% except as required to maintain 50 km/h. Superelevation in the Stations shall be no greater than 2%.

Superelevation shall be developed as outlined in the TAC *Geometric Design Guide for Canadian Roads, 1999, Chapter 2.1: Alignment and Lane Configuration,* where practical. Exceptions shall require the prior approval of WT. Note that station areas have a busway crossfall of 2 % *towards centreline* (drainage is in the centre, to avoid ponding at the curb and splashing passengers). The longer the transition of the rollover at stations, the greater will be the improvement in the ride.

Spiral Curves

All spiral transition curves used shall be in accordance with current practice, as shown in the TAC *Geometric Design Guide for Canadian Roads, 1999*, *Chapter 2.1: Alignment and Lane Configuration*. Accommodation of future LRT use shall take LRT spirals into account, where possible, as defined by current LRT criteria.

Reverse Curves

Back-to-back reverse circular curves shall not be used on busways unless appropriately spiralled. When reversal in alignment is unavoidable reverse circular curves shall be established in accordance with the TAC *Geometric Design Guide for Canadian Roads, 1999*, *Chapter 2.1: Alignment and Lane Configuration*.

Compound Curves

On busways, where two or more circular curves are to be connected forming a compound curve, the geometry shall be adjusted so that the maximum permissible speed remains consistent through all parts of the compound curve.

Broken back curves should be avoided. The use of compound curves is preferable. Rules for insertion of compound spirals shall be followed per the TAC *Geometric Design Guide for Canadian Roads, 1999*, *Chapter 2.1: Alignment and Lane Configuration*.

Minimum Curve Length

Minimum curve lengths shall be 90m including the spiral lengths, which conforms to the recommendations for LRT. This value may be reduced in station areas and in areas where the future LRT will not operate.

Stations

Since the busway shall be designed to permit buses to pass each other within station areas, all stations whether on guided or unguided busways shall have paved passing lanes.

Station platforms should be on tangent to the extent practical and the tangent shall extend at least 20m beyond each end of the station platforms to provide for superelevation runout of 1:200 over two lanes. Prior approval of Winnipeg Transit is required if the Planner/Designer proposes to reduce this requirement or locate a platform on a curve. Note that the reverse crown of the station area where parallel platforms are used may require compromise for superelevation runouts where horizontal curves are in the reverse direction to the station pavement crossfall. In such cases, splined pavement grades are normally required to obtain smooth transitions.

4.4 VERTICAL ALIGNMENT

4.4.1 Maximum Grades

Main Busway

The maximum desirable longitudinal grade for the main busway shall be 3.0%. The normal permitted maximum is 5.0%.

This desirable standard for maximum gradient is based on flexibility for conversion to a light rail system. While buses can accommodate grades of up to 10% and LRT up to 6%, the desirable and maximum grades as recommended shall be considered as standard. Any increase in the desirable maximum gradient requires the prior approval of Winnipeg Transit.

Stations

The desirable gradient through stations for use by buses and LRT shall be 0.50 % and should extend at least 14m beyond the end of each platform before the start of a vertical curve, if possible. Maximum gradients through the stations shall be 2 % for buses only and 0.80 % for LRT*.*

Where practical, stations should be located on crests of the grading. This reduces braking effort and increases acceleration. Station location shall avoid vertical low points.

Ramps and Access Roads

The desirable maximum gradient for ramps and access roads is 6 % with an absolute maximum of 10 % used subject to approval of Winnipeg Transit where necessary due to topographic or property problems.

4.4.2 Minimum Grades

Urban Sections

The desirable minimum longitudinal grade for curbed unguided and guided sections of the main busways, ramps and access roads shall be 0.50%.

Rural Sections

On rural unguided cross-sections (no curbs, open drainage) of busways, ramps and access roads, the grades may be 0% where sufficient pavement cross-fall (2 % minimum) and adequate ditch grades (0.2 % minimum) are provided.

Station Areas

The minimum desirable longitudinal grade for station areas shall be 0.50%.

4.4.3 Vertical Curves

General

All changes in longitudinal grades shall be accomplished by the use of parabolic vertical curves.

Busway vertical curves for a design speed of 90 km/h are satisfactory for conversion to LRT.

Crest and Sag Curves

Crest curve design is based on a driver eye height of 2.1m, a stopping sight object height of 0.2m and a maximum deceleration of 1.5 m/s^2. Sag curve design is based on a headlight control height of 0.6m and a 1° upward angle of the headlight beam from the plane of the vehicle. The resulting values for crest and sag curves are:

For 90 km/h design speed:

- crest curves: K = 65 minimum;
- sag curves: K = 59 minimum.

For 60 km/h design speed:

- crest curves: K = 17 minimum;
- sag curves: K = 17 minimum.

Reduced values of K may be used in the vicinity of stations if necessary.

Minimum Length of Main Busway Vertical Curve

On the main busway, the length of vertical curve shall be established in accordance with the TAC *Geometric Design Guide for Canadian Roads, 1999*, *Chapter 2.1: Alignment and Lane Configuration*.

4.5 RELATIONSHIP BETWEEN HORIZONTAL AND VERTICAL ALIGNMENT

The Planner/Designer shall consider the co-ordination of horizontal and vertical alignments following the general principles outlined in the TAC *Geometric Design Guide for Canadian Roads, 1999*.

4.6 AUXILLARY STATION LANES

4.6.1 General

Speed change lanes shall be provided on the Busway for station lanes where operating speeds of various functions differ and the projected bus volumes exceed the criteria for two-lane busway stations. Station speed change lanes are shown on drawings E-2, E-3 and E-5. A station service/maintenance area, accessible over a dropped curb, shall be provided wherever possible immediately up or downstream of each platform to permit service and maintenance vehicles to park off the station stopping lanes so as to not interfere with bus operations.

4.6.2 Acceleration Lanes

Where the projected bus volumes exceed the criteria for a two-lane station, 20m long acceleration lanes and 21m long acceleration tapers shall be provided in combination with a minimum sight distance requirements for a 50 km/h design speed from the downstream end of the platform, to permit buses leaving the station to use the main busway lane to accelerate to their cruising speed.

4.6.3 Deceleration Lanes

The desirable deceleration lane and taper lengths for four-lane stations are governed primarily by passenger comfort. In most circumstances some deceleration can occur in the main busway lane without any impact on the operation of non-stop bus services. Deceleration lane and taper lengths of 20m and 21m respectively are therefore adequate. At stations with very high bus volumes and only a small proportion of stopping buses it may be desirable to lengthen the deceleration lane to 40m to permit the stopping bus to decelerate from 40 km/h without causing any delay to the non-stop services. The prior approval of Winnipeg Transit shall be obtained before any decision to lengthen the deceleration lane in this manner is taken.

4.7 BUSWAY INTERSECTIONS

4.7.1 General

There are five types of busway intersection:

- Grade separated crossing of a busway by an arterial, controlled access highway, or rail line.
- Busway access ramps.
- At-grade (signalized) crossing of a busway by an arterial or rail line.
- At-grade (signalized) arterial street intersection where BRT operations are on-street.
- At-grade (stop sign control) crossing of a busway by a service road or minor access road.

The geometry for the design of all such intersections shall be approved by Winnipeg Transit. The structural aspects of grade separation are addressed in Chapter 8. For at-grade intersections, it is desirable for the angle of intersection to be as close to 90^o as possible - but no less than 70^o.

Two-way access roads and ramps for bus movements on and off busways are required. In most instances the primary bus movement directions are access in the CBD direction of the busway and exit from the non-CBD direction of travel. However, where feasible, all movements shall be provided at the busway/ramp intersections to ensure operational flexibility. A typical intersection is illustrated on Drawing D-3. For very minor turning volumes or where adjacent to a station, the intersection treatment may be reduced to that of an "entrance" treatment. Requirements for auxiliary and turning lanes must be based on bus volumes at the intersection. Note that deceleration at intersection approaches is not intended to occur solely in the deceleration lane. Where possible, busway access ramps shall be located within the station area so that the auxiliary and turning lane functions can be combined. For guided busways the access ramp intersection shall comprise a section of unguided busway with the requisite auxiliary and turning lanes

Stations are often located at at-grade signalized intersections on busways and on-street BRT operations. Intersection design shall be closely co-ordinated with vehicle and pedestrian movements associated with the station. Station platforms should be on the far side of the intersection to permit extended green phase signal bus priority and to permit the platform to shadow any left turn lane. Bus priority treatment shall be built into all intersection approaches.

4.7.2 Minimum Radii for Turning Buses at At-Grade Intersections

Minimum radii are used when speeds and the volume of turning buses are low and property costs are high. The desirable radii shown in Table 4.7A are for 14.5m long rigid buses. This is not the proposed design bus but experience suggests that such buses may occasionally use the busway and therefore should be used to determine minimum radii requirements.

Table 4.7.A – Minimum Intersection Radii

Turning Speed (km/h)	Radii (m)
0 – 15	15 minimum
15 -25	20 minimum
25 - 35	23 desirable

Note: Minimum radii for maintenance and other small vehicles at at-grade intersections between arterial roadways and busways shall conform to the TAC Geometric Design Guide for Canadian Roads, 1999, Chapter 1: Design Controls.

4.7.3 Turning Vehicle Paths

To aid in the geometric design of Transit facilities, a set of turning and swept area templates are provided in Drawings A-3 to A-9. Reference should also be made to Chapter 3 - Busway Clearances and Performance.

The paths shown on these templates represent the area swept out by the outer front overhang and the innermost rear wheel for the design vehicle minimum turn radii (MTR). The templates are provided for turning angles of 30^o, 60^o, 90^o, 120^o, 150^o and 180^o. The MTR is based on the maximum turn angle of the steering axle, and is applicable to low speed operations only (i.e. less than 15 km/h). For turning angles other than those shown, templates may be created using current, readily available software.

The possibility of implementing bus turnaround areas should be investigated at key locations along the busway to provide flexibility for vehicles to terminate their routes at these locations along the busway, and thus minimize deadheading.

4.8 SUMMARY OF CRITERIA

These standards have been set by rider comfort, safety and drainage requirements and are to be used as desirable minimums. See Table 4.8A – Busway Geometric Criteria Summary.

Table 4.8.A – Busway Geometric Criteria Summary

CRITERIA		RECOMMENDED*
Design Speed - Mainline and Motorway Ramps		90km/h
Design Speed - Station and CBD Areas		60km/h
Design Speed - Absolute Minimum		50km/h
Design Speed - Arterial Ramps and Access Roads		40km/h
Stopping Sight Distance (Passenger Comfort)	for 90 km/h design speed: for 60 km/h design speed:	236 m 84 m
Passing Sight Distance (station areas only)		TAC Standards
Horizontal Sight Distance		TAC standards
Minimum Horizontal Curve Radius, Mainline		R = 330 m
Minimum Horizontal Curve Radius, Stations and CBD areas		R = 120 m
Minimum Horizontal Curve Radius, Absolute Minimum		R = 80 m
Minimum Horizontal Curve Radius, Ramps and Access		R = 45 m
Minimum Turning Radii at Intersections		23 m desirable 15 m minimum
Spirals - all curves less than 870 m radius		TAC standards
Maximum Desirable Superelevation (above 50 km/h)		3 %
Maximum Superelevation at Stations		-2 % (fall to center)
Superelevation Runout	Main Busway At Stations	1 : 400 1 : 200
Minimum Tangent at Station Ends (Platform), Desirable		20 m beyond
Maximum Grade, Mainline, Desirable		3 %
Maximum Grade, Mainline		5 %
Minimum Grade, Mainline	rural section: urban section:	0 % 0.5 %
Maximum Grade, Stations (Desirable for LRT & Buses)		0.5 %
Maximum Grade Stations (Maximum for LRT / Buses)		0.8 % (LRT); 2.0 % (Bus)
Maximum desirable Grade, Access Roads and Ramps		6 % (10 % maximum)
Minimum Grade (Curbed main Busway, ramps, access roads and stations)		0.50 %
Crest Curves - Desirable Minimum (Minimum for Passenger Comfort)	Main Busway: At Stations:	K = 65 K = 17
Sag Curves - Desirable Minimum (Minimum for Passenger Comfort)	Main Busway: At Stations:	K = 59 K = 17
Minimum Intersection Angle		70°

- Recommended or desirable values are to be applied where possible. For variations in maximum or minimum criteria, refer to the applicable section of text.

END OF CHAPTER

CHAPTER 5

BUSWAY DESIGN

CHAPTER 5 - BUSWAY DESIGN

5.1 INTRODUCTION

Busway design standards were originally derived directly from relevant highway standards. Since then, actual operating experience has confirmed that in many instances these standards can be modified with consequent savings in cost. A busway operates at a relatively low peak hour volume with vehicles of a similar size and performance operated by professional drivers, licensed to a higher standard than the general public.

The standards in this chapter reflect this operating experience and the Planner/Designer should approach the planning and design process with this in mind.

As is noted in Section 2.5, the busway planning and design may, in certain areas, accommodate a possible future conversion to light rail transit to the extent that this is cost effective.

This chapter focuses on the design of dedicated bus-only roadways and guided busways. Provisions for on-street BRT operations are addressed in Chapter 6.

Key background documents include the current version of *A Policy on Geometric Design of Highways and Streets* (American Association of State Highway and Transportation Officials – AASHTO), referred to as the “AASHTO Green Book”, Report 155 of the National Co-operative Highway Research Program (NCHRP) and TAC *Geometric Design Guide for Canadian Roads, 1999.*

5.2 CROSS-SECTIONS

5.2.1 General

The standards show the various cut and fill arrangements developed for typical situations. The Planner/Designer shall consider economic and physical factors, ease of maintenance, and property requirements in determining the appropriate section.

Clearances at structures are shown in Chapter 8.

5.2.2 Busway Sections

General

Typical cross-section details for two-way busways in their own rights-of-way are shown on Drawings B-1 to B-7.

Typical station area cross-section details are shown on Drawings E-1 to E-6.

Details of transition sections between a conventional unguided busway and a guided busway are shown on Drawing C-2.

Rural Sections (No Curbs)

Lane widths of 3.5m are acceptable for busway operations.

Shoulders are not necessary on busways, however a 0.6m wide hard surface, adjacent to the edge of the lane pavement, should be provided on all unguided busways. Shoulders shall be paved throughout or consist of curb and gutter as indicated in the Drawings.

The minimum paved offset between the edge of a lane and any barrier shall be 0.6m. In such situations, the lane shall be designed as a 4.1m wide lane (3.5m + 0.6m) and painted as a 3.5m wide lane plus 0.6m offset.

Roundings shall be typically 1.0m and 1.2m where concrete barrier is used.

Desirable side slopes, for both cut and fill sections, shall be 4:1 or flatter where material is available. Maximum earth fill and cut slopes shall be 3:1.

The minimum desirable right-of-way offset from sectional features such as ditches, etc., shall be 1.5m. Refer to Drawings B-4, B-5 and B-6.

Urban Section (Curbed)

Lane widths shall be 3.5m plus a curb offset of 0.6m for a total busway pavement section width of 8.2m. Refer to Drawings B-1, B-2 and B-3.

The width of a bus bay or parking area such as a station platform may be reduced to 3.0m. A lane width of 3.0m may also be tolerated for short tangent sections of busway where buses will be moving at slow speeds through a tightly constrained area.

An asphalt maintenance strip or shoulder of a minimum width of 1.0m shall be provided adjacent to the curbs for partial off-road parking of maintenance vehicles and disabled buses. Reductions in the width of the maintenance strip may be made with the prior approval of Winnipeg Transit.

Where it will be required to maintain the grass on side slopes, 4:1 or flatter slopes are desirable with a maximum of 3:1. Refer to Drawings B-1, B-2 and B-3.

Modifications to the foregoing figures shall be made only with the approval of Winnipeg Transit.

Guided Busway Section

Guided bus lane widths shall be 2.6m between curbfaces with a minimum median distance between twin-track guideway curbfaces of 600mm for a total two-way busway guideway width of 5.8m from outer curbface to outer curbface. Refer to Drawings B-5, B-6 and B-7. The typical curb side bus mirror projects 300mm beyond the outer curbface and an appropriate offset to adjacent lanes and structures shall be added to the 5.8m guideway width to establish the busway right-of-way.

The desirable minimum offset between the outer curbface of the guideway and an adjacent highway lane curbface shall be 1.0m.

Where it will be required to maintain the grass on side slopes, 4:1 or flatter slopes are desirable with a maximum slope of 3:1. Refer to Drawings B-5, B-6 and B-7

A transition section shall be provided at all entry points to a guided busway including between guided and unguided busway sections, at access ramps between the adjacent road system and the busway, at either end of unguided busway stations on a guided busway and at all at-grade crossings of intersecting streets. Refer to Drawing C-2. In the transition section, one guidance curb (usually the offside curb) is started 5 to 8 m ahead of the other guidance curb which is reduced in height so that the nearside guidewheel can pass over the curb as the driver brings the offside guidewheel into contact with the offside guidance curb. A 12 m long entry flare guides the bus into the standard 2.6 m guided busway.

Station Sections

Station stopping lane widths shall be 3.0m where a separate through lane is planned as shown on Drawings E2, E-3 and E-5.

Ramp Sections

There may be some situations where it is desirable to link the busway with a crossing or adjacent high-standard roadway or controlled access highway. Conventional one-way or two-way ramps are used.

Single lane ramps shall have a minimum width of 4.2m with 1.2m shoulders. Multiple lane ramps shall have 3.5m wide lanes corresponding to the busway standards.

In the case of an urban section ramp, a curb and gutter of 0.6m width shall be added to each side of multiple lane ramps.

The Planner/Designer shall consider the use of ramps for maintenance vehicle access to the busway.

Ramp sections are shown on Drawings D-1 and D-2.

5.2.3 Pavement Widening

Main Busway

All curved sections of an unguided busway shall include extra pavement widening where the radius is less than 330m.

Design values for widening shall be obtained from the TAC *Geometric Design Guide for Canadian Roads, 1999*, and using appropriate tracking curves to ensure the widening matches the design vehicles.

On curved sections on a guided busway where the radius is less than 150m, the radius of the inside guidance curb shall be reduced to avoid rear tire scrubbing. The amount of the radius reduction shall be sufficient to accommodate the rear wheel track of the design bus. On very tight radius curves the inner guidance curb may be eliminated.

Ramps, Access Roads, Intersections

Ramps or access roads and widenings at intersections shall have widened lanes in accordance with the requirements of the TAC *Geometric Design Guide for Canadian Roads, 1999*. At intersections, the design shall be reviewed using the Design Bus Turning Template, Drawing A-3.

5.2.4 Intersecting Roadways and Railways

The cross-sections of intersecting roadways and railways shall be subject to the approval of Winnipeg Transit. The modification of busway and public road median and boulevard widths at structures as well as future requirements shall be considered.

5.2.5 Bus Clearances

The dimensions and turning envelope of a typical transit bus are illustrated on Drawings A-1 *to* A-*9.* These dimensions shall be used as the model vehicle where the design is being considered for reduced standards. Reference shall also be made to Chapter 3, Bus Clearances and Performance.

5.3 DRAINAGE

Busway drainage design shall be consistent with the current standards and practices used by the City of Winnipeg for the design of the roads under its jurisdiction. The design objective for drainage systems is to assure reasonable protection of the busway system and facilities from storm water runoff damage. It is also necessary to provide some reasonable protection to Winnipeg Transit from liability for damage to other property from storm water runoff either passing through or resulting from the construction of a busway, based on accepted engineering principles and standards.

Where a busway interfaces with a roadway or railway operated by another owner, the design of the drainage facilities shall conform to the more stringent standards, either those given herein or those of the other authority and the approval of the other roadway or railway controlling authority shall be obtained in writing.

Where a guided busway section is employed, the guideway running tracks shall be sloped so as to drain into the area between the tracks that shall have a pervious surface over a tile drainage system.

5.4 SAFETY AND SECURITY MEASURES

5.4.1 Right-of-Way Fencing

Where the busway is located in its own right-of-way, a 2.5m high vinyl coated galvanised steel chain link security fence with a top rail shall generally be provided throughout the length of the busway for safety, pedestrian control, and to prevent trash dumping. Exceptions to this requirement may occur in park settings with the approval of Winnipeg Transit. Also, engineering judgement may dictate exceptions in areas of precipitous slopes or other natural barriers to access. “No Trespassing” signs shall be mounted on the fence at appropriate intervals.

Where retaining walls, abutments, buildings, etc. form a portion of the right-of-way to be protected, and are suitable for top-mounted fencing, then the height of the wall may be considered as part of the fence height (total height minimum 2.5m).

Where required, fence gate access may be provided, with suitable locking devices, to prevent unauthorized use. Locking devices shall be standard throughout the busway. Note that in the case of unguided busways, the gates may be "crash gates" capable of entry by a fire truck. Provision should be made for emergency vehicle access to busway right of way (i.e. through special access points) where this is feasible.

Provision should be made in the design of all busway entry and exit points for the future installation, if necessary, of boom gates or other positive traffic control devices to permit the closure of the busway during off hours to prevent its unauthorized use.

5.4.2 Pedestrian Access Fencing/Railings

Without limiting the above, pedestrian access routes within the right-of-way and immediately adjacent to the busway may be controlled as follows:

- 1.2m fence or pedestrian barrier.
- 2.5m high chain link fence on top of a retaining wall of sufficient height to discourage pedestrians and meet the requirements of the local municipality or building codes.

5.4.3 At-Grade Pedestrian Busway Crossings

At-grade pedestrian crossings of the busway may be permitted where buses on the busway have a clear line of sight of the crossing that significantly exceeds the emergency stopping distance of the buses plus the pedestrian crossing time. The crossing location shall be fenced so that pedestrians are discouraged from crossing other than at the proper location and equipped with flashing and audible warning alarms activated by a pavement loop system to indicate the presence of an approaching bus. Signage shall clearly indicate that pedestrians should only cross when there are no buses visible.

On guided busways a 2.0 m break in the guideway curbs shall be provided to permit a level crossing of the busway as shown in Drawing C-3

5.4.4 Traffic Barriers

General

Barriers shall be designed to City of Winnipeg standards supplemented by the NCHRP Report No. 118 data presented below.

Clear Zone

The Planner/Designer shall use judgement when applying the clear zone offsets to non-guided busway sections. Where the cross section or slope of the terrain tends to channel errant vehicles towards a hazard outside the clear zone, or for critical isolated hazards, such as permanent bodies of water, bridge piers, etc., just beyond the clear zone, where the consequences of a collision may be extremely severe, consideration shall be given to providing protection for the buses.

The Planner/Designer shall exercise sound engineering judgement and consider protection in some special cases where such obstacles are likely to be hit due to geometric roadway conditions such as on the outside of curves, on steep grades at beginning of curves, etc. Protection shall also be considered in sensitive areas such as school playgrounds or reservoirs.

The Planner/Designer shall be aware that the clear zone offsets provide a degree of protection for approximately 80% of errant vehicles. While this may be a cost-effective measure across the entire system, in isolated high-risk locations the clear zone offsets may be increased, especially when there is little or no additional cost involved. Table 5.4.A shows the fixed objects in the clear zone that require protection.

Table 5.4.A – Fixed Objects Requiring Protection on Unguided Busways

Fixed Objects within the Clear Zone	Protection Required	
	Yes	No
1. Sign Support (Ground Mounted) a) Post of breakaway design b) Sign Bridge Supports c) Concrete Base extending 100 mm or more above ground	X X	X
2. Lighting Poles And Supports of breakaway design		X
3. Bridge Piers and Abutments at underpasses	X	
4. Retaining Walls and Culvert Headwalls 100 mm or more above ground	X	
5. Trees less than 100 mm diameter		X
6. Trees greater than 100 mm diameter	X	
7. Utility Poles		X
8. Lighting Poles with High Mast Lighting	X	

Clear Zone Width

The recommended clear zone width to be applied is indicated in Table 5.4.B for an operating speed of 80 km/h on unguided busways.

Table 5.4.B – Clear Zone Widths for Unguided Busways

Embankment Slope	*Clear Zone Width (Metres)
> 4:1 Fill	3**
4:1 Fill	2.75
6:1 Fill	2.0
Flat up to 6:1 Cut	1.8
4:1 Cut	1.7
> 4:1 Cut	1.5

* Distance measured from the edge of the through lane.
** In addition to the slope width.

Embankment Protection

Protection from rollover on embankments is based on a maximum 4:1 recovery slope. Table 5.4.C indicates the recommended barrier requirements for unguided busways.

Table 5.4.C – Barrier Requirements for Embankments on Unguided Busways

Embankment Slope	Embankment Height Requiring Protection (Metres)
1½:1	1.5
2:1	3.0
3:1	10.0
4:1 or flatter	No protection required

Barrier Placement

Barriers shall be placed with proper end treatments in accordance with the TAC *Geometric Design Guide for Canadian Roads.*

Barrier Selection

A concrete ”tall wall” barrier of 1070 mm height is recommended in all cases in order to provide more strength than that provided by steel beam guide rail, as well as for ease of maintenance and for matching to walls used on bridges.

5.5 UNGUIDED BUSWAY PAVEMENT STRUCTURE

5.5.1 General

Guidelines for the design of busway pavements stem from direct experience with the design of flexible and rigid highway pavement systems. These guidelines are proposed for use in the planning and preliminary design stages but do not preclude the need for detailed pavement design. They are proposed to be used when alternative pavement types and preliminary pavement thickness are being determined. Subsequent detailed investigation, necessary prior to final design, may indicate the need for modifications to the minimum recommended pavement thickness given herein (refer to 5.5.3).

5.5.2 Pavement Design Factors

Factors such as construction traffic, design traffic, subgrade conditions, environmental effects, availability of acceptable construction materials, performance of similarly loaded pavements in the area, and economics shall be considered in order to arrive at a suitable pavement design.

Traffic

Pavement design is directly influenced by the expected number of heavy axle loadings in the design life of the proposed facility. For the purposes of design, the traffic volume is represented by the Equivalent Number of Standard Axles (ESAs) using the design period of 20 years for flexible pavements and 40 years for concrete pavements. A whole life analysis of the alternatives is required. The influence of construction traffic shall be considered in the final design process, particularly with respect to the thickness of subbase material and the native subgrade conditions. The axle loadings of the design bus are presented in Chapter 3.

Subgrade Conditions

BRT corridors may encounter the full range of soil types, from soft sensitive silty clays to relatively competent dense coarse-graded tills. The softer subgrades permit larger pavement deflections under load and therefore require thicker pavement sections to control these load deflections to a desirable (or design) maximum. In some cases it may be appropriate to replace or treat the subgrade.

Environmental Conditions

Local geotechnical conditions may dictate variations in pavement thickness to improve the stability of the pavement structure susceptible to problems caused by expansive clays below the natural surface or in earthworks.

Other Factors in Pavement Selection

- Past performance of similar pavements in the area.
- Consideration of high water tables or drainage problems that cannot be cost-effectively eliminated.
- The availability and need to conserve aggregates.
- Braking action in the station areas can produce unravelling and other distortion problems with flexible types of pavements. Concrete pavement is preferred to avoid these problems.

5.5.3 Thickness Design

The BRT pavement structure shall be a rigid pavement design.

Pavement structural design shall be in accordance with the current acceptable design practices of the City of Winnipeg. The design shall take into account the depth of existing adjacent pavements ensuring adequate drainage paths are provided at the underside of the pavement structure.

Rigid Pavement Thickness Guidelines

For planning purposes, a typical minimum concrete pavement thickness may be considered as:

Concrete Slab-250mm

Free Draining Base -150mm

Sub Base -150mm to 600mm

Assumptions:

- Full width subbase.

- Positive drainage of pavement structure.
- Plain concrete pavement.
- Tied transverse joints.
- Dowelled longitudinal joints.
- All materials conform to current City of Winnipeg specifications.

Recommendations by pavement design specialists for pavement structures may pre-empt the minimum equivalent thickness stated above.

5.5.4 Related Design Factors

Geotextiles

Consideration shall be given to use of "geotextiles" (filter fabrics) below the pavement structure to prevent contamination of the subbase and subgrade materials where warranted or as required due to geotechnical recommendations.

Conversion to Light Rail System

The outlined typical pavement structures could be converted to a light rail system in the future if required. For the rigid pavement design, it may be possible to support the track system directly on the roadway slab, depending on the condition of the concrete slab at the time,. Alternatively, the concrete slab would be removed and be replaced with a track support system. Refer to Section 8.5.3 regarding structural decks.

5.6 GUIDED BUSWAY TRACK DESIGN

5.6.1 General

Guidelines for the design of guided busway track are based on the designs initially developed in Essen and Adelaide and later adapted for the Leeds and Bradford guided busway schemes. These guidelines are proposed for use in the planning and preliminary design stages but are subject to detailed design review and confirmation. They are proposed to be used when alternative guideway types are being investigated. Subsequent detailed investigation, necessary prior to final design, may indicate the need for modifications in the minimum recommended track and subgrade thickness given herein (refer to Section 5.6.3).

The proposed guideway design consists of two reinforced concrete guideways formed directly on the subgrade with no horizontal tie connections between the two tracks. In exceptional circumstances, where the track requires a piled footing or expected operation involves buses travelling at very high speeds (100 km/h) on a curved alignment and there is concern about potential horizontal movement between the two tracks, a track and tie section may be necessary as was employed in Adelaide. In practice, a bus guideway is subject to much lower horizontal forces than is the case for a streetcar track because the bus is steered rather than forced around curves. A maximum force of 15kN is used for design purposes but in practice the normal lateral forces are below 5kN.

The buses using the guideway are fitted with two 180 mm diameter solid rubber-tired guidewheels in front of the front wheels that are mounted on solid forged arms linked directly to the steering mechanism of the bus. The width over the outside surfaces of the guidewheels is 2.61 m and thus they project 55 mm on either side of a 2.5 m wide bus. This causes no problems with off-guideway operations and the wheels are therefore not retractable. This overall guidewheel width of 2.61 m provides a 10 mm interference fit with the 2.6 m wide curbface to curbface guideway width. This prevents any lateral movement of the bus when travelling in the guideway and absorbs any minor imperfections in the curb alignment. The arm connecting the guidewheel to the steering mechanism of the bus is designed to break off if subject to a much larger force than it encounters during its normal curb guidance function so as to prevent damage to the steering mechanism.

5.6.2 Track Design Factors

Factors such as construction traffic (the contractor may propose the use of specially modified construction vehicles capable of operating on the guideway), design traffic (buses and possible snow clearing vehicles), subgrade conditions, environmental effects, availability of acceptable construction materials, performance of similarly loaded pavements in the area, and economics shall be considered in order to arrive at a suitable track design.

Traffic

Track design is directly influenced by the expected number of heavy axle loadings in the design life of the proposed facility. For the purposes of design, the traffic volume is represented by the Equivalent Number of Standard Axles (ESAs) using a design period of 40 years. A whole life analysis of the alternatives is required. The influence of construction traffic shall be considered in the final design process if its use of the guideway is to be permitted, particularly with respect to the thickness of subbase material and the native subgrade conditions. The axle loadings of the design bus are presented in Chapter 3.

Subgrade Conditions

BRT corridors may encounter the full range of soil types, from soft sensitive silty clays to relatively competent dense coarse-graded tills. The softer subgrades permit larger track deflections under load and therefore require thicker track sections to control these load deflections to a desirable (or design) maximum. In some cases it may be appropriate to replace or treat the subgrade.

Environmental Conditions

Local geotechnical conditions may dictate variations in track thickness to improve the stability of the track structure susceptible to problems caused by expansive clays below the natural surface or in earthworks.

5.6.3 Track Design Guidelines

Drawing B-5 shows a representative example of a BRT guideway track design. The designer shall confirm the track thickness and concrete mix design, granular subbase design and reinforcing steel detail in light of the actual subgrade conditions.

The construction of the most recent BRT guideways has employed a cast in-place construction technique with the reinforcement placed directly on top of the granular subbase. The 180mm high by 200mm wide reinforced concrete running beam that supports the 180mm high guideway upstand or curb is poured in a separate operation unless a slip form construction technique is employed; in which case, the running beam and the curb upstand are poured as integral parts of the track. Quality control of the horizontal distance of 2.6m between the curb faces of each guideway is essential to ensure a smooth ride for the busway buses.

The track itself is 750mm wide and 240mm deep with a 10mm fall away from the curb upstand to facilitate drainage. A smooth track surface is required to ensure a vibration free bus operation. The positioning and width of construction joints in the track to accommodate expansion and contraction of the track longitudinally are also critical for a smooth ride for busway buses. The nominal intervals for expansion and contraction joints shall be every 30m and every 5m respectively. The expansion joints shall include a dowel and sleeve system to prevent the differential movement of track sections that shall be poured in alternate sections. Contraction joints shall be formed by saw cutting the track and curb and the use of a suitable epoxy filler. Special attention shall be given to the location of contraction joints on curved track sections to minimize cracking.

The guideway track shall be formed over a nominal 150mm thick lean mix concrete on top of the subbase material. Nominal granular subbase depths shall be 450mm to 750mm depending upon sub base conditions. The use of a geotextile material below the sub base material to prevent contamination of the subbase and subgrade materials shall be used where warranted or as required by geotechnical recommendations. A properly drained sub base is of critical importance to ensure no differential movement between track sections.

5.6.4 Guideway Drainage

Guideway drainage shall be achieved by providing a 10mm fall away from the curb upstand on each track so that the water will drain into the 1100mm wide central drainage channel between the tracks. The drainage channel shall be designed either with a suitable porous material over a tile drainage system or as a hard surface drainage channel connected directly to the corridor drainage system.

5.6.5 Conversion to Light Rail System

It is desirable that the introduction of any future rail operation be done with minimum disruption to BRT operations. For this to occur, the LRT track work must be capable of being undertaken during off-peak hours outside the peak periods by restricting the area of the track work to the central drainage channel between the guideway tracks.

Guided busways were developed initially to permit the colocation of streetcar and bus operations. In the initial guided busway in Essen, however, the streetcar gauge was 1000mm, which requires a steel tie length of 1535mm assuming a construction detail similar to that used for the embedded streetcar tracks in Toronto. As the maximum width of the central drainage channel between the BRT tracks that will still accommodate a standard bus is 1730mm, a 1000mm rail gauge track can be retrofitted between the BRT tracks in the future. The only initial investment required to permit such a future conversion would be modifications to the subbase to include a concrete slab and a narrowing of the BRT tracks from 750mm to 530mm.

The future use of 1435mm standard gauge track is more problematic. With this track design, BRT operations could be maintained during the LRT conversion only if the track is installed during the initial BRT construction. To avoid this initial investment, an alternative to the pandrol type clip would be required so that the overall steel tie length could be reduced to no more than 1730mm rather than the 1970mm required for a pandrol type clip.

5.7 BUSWAY DETAILS

5.7.1 Communication Ducts

Reference shall be made to the local Code of Practice for Road Lighting. The following is a general design guideline.

Four 100mm diameter communication ducts shall be provided throughout the length of the busway. The location of communication ducts shall be approved by Winnipeg Transit, however, they should be placed adjacent to an urban cross-section Busway, in all structures, and under all platforms and paved surfaces to avoid future disruptions. Where the Busway is to be covered by Closed Circuit Television (CCTV) cameras, duct location should reflect the likelihood that such cameras will be placed on the east or south side of the Busway to minimize interference by bright sunlight. Consideration should also be given to communication ducting requirements or opportunities associated with crossing or adjacent road or rail corridors.

Ducts placed adjacent to an urban cross-section unguided busway and for a guided busway shall be direct buried, as illustrated in Drawing C-1. All communication ducts shall commence and terminate beyond the hard surface.

Pull points or electrical pits shall be placed at minimum distances of 60 m, maximum distances of 100 m, and at all major directional changes.

Communications duct crossing of the busway shall be provided at each station. Further details regarding communications duct routing should be determined based on investigation of communications technologies and cable sizes.

Consideration shall be made to rodent-proof ductwork, particularly in areas near food centres or water sources.

5.8 UTILITIES

5.8.1 General

To facilitate co-ordination, utility agencies shall be consulted at the earliest stages of design. Minimizing potential impacts to existing utilities, particularly disruptions to service, will be a high priority during implementation. As more detailed information on utility relocations becomes available during later design stages, specific mitigation measures shall be identified. General measures to minimize utility impacts include:

- Construction contractors being required to exercise care and precaution to prevent disruptions of service through contract specifications and terms.
- Agreements with private utilities to relocate lines that they own.
- Tandem relocations of lines wherever and whenever possible.
- Construction/relocation during off-peak hours.
- Utility relocations done as a part of the construction of any grade changes to avoid additional disruption of utility service and traffic.

Utilities shall be discouraged from locating within the busway right-of-way and where this occurs, consider the location of access points, and ensure that covers are properly designed to withstand adjacent heavy vehicle operations. No surface iron work shall be permitted on the travelled portion of the busway. In some clays and other sensitive materials, under-crossings of the busway shall be avoided if possible. Any exceptions shall be subject to the prior approval of Winnipeg Transit.

5.8.2 Utility Agencies

A list of utility agency addresses and telephone numbers is available from Winnipeg Transit.

5.9 SIGNAGE AND TRAFFIC CONTROL

Busway signage and traffic control shall comply with Winnipeg Transit and City of Winnipeg guidelines:

At busway entry points and at stations, special busway signage shall also be installed.

Signage shall be provided at appropriate locations on busways, ramps and busway approaches to indicate the following:

- Maximum operating speeds.
- Cautionary operated speeds.
- Upcoming intersections.
- Changes in roadway geometry.
- Stop and yield conditions.
- Pedestrian prohibitions and at-grade crossings.
- Busway entry prohibitions.
- Upcoming merges.
- Bicycle and private vehicle prohibitions.
- Directional and informational signs as appropriate.

Based on local station features, suitable directional and information trail blazer signage should be considered to direct potential busway patrons from controlled access highways, arterial roads and suburban streets to busway parking areas and drop off zones.

At all busway ramps and entry points, signage shall indicate that entry onto the busway is restricted to authorized vehicles only. At the same location advisory signage shall show busway operating speeds and the general prohibition on passing except where the busway is specifically widened for this purpose.

The Planner/Designer shall review all access road and ramp intersections with adjacent public streets for traffic signal control. Signalized traffic control shall be used at all intersections with other streets and where necessary at intersections with restricted sight distance (i.e. where walled). Traffic signals will otherwise only be used to alert busway vehicle drivers in sections of the busway that are determined to require signals for safety considerations such as in tunnels, bridges, and contraflow lane sections, etc. Such signs shall be spaced up-stream of the potential hazard in locations that permit the drivers to detour onto the local street system.

All traffic control signals at BRT intersections (including on-street operation) shall have in-pavement detector loops or other bus identification devices installed on bus approach routes, tied to the priority treatment at the traffic signal controller. Signal timing and phasing shall be designed to minimize any disruption to the smooth flow of buses in the BRT corridor.

The Planner/Designer shall also make provision for automated advisory signage (triggered by approaching buses), including accommodation for persons with vision impairment, at any at-grade crossings of the busway.

The busway shall have pavement markings consisting of a single solid yellow line on centreline throughout and solid white edge of pavement lines at stations and channelizations.

The Planner/Designer shall produce a detailed signage and striping drawing for each section of the Busway for approval by Winnipeg Transit.

5.10 RAILWAY CORRIDOR DESIGN CONSIDERATIONS

5.10.1 General

Where the busway alignment is adjacent to active railway tracks, the Planner shall ensure that the busway is designed to meet the specific railway design criteria and standards. Following are some general guidelines drawn from experience elsewhere.

5.10.2 Design Criteria

The Planner/Designer shall consult the railway to obtain the railway's minimum criteria for each right-of-way section with respect to:

- Design speed.
- Maximum horizontal and vertical geometry.
- Horizontal and vertical clearances.
- Superelevation criteria.
- Storm frequency for drainage design/minimum pipe size and pipe material.

- Minimum depth for ballast and sub-ballast.
- Live/impact loads for structural design.
- Minimum widths of bridges.

5.10.3 Geometry

Rail authority criteria will govern but the following criteria are provided as guidelines.

Typical Horizontal Clearances

Minimum offset from the centreline of the railway tracks to the edge of the busway right-of-way is 5.50 m. A concrete barrier shall separate the two facilities if the distance between the centreline of the railway tracks and the edge of pavement of the busway is less than 6.1 m on tangent or 6.4 m on curve.

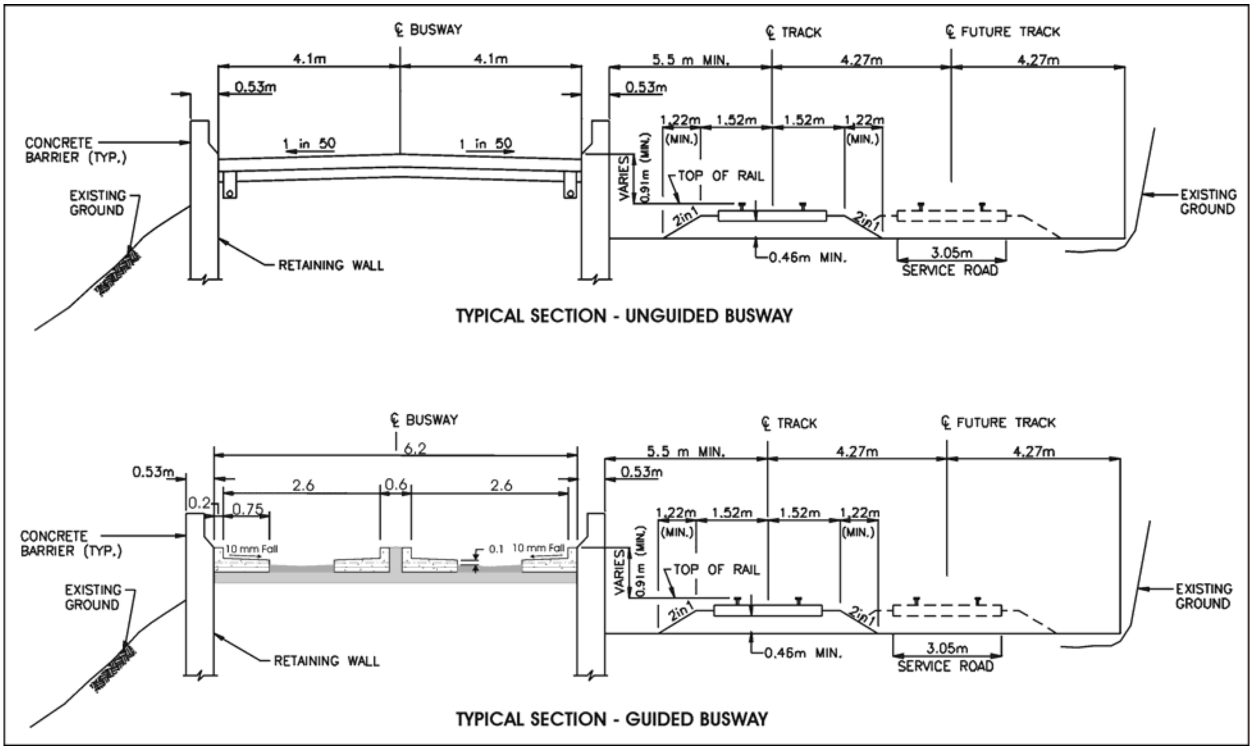
For overgrade bridges, the minimum horizontal clearance measured from the centreline of track to the near face of the obstruction must be 6.1 m for tangent track and 6.4 m for curves.

Typical Vertical Clearances

Where a busway is adjacent to a railway and the railway is not a slow speed railway, the railway top of rail shall be a minimum of 1.0 m below the busway top of pavement where possible.

This provides for a minimum 1.0 m high crash wall as shown on the typical section on Figure 5.10A.

Figure 5.10A – Typical Crash Wall in Rail Corridor



For an overgrade bridge the minimum clearance above the top of the higher rail shall be 7.0 m where no future electrification is contemplated.

5.10.4 Drainage

Maintaining the existing drainage and providing for future drainage improvements is of the utmost importance.

Drainage plans must be included with the general plans submitted to the railway for approval. These plans must include hydrologic and hydraulic studies and computations showing the frequency and duration of the design storm used, as well as the method of analysis.

Lateral clearances must provide sufficient space for construction of the required track ditch parallel to the standard roadbed section. If the ditch cannot be provided, or the pier will interfere with the ditch, then a culvert of sufficient size must be provided.

Ditches and culverts must be sized to accommodate all increased run-off due to the construction and the increased size must continue to the natural outlet of the ditch. Ditches must be designed in accordance with good drainage engineering practices and must meet all local codes and ordinances.

5.10.5 Structures

In joint-use corridors, railway loading shall govern the design of new bridges or rehabilitation of existing ones. Structural clearances shall be the greater of the two facilities. A crash wall shall be required to separate the railway and busway on the structures where grade differentials are not practical.

5.11 BUSWAY/ARTERIAL ROAD SEPARATION TECHNIQUES

5.11.1 General

In arterial road corridors, BRT operations often make use of one or more of the bus lane and spot priority treatments discussed in Chapter 6. These priority treatments are not always ideal because of the high level of enforcement that is usually required to ensure the reliability of the BRT service. Where there is sufficient right-of-way to provide horizontal separation of the busway from the adjacent arterial road lanes, therefore, an exclusive busway with at-grade intersections is preferred.

5.11.2 Median Barriers

In the typical situation where the busway is parallel and in close proximity to an arterial roadway, it is normal practice to require that the operating speed of the busway is no more than 10 km/h more than that of the arterial so that raised curbed median strips can be employed to separate the busway and arterial lanes.

Drawing B-8 shows typical details the median barriers for unguided and guided busways

END OF CHAPTER

CHAPTER 6

PROVISIONS FOR ON-STREET BRT OPERATIONS

CHAPTER 6 - PROVISIONS FOR ON-STREET BRT OPERATIONS

6.1 INTRODUCTION

The general approach to planning and implementing on-street BRT services shall recognize the ability of BRT to carry trips more efficiently than the automobile from a street capacity point of view and shall assign a higher priority to BRT operations over general traffic movement wherever possible.

Facilities to provide this priority shall include one or more of intersection signal priority, queue jump lanes and continuous bus lanes as circumstances dictate. On-street BRT station stops shall provide a high quality passenger waiting environment that is distinctly superior to that of the normal bus stop.

6.2 BRT BUS LANE REQUIREMENTS

6.2.1 Clearance and Profile Issues

Arterial bus lanes may be designated on shoulders, curb, inner and median lanes.

The bus clearance requirements for the bus lane follow:

- Overhead obstructions shall be a minimum of 4.0 m above the street surface; and
- Obstructions (posts, signs, vegetation) shall not be located within 0.6 m of the edge of the traveled lane to avoid being struck by a protruding bus mirror.

The bus lane will typically have a 2 % crossfall to the curb as part of the drainage system. At intersections, the crossfall on the perpendicular street may generate a slight “bump” in the profile of the bus lane particularly where it is a curb bus lane. Careful attention shall therefore be paid to the details of the pavement grades through each intersection, the intent being to make travel in the bus lane as smooth and comfortable as possible while protecting the functionality of the drainage design. Normally, the gradeline of the major road shall be carried through the intersection and that of the minor road should be adjusted to it. This design involves a transition in the crown of the minor road to an inclined cross section at its junction with the major road by introducing a sag vertical curve on the intersecting street.

Since superelevation transition lengths for safety and comfort shall be based on the relative grade differential between the edge of pavement and the centreline profile (see TAC *Geometric Design Guide for Canadian Roads*) the same principle shall apply to the intersecting street situation. For example, for a 55 km/h design speed on a two lane road, the maximum permissible relative grade is 0.63 %; the intersection crown transitions at the curb line should therefore adhere to this criterion.

6.2.2 Turning Traffic and Driveways

Vehicles may enter a right curb bus lane in order to complete a right turn into a crossing street or driveway; they should not turn directly to or from the second lane. A distance of 100 m upstream of the entrance is adequate and appropriate.

For a right curb bus lane, vehicles turning right from a side street should turn directly into the second lane, as indicated by the signage and pavement marking schemes illustrated in Sections 6.2.4 and 6.2.5 respectively. This provision only applies during the hours of bus lane operation.

Alternatively, if the reserved lane passes through several short city blocks, the turning vehicle may be allowed to use the lane within one block of the turn. Enforcement is eased in that case by the fact that any ineligible vehicle passing straight through an intersection can be automatically cited (although lenience is required if there are entrances (e.g. a service station) immediately downstream of the intersection).

The design of the corner curb radius shall consider the following:

- Design vehicle characteristics, including bus turning radius.
- Width and number of lanes on the intersecting street.
- Allowable bus encroachment into other traffic lanes (including the potential to set back the stop bar on the intersecting street to allow a turning bus to swing into the opposing lane in order to complete the turn – no right turn on red allowed).
- On-street parking.
- Angle of intersection.
- Operating speed and speed reductions.
- Pedestrian crossing patterns.

6.2.3 Bus Lane Enforcement

A bus turnout may be extended in length to provide a clear space for enforcement activities – either for a police vehicle to sit in the turnout and observe lane usage, or to direct violators into so that ticketing can take place without disrupting the flow of buses in the lane or at the bus stop. The space may also be used for a transit inspector's vehicle. A 15 m extension with a 1:1 return taper provides an adequate area for this purpose.

Posting a roadside or overhead sign to emphasize the consequences of Bus Lane violation can be useful both as a deterrent and as an education device. The practice has been reported to be effective in reducing violation and maintaining public respect for the facilities. For the posting of fines to be effective, however, the fine level must be substantial enough to act as a deterrent and actual police enforcement must occur on a regular basis.

Overhead Bus Lane Penalty sign (English/French), Ottawa, Canada

The use of bus-mounted video or still cameras for detecting Bus Lane violators is established in London (England) and elsewhere and requires no special infrastructure or design features on the lane.

Vehicle detector loops can be used for enforcement if the loops are equipped to read bus-mounted identification tags. Selected loops can be linked to a nearby pole-mounted camera such that any vehicle passing over the loop without registering a tag can trigger the camera to photograph the vehicle and license plate (in much the same way as red light cameras operate). Some other non-loop bus detection systems may be able to be adapted to perform a similar function.

6.2.4 Bus Lane Signing

Signs and pavement markings are the key methods of informing bus drivers and motorists alike of the existence of an on-street transit facility. The Manual of Uniform Traffic Control Devices (MUTCD) for Canada (Fourth Edition) (Transportation Association of Canada, September 1998) has specific signage and pavement marking guidelines for Reserved Bus Lanes.

MUTCD Section A 2.9.8 ("Reserved Lane Signs") defines the signs to be used when mounted over the lane (RB-80) or on ground-mounted poles at the roadside (RB-81). The supplementary tab RB-80S1 is used at the start of the Reserved Lane and RB-80S2 at the end of the lane.

The Reserved Lane signs features symbols of the various vehicle types permitted to use the lane: bus, taxi, carpool, and bicycle. In the case of a typical curbside Reserved Bus Lane, only the symbols for bus and bicycle would be used. If the Reserved Bus Lane operates only during specific hours and/or days, those restrictions are noted on the sign (e.g. 07:00 – 09:00 Mon – Fri).

Another standard element of a Reserved Lane sign is an elongated diamond located in the upper left corner of the sign. The diamond is white, on a black background. The white diamond is the North American symbol of a specially-designated lane.

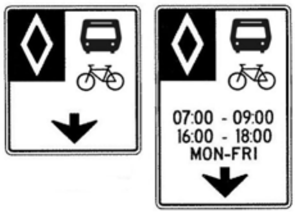
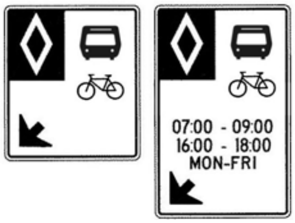
Any guide sign aimed specifically at Reserved Lane traffic should use the diamond symbol.

At the start of a Reserved Bus Lane, an overhead or roadside notification sign is desirable to advise motorists of the changed road conditions ahead. This is particularly important if the Reserved Lane takes the place of one of the general traffic lanes on the approach. MUTCD sign WB-7 (with appropriate time of operation tab WB-7S if needed) is used. A distance tab WA-30S may also be used if desired.

Reserved Lane sign spacing shall be determined by engineering judgement based on prevailing speed, block length, distance from adjacent intersections, and other considerations. Signs should be positioned at intervals of approximately 15 seconds of travel (per the posted speed limit on the roadway). The maximum spacing between signs should not exceed 30 seconds.

Posted Speed	**Reserved Lane Sign Spacing**	
	Desirable	**Maximum**
50 km/h	200 m	400 m
60 km/h	240 m	480 m
70 km/h	280 m	560 m
80 km/h	320 m	640 m

Figure 6.2A – Reserved Bus Lane Signs (from MUTCD for Canada)

RB-80 – Reserved Lane Sign* - Overhead (24h / part time)	RB-81 – Reserved Lane Sign* - Roadside (24h / part time)	RB-80S1 – Supplementary Tab Sign for RB-80	RB-80S2 – Supplementary Tab Sign for RB-80
			

WB-7 – Reserved Lane Ahead Sign	WB-7S – Supplementary Tab Sign for WB-7	WB-8 – Reserved Lane Crossing Sign	WA-30S – Distance Advisory Tab Sign for WB-7
			

RB-41R – Right (Left) Turn Only Lane Sign	RB-11S1 – Supplementary Tab Sign for RB-41R	RB-11S2 – Supplementary Tab Sign for RB-41R
		

* figures shown for HOV 3+ lane; may delete any symbol (or add bicycle symbol) as appropriate

The "Reserved Lane Ahead" sign WB-7 should be placed approximately 15 seconds travel time ahead of the start of the Reserved Lane.

There are situations where the Reserved Lane is used by other vehicles to make turns to or from the roadway. Typically, this would occur at a signalized intersection, where the Reserved Bus Lane is also used by vehicles turning right to a side street. In this situation, the MUTCD Right Turn Only sign (RB-41) would be mounted above and/or adjacent to the right lane. The sign would have a tab RB-11S1 ("Except Buses"), or a modified version stating "Except Buses and Cyclists". In the event that the Reserved

Bus Lane operates only during specific hours and/or days (e.g. 07:00 – 09:00 Mon – Fri)., those restrictions are noted on a separate tab RB-11S2.

Appropriate “No Parking” / “No Stopping” signs (per MUTCD RB-51, RB-52, RB-55, RB-57) shall also be prominent at the roadside for effective curb Reserved Lane operation.

It is advisable to use a sign on crossing streets approaching an arterial with a right curb Reserved Lane to advise right-turning motorists that they will turn into the second lane directly from the side street. MUTCD sign WB-8 is the applicable sign in that case. In the event that the Reserved Bus Lane operates only during specific hours and/or days (e.g. 07:00 – 09:00 Mon – Fri), those restrictions are noted on a separate tab RB-11S2. Sign WB-8 need not be used on every single crossing street; it is most relevant to streets with high volumes of right-turning vehicles or where operational problems or violations are observed.

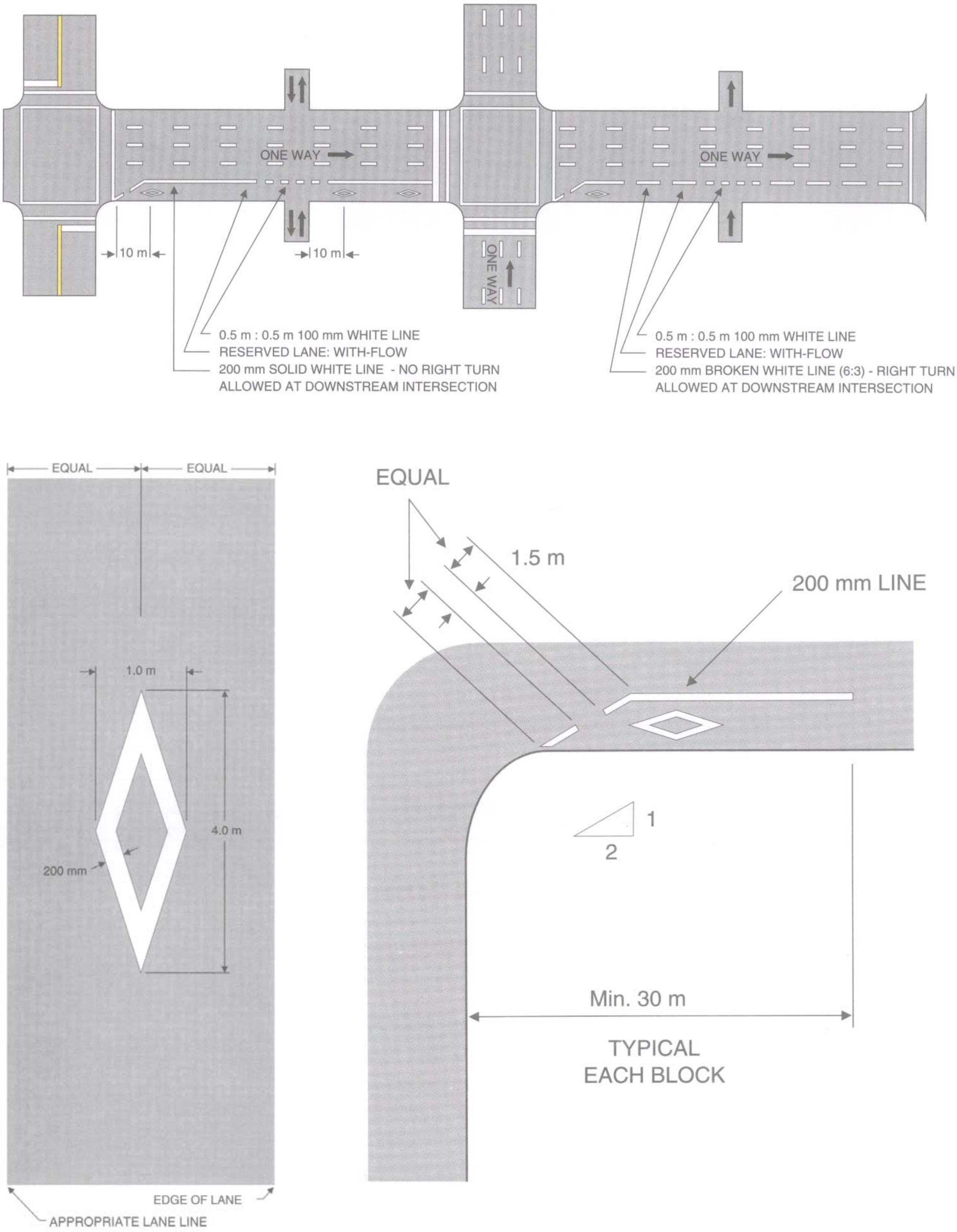
6.2.5 Pavement Marking

The diamond symbol for a Reserved Bus Lane is 4.0 m long x 1.0 m wide, centred in the lane. It is white, with 200 mm wide linework, as shown in the MUTCD Figure C1-4. The diamond symbol should be located in conjunction with each Reserved Lane sign (RB-80 / RB-81) along the lane. Supplementary diamonds are located 10 m downstream from each entering / crossing street.

The MUTCD for Canada describes the appropriate lane lines for a permanent 24h/day concurrent flow (right curb) Reserved Bus Lane in Section C2.7.3 and in Figure C2-15. The details of the pavement marking at an intersection are shown in Figure C2-17. Provision must be made for turning traffic, crossing traffic, and for segregating general traffic from the Reserved Lane.

A part-time Reserved Lane must operate as a general traffic lane for most of the time, so standard dashed lines are used in that case. As an alternative, a set of parallel dashed lines can separate the Reserved Lane from adjacent lanes. Part-time lane designation relies entirely on signage and on the diamond symbol on the lane.

Figure 6.2B – Reserved Bus Lane Pavement Marking (from MUTCD for Canada)



6.3 ALTERNATIVE BUS LANE CONFIGURATIONS

A Reserved Bus Lane (full time or part time) may be designated in any part of the roadway:

- Right shoulder (Sec. 6.3.1).
- Right curb lane (Sec. 6.3.2)
- Inner lane (i.e. second lane) (Sec. 6.3.3)
- Median lane (Sec. 6.3.4)
- Contraflow operation in the right lane or left lane of a one-way street (Sec. 6.3.5)
- Contraflow operation in the median lane of a divided roadway (Sec. 6.3.6)

Each option is described in the following Sections. The right curb lane is the most common application, although each of the others has merit in particular operational settings.

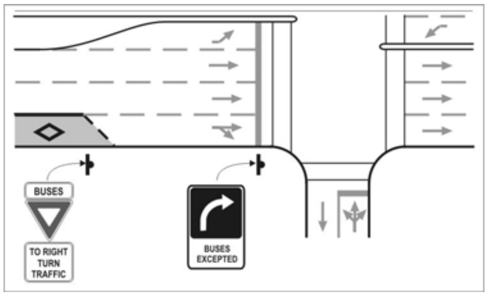
6.3.1 Arterial Road Shoulder Bus Lane

If a shoulder is to be used by buses, it shall be structurally and geometrically adequate. The shoulder pavement strength shall be designed to reflect regular use as a traveled lane and shall be consistent with the pavement of the adjacent general traffic lanes. The travelled portion of the shoulder shall be no less than 3.0 m wide and preferably 3.5 m wide. Beyond the traveled portion, an additional paved "shoulder" of at least 1.0 m width shall be provided as a buffer between the edge of the shoulder lane and any obstructions, piers, sign supports, walls, ditch edges, or guiderails.

Shoulder Bus Lane
(US 29, Maryland)

All specifications in terms of sight lines, illumination, offset from obstacles etc shall be the same as for a normal traffic lane. Where necessary suitable protection shall be retrofitted within the clear zone

If the shoulder becomes the right turn storage lane at an intersection, standard right turn queue length analysis procedures shall be used to define the point where motorists are permitted to enter the lane to turn right. Pavement marking and optional signage shall be provided to indicate this point. Buses approaching this point shall either continue through in the right lane or merge left to bypass any queue that has developed in the turn lane. All vehicles in the lane, other than buses, shall be required to turn right. A channelized free-flow right turn may be provided to minimize the amount of queuing in the bus / turn lane.



The shoulder shall revert to its normal function as a breakdown facility during non-congested periods, while buses use the general traffic lanes. In the event of an incident or a stopped car blocking the shoulder during times of Bus Lane operation, buses shall be required to merge into the rightmost general traffic lane to skirt the obstacle, then re-enter the shoulder downstream of the blockage.

6.3.2 Right Curb Bus Lane

Curb lanes to be used as Reserved Bus Lanes shall be not less than 3.3 m and preferably 3.6 m wide. If the curb lane is to be shared by buses and bicycles, it should be a minimum of 5.0 m wide (a 1.4 m wide bicycle lane would be marked alongside the curb). Refer to the Section 20 of the Community Cycling Manual (Canadian Institute of Planners, 1990) and/or Chapter 6 of the Urban Supplement to the Geometric Design Guide for Canadian Roads (Transportation Association of Canada, 1995) for additional guidance regarding bicycle provisions.

Signing, regulations, effective penalties, and an active towing strategy during the period of bus lane operation shall be provided.

At intersections the bus lane shall either extend to the stop bar, with right turns allowed from the lane or a separate right turn bay shall be provided. Right-turning vehicles shall be allowed to enter the bus lane in advance of the intersection a distance of approximately 2.5 m per second of green time at 95 % saturation and 1m per second of green at 70 % saturation. Pavement marking and optional signage shall be provided to indicate where right-turning vehicles may enter the bus lane.

There is little benefit to implementing a curb lane bus lane if the right turn lane approaching an intersection is regularly blocked with queued vehicles. To minimize the disruption to through movement of buses, the following options shall be considered:

Stopped vehicle obstructing Bus Lane, Toronto

- Ban right turns during the period of bus lane operation.
- Direct right turning vehicles to unsignalized cross streets (for example, in a grid network, turns can be made one street in advance of a major crossing arterial then through the grid to the desired cross street, thereby allowing right turns to be banned at the major arterial).
- Allow right turns on the red phase of the signal.
- Use a short signal cycle, to provide frequent opportunities for right-turning vehicles to enter the cross street.
- Provide a free lane away from the turn on the cross street, so right-turning vehicles can move easily into the cross street
- Avoid a double left turn in the opposing direction on the main street, so that right turns and opposing lefts can occur simultaneously.

The preferred method of providing a separate right turn lane for right-turning vehicles is to provide a separate right turn lane to the right of the bus lane. The length of the lane shall be adequate to store the maximum queue so that it doesn't spill back into the bus lane. A break in the pavement marking, supplemented by advance guide signs, shall be provided to direct turning vehicles safely across the bus lane and into the turn lane.

Allowing vehicles to turn right from the rightmost general purpose through lane (i.e. the second lane) is not recommended, unless it is on a protected phase and the turning vehicles can queue without disrupting the flow of through traffic.

The preferred method of terminating a bus lane shall be to bring it to the stop bar at a signalized intersection and then drop the designation at the other side of the crossing. The lane on the exit may then continue in general use or be dropped downstream. This technique is appropriate for a bus lane in the right, inner, or left lane.

6.3.3 Inner Lane Bus Lane

A bus lane may occupy the second lane from the curb, leaving the curb lane free for general traffic, parking, deliveries, bicycle use, right turns and storage, and/or bus stops. This arrangement can overcome many of the drawbacks of a curbside bus lane.

At least two lanes shall remain available for general traffic under an inner lane bus lane arrangement. As the curb lane will have little functionality for through traffic, this means that inner lane bus lanes shall only be employed on eight lane two-way streets or four lane one-way streets.

An inner lane bus lane shall be no less than 3.3 m and preferably 3.6 m wide. To provide any additional lane width necessary the curb lane may be reduced to 3.0 m wide.

Bus Lane in Second Lane, Ottawa

Allowance shall be made for motorists to gain access to the curb lane. For curb lanes serving through traffic, this shall be limited to allowing autos to cross the Bus Lane to make right turns at intersections. For mid-block driveways and parking, autos shall be allowed to cross (but not drive in) the Bus Lane. Designated zones for vehicles to cross the Bus Lane and gain access to a right turn lane shall be marked in advance of the intersection.

6.3.4 Left Median Bus Lanes

The left most lane against the center island of a divided multi-lane arterial may be designated as a bus lane. At least two adjacent lanes shall remain available for general traffic, which limits this application to six-lane or eight-lane arterials.

The bus lane shall be no less than 3.3 m and preferably 3.6 m wide. To provide any additional lane width necessary the curb lane may be reduced to 3.0 m wide.

Median concurrent flow (left side) bus lane (Paris)

Unless there is no demand for left turns or left turns are banned during the period of bus lane operation, allowance shall be made for left turning vehicles. Either the left turning vehicles shall cross the bus lane via a designated break in the lane into a protected left turn slot which may be signalized or non-signalized or a left turn lane shall be inserted between the bus lane and the leftmost through lane. In this case, left turns shall occur on a protected signal phase.

Special signage and pavement marking shall be provided to guide vehicles turning left into the arterial from crossing streets into the general traffic lane rather than the bus lane.

Right turns from the left-side reserved lane shall be prohibited. If a high volume of right turning buses uses the lane, an advance signal and/or a dedicated right turn bay shall be provided.

6.3.5 Right Side or Left Side Contraflow (One Way Street) Bus Lanes

On a one-way street, a bus lane may be provided in the direction opposite to the main flow. Careful consideration shall be given, however, to the planned or potential operational strategy for bus operations, since there is little or no opportunity for a bus in a single contraflow lane to pass a stopped or disabled vehicle. If several buses are operating in a platoon, the last bus is governed by the "worst case" of the preceding stopped buses; if there are heavy boarding volumes or disabled passengers to be served, the risk of a following platoon backing up across the cross street shall be considered. If curb space is available, an indented bus bay shall be used to minimize such conflicts and provide operational flexibility.

Right Side Bus Lane on one-way street, Honolulu

The contraflow lane shall be designed for permanent use, not temporary or peak-only operation and shall not be implemented for bus volumes of less than 20 to 30 buses in the peak hour.

A right side contraflow bus lane on a one-way street is simply a restriction on the use of what is functionally a two way system. There are therefore no special requirements to physically separate the bus traffic from opposing traffic flow. If desired, however, the opposing lanes may be physically separated by a raised concrete strip, flexible delineators, or pylons. Buses may operate with parking lights flashing while in a contraflow lane, to alert oncoming motorists of the opposing traffic on what might otherwise be expected to function as a one-way street. The lane width shall be 3.6m, with a narrowing of up to 0.3m permitted in short constrained areas.

Signage and pavement markings for "Contraflow" bus lane on one way street, Los Angeles

A left side contraflow bus lane on a one way street shall be physically separated, from the other general purpose lanes, because it is on the "wrong side" in terms of motorist expectations. If possible, the bus lane shall be wider – up to 4.3m – if the separation takes the form of a concrete wall, pylons, or cones.

Consideration shall be given to pedestrian safety. In a busy pedestrian environment where people are in the habit of crossing the street mid-block, there is considerable risk that they will step off the curb into the bus lane while concentrating on finding a gap in the "one way" flow of auto traffic. This is a particular risk where the bus lane has been retrofitted to what was once a one-way street. In such a situation, it is recommended that a physical barrier be placed at curbside to channel pedestrian crossings to signalized crosswalks, and to prevent mid-block crossings. Careful consideration shall be given to the design of the barrier, so that it is safe and attractive and fits into the streetscape plan.

Consideration shall also be given to the design and signage of all intersections to address the risk that motorists will turn without looking at the bus lane, and either inadvertently enter the bus lane in the wrong direction or cross the lane while heading for a gap in the main flow. Turn restrictions may be required.

6.3.6 Median Contraflow (Two Way Street)

In a suburban arterial setting where there is a directional imbalance between flows during peak periods and there is little opportunity to assign one of the peak direction lanes to bus priority use, it may be possible to "borrow" the inner lane from the counter-peak direction for use as a peak period bus lane. In another case, a brief segment of contraflow lane could be used in the vicinity of a median island platform or bus stop in a single reversible lane corridor.

Median Contraflow Bus Lane (Blvd Pie IX, Montreal)

Like the left lane concurrent flow configuration discussed above, this is more suited to express or through buses than to local services which stop on every block. Such local services should remain in the curb (mixed traffic) lane.

The bus lane should be physically separated from the oncoming general traffic lane by daily placement of pylons or pop-up flexible delineators. Buses may operate with headlights on or parking lights flashing while in a contraflow lane, to alert oncoming motorists of the (unusual) opposing traffic.

Median contraflow HOV lane, Honolulu

Careful consideration should be given to the potential evolution of traffic patterns over time; a commitment to the median contraflow configuration (e.g. through construction of median bus platforms and shelters) is premised on the directional imbalance during peak periods being a permanent operating condition.

Access to and from the ends of the median contraflow lane can be provided by means of median crossovers. The design of the crossover will be dependent on the speed of the traffic. Where no median exists, continuous access can be provided along the length of the lane in the same manner as for concurrent flow inside lanes.

Left turns in either direction to or from the arterial have to be controlled (using protected phases at signalized intersections) or eliminated. Special signage and pavement marking is appropriate to guide vehicles turning left into the arterial from crossing streets into the general traffic lane rather than the oncoming bus lane.

6.3.7 Controlled Access Highway Shoulder Lane

Controlled access highways can often provide a corridor for BRT type service at a relatively low cost compared with building a separate transit right-of-way busway. When the highway operates at a high level of service, BRT buses can use the general-purpose lanes between strategically located BRT stations at interchanges.

When the highway is congested, a common strategy is to permit the BRT buses to use the highway shoulder as a high speed bus priority lane.

Weaving conflicts are avoided by having the buses exit and re-enter the freeway at each interchange. In so doing they cross the interchange arterial at grade (with signal priority) to serve a far side stop for transferring passengers from local routes. Alternatively, weaving conflicts are avoided by having the buses enter the adjacent general-purpose lane in advance of the interchange and then re-enter the shoulder lane downstream of the interchange. Typical bus volumes in shoulder lanes can range up to about 100 buses in the peak hour.

Controlled access highway shoulder lane, Ottawa

Buses usually operate up to the posted highway speed and, therefore, there are often significant speed differentials between the speed of the buses and that of the traffic in the adjacent general-purpose lane.

Drawing B-9 shows a typical shoulder lane cross-section in use in Ottawa since 1992. Even with the minimal 1m refuge outside the 3.5m shoulder bus lane and no buffer strip between the bus lane and the adjacent general-purpose lane, which is 3.75m wide, this lane has performed well.

6.4 SPOT TREATMENTS FOR BUS PRIORITY

6.4.1 Bus-Only Links

There may be occasions where BRT buses can avoid out-of-way travel by taking a short bus-only link road. The design of the link shall follow normal practice, and signage needs shall be clear in designating the road segment for use by authorized vehicles only.

If the link has a high risk of being used by unauthorized vehicles, consideration shall be given to:

- Increasing the size and amount of static signage;
- Installing signal control or physically gating the roadway, with opening either by bus-mounted transponder, driver swipe card, in-pavement detector loop, or similar remote actuation;
- Inserting a "trap" (for example, a concrete channel that can accommodate a bus axle height and wheel width but which cannot be crossed by a smaller vehicle); or

Bus-only link (Brisbane, Australia)

Automated electronic enforcement is also possible via a pole-mounted camera, activated by an approaching vehicle.

6.4.2 Queue Jumps

Bus queue jumps shall be provided in any situation where a recurring queue of general traffic forms and affects the speed and/or reliability of BRT buses using a mixed flow lane. The queue jump shall normally take the form of an appropriately-signed dedicated lane. The key to the queue jump's effectiveness is the speed, ease, and comfort of the bus re-entry into the general purpose lane.

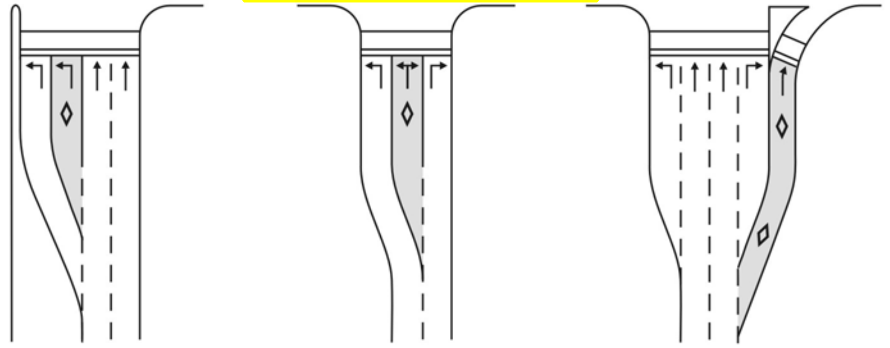
Effective yet low-cost bus priority measures can also be implemented by way of bus-only turn lanes or exemptions from turn prohibitions at intersections.

Examples of exemptions from turn prohibitions include:

- "Right Lane Must Turn Right" / "Buses Excepted"
- "Turns Prohibited 7 AM – 9 AM" / "Buses Excepted"

Adequate physical provision must be made for the allowed bus movement and consideration shall be given to the enforceability of the queue jump.

Bus-only Turn Lane Concepts



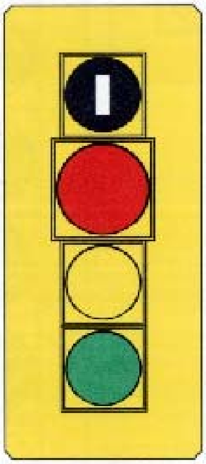
6.4.3 Traffic Signal Operations for Transit Priority

Granting priority treatment to buses at signalized intersections can contribute significantly to being able to operate buses in a fast, reliable, manner on an arterial street. This can be done as a standalone initiative independent of whether there are bus lanes on the street. The basic principle is that a bus is detected approaching a signalized intersection and the signal timing and phasing is adjusted to provide the bus with clear passage through the intersection. This may save the bus up to one minute or more of waiting at a red light, but more importantly, contributes to the ability to adhere to schedule. When transit signal priority is implemented along a lengthy corridor, the cumulative travel time savings can be significant.

Active signal priority can take the form of:

- Extending the green phase to allow bus to receive a green signal.
- Advancing the green phase by reducing length of other phases.
- Providing a special bus phase.
- Omitting phases in order to advance the bus phase.
- Priority phase sequences to favour the bus route.
- Compensating non-bus phases with additional time following the bus priority phase.
- Modifying offsets in a coordinated system to favour bus operation.

There are various means of detecting a bus approaching an intersection – in-pavement magnetic induction loops, side-fired radar, optical strobe, ultrasonic, microwave, GPS, and photographic devices are all in use. The detection location must be far enough in advance of the signal that there is time to adjust the signal timing, introduce an amber and all-red phase, and allow the bus to approach the site without dropping its speed and momentum. This distance will vary according to the operational speed of the road and the technology used.



Transit signal on a typical signal head

Detection may be “dumb” and simply look for a vehicle type or axle spacing that represents a bus, or it may be a “smart” system that can register the bus’ identification tag and check whether it is in service and whether it is ahead of or behind schedule and the speed it is travelling. This information can be used to decide whether to provide priority to a specific bus and to determine the length of the green phase needed.

Once a bus is detected, the bus detection system must communicate its presence to the traffic signal controller. If the signal is already on a green phase, the controller will typically extend the green phase until the bus has passed. If the signal is showing red, the controller will truncate the green on the cross-street and move to green on the bus approach as early as possible. Any changes are limited by pedestrian phases, which cannot be shortened. The cycle length may change or selected phases skipped to accommodate the bus needs.

A bus-only move may be defined at a signalized intersection through the use of a transit-only signal head (i.e. a vertical white bar on a black background, as illustrated, per MUTCD Fig. B3-10) or by a separate transit-only signal (i.e. a two-phase signal with the vertical white bar either on or off) alongside or instead of a conventional three-head green-amber-red signal.

In certain situations, a passenger may wish to hail a bus that would otherwise operate as an express service. To simplify this process and make it more reliable, consideration shall be given to use of passenger-activated signals at or in advance of the bus stop advising the bus operator of the waiting customer. For example, one freeway interchange in Ottawa (Canada) has bus stops at the foot of the exit ramp, which are only served by express OC Transpo highway buses when a “request stop” sign (a simple shoulder-mounted “OC” signal) is illuminated on the highway in advance of the exit ramp. The sign is simply activated by a passenger waiting at the stop; if the sign is not lit up, the bus operator can pass by the exit without delaying the through passengers unnecessarily.

Where a high volume of buses must make a left turn at a signalized intersection from the right lane (for instance, from a right curb bus stop) a second stop bar and signal shall be located back from the intersection stop bar and at the head of a bus stop or bus bay. The advance signal shall be far enough back from the cross street signal that motorists do not confuse the two. The advance signal to bring through vehicles to a stop shall be triggered by either the bus moving forward over an in-pavement detection loop or by another electronic means (e.g. bus-mounted transponder, side-mounted radar beam, or similar). The signal shall be coordinated with the left turn signal, such that the bus moves freely through the intersection after receiving the advance green.

6.5 BRT BUS STOP DESIGN

6.5.1 Stop Spacing and Location

BRT stops shall be more widely spaced than normal bus stops to permit higher speed operations. The normal minimum stop spacing shall be in the order of 750 metres.

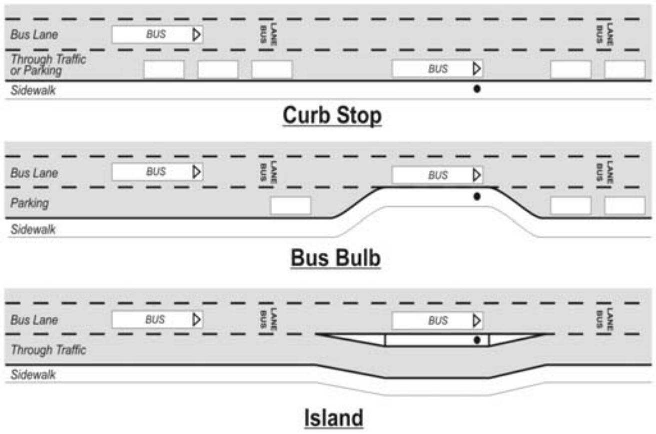
Indented bus bays or turnouts to permit through buses to bypass a stopped bus shall only be used when the BRT service operates in an adjacent exclusive bus lane. Design parameters for bus bays are found in Section UK-7 of the *Urban Supplement to the Geometric Design Guide for Canadian Roads* (Transportation Association of Canada, 1995). The total length of a two-bus turnout provision in a 3.0 m wide curb lane shall be about 55 m with an entry taper of no less than 5:1 and exit taper of no less than 3:1.

BRT stops at major intersections shall be located on the far-side of the intersections to facilitate signal priority unless local conditions make this infeasible.

With BRT operations in the second lane and the curb lane functions limited to stopping, parking and turns, consideration shall be given to the use of either curb or bus bulb station locations.

The use of a curb stop shall be considered when there is a mix of stopping and through buses. The design is the same as that of a bus bay. This arrangement maintains the bus lane for unobstructed use and since non-bus traffic is banned from the second lane, bus drivers can easily re-enter the bus lane from a stop.

Alternative Mid-block Bus Stop Concepts for Second Lane Bus Lanes



When most or all buses must stop, curb line shall be extended out to meet the buses in the second lane bus lane to create a bus bulb stop. The bulb shall be designed to provide a well-defined waiting area for bus passengers, out of the way of pedestrians moving along the sidewalk and away from shop entrances. It shall be a minimum of 3 m wide so as to provide sufficient space for all the normal BRT station features and be between 30 m and 55 m long with 1:1 tapers to the curb line.

If the curb lane is to be maintained for moving traffic, streetcar-style island platform stations shall be used. The platform sizing and facilities shall be the same as for a bulb platform but where necessary the width may be reduced to 2m. Appropriate protection from errant vehicles in the curb lane shall be provided.

For a center bus lane stations shall be provided either on in-street island platforms or on a central (median) island platform. Use of a single central island platform either requires the buses to cross over the median to a contraflow position, or, the use of buses with double-sided doors.

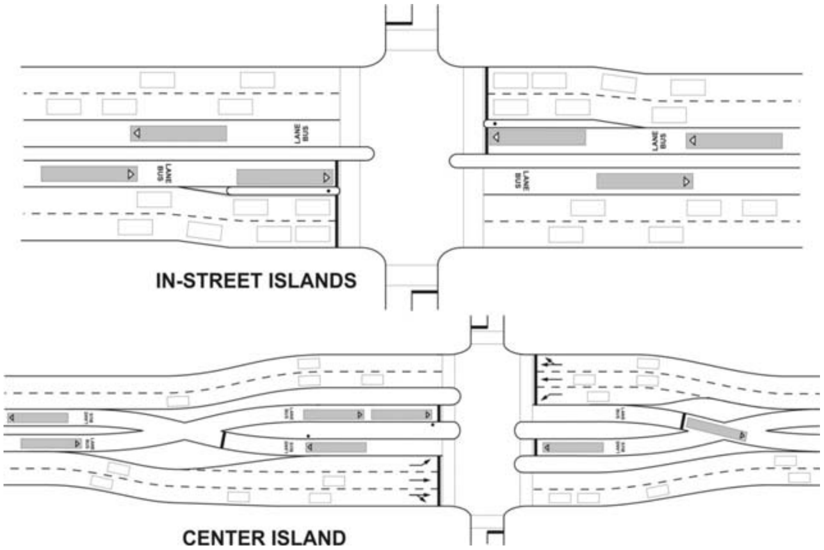
Where a crossover is employed, measures to minimize the risk of a head-on collision and to prevent its use by unauthorized vehicles shall be introduced. Consideration shall also be given to the separation between stopped buses and oncoming traffic, whether by paint, delineators, raised curbing, or a physical barrier.

Island platforms shall normally be located at or very near a signalized intersection; the signal timing, phasing, and bus priority features shall be carefully designed so as to optimize the movement of passengers and buses to and from the platform.

For right side contraflow bus lanes conventional curbside stops shall be used located where possible in indented bus bays to minimize the risk of a stopped bus blocking the lane for following vehicles.

A left side contraflow lane may be used as a peak period route for express buses but either double-sided bus doors or in-street island platforms will be needed to serve any stops.

In-street Island and Centre Island Bus Stop Concepts for Left Side Bus Lanes



Where a BRT stop is not located in an exclusive bus lane, an exclusive bus zone shall be designated for loading and/or unloading passengers. The bus zone lengths shall be as indicated in Tables 6.5A and 6.5B. If the bus zone is located in an area where parking is otherwise permitted, the zone length shall be marked to keep the area free of parked or stopped cars at all times. Parked vehicles in a BRT bus zone shall be towed away immediately.

Table 6.5A – BRT Bus Zone Lengths (Speed Limit 65 km/h or less)

Type	Taper In	Stop	Taper Out	Total Bus Zone Length
Near Side	18m	30m to 55m	Cross street width	45.5m + 6m to edge of cross street
Far Side	Cross street width	30m to 55m	12m	33.5m from cross street + 18m if right turns from cross street enter zone
Mid Block	18m	30m to 55m	12m	51.5m

Table 6.5B – BRT Bus Zone Lengths (Speed Limit greater than 65 km/h)

Type	Taper In	Stop	Taper Out (2 lane Road)	Taper Out (4 lane Road)
	12m min. 18m des	30m to 55m	0.375 x speed limit (km/h) acceleration + 0.1 x speed limit taper	0.1 x speed limit (km/h) acceleration + .375 x speed limit taper

The stop length shall be determined by the number bus arrivals per hour and the average per bus dwell time based on the method of fare payment and expected passenger boarding volume. The first bus at the stop shall move to the head of the stop. The second and third buses arriving while one bus is stopped at the head of the stop shall pull up tight to the rear of the preceding bus.

6.5.2 BRT Stop Platform

The stop platform shall comprise a flat concrete pad adjacent to the roadway, large enough to accommodate a passenger shelter, benches, or other facilities without interfering with the through movement of pedestrians on the sidewalk. The pad shall be at least 2.5m wide and a minimum 30 m long. Specific dimensions will depend on the size, shape, and orientation of passenger shelters, and on the number of waiting passengers. For very high volume stops the maximum platform length shall be 55 m.

The curb line and sidewalk shall extend the full length of the platform to allow safe and efficient passenger alighting (and, in a proof-of-payment system, boarding) at the rear doors of the bus. The curb height shall be between 0.15 m and 0.22 m.

The stop platform and shelters shall be located such that oncoming buses are clearly visible early enough from inside the shelter for waiting passengers to be able to react and move to the platform waiting area prior to the bus arrival.

The urban design, lighting, visibility, grade, and accessibility of both the stop and of approach pathways shall be carefully considered. All bus stops shall be accessible by hard-surfaced sidewalk or pathway that is cleared and maintained in all seasons.

The bus stop / bay lane surface shall be a durable, stable material able to resist the heavy bus stopping loads (12,000 kg) and avoid pavement failure or rutting and ponding which can lead to buses splashing waiting customers. Consideration shall be given to the use of reinforced concrete pavement pads. In the case of a bus bay, if a curb and gutter (urban) drainage system is in place, the bus bay shall drain to a continuous gutter at the edge of the traveled lane, rather than to the curb.

END OF CHAPTER

CHAPTER 7

BUSWAY STATIONS

CHAPTER 7 - BUSWAY STATIONS

7.1 INTRODUCTION

Stations are of paramount importance in the functioning of the busway system as a rapid transit facility. Station layouts shall follow design standards subject to the dictates of site conditions and footpath connections to the local surroundings and street network. In most cases busway stations will also include facilities for transferring to and from local bus service, for kiss and ride and for bike and ride. At designated stations, park and ride facilities shall also be provided.

Station buildings shall be designed in accordance with a common busway station architectural design theme. They shall use common components, shall be readily identifiable while architecturally enhancing their surroundings and shall incorporate a common and easily recognisable arrangement of functions.

Stations shall be designed to minimize the accumulation of dirt and trash by avoiding, where possible, ledges, crevices, open soffits and protrusions in the design. Materials shall be selected for ease of cleaning, durability and their resistance to vandalism. The station design shall, to the maximum extent possible, minimise the need for specialised maintenance and cleanup equipment and procedures.

The life cycle costs should be assessed for all station elements, particularly relating to maintenance costs. Surfaces and elements should be selected only after an assessment is made to ensure that the proper maintenance equipment required can be accommodated through doorways/openings, etc.

Stations shall convey a feeling of personal security through the use of an open design that maximises the use of glass and transparent materials, eliminates blind corners and dead ends and employs a lighting scheme that is bright and cheerful yet durable, maintainable and cost effective.

The issue of whether vending machine facilities should be installed in stations now or in the future should be addressed in the design phase to ensure that appropriate provision is made for space, power and water needs. The Planner/Designer shall also refer to the current Winnipeg Transit policies with respect to the displaying of advertising and artwork in stations, and make reasonable provision for these features.

The optimum busway operation and preferred passenger boarding environment is achieved when the pedestrian crossing of the busway at the station is grade-separated. An at-grade channelized pedestrian crossing of the busway may be substituted for the pedestrian grade separation at stations with low to medium passenger and bus volumes.

The station design, in so far as it affects the per passenger bus boarding time, directly influences the passenger carrying capacity of the busway. Important factors that affect the per-passenger boarding time are the fare payment system, the bus floor height and the bus/platform docking procedure. The Planner/Designer should ensure that the station design can accommodate the eventual use of honour/fare prepayment systems and also investigate the implications of installing an appropriate form of precision docking for buses at the station platforms.

Where there is potential for future joint development that incorporates a station directly into a building adjacent or over the busway, this shall be taken into account in the station design in consultation with Winnipeg Transit and the building owner.

7.2 SYSTEM OF OPERATION

7.2.1 Buses

Buses will stop at platforms able to accommodate up to three articulated buses. Stopping lanes are extended, depending on the bus volumes and stopping frequency, in both directions to provide for storage and for deceleration/acceleration from, and to, the through bus speed. Buses not required to stop at a particular station shall be able to proceed through the station area relatively unimpeded. Busway layouts for different types of stations are shown on Drawings E-1 to E-5.

The maximum operating speed through stations shall be 50km/h for stations with grade-separated pedestrian crossings and 40 km/h for stations with at-grade pedestrian crossings. The station speed zone shall extend sufficiently far upstream and downstream from the ends of the station platforms such that a bus can comfortably decelerate from 80 km/h to 0km/h and accelerate from 0 km/h to 50km/h respectively.

7.2.2 Passengers

At the stations, passengers will access the busway by walking from nearby residences and businesses, transferring from local bus routes, and where provided, from adjacent kiss and ride, bike and ride or park and ride areas. Direct passenger access to the platforms will be provided since "paid" areas are not normally required. Entrances can be at the platform ends or at a convenient point along their length.

Passenger convenience, comfort and safety, including that for persons with disabilities, shall be given foremost consideration. Where a pedestrian grade separation of the busway is required, the use of elevators rather than extensive ramp systems is the preferred method of providing access for physically challenged persons.

7.3 STATION TYPES AND LOCATION

7.3.1 Standard Station Layouts

For low bus and pedestrian conditions where peak direction bus flows are typically less than about 60 buses per hour, the two-lane mini-station configurations with at-grade pedestrian crossings shown in Drawing E-1 and E-4 may be employed. Express buses may use the opposing lane to pass a stopped bus at a platform in the case of the unguided station shown in Drawing E-1. Pedestrian fencing shall be employed, as shown on these drawings, to define the pedestrian crossing location. Where the peak direction bus flows are between 60 and about 100 to 120 buses per hour, an at-grade pedestrian crossing may be used with the four-lane station layout shown in Drawing E-2. In this station layout, separate passing lanes with a fenced median and a channelized pedestrian crossing are provided. For all these station layouts, the at-grade pedestrian crossing shall be located such that pedestrians cross behind buses loading and unloading at the station platforms, so that they are clearly visible to non-stop buses in the through lanes

Stations where a high volume of boarding and alighting passengers is projected shall include a pedestrian grade separation and the preferred head-to-head platform configuration as shown in Drawings E-3 and E-5. Where practical, to avoid the cost of a separate pedestrian bridge, the station design and platform locations may be varied to permit the use of an adjacent highway bridge across the busway.

Where the right-of-way is restricted or initial ridership levels are low, platforms may be reduced in width and length with the prior approval of Winnipeg Transit. Platform lengths may be reduced from 55 m to 30 m and platform widths can vary from 5m – 3m.

7.3.2 Station Location

Stations shall be located as close as practicable to cross streets carrying local bus routes and to origin or destination nodes, such as residential or employment centres. Integration with new, or expanding, commercial and institutional developments shall be encouraged. Consideration shall be given to the location of mini-stations to provide walk in access to specific residential and commercial developments within 300 m ± of the busway. Such stations shall be served by a limited number of stopping buses and may be within 500 m of an adjacent station. The final station locations shall be approved by Winnipeg Transit.

7.4 STATION PLATFORMS, MEDIANS, SHELTERS AND BUILDINGS

7.4.1 Platforms

Station platforms shall normally be 150mm thick reinforced concrete slabs with desirably 200mm barrier curbs that can be adapted for precision docking.

The desirable platform plan dimensions are 55m x 5m but this may be reduced to the dimensions shown in the drawings where high passenger volumes are not projected or where physical and property constraints dictate.

Platform surfaces shall have a broom finish with a contrasting and detectable tactile edge strip as per Winnipeg Transit's *Design Guidelines for Safe and Accessible Bus Stops*. The platform crossfall shall slope down to the curb at 2% maximum. The longitudinal platform grade shall exactly match that of the busway so as not to disrupt the operation of lift equipped vehicles.

A review of “slip and fall” opportunities should be conducted for platforms, particularly those on grade. All platform surfaces shall be selected based on Winnipeg Transit standards to ensure that surfaces, tiling, etc. are not chosen solely for aesthetic reasons.

Prior to finalising platform layouts and locations, the shelter system for the stations shall be defined and developed architecturally to the point where assurances can be given that further platform changes will not be required to accommodate the shelter system. Moving the platforms may also cause alignment revisions. Typical platform layouts are shown in Drawing E-8.

7.4.2 Station Medians

All stations with bus passing lanes shall include a station median barrier. The cross-section of the typical station median barrier is shown in Drawing E-6. The median barrier shall consist of a standard concrete barrier surmounted by a 1.2m high aluminium pedestrian barrier. The barrier shall extend for a minimum of 15m beyond the ends of either platform. Only in locations where property constraints or bus access ramps do not permit this extension will shorter extensions be permitted and only when authorized by Winnipeg Transit.

For stations with at-grade pedestrian crossings, pedestrian movement across the busway shall be accommodated by designing the median barrier with a 3 m wide pedestrian crossing break plus the tapered ends to the barrier on either side of the crossing. This crossing shall be located so that pedestrians would cross behind buses stopped at the station.

7.4.3 Shelters

Station structures shall conform to the established standard busway design theme established by Winnipeg Transit and shall provide a safe open environment with high visibility and no hidden corners or blind spots. The visibility of approaching buses is fundamental to the design of busway stations. Therefore, there shall be no physical features which will impair the ability of passengers to see approaching buses, when viewed from the platform and shelter area, particularly from locations where benches are provided. Waiting bus passengers must also be visible to bus drivers. Possible platform and shelter layouts are shown on Drawing E-8.

Where walls are required, glazing together with louver mesh, punched metal or lattice shall be used to augment security and introduce natural light. Primary station materials shall be concrete, galvanised steel, aluminium, masonry and glass. In no case shall any windows or glass doors be tinted as this creates a visual problem in seeing outwards from the shelters during darkness. All materials and components shall be high quality, durable, vandal proof, corrosion resistant and easily maintained. Final approval of elements and materials will be by Winnipeg Transit. Station structures shall be designed on a basic module that minimises the parts inventory that must be maintained by Winnipeg Transit and shall conform to the requirements of the Manitoba Building Code.

The functional design of shelters shall take into account the protection of passengers from the elements of cold, rain, wind and sun. At a minimum, the primary shelters on each platform shall be heated. Glass walls may be of partial height to allow cooling breezes while providing protection from wind driven rain but must be capable of being closed to the ceiling in winter months when any heating system is operational. Shading provisions shall be accomplished by opaque ceilings/roofs in all cases.

Station shelter requirements shall be established in consultation with Winnipeg Transit. Generally, a single shelter shall be located on the platform adjacent to the designated lead bus stop. For the inbound platform, the minimum standard shelter shall be 15m long by 2.5m wide with a 1.0m wide canopy overhang in front. The face of any canopy overhang shall not encroach within 1.2m of the travelled busway curb unless the vertical busway clearance is met. Shelters of this size are capable of providing weather protected waiting environments for approximately 60 passengers, based on a per passenger waiting space of 0.6 square metres.

The required shelter capacity shall be established by using a 5 minute passenger volume computed as 15% of the peak hour volume. A standard 15m by 2.5m shelter is therefore applicable in stations with peak hour volumes of up to approximately 400 boarding passengers. Standardised shelter sizes allow standard furniture treatments and public familiarity and minimise the need to stock components for maintenance purposes. Where peak hour boarding passenger volumes of more than 400 are expected, a 55m long platform shall be used and a second 15m shelter installed.

In a highly-directional travel corridor, the outbound platform will have a lower waiting and boarding passenger volume than the inbound platform. The shelter plan dimensions for the outbound platform may therefore be reduced to 7.5m long by 2.5m wide.

A minimum amount of seating shall always be provided in each shelter to meet the needs of persons with disabilities on a priority basis. A minimum 5m length of bench shall be provided in each shelter. This seating shall be combined with sufficient clear floor waiting space for wheelchairs.

7.4.4 Pedestrian Crossing Structures

Where grade separated pedestrian crossings of the busway are provided, the minimum desirable interior cross-section for pedestrian tunnels shall be 6m wide by 2.7m high.

The minimum desirable interior cross-section for pedestrian overpasses shall be 3m wide by 2.5m high.

7.4.5 Ticket and Information Areas

A covered area shall be provided adjacent to the main platform entry point. This space shall accommodate ticket vending machines, telephones and information displays in accordance with Winnipeg Transit requirements.

7.4.6 Other Buildings

The need for other station buildings is a function of the station size. For stations not equipped with elevators or escalators, an electrical cabinet located at the downstream end of one of the platforms so as to be easily accessible from the station service bay will suffice.

At large stations with elevators and/or escalators elevator towers, electrical and mechanical rooms shall be provided. Other buildings also may be provided to house additional station functions as determined by Winnipeg Transit. These may include operators' washrooms, supervisors' work stations, staffed ticket offices, janitorial storage requirements. Such other buildings are to be durable and vandal resistant and must be designed to meet all local codes as well as seismic safety requirements.

7.4.7 Walkways

The walkways connecting the station platforms to the sidewalk system in the adjacent community shall be constructed of 150mm thick reinforced concrete. Where possible the walkways shall be a minimum of 2.5 m wide to facilitate access for winter and other maintenance. The footpaths shall be designed to City of Winnipeg standards.

7.5 PROVISIONS FOR PERSONS WITH DISABILITIES

7.5.1 General

The station design requirements for persons with disabilities are based on those adopted for the design of the Pittsburgh West Busway which were in turn based on the *Design Manual for Implementation of Americans with Disabilities Act (ADA*). As later amended by the *Americans with Disabilities Act Accessibility Guidelines (ADAAG)* and the *American National Standard, Accessible Buildings and Facilities, ANSI A117.* These design requirements shall apply to all station shelters, buildings and other facilities. It shall be the Designer's responsibility to ensure that these design requirements are equal or superior to any other standards currently followed by the City of Winnipeg.

The disability requirements are complex in range and a basic paraphrased summary is provided in this section for the initial guidance of the Planner/Designer. Requirements lower than those given for the minimum busway station are not restated.

7.5.2 Station Requirements

The following points apply:

- Platforms shall connect with streets or sidewalks by an accessible route that is coincident to the maximum extent feasible with the route for the general public.
- At least one accessible route per station shall be provided.
- The slope of the platform parallel to the busway shall be the same as the busway.
- The maximum crossfall shall be 2%.
- Shelters shall permit a wheelchair or mobility aid user to enter from the public way and to reach a location with a minimum clear floor area of 750mm by 1200mm entirely within the perimeter of the shelter.
- Platform edges bordering a drop-off and not protected by barriers or fences shall have a detectable tactile warning strip of 600mm minimum and preferably 1000mm width across the full length of the drop-off and set back by 500mm.
- Tactile surface strips and colour contrasting of materials is required to assist the visually impaired.
- If public telephones are present, at least one public text telephone shall be used for such devices as Telecommunications Devices for the Deaf (TDD).
- Where a Public Address system is used, another means of conveying the same information shall be provided in order to accommodate the hearing impaired.
- Elevator cars shall have (minimum) dimensions of 1295mm by 1725mm and shall be glazed or provided with windows to provide unobstructed views.
- All elevator hoisting entrances shall have raised floor designations provided on both jambs. The centre line of the characters shall be 1.5m from the floor. Such characters shall be 50mm in height
- All signs shall be provided with the proper font, finish and contrast and, where not meeting accessibility standards, shall provide accessible directions to at least one

sign with the raised and Braille characters and pictograms and mounted in a standard location and at a standard height.

- All machines, such as fare vending machines shall comply with the controls, clearance and reach range and meet the requirements for persons with visual impairments.

7.5.3 Accessible Facilities

Design guidelines for accessibility to facilities and buildings by persons with disabilities shall be applied.

A summary listing of the basic design guidelines for the busway facilities follows:

- Minimum unobstructed width = 1000mm, 1200mm if wheelchair accessible.
- Maximum floor opening width = 13mm.
- Minimum mounting height of operable items = 890mm.
- Maximum mounting height of operable items = 1500mm.
- Minimum sidewalk width = 1200.
- Minimum door opening = 900.
- Maximum threshold height = 12mm (with tapered edges at 1:2).
- Maximum door opening force = 22 N.
- Minimum height viewing glass = 900mm.
- Minimum one-way ramp width between handrails = 1000mm.
- Maximum grade for non-ramp = 1:20.
- Maximum ramp grade = 1:12.
- Minimum ramp level area at turns = 1500 mm.
- Minimum ramp level length at rest areas = 1500 mm.
- Maximum length of ramp section = 10.0 m.
- Handrail height range = 860 to 965 mm.
- Handrails on both sides plus intermediate handrail.
- Minimum ramp curbed height where not solid = 1250mm.
- Top of guard rail height for ramp up to 9 m high = 910mm.
- Top of guard rail height for ramp over 9 m high = 1500mm.
- Minimum two-way public stairs width including handrails = 2500 mm.
- Slope of stairs = 30°, with 285mm stair treads.
- Maximum number of stairs between rest areas = 14.
- Minimum stair platform length at rest areas = 1200mm.

7.6 INFORMATION, SIGNAGE AND GRAPHICS

7.6.1 General

Information and directional signage and services shall be provided so that an infrequent transit user with limited geographic knowledge of the neighbourhoods served by each busway station shall be able to use the busway system easily and with confidence. Reference shall be made to a standard information and guidance sign system shown in Winnipeg Transit's *Signage Design Manual* and the general principles of the Manual of Uniform Traffic Control Devices (MUTCD).

On entering the station, information on fare payment methods and trip planning shall be clearly visible, discernible and accessible for pedestrians. Clear directional signage shall be provided from this point to the stop or stops on the station platform. At each stop the basic information shall be repeated to confirm the fare and trip planning decisions made by the passenger. For the passenger arriving at the station on a busway, route information about connecting local services and the station vicinity within walking distance shall be provided at each station stop and the station exit.

Initially, all such information may be provided using conventional static maps, schedules and written material with accommodations for persons with sight impairment. The Planner/Designer shall, however, make provision for either initial or future installation of automated dynamic real time information systems in accordance with ongoing technological development in this field. This will require the installation of conduit for power and data as well as a shelter design that can accommodate displays in a glare-free environment.

7.6.2 Information Signage

Station Identification

Station Identification signs should be visible from all approach roads and should present a standardized logo and message. Letter sizes and fonts should meet the requirements of the disability regulations and Winnipeg Transit's signage system. An illuminated sign would normally be required and electrical provisions should be allowed for in the design. Additional station identification signs shall be located at several points along each platform so as to be easily visible by passengers seated or standing on buses travelling on the busway.

System Map and Schedule

Passenger information displays such as timetables, route maps and directional orientation, should be wall-mounted, under mar-resistant transparent material, in locations convenient to passengers and in compliance with disability requirements using standard formats and dimensions established by Winnipeg Transit.

Where signage is encased in map cases, electrical provisions shall be provided in the station design. Consideration should be taken in the design of map cases to ensure that the material used will withstand wear and that it can be easily kept clean – passengers will touch the case while reading the map.

Bus Stops

Standard busway bus stop tabs and poles shall be installed in locations designated by the Winnipeg Transit. The signage shall comply with disability requirements. Electrical provisions should be provided in the station design.

Dynamic Signage

Dynamic signs (Changeable Message Signs, Variable Message Signs) may be mounted at selected locations; normally at the front of the platform and with a letter height (150mm minimum) that can be read from a distance. Alternatively, separate smaller signs can be provided at each bus stop and integrated with the bus stop tab and pole. Power and communications provisions for this signage shall be provided in the station design.

Passenger Information System

A real time passenger information system with bus scheduling information may be displayed with up to date schedule changes on electronic displays that may include an audible component. Installation locations that are convenient for all passengers (such as near the station entrances and exits) shall be selected in each station and provisions for power and communications transmission shall be provided in the station design.

To accommodate the needs of hearing-impaired passengers, station entry points for pedestrians should include audible information cues to find the access points to the PA system, which should provide audio substitutes for the electronic display system.

Public Address System

Consideration shall be given to providing a PA system operated from the Busway Operations Centre but with the capability of being interrupted locally at each station by authorized personnel. The PA system should comply with disability requirements for visually impaired persons to confirm information received in other forms.

Even if no immediate PA installation is proposed, the station design shall include conduit system provisions for a PA system.

Information Telephones

Information telephones of the "lift-to-talk" or "press button to talk" style of a distinctively high visibility colour shall be provided for in the station designs. There should be a minimum of one phone per platform located in each covered ticket and information area. This phone will be linked to Winnipeg Transit's *Passenger Information System.*

Selected telephones shall be provided with a Telecommunications Device for the Deaf (TDD) in accordance with the requirements for the disabled.

Provision shall also be made for the future installation of pick up phones linked to local taxi services.

Public Telephones

A minimum of one pay-phone per platform, located in each covered ticket and information area, shall be allowed for by provisions in the station design.

At least one telephone shall be provided with a TDD. Actual requirements are to be arranged by the Planner/Designer with the telephone company.

7.6.3 Graphics

System maps shall be provided in weather-tight, illuminated and vandal-proof map cases. These shall comply with the requirements for the disabled and will conform generally to the dimensions to be specified by Winnipeg Transit. One system map in each shelter and in each covered ticket and information area shall be the minimum allowed. Conduit provisions and mounting space shall be allowed for in the station design.

7.6.4 Directional Signage

Signage shall be installed and shall conform to the specifications provided by Winnipeg Transit and in accordance with the MUTCD. The Planner/Designer shall ensure that the station designs incorporate appropriate locations for the installation of the signage.

7.6.5 Communications Ducts

To provide for future flexibility for the installation of communications and information technology, conduits shall be provided throughout the total length of each busway and through all structures along its length, under both platforms and across the busway at each station (refer to Chapter 5, Section 5.7 and Chapter 13, Section 13.5). The Designer shall also co-ordinate the incoming telephone ducting, cabling and siting of telephones with the local telephone company.

Provision of communications for busway use may be integrated with conduit for other uses. A thorough examination of communications architecture should dictate the provisions.

7.7 PASSENGER SECURITY

7.7.1 Security Principles

Most stations will not be staffed on a permanent basis and all stations will be unstaffed at times. It is therefore of critical importance that there be no places where persons who may be lurking could hide or be perceived to be hiding and that passengers have a strong perception of personal safety. Lighting shall be designed in accordance with the requirements of Winnipeg Transit standards and the values given in Chapter 13.

Lines of sight should be clear and all furniture and other objects should be designed and placed with visibility in mind. Provisions shall be made for 24 hour video monitoring of key areas.

It is important that, where possible, tempered safety glass be used for shelters and other buildings. Glass walls are best but multi-windowed buildings with less than

300mm solid portions between windows can be used. Where a glass roof is not provided, skylights help to enhance the natural lighting of the areas. Under no circumstances should tinted glass be used on walls as this masks the interior of buildings and creates doubt in the minds of outdoor observers as to whether or not suspicious persons may be inside. It also reduces visibility for passengers looking out at night. Transparent plastics or polycarbonates are not recommended as substitutes for glass because of their tendencies to scar and discolour over time.

Other important concepts are as follows:

- At least one exit (stairs, ramp, etc.) shall be in sight from all points.
- An emergency alarm shall be within 18m of any point and prominently marked and easily visible.
- Proper illumination is required at all times except when the busway is closed, in which case minimal security lighting and that necessary for video monitoring shall be provided.
- Shelters and buildings shall not be designed with waiting areas in which a person could be trapped without unimpeded access to an exit.
- Vandal-proof stainless steel mirrors shall be provided wherever a clear line of sight around a barrier is not possible.
- Colour contrasting of materials to aid the visually impaired shall be used.

7.7.2 Safety Principles

The provision of station platforms and shelters that are, and appear to be, safe is one of the most important aspects of passenger security. In addition to visibility, considerations that shall be addressed by Planner/Designer include:

- Since the station areas are basically outdoor facilities, birds may find their way into the shelters and building systems and their droppings are unsafe, particularly on stairways. Care shall be taken to eliminate possible bird roosting or nesting spots. All slopes shall be steep, all corners rounded and all unavoidable ledges treated with anti-roosting fabric.
- All stair treads should be treated with an anti-skid surface and the stair design shall ensure that stair nosings cannot break off.
- All lighting fixtures, map cases and other appurtenances should be made as vandal resistant as practical since debris from broken glass, etc. will be a hazard.
- Stairs and platform edges should be of high visibility colours to assist visually impaired passengers.
- All flooring materials shall be skid proof and conform to any requirements for the disabled.
- Barriers shall be provided at the bottom of stairways that descend perpendicular to the busway in order to prevent passengers (children) from accidentally entering the busway after running down the stairs.

7.7.3 Communications

Emergency Alarms

In all stations, emergency alarms or phones must be provided for those who are (or feel they are) threatened, those who experience mishap and for those who may be ill.

The recommended emergency alarm is a simple lift-to-talk or preferably press-to-talk telephone, in the international distress colours of yellow and black. At least one telephone shall be provided with a TDD in accordance with the guidelines for the disabled. The emergency phone system will be linked into the Busway Control centre and the Emergency Response System.

The emergency phones shall be installed within 20m of every point in the station and in clear proximity to the primary busway stop to be designated by Winnipeg Transit for evening operations. Care shall be taken to ensure that other signage and information displays do not obscure the emergency phone signage.

Elevators shall be provided with automatic "stuck elevator" alarms. Fire protection equipment, gas sniffers, lighting panels, etc. shall all be alarmed for malfunction and shall report back to Winnipeg Transit's Busway Control Centre through a main alarm panel.

Video Monitoring System

A video monitoring system is recommended as an overall busway operations and personal security aid. The monitoring system can perform several functions:

- Monitor station security particularly during night hours.
- Monitor passenger flow.
- Monitor bus operations.

The Designer shall take account the potential use of CCTV monitoring systems by designing the station layouts to facilitate monitoring by a minimum number of cameras.

7.8 FARE COLLECTION

Every attempt should be made to encourage prepayment of fares through the advance purchase of various types of passes and tickets to the greatest possible extent. The Designer shall therefore make provision for the space and power and communications requirements necessary for the future installation of accessible fare vending machines at appropriate locations in each station as illustrated on Drawing E-8.

7.9 STATION FURNITURE

7.9.1 Seating

Seating requirements in shelters and on the platforms shall be reviewed with Winnipeg Transit. All seating surfaces shall include design considerations for frail, elderly and semi-ambulatory passengers on a priority basis. Seat plans shall include at least one bench of a minimum of 5m length in each shelter and shall allow for integration of wheelchair locations. Possible bench locations are shown on Drawing E-8.

Seating should be provided in areas under shelter to provide shade and cover during rain/snow. Adequate spacing should be provided between seats to allow for wheelchairs to fit between.

Consideration should be taken when selecting the type of seating to ensure that it is not conducive to skateboarding.

Seating should be of a consistent type to maintain passenger expectations and avoid injuries (e.g. provide backs on either or none of the all stations benches).

7.10 PASSENGER ACCESS

7.10.1 Local Walk-on Facilities

Every station will have some need for local "walk-on" facilities. These facilities generally consist of:

- Walkways connecting platforms to municipal sidewalks on nearby streets.
- Ramps connecting as above (maximum length 90m).
- Stairways, which cannot be the only path of travel between any two pedestrian points, connecting as above (as close to platforms as practical).
- Sidewalks connecting either-side platform to any Kiss and Ride, Park and Ride, and Bike and Ride facilities.
- Sidewalks, ramps or stairs connecting either-side platforms to footpaths or bus bays with local bus stops.

7.10.2 Busway Crossings

Where at-grade pedestrian crossing of the busway is provided, the station platforms will require depressed kerbs at the busway crosswalk locations opposite the opening in the median island and as per requirements for the disabled. Provisions shall be made for such busway crosswalks to be equipped with dynamic signalling equipment to alert passengers of the imminent arrival of any approaching buses and any other vehicles.

7.10.3 Facilities for Persons with Disabilities

Access to local sidewalks that meet the City of Winnipeg’s accessibility guidelines must be provided. At least one access point to either-side platforms from the municipal sidewalks is required. The accesses would normally consist of sidewalks or ramps. Where long walkways are required, resting areas equipped with at least one seat shall be provided at intermediate points.

7.10.4 Bike and Ride

A single covered Bike and Ride parking facility shall be provided at each station, as close to the station platforms as practical to discourage unauthorized locking of bicycles in walking areas and to minimize the walking distance from each platform.

The Designer shall provide for a hard surface space of at least 3m by 3m for bicycle parking and shall provide for a heavy duty bicycle rack which will provide a measure of security to passengers.

Bike and Ride parking shall be located at least 1m beyond any walkway areas. Bicycle racks should be placed in areas that would allow cyclists to access the platforms without illegally crossing the busway.

7.11 MATERIALS AND ARCHITECTURAL STANDARDS

7.11.1 Concrete

The basic structural material for the platforms shall be reinforced concrete. Station buildings may be concrete also. All formed surfaces that are to remain exposed shall be given a sand-blasted or sack-rubbed finish and treated with an anti-graffiti system. The top surface of platforms, medians and walkways shall receive a broom finish. A layer of prefinished pavers may also be used.

7.11.2 Structural Steel

Station buildings may be constructed of steel if concrete is not suitable.

The steel frames for links, shelters and skylights shall be fabricated from hollow structural sections (HSS) or other consistent members as approved by Winnipeg Transit. All exposed structural steel shall be galvanised and painted and shall receive a shop applied, special coating consisting of:

- Epoxy zinc primer.
- High build epoxy mastic intermediate coat.
- A two component polyurethane top coat.

The colour of the top coat shall be as determined by the architect. Design of joints and corners of the same or different materials should be rounded to a radius no less than 25mm when possible wherever pedestrians might contact them.

7.11.3 Windows and Doors

Window members shall be fabricated of aluminium. All exposed aluminium surfaces shall be prefinished to the colours specified by the Winnipeg Transit. Doors shall be heavy duty galvanised steel with grade 1 hardware.

7.11.4 Glazing

Glass types and locations to be as follows:

- Vertical glass - minimum 10mm thick clear tempered.
- Curved roof – laminated glass consisting of two (2) minimum 5mm thick lites of annealed glass with minimum 0.75mm vinyl interlayer. Type 1 interior lite to be clear, exterior lite to be tinted bronze (49% visible light and 56% solar energy reduction)

- Flat roof - (minimum slope 2%) laminated glass consisting of two (2) lites (5mm thick) of tempered glass with 0.75mm vinyl interlayer, overall thickness to be confirmed. Glass shall be Type 1. Interior lite to be clear, exterior lite to be tinted bronze (49% visible light and 56% solar energy reduction).
- Vertical fixed windows (e.g. elevator tower glazing) specification is based on single glazed 10m thick clear tempered glass.
- Canopy ends (optional) - minimum 10mm thick bronze tinted tempered glazing to 56% solar energy reduction, Type 1.

7.11.5 Benches and Handrails

Benches shall be constructed of vandal proof materials acceptable to Winnipeg Transit and as specified by the architect. Handrails shall be constructed of stainless steel.

7.11.6 Floors

Floors in all non-shelter enclosed areas including stairs and any staff work stations shall receive a non-skid, concrete or steel finish. All other floors shall be painted concrete or epoxy treated as approved by Winnipeg Transit except for any staff washrooms, which shall be ceramic tile, and any ticket offices which may be carpeted or vinyl-tiled as directed by Winnipeg Transit.

7.11.7 Roofing

Solid roofing on all station buildings shall be as per Winnipeg Transit standards.

7.11.8 Hardware

Steel Doors

- Hinges to be 1½ pair butts, 155mm x 110mm.
- Lockset lever handles shall have return to door face on outer end of handle.
- Locks to be master keyed to Winnipeg Transit Standards.
- Closer operating force shall be adjustable to the maximum permitted under regulations for disabled access.
- Kick plates to be stainless steel, 300mm high.
- Threshold to be extruded aluminium alloy 6063-T6, 180mm wide x 12mm high.
- Door handles to be stainless steel ‘D’ type of 300 mm height with stainless steel back plate.

7.11.9 Aluminium Pedestrian Barrier

An aluminium pedestrian barrier, 1.2 m high, on top of the raised median shall be installed on the busway through the station area as shown on Drawing E-6.

Barriers shall be fabricated of aluminium extruded shapes, sheet and plate.

Bolts, set screws, nuts and washers shall be stainless steel except for anchorages which may be galvanised if protected with nylon washers or bushings. Anchorages shall be 20mm by 200mm.

7.12 STATION ROOMS

7.12.1 Introduction

At certain large stations additional facilities beyond those found at standard stations may be required.

The functional analysis of each station, undertaken as part of the preliminary design, may indicate the current or future need for one or more of:

- Supervisors’ Work Station.
- Ticket Sales Area.
- Electrical Room.
- Generator Room.
- Janitor / Storage Room.
- Elevator Machine Room.
- Drivers’ Restrooms.
- Drivers’ Lunch Rooms.
- Corridors.
- Stairs.
- Vestibules.

These facilities shall be sized dependent on the anticipated passenger capacity, flow, lengths of waiting, pick-up and drop-off facilities, etc. The sizes quoted in this section have been found to be the minimum acceptable to operations staff and may have to be increased to meet demand or local Codes. All rooms must have accessible entrances.

7.12.2 Supervisors' Work Station

The minimum size for a supervisors' workstation shall be 3m x 3m located to be accessible and given a prominent view of platforms and any bus lay-up area. Painted drywall should be used on walls and ceiling. Floors shall have a non-skid surface.

7.12.3 Ticket Sales Area

Requirements for a ticket/pass sales area should be established in consultation with the Winnipeg Transit and must be accessible and usable for both employees and passengers. Painted drywall should be used on walls and ceilings. Floors should be vinyl tile or carpeting. A lobby area shall normally be provided in conjunction with any ticket sales facility so that passengers waiting to purchase tickets and passes do not obstruct other passenger activities.

7.12.4 Electrical Room

A minimum size of 2.5m x 1.8m should be considered but the actual size should be designed for present and future requirements. This is a utility area and exposed concrete walls, ceilings and floors (painted) are used. Floor paint shall be resistant to hydrocarbon-based liquids.

7.12.5 Generator Room

The minimum size is 3.0m x 4.5m. Actual dimensions depend on generator size. Exposed concrete walls, ceilings and floors (painted) are used. Floor paint shall be resistant to hydrocarbon-based liquids.

7.12.6 Janitor/Storage Room

The minimum size is 3.0m x 3.0m but actual dimensions depend on station function and maintenance equipment requirements as established by Winnipeg Transit. Exposed concrete walls, ceilings and floors (sealed / painted) are normally used.

7.12.7 Elevator Machine Room

The minimum size is 3.0m x 3.0m x 2.5m high. The machine rooms are normally located at the lowest floor adjacent to the hoistways. Exposed concrete walls, ceilings and floors (sealed / painted) are normally used. Floor paint shall be resistant to hydrocarbon-based liquids.

7.12.8 Drivers' Toilets and Meal Rooms

All such facilities must be accessible to enter and to use in accordance with the *National Building Code* as supplemented by the *Manitoba Building Code* and City of Winnipeg Bylaws.

If in a separate building, the minimum size is 35m^2 including the following elements:

Male Restroom 3.6m x 1.8m,

Female Restroom 3.0m x 1.8m

Janitor's Closet 1.0m x 1.0m

Lobby Area and Driver's Meal Room 3.6m x 6.0m

If toilets are accessed from lobbies, the lobby areas may be part of the corridor space and the Janitor's closets can be omitted.

Provisions shall be made in the Lobby Area/Driver's Meal Room for drinking fountain, coffee and juice or soft drink machines (non-public areas only). If these items are installed, they must be accessible to approach and use in accordance with appropriate standards.

Ceramic tile is normally used on walls and floors, with painted drywall on ceilings.

7.12.9 Corridors

The corridors are in the service (non-public) area for access to various rooms. A minimum width of 1220mm should be used. Exposed concrete walls, floors and ceilings (painted) are normally used, although steel can also used.

7.12.10 Stairs

Stairs should have a desirable width of 2500mm however, a minimum width of 1200mm is acceptable. Stairs should be composed of steel or reinforced concrete, and be finished with a non-skid surface. Safety stair nosing strips shall be provided on all interior stairs.

7.12.11 Vestibules

Vestibules shall comply with the requirements of the disability regulations.

7.13 STATION MAINTENANCE CONSIDERATIONS

7.13.1 General

Station complexes shall be designed to reduce the amount of maintenance in terms of material and labour costs. Since many stations will be unattended during normal operating hours, it is imperative that proper design considerations be included to keep maintenance requirements to a minimum. The ideas and requirements included here have been used effectively on past projects and are representative of the initiatives expected.

Ash and cigarette receptacles should be provided on platforms regardless of smoking regulations because passengers will smoke in outdoor areas whether it is allowed or not. The cost of implementing receptacles can be offset by the cost savings of having to clean cigarette waste from the platforms.

7.13.2 Reduction of Bird, Animal, Pest and Vermin Problems

There shall be no horizontal surfaces on which birds can hide from view and build nests or pollute walls or passengers. Surfaces that may allow bird roosting shall be rounded where metal is used or bevelled to 45^o where concrete surfaces are used.

There shall be no concealed hollows or spaces where animals will be tempted to nest.

There shall be no holes greater than 5mm diameter (without insect screen) entering items such as lighting fixtures, fans, air ducts, etc. where mice, bees, wasps, etc. will be tempted to nest.

7.13.3 Reduction of Winter Problems

Trees and planting on or near platform shall be enclosed in raised planters not less than 55mm above the grade of the platform so that salt does not run into and ruin the plantings and so that the form of the planters is readily visible to operators of snow removal equipment.

There must be an area of at least 10% of the platform area that can be used for temporary snow storage. This area must be adjacent to or within a few feet of the platform and not occupied by plantings or items such as bike racks, etc.

A ramp shall be provided at the downstream end of the platform for maintenance vehicle access.

All water pipes and drain pipes subject to freezing must be provided with electrical heat tracing systems.

All electronic devices shall be installed in areas where the low temperature is within the rating of the devices; otherwise heated cabinets shall be provided.

7.13.4 Reduction of Heat Problems

Some doors, windows or panels shall be capable of remaining in the open position in order to allow natural wind cooling of interior spaces. Otherwise, station architecture could address reducing heat through omitting doors, windows or panels.

Telephones and electronic devices shall not be installed where they would be subjected to direct sunlight. Electronic devices shall be installed in areas where maximum temperatures do not exceed the equipment rating or the areas shall be otherwise cooled by mechanical means.

7.13.5 Reduction of Vandalism Problems

All vertical surfaces shall be finished in a graffiti resistant surface.

All lighting fixtures and other exposed appliances shall be equipped with vandal resistant screens.

Where practical, walls shall be of glass or other transparent materials so that there are a minimum number of areas in which to stand unobserved by passers-by.

7.13.6 Reduction of Cleaning Problems

All lighting fixtures, fans, ventilation devices and wall mounted appliances shall be capable of being washed down, without damage, by a standard water hose at 550 kPa.

Where janitor's closets are provided, janitor's slop sinks as well as remote water taps shall be included. A hose connection shall be provided to serve a 30m long hose.

Tunnels should be designed (where possible) such that much of the maintenance work can be accomplished from outside, thus minimizing the need to close lanes on the busway.

Taps should be provided at appropriate locations to minimize the need for maintenance workers to carry water tanks large distances.

7.13.7 Basic Materials

All materials, components and finishes shall be high quality, durable, vandal resistant and corrosion resistant as set out in Section 7.11. Such components provide built-in low maintenance features.

7.13.8 Maintenance Materials Stocking

As far as practical, the Designer shall use modular features and common components throughout the stations so as to reduce the variety, volume and costs of spare component stocking for maintenance purposes.

END OF CHAPTER

CHAPTER 8

STRUCTURES

CHAPTER 8 - STRUCTURES

8.1 INTRODUCTION

These guidelines are for the design of rapid transit structures. Bridges shall be designed in accordance with the current edition of the *AASHTO Specification for Design of Highway Bridges.*

8.2 SCOPE

This chapter sets out guidelines for the design of busway structures with spans not exceeding 100 m. The standards set forth here are minimum requirements that are consistent with current practice. For items not specifically covered in this manual, the current local standards shall be referenced for the design of busway structures. Deviation from this or the supplemental code of first preference shall be subject to the approval of Winnipeg Transit. For specific requirements related to future LRT conversion, refer to publications listed in Subsection 8.3.3.

Reference should be made to the publications provided in Chapter 4 and also to the local Bridge Code.

8.3 SUPPLEMENTAL CODES/GUIDELINES

8.3.1 Busway Structures, Pedestrian Structures and Retaining Walls

- Canadian Highway Bridge Design Code (Latest Edition).
- *Railway Underpass – AREMA Manual for Railway Engineering (Latest Edition).*
- *Canadian Geotechnical Society.*
- *Canadian Foundation Engineering Manual 1992*

8.3.2 Station Buildings and Related Structures

- *National Building Code as supplemented by the Manitoba Building Code and City of Winnipeg Bylaws*.

8.3.3 Light Rail Transit Design Requirements

- *Analysis and Design of reinforced Concrete Guideway Structures – ACI Committee Report 358.1 R-92 (referred to as "ACI Code")*
- *Design Criteria for the GO-ALRT Elevated Guideway and Special Structures – Ministry of Transportation Ontario, 1983 (referred to as "MTO Criteria")*
- *Canadian Highway Bridge Design Code (Latest Edition).*

8.4 GENERAL PROVISIONS

8.4.1 Conversion of the System

All busway structures shall be designed in accordance with latest edition of the AASHTO Specifications. In the design of superstructure cross-sections, consideration shall be given to aligning the centreline of the webs of the primary members of girder structures with the future LRT rail locations.

8.4.2 Design and Analysis

Detailed rational methods of design and analysis are preferred. These shall be subject to the approval of Winnipeg Transit. The method of Load Factor Design shall be followed, supplemented by vibration and ride comfort criteria. Non-composite design should be pursued where vertical under-clearance permits.

8.5 GENERAL FEATURES

8.5.1 Clearance

Clearance Under and Over Roads and Railways

Horizontal and vertical clearances for structures over the busway shall conform to Drawing F-6.

Horizontal and vertical clearances for underpass structures carrying the busway shall conform to the requirements as prescribed by Winnipeg Transit and/or the City of Winnipeg Public Works Department. Deck cross-sections on underpass structures shall conform to Drawing F-1 or as dictated by local standards.

Clearances over railways shall conform to the requirements of the appropriate railway authorities.

Construction clearances over roadways shall conform to the requirements of the City of Winnipeg Public Works Department. Where no special requirements are imposed, the clearances shown on Drawing F-5 shall apply.

It is noted that the busway minimum vertical clearances under roadways will not necessarily accommodate large trucks and that these minimum clearances should be used only with prior approval of Winnipeg Transit.

Navigational Clearance

Navigational clearance, if applicable, shall conform to the requirements of the authority having jurisdiction over the waterway.

Hydraulic Clearance

The structures shall conform to the minimum return interval for overtopping and the afflux requirement specified by the *Flood Protection Studies for the City of Winnipeg* and shall be designed to City of Winnipeg standards pertaining to the particular waterway.

8.5.2 Railings

All underpasses carrying the busway shall be provided with a solid concrete barrier 813mm high surmounted by a 302mm high traffic railing on the outside edge of the shoulder as shown on Drawing F-1.

The concrete barriers shall be designed to accommodate the future provision of security fencing or noise attenuation panels to a height of 1000mm above the top of the barrier.

A solid concrete barrier 813mm high surmounted by a 302mm high traffic railing shall separate pedestrian/bicycle and vehicular traffic on all underpass structures carrying the busway with pathways/bikeways. On the outside edge of the sidewalk, a standard steel post and rail pedestrian railing shall be provided to a height of 1100mm for pedestrians only and to a height of 1200mm where bicycles are present.

Exterior railings adjacent to sidewalks and recreational pathways on busway underpasses shall be similar to the steel pedestrian barrier shown on Drawing F-1 and shall meet the following height requirements:

sidewalks	1100mm
recreational pathways	1200mm

The standard rail elements specified above shall be used whenever possible on busway overpass structures that are to be maintained by Winnipeg Transit.

Barriers on the outer edge of all structures over the busway that accommodate pedestrians shall be a 1000mm high concrete parapet wall surmounted by an inwardly curved 1400mm high pedestrian fence, to give a combined height of 2400mm as dictated by local standards.

8.5.3 Decks

All busway structures, unless otherwise approved by Winnipeg Transit, shall have concrete decks. The minimum compressive strength of concrete in the decks shall be 35MPa.

Except for structures designated 'Buses Only', direct fixation of future LRT rail on continuous concrete pads, constructed directly on the deck without ballast, shall be allowed for on Busway underpasses in accordance with Drawing F-8. Shrinkage reinforcement shall be placed in areas reserved for the future rail. Longitudinal reinforcement and prestressing ducts shall not be placed within 0.2m of the top of the deck for a distance of 0.25m either side of the centreline of the future rail locations. The placement of deck voids away from locations directly below future rails is preferred.

8.5.4 Drainage

A minimum transverse slope of 2% shall be provided on bridge decks. Drainage on long structures shall be facilitated by means of scuppers and downspouts as required. No scuppers shall be permitted on spans passing over roads, bikeways or sidewalks.

8.5.5 Joints

The maximum allowable continuous length of superstructure span shall be based on the acceptable characteristics of thermal behaviour of the entire structure including its interaction with the continuous welded rail tracks assumed for the potential future LRT rail system (for structures not designated 'Buses Only').

No open deck joints shall be permitted. All deck joints, whether fixed or expansion type, shall be armoured using steel angles or epoxy dams and sealed with extrusion type seals. Any other treatment of deck joints shall be subject to the approval of Winnipeg Transit.

Expansion joint cover plates on pedestrian surfaces shall be hot dipped galvanised checker steel plate.

8.5.6 Relieving Slabs

Relieving slabs shall be used at the ends of all bridges and shall be full width including shoulders and sidewalks.

8.5.7 Maintenance Inspection

Structures shall be designed to allow for ease of cleaning and future maintenance inspection. Inspection walkways and safety railings are to be considered where appropriate. These items shall be reviewed with Winnipeg Transit early in the design process.

Bridge structures should be equipped with anchor devices to attach climbing equipment to. This will make cleaning the outside of glass and ceilings in the elevator towers easier. It would be preferable from an operational viewpoint to have workers suspended to do this cleaning, rather than using a cherry-picker.

8.5.8 Aesthetics

Care shall be taken to enhance the aesthetic composition of structures by the use of single columns, tapered columns, tapered fascias of superstructure and the like.

Especially in the case of overpasses, superstructures shall be detailed so as to reduce the apparent total depth and to blend into the landscape.

Aesthetic relief shall be considered, subject to the approval of Winnipeg Transit, on large expanses of exposed areas of abutments, retaining walls and wingwalls in the form of a controlled formwork panel design with recessed panel joints and tie holes or other appropriate methods.

Structures shall be designed to minimise details such as ledges, projections or pockets that would collect debris or encourage bird roosting.

8.6 LOADS

8.6.1 Dead Load

The dead load shall include the weight of the deck, the wearing surface (if applicable) and an allowance of 3.0kN/m per track for deck resurfacing and future LRT conversion.

8.6.2 Snow Load

For the design of structures carrying station platforms and/or pedestrian bridges, snow load on the roofs shall be considered as a live load when combining loads and their factors at service and strength limit states.

8.6.3 Live Load

All busway structures shall be designed for the live loads specified in the *ASSHTO Specification for the Design of Highway Bridges (#525)* or applicable LRT loading whichever governs. Except for busway structures designated as 'Buses Only', busway structures shall be designed for all loads (including those outlined in Sections 8.6.5 to 8.6.10) associated with the Busway Rail Loadings as given on Drawing F- 7.

For design purposes the vehicle empty weight shall be considered as 75% of the vehicle crush weight (VCW). The designer shall determine the vehicle type, spacing and arrangement producing the most critical conditions of stress, stability and serviceability. For Fatigue Limit State, the vehicle weight to be used shall be 80% of the VCW.

8.6.4 Dynamic Effects

Rational methods of dynamic analysis allowing for the relationships between vehicle characteristics and mass damping and stiffness of bridges are preferred. However, in lieu of such methods, the following guidelines may be used.

a) The natural frequency of busway structures designed for rail loadings should preferably be a minimum of 3.0 Hz.

b) Vertical live rail loads shall be increased by the dynamic load allowance unless otherwise specified. The dynamic load allowance specified shall not apply to other loads.

c) The dynamic allowance for rail live loads shall be determined using Figures 8.6.A and 8.6.B where V_c is given by

$$V_c = \frac{C_R F}{f_o} \quad \text{where} \quad C_R F = \frac{\text{vehicle speed, m/s}}{\text{span length, m}}$$

and f_o = the fundamental natural frequency of the structure in Hz.

When the ratio in these figures is exceeded, a more detailed analysis will be required. For localised loads used in deck design, such as wheel loads due to derailment, a dynamic load allowance of 2.0 shall be used.

d) For footings and piles that support footings, the dynamic load allowance shall not be considered as a design load.

8.6.5 Longitudinal Forces

Longitudinal forces, as a percentage of the static rail live load, shall be applied to the structure to account for braking and acceleration of vehicles. These forces shall be determined as follows:

- Fatigue and Service Limit States - 15% of static vertical live load
- Strength Limit States - 30% of static vertical live load

The longitudinal force shall act simultaneously with the vertical live rail loads on all axles and may be applied in either direction, forward in braking or reverse in acceleration. The force shall be applied 2.1m above the top of rail elevation.

Longitudinal forces shall be distributed to the various components of the structure taking into account the relative stiffness of the components including bearings.

8.6.6 Hunting Force

Lateral forces as a percentage of the total vertical static rail live load shall be applied at the top of rail elevation in either direction at one axle location and on one side of the wheel only as follows:

Hunting Forces - 8% of static vertical live load

If centrifugal and hunting forces act simultaneously, only the larger force need be considered. The hunting forces shall be applied simultaneously with the vertical rail live loads.

8.6.7 Centrifugal Force

On curved structures a centrifugal force acting horizontally outwards and at right angles to the direction of travel shall be applied at 2.1 m above the top of rail elevation. The magnitude of this force expressed as a fraction of the total static rail live load may be calculated as follows:

$$CF = \frac{V^2}{Rg}$$

where $V = 30m/s$
and R = radius
g = gravity

Where $V < 30m/s$ on tight curves, the operating speed may be used.

8.6.8 Derailment Force

The structure shall be designed to resist the force effects caused by a single derailed standard car standing stationary such that the centreline between wheels is 1.5m from the inside face of the barrier element.

Provisions for future modification of the barrier elements at the time of LRT conversion shall be made such that the barrier can resist a horizontal force of 50% of the VCW on the barrier distributed over a length of 5.0m and acting 450mm above the top of rail elevation. Supporting superstructure elements shall be designed to resist this force at the time of construction.

8.6.9 Thermal Effects

Both seasonal (extreme temperature variations from that prevalent during construction) and local temperature fluctuations (temperature differences between top and bottom or inside and outside of an element) shall be accounted for in determining the structural response to stress and movements.

Where continuously welded rail is to be directly fixed to the deck, rail/structure interaction loads shall be considered including:

- Thermal Rail Forces
- Thermal Rail/Structure Interaction Loads
- Broken Rail Forces
- Unbalanced Thermal Forces
- Track Fastener Restraint Loads

Guidance may be obtained from the MTO criteria and from the ACI code.

For design purposes, a standard 115RE rail section with the following properties for one rail shall be assumed:

Area	=	7260 mm^2
Depth	=	168 mm
Moment of Inertia	=	27x10^{6}mm^4
Section Modulus (Head)	=	0.295x10^6 mm^3
Section Modulus (Base)	=	0.361x10^{6}mm^3
Weight	=	57.15 Kg/m

Figure 8.6A – Dynamic Allowance for Simple Spans

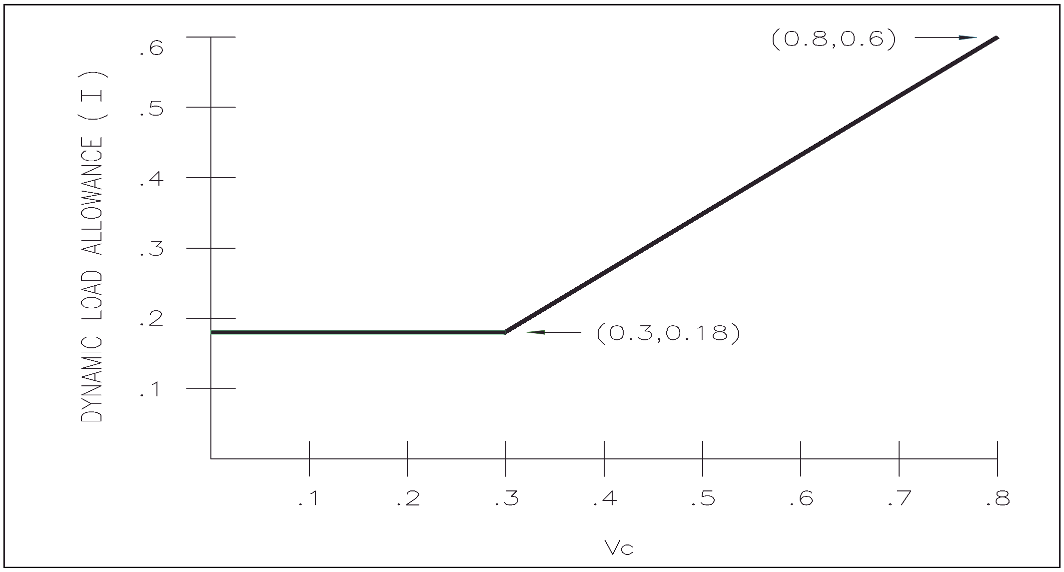
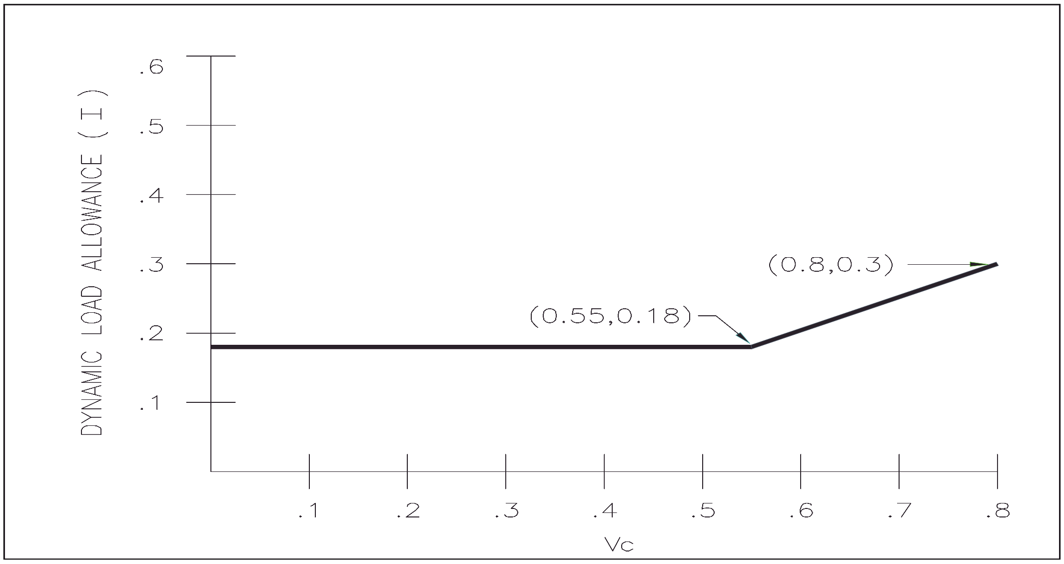


Figure 8.6B – Dynamic Allowance for Continuous Spans



8.6.10 Earthquakes

Earthquake loading is not a requirement in Manitoba.

8.6.11 Loads on Appurtenant Structures

Public Areas

Live load on platforms, ramps and stairways shall be 5.0kN/m^2.

Maintenance Vehicles

If platform and ramps are greater than 3.0m in width and accessible to maintenance vehicles, the live load specified in Section 8.6.4, for buses only, shall be considered in these areas. These loads shall only be considered at the Strength Limit States.

Pedestrian Bridges, Walkways and Stairways

All pedestrian bridges shall be designed in accordance with AASHTO specifications. All bridges and stairways shall be covered and fenced. The wind loads on enclosure structures mounted on pedestrian bridges shall be the same as specified for bridges.

Expansion joint cover plates on pedestrian surfaces shall be hot-dipped galvanized checker steel plate.

8.7 LOAD APPLICATION

8.7.1 General

Except as specified in Sections 8.7.2 to 8.7.4 inclusive, all loads shall be applied as specified in accordance with the current edition of the AASHTO specification.

8.7.2 Rail Loadings

The application of all specified rail loadings shall be such as to produce the maximum effects in the structure. Structures with single or multiple tracks shall be loaded with units of single or multiple train vehicles (VEW or VCW) such that flexure, shear and torsion effects are maximised along the structure. For flexure and shear effects, all tracks shall be loaded simultaneously by whole vehicle trains located to produce maximum effects. For torsion, on straight or curved structures, tracks shall be loaded to produce the maximum effect. Provision shall be made at piers or abutments to transfer the total torsional moments to the substructure.

8.7.3 Vibrations

a) Bridges supporting station areas and pedestrian bridges shall be isolated from the main busway structure and carried on independent superstructures to reduce the effects of vibrations due to live loads.

b) In cases where the above is not possible, the structures shall be designed to satisfy the human tolerance levels to bridge vibrations as given in the AASHTO specification.

c) The effects of bridge vibration shall be examined in a rational manner in order to ensure that structure serviceability and vehicle ride quality are satisfactory. The static deflection of the structure subject to a single LRT vehicle (at 80% of VCW) shall also meet the limitations given in the AASHTO specification.

d) The Designer shall consider the vibration impacts of the busway on adjoining buildings.

8.7.4 Fatigue

Areas of stress fluctuations and section discontinuity such as connections etc. must be carefully analysed for the effects of fatigue.

Fatigue effects for rail loadings shall be designed in accordance with the current version of the AASHTO specification.

8.7.5 Long Term Effects

Dead load deflections including time-dependant deformations such as shrinkage, creep, prestressing losses etc. shall be counteracted in full by appropriately cambering the structural elements.

8.8 LOAD COMBINATIONS AND LOAD FACTORS

Highway/Busway live loads shall not be combined with the specified rail live loads. Load combinations and load factors given in the AASHTO specification shall be used except when analysing the structure for rail or associated loads. Load combination and load factors specified on Tables 8.8.A and 8.8.B shall be used when rail live loads are considered.

8.9 SPECIAL CONSIDERATIONS

8.9.1 Stray Current

Provisions shall be made for the electrical isolation of bridge superstructures for future LRT operations.

Table 8.7A – Allowable Fatigue Stress Ranges

Stress Category	**Allowable Stress range Fsr$_2$ (MPa) for 5.5 x 10^6 Variable Stress Cycles$_1$**
Redundant Load Path Structures$_7$	
A	125 (83)$_5$
B	90
B'	70
C	70
	83$_3$
D	48
E	31
E'	18
F	55
Nonredundant Load Path Structures	
A	125 (83)$_5$
B	90
B'	70
C	62
	76$_3$
D	34
E$_4$	16
E'	9
F	42

FOOTNOTES TO TABLE 8.7.A

1 The number of cycles pertains to standard vehicles when applied to main members. For individual components whose design is controlled by axle loads, the number of cycles applied shall be that of individual axles of the standard vehicle.

2 The range of stress is defined as the algebraic difference between the maximum stress and the minimum stress. Tension stress is considered to have the opposite algebraic sign from compression stress.

3 For transverse stiffener welds on girder webs or flanges.

4 Partial length welded cover plates shall not be used on flanges more than 0.8” thick for non redundant load path structures.

5 For unpainted weathering steel. A709, all grades, when used in conformance with the FHWA *Technical Advisory on Uncoated Weathering Steel in Structures*, dated October 3, 1989.

6 Structure types with multi-load paths where a single fracture in a member cannot lead to the collapse. For example, a simply supported single span multi-beam bridge has redundant load paths.

7 Structure types with multi-load paths where a single fracture in a member cannot lead to the collapse. For example, a simply supported single span multi-beam bridge has redundant load paths.

Table 8.8A – Load Combinations and Load Factors

LOAD COMBINATION	LOADS														
Limit State	**D**	**E**	**PS**	**TFR**	**L+I**	**T**	**S+CR**	**W**	**WL**	**SF**	**LF**	**(Use one at a time)**			
												EQ	**BR**	**DR**	**CT**
Fatigue	1.0	1.0	1.0	1.0	1.00						1.0				
Service I	1.0	1.0	1.0	1.0	1.0	1.0	1.0		[0.3]	[1.0]	1.0				
Service II	1.0	1.0	1.0			1.0	1.0	1.0							
Strength I	α_D	α_E	1.0		1.7										
Strength II	α_D	α_E	1.0		1.4		1.0	1.5	1.5						
Strength III	α_D	α_E	1.0		1.4	1.5				1.5	1.4				
Strength IV	α_D	α_E	1.0		1.4							[1.5]	[1.2]	[1.4]	[1.3]

Legend

BR : Broken Rail Loads
CT : Vehicular Collision Force
D : Dead Loads
DR : Transit Vehicle Mishap Loads due to Derailment
E : Earth and Hydrostatic Pressure other than Dead Load
EQ : Earthquake Loads
:
LF : Longitudinal Forces from Live Load
L+ I : Live Load Plus Impact including Hunting or Centrifugal Forces

PS : Secondary Prestress Effects
S+CR : Shrinkage and Creep
SF : Stream Flow Pressure
T : Temperature Effects
TFR : Track Fastener Restraint Loads
W : Wind Load on Structure
WL : Wind on Live Load
[ ] : Indicates inclusion of only one of bracketed loads which produces the most critical effect.
Example 1: $\alpha_D + \alpha_E + 1.4\ (L+ I) + 1.3\ CT$.
Example 2: $\alpha_D + \alpha_E + 1.4\ (L+ I) + 1.5\ EQ$.

Table 8.8B – Values of α_D and α_E

Type of Load	**Load Factor α_D or α_E**	
	Maximum	**Minimum**
Dead Loads		
• Components and Attachments	1.3	0.9
• Wearing Surfaces and Utilities	1.5	0.85
• Earth Fill	1.0	1.0
Earth Pressure	1.3	0.5

END OF CHAPTER

CHAPTER 9

PARK AND RIDE LOTS

CHAPTER 9 - PARK AND RIDE LOTS

9.1 INTRODUCTION

Park and ride lots are an important element in the busway system to serve passengers living in areas with little or no local bus service. They shall be located adjacent to busway stations and be readily accessible from the nearest major roadway. Certain park and ride lots may serve some local bus routes as well as busway buses, and therefore, they must be designed accordingly. Details of bus use and bus movements shall be obtained from Winnipeg Transit before commencing planning or design.

The location and size of each park and ride lot shall be determined in conjunction with Winnipeg Transit through projected needs, available property and the ability of the street system to feed the lot. Unlike rail transit, it is not necessary that the park and ride lot be within walking distance of a busway station so long as it is served by a frequent (preferably all day) busway bus service that travels quickly to the busway. This allows potentially valuable developable land next to the station to be put to a higher and better use.

9.2 LOT ACCESS

As it may be necessary to install traffic signal control at the lot entrance at a later date, traffic operations shall be taken into account when planning access to the lot. Projected vehicular traffic volumes, auxiliary lanes and signal phasing shall be reviewed accordingly. The Designer shall pay particular attention to the peaking characteristics of commuter park-and-ride demand and its implications for access design. For this purpose, the parking characteristics of existing public transit parking lots shall be used as a guide. At locations providing both access to park and ride facilities and the busway, a separate entrance to the busway is desirable (available land permitting) to avoid the possibility of cars enterering the busway.

It may be necessary to provide internal local bus access for larger lots (greater than 500 spaces), remote from busway stations, however, on-street bus stops are normal for small lots.

9.3 INTERNAL LOT LAYOUT

The Designer shall consider the following items:

9.3.1 Bus Loading Area

All parking areas within the lot shall be oriented towards the bus loading area. For smaller lots remote from busway stations, the loading area shall be located on the periphery of the lot as this is the most efficient use of the available property. For large lots (greater than 500 spaces), the loading area may be located within the lot to reduce passenger walking distances. Winnipeg Transit shall be contacted regarding the space requirements for bus lay-up areas (refer also to Chapter 10, Bus Lay-Up Areas).

9.3.2 Parking Type Locations

General

Parking spaces shall be located to minimize the walking distance to the bus loading area. Parking shall be provided for people with disabilities, bike and ride and kiss and ride, and short and long term car parking. Parking for people with disabilities shall be immediately adjacent to the busway station, or to bus loading areas. Kiss and ride and short term parking should be located next, with long term parking developed furthest from the busway station or bus loading area. Short term parking may be part of a kiss and ride area.

Parking for People with Disabilities

Parking spaces for people with disabilities shall be placed as close as possible to the bus loading area. Persons with disabilities shall not be forced to travel behind parked cars or to cross aisles or internal roadways. Accessible routes shall be clearly designated and delineated.

The number and size of parking spaces for persons with disabilities that are to be provided is determined by municipal ordinances and by the policies of Winnipeg Transit. Appropriate signing and pavement markings are required for these spaces, along with depressed curb access to the bus loading areas.

Short Term Parking/Kiss and Ride

Short term parking is required for kiss and ride operations and for taxis, newspaper vendors, maintenance staff, etc. that will frequent the site. These areas, which will have a high turnover rate, shall be adjacent to or as close as practical to the bus loading area and shall be situated to be easily recognizable and easy to use by parking lot patrons. These areas shall also be easily visible from the bus unloading area and shall be physically separate so as not to appear as an integral part of the long term parking area. Evening use of the kiss and ride facility will determine parking capacity requirements, as drivers usually wait a short time for the bus passengers. Unless directed otherwise by Winnipeg Transit, two percent of total parking spaces shall be reserved for short term parking.

Kiss and ride facilities shall be designed as drive through spaces or as parallel spaces with an adjacent sidewalk as shown in Figure 9.3A. Access lanes in the vicinity of the parking spaces shall be wide enough to allow space to manoeuvre around a parked vehicle.

Where possible, access to kiss and ride spots shall be separate from that of the long term parking. The Planner/Designer shall also make provision for a vehicle to recirculate in the event that a space is not available to wait to pick up a passenger.

Long Term Parking

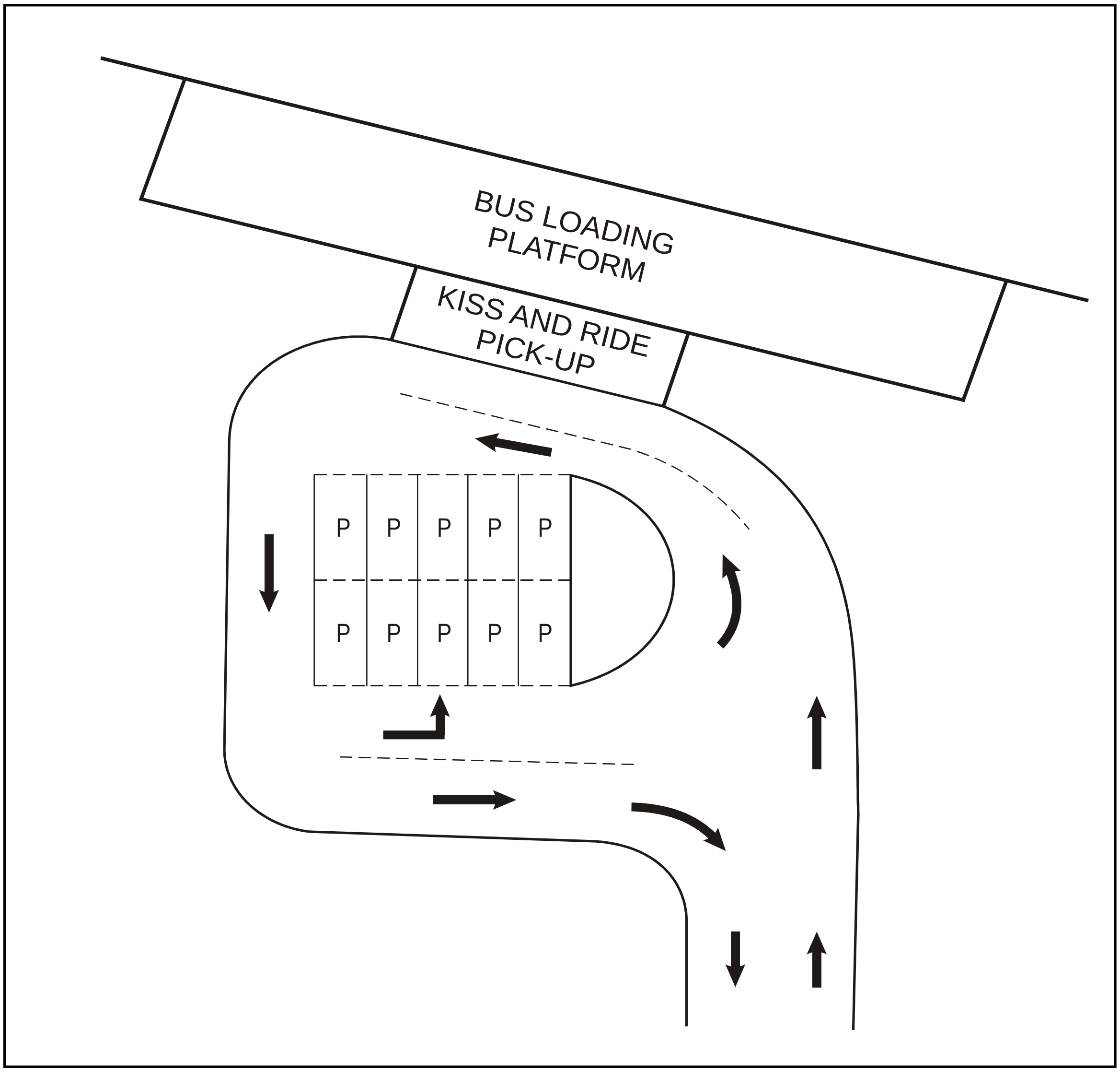
Long term (all day) parking areas shall be located to be equidistant to the bus loading area where practical but shall not interfere with the previously mentioned higher priority parking areas. All normal commuter parking spaces shall be within 180m of the bus loading platform since commuters will often choose to park illegally rather than walk beyond this distance.

9.3.3 Internal Circulation

Internal circulation patterns shall minimize vehicular and pedestrian conflicts, travel distances, conflicting movements and the number of vehicular turns. The lot layout shall permit a driver to search for a parking space without impeding traffic flow and shall be designed to minimize congestion at the lot entrance.

It is desirable that the pedestrian walking distance from each parking space to the bus loading area be less than 120m with 180m considered to be the practical limit and 300m considered the absolute maximum. Parking beyond 180 m will be used normally only for special events. Pedestrian circulation should be directed along aisles or perimeter sidewalks should be used to minimise conflicts with parked cars and circulating cars on internal roadways.

Figure 9.3A – Typical Kiss and Ride Facility



9.4 MISCELLANEOUS INSTALLATIONS

9.4.1 General

The following items may be required at park-and-ride lots, however, the need for these requirements shall first be reviewed by consulting Winnipeg Transit.

9.4.2 Bus Shelters

Bus shelters, for lots located away from busway stations, may be required adjacent to the bus loading areas. Details of bus shelter locations and design shall be obtained from Winnipeg Transit. Where provided, these shelters shall be located to give good visibility of any taxi or kiss and ride waiting area.

9.4.3 Telephones

Emergency, public and/or information telephones may be required by Winnipeg Transit. Public telephones are used by bus passengers arranging for taxi and car pick-ups. Details of telephone requirements shall be obtained from Winnipeg Transit.

9.4.4 Landscaping

Landscaping may be required to screen the lot from adjacent residential areas and to provide shade. It may also be a requirement as an extension of the landscaping in busway station areas. Any landscaping within the lot shall be kept low to maintain driver sight lines and prevent visibility obstruction of pedestrians (security). Landscaping shall not obstruct signage or interfere with lighting or video monitoring of the lot. Hardy, weather resistant, maintenance free planting material shall be used and the landscaping shall be designed by a Landscape Architect. Refer to Chapter 11, Landscaping.

9.4.5 Electrical Outlets

Where practical, electrical outlets shall be provided for each parking space.

9.4.6 Security

Fencing may be required as a security and pedestrian control measure. Fencing needs should be discussed with Winnipeg Transit.

Surveillance cameras may be appropriate to improve personal security and parking lot security. Lighting is also important in this respect.

9.4.7 Bike and Ride

Bike and ride parking facilities shall be as close to the station platforms as practical to prevent unauthorized locking of bicycles in walking areas.

The Planner/Designer shall provide for a hard surface space of at least 3.0m x 3.0m for bicycle parking and shall provide for a heavy duty bicycle rack and an adjacent space for bicycle lockers.

Bike and ride parking shall be located at least 1.0m beyond any walkway areas.

9.4.8 Other Facilities

Winnipeg Transit shall be contacted regarding the need and standard design for information signing, route maps, waste receptacles, newspaper vending stands, vending services, etc. Minimum information displays shall normally include methods of fare payment, service information about commuter routes and local routes serving the lot and the information telephone number for Winnipeg Transit service and local taxi companies.

9.5 DESIGN DETAILS

9.5.1 Pavement and Drainage

Park and ride lots shall be asphalt paved with catch basins/gullies draining to a storm sewer drainage system. The collection and treatment of stormwater run off shall be designed to comply with the requirements of the City of Winnipeg Water, Waste and Disposal Department. The perimeter of the parking lot shall be curbed. Where gratings are provided in any accessible route they shall be in accordance with requirements for the disabled and shall be bicycle safe.

Load carrying pavement designs shall be provided for bus driveways and bus loading areas.

9.5.2 Parking Space Layout

Each parking lot shall be designed to best suit the particular site. Parking aisles shall normally permit two-way traffic and should be aligned to facilitate convenient pedestrian movement. The general requirements of local standards shall be adhered to along with specific requirements herein.

Individual parking spaces shall be oriented at 90^o to a two-way aisle where possible as right-angle parking and two-way aisles provide the most effective use of space and greatest patron convenience.

The minimum sizes of parking spaces and aisles shall conform to the minimum sizes required by Winnipeg Transit. The minimum size of parking space acceptable to Winnipeg Transit is 2.5m x 6.1m. Clear aisle widths for two-way traffic shall be 7.2m. Clear aisle width for one-way traffic shall be 6.0m. Designated accessible parking spaces shall be provided as per requirements for the disabled and shall be 4.0m x 6.1m.

The ends of all parking rows may be defined with curbed end islands. The use of curbed end islands shall, however, be kept to a minimum to minimise costs and to simplify cleaning operations. Curbed islands may be used to protect lighting poles and signage or bollards may be used to define aisles in irregular lots.

Access to the lots and movement within the lots shall be reviewed for the adequacy of movement of maintenance equipment such as snow clearing and sweeping machines.

Large parking lots shall be subdivided into sections to reduce the scale and for ease of reference by users. Walkways and landscaping may be used for this purpose. Vehicular movement from one section to another shall not be restricted.

1.2m x 1.2m spaces with provisions for power supply shall be provided within 30m of all parking spaces for the possible future installation of pay and display ticket vending machines.

9.5.3 Entrance Design

Entrances to park and ride lots shall be designed with medians of sufficient width to install a kiosk. The medians should be of sufficient length to provide for two parked exiting vehicles at the kiosk, with a gate beyond the kiosk. For entering vehicles, the median should provide for one parked vehicle at a card reader/ticket spitter location, with a gate beyond. Provisions shall be made in the medians for future power supply and communication requirements. Medians 2.5m wide by 15m long are usually sufficient.

Both the entrance and exit pavement widths between the median curb and outside edge of curb shall be 4.2m minimum.

9.6 LIGHTING

Lighting shall be provided for all park and ride, kiss and ride and bike and ride lots. Details of lighting requirements are contained in Chapter 13, Electrical, Section 13.3.

END OF CHAPTER

CHAPTER 10

BUS LAY-UP AREAS

CHAPTER 10 - BUS LAY-UP AREAS

10.1 INTRODUCTION

Bus routes are normally scheduled with lay-up or recovery time at one or both ends of the route. Typically, lay-up time of three to five minutes is scheduled for every sixty minutes of running time. It is usually preferable to schedule the running time slightly tight so as to minimize the possibility of the buses running ahead of schedule. On occasion, this means that the buses will be behind schedule and the recovery time at the end of the line allows the buses to depart on time on the next trip, except when unusual delays occur. The recovery time may also be used by the bus drivers for refreshment and washroom breaks.

Recovery time is also required when bus routes are interlined. In this case, instead of a bus being assigned to a single route, it may make trips on several different routes. This is usually done in the case of uni-directional routes such as express routes to minimize the amount of deadheading that is necessary.

Bus lay-up areas are required where the scheduled recovery time on a large number of routes occurs at the same time and place. Normally this is the case on the periphery of the downtown and at major transit focal points and busway stations.

10.2 DETERMINATION OF REQUIREMENTS

Winnipeg Transit shall specify the number of spaces required in each bus lay-up area. From an analysis of the current and projected route schedules, the likely maximum peak accumulation of buses shall be determined. Allowances shall also be made for a projected mix of standard and articulated buses.

Where the lay-up area is part of a busway station, the number of bus lay-up spaces shall be compatible with both the existing station operation and possible future dynamic operations. Under this latter method of operation, the number of passenger loading bays is minimized through greater utilisation of each loading bay. This is achieved by having buses remain in their lay-up areas until just before they are due to leave the station.

This means that no lay-up occurs at the loading bays.

The Planner/Designer shall consider whether the need exists or will exist for provision of parking for drivers, station attendants, or other users within or incorporated in a bus lay-up area.

10.3 DESIGN GUIDELINES

10.3.1 Access to Busway

As direct as possible access shall be provided between the bus lay-up area and a busway. This access shall allow buses to move on and off the busway in all directions. The bus lay-up area shall be sized sufficiently to allow buses entering from either direction to use it as a turn-around so as to be able to exit in either direction.

Access shall also be provided between the bus lay-up area and the adjacent arterial street system.

To achieve the desired flexibility in access, the Planner/Designer shall minimize the internal circulation of buses either in the bus lay-up area or around an adjacent station.

Where bus lay-up areas are contiguous with a busway station, the bus lay-up area shall be designed for maximum visibility from the station by supervisory personnel.

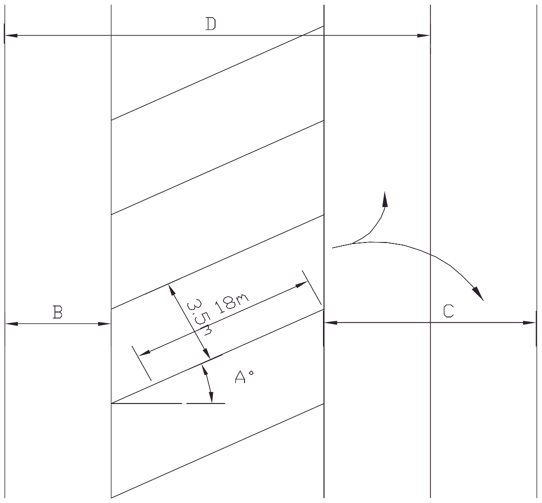
Lay-up areas should not be accessible by busway patrons.

10.3.2 Parking Areas

Bus parking bays in the lay-up area shall be 3.5m x 12.0m for standard sized buses and 3.5m x 18m for articulated buses. Minimum geometric standards for turning roadways in and out of the bus parking bays shall be as shown in Figure 10.3A. For bus parking bays located end to end (parallel parking) rather than side by side (angle parking) their spacing and relationship with the width of the adjacent roadway to allow for the random departure of a bus from any lay-up bays shall be as shown in Figure 10.3B.

Dimensions for car parking provisions can be found in Chapter 9.

Figure 10.3A – Bus Lay-Up Areas (Angle Parking)

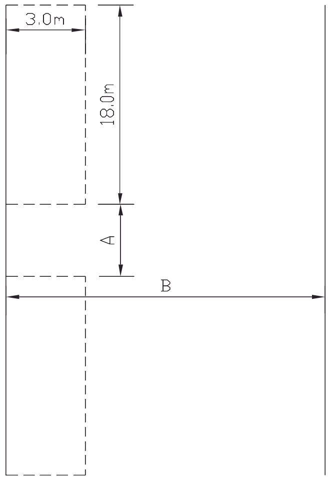


A°	B	C	D
0	26.0	17.0	70.0
5	24.5	18.0	67.0
10	23.0	19.0	64.5
15	21.5	20.0	61.0
20	20.0	21.0	58.0
25	18.5	22.0	54.5
30	16.5	23.0	50.5
35	15.0	23.5	46.0
40	13.0	24.5	42.0
45	11.0	25.0	37.0

10.3.3 Bus Drivers' Facilities

Drivers' restroom facilities are preferred in a separate building adjacent to the bus lay-up areas, and preferable out of sight of the public (this may be done with landscaping). See Chapter 7, Section 7.12.2 for further design details.

Figure 10.3B – Bus Lay-Up Areas (Parallel Parking)



A	B
12.4	7.3
11.2	7.6
9.9	7.9
8.7	8.2
7.5	8.5
6.3	8.8

END OF CHAPTER

CHAPTER 11

LANDSCAPING

CHAPTER 11 - LANDSCAPING

11.1 INTRODUCTION

Well conceived landscaping is an effective means of softening the impact of the busways on their surroundings and helping them look like an attractive part of the community.

High standards established by local Landscape Architectural practice should guide the Planners/Designers who shall be landscape architects in their approach. These standards should be applied to busways in a manner which will exemplify the highest state of the art. Reference shall also be made to the following planting guidelines:

- Planting beds shall be designed as an integral part of the overall station and corridor design.
- All stations shall have areas of shade from trees on or adjacent to the platform.
- Deciduous trees shall have a minimum clear stem height of 1.8m when planted.
- Deciduous trees shall be planted a minimum of 3.5m from the edge of any hard surface.
- Coniferous trees shall be planted a minimum of 3.0m from the edge of any hard surface except where trees are within a planting bed where the minimum shall be 2.0m
- All trees planted in a sodded area shall have a tree well of 1.5m to 2.0m in diameter and the tree well edge shall be a minimum of 1.0m from the edge of any hard surface.
- The mature height of shrubs adjacent to pedestrian areas shall be less than 1.2m and any larger shrubs shall be planted away from these areas or if in these areas they shall be treated as multi-stem ornamental trees and pruned to provide a clear stem height of 1.2m.
- Shrub beds shall be a minimum of 1.0m wide for plant material with a mature height of less than 1.0m and where the bed is adjacent to a hard surface, the planting material shall be set back 0.6m from the edge of the bed.
- Where a planting bed is used as a pedestrian barrier, the bed shall have a raised curb or be in a raised planter. Consideration of the density of planting for these beds shall be made by the designer.
- Planting in median areas shall not block lines of site for pedestrians or drivers and the plant material used shall be chosen for is drought resistance, salt tolerance and low maintenance requirements.

11.2 DESIGN OBJECTIVES

Landscaping in and adjacent to the busway corridor, at station areas and near public roadways, retail or prestige commercial premises or private residences will satisfy a variety of needs. Existing vegetation, especially healthy trees, shall be preserved wherever possible to maintain a visual buffer and to help blend retaining walls and noise walls into the existing environment.

Landscape plantings shall:

- Enhance the aesthetic qualities of natural features adjacent to the busways.
- Blend the busways into their surroundings.
- Serve as a buffer between the busways and adjacent land uses.
- Guide pedestrians and cyclists to authorised crossings or access points on the busways.
- Integrate noise mitigation devices with the landscape.
- Fill or mask dead areas within the busway rights-of-way which may otherwise collect debris.
- Screen unattractive views.
- Frame attractive views.

To promote a hardy blend of trees, shrubs and groundcovers, the Landscape Architect shall take into account the current local nursery availability and consider plant material with proven resistance to drought, diesel fumes and other harmful effects encountered in the harsh urban environment of the busways.

11.3 SUITABILITY AND AVAILABILITY OF PLANT MATERIAL

The plant palette available for use in Winnipeg is generally acceptable. A full member of the Manitoba Association of Landscape Architects shall be responsible for all plant choices, sizes and planting materials for all areas of construction.

The Landscape Architect shall take account of the following:

- The availability of plant material.
- Planting location, exposure and plant characteristics such as soil moisture tolerance, disease and insect resistance, hardiness and pollution tolerance.
- Plant material maintenance requirements.
- The unacceptability of monoculture development.
- City of Winnipeg requirements and guidelines as per Section 11.1

11.4 LOW MAINTENANCE DESIGN GUIDELINES

In undertaking landscape design for busway projects, the Landscape Architect shall pay particular attention to the long-term benefits to be gained from a design which reduces future maintenance problems.

A well-considered low maintenance design will ensure a reduction in the frequency and extent of landscape related maintenance, thereby limiting the high costs associated with expensive maintenance procedures.

Low maintenance plant material and planting practices shall comply with the following standards:

- Following their establishment period, trees and shrubs shall only require watering during periods of drought and mature trees shall require no watering.

- Pruning shall only be required once per year for trees and shrubs shall not require pruning for size or form until mature growth has been achieved.

- Shrubs and groundcovers shall be xeriscape plants where water is not readily available.

- Shrub beds shall have filter cloth and mulch to reduce water requirements and weed growth.

- Tress shall be provided with a tree well formed of soil and topped with filter cloth and mulch to reduce water requirements and weed growth.

- Sod shall be of a drought tolerant species and where speciality sod is unavailable, over seeding of drought tolerant species shall be performed.

- Sod shall not be installed in areas where extensive hand trimming will be required for maintenance.

- Areas to be covered by creeping ground covers shall be mulched to a sufficient depth to deter weed growth.

- Extensive landscaping around buildings shall be provided with an irrigation system or quick coupling valves.

11.5 HARD-SURFACE TREATMENTS

Hard-surface treatments may consist of concrete (matching sidewalks), asphalt aprons, concrete unit pavers of specified colour, grouted field stone, grouted cobble stone and reasonable facsimiles. Loose materials such as stones or bark chips shall not be used.

The following areas shall be considered for hard-surfaces rather than grass or bedding surfaces:

- Strips around buildings of 300 mm minimum width where there is no adjacent planting bed.
- Under building overhangs exceeding 750mm.
- Boulevard areas between hard surfaces less than 1.5 m width.
- Within 150 mm around the perimeter of any benches, waste receptacles, lighting poles, fire hydrants, pad-mounted equipment, manhole covers, etc that are not wholly within a landscaped area.
- Small areas that form an obvious "short cut" for walking.

11.6 GROUND COVER TREATMENTS

Ground cover plantings may be used in areas that are at least 600 mm beyond the hard surfaces of the busway. Such plantings shall be adequately mulched to deter weed growth. All plantings shall follow the guidelines listed above.

END OF CHAPTER

CHAPTER 12

ENVIRONMENTAL CONSIDERATIONS

CHAPTER 12 - ENVIRONMENTAL CONSIDERATIONS

12.1 INTRODUCTION

Minimizing environmental impact is an important requirement for the selection of the preferred busway concept. Concern for environmental impacts and their mitigation, therefore, shall be a requirement of the busway planning and design process.

Key considerations include:

- The preservation of aesthetically and socially desirable features.
- The conservation of historically important attributes.
- The maintenance of natural and man-made environments.
- The potential to improve living conditions adjacent to the proposed project.
- The creation of busway infrastructure of a high architectural quality.
- Obtaining the best advantage of views from the busway by its users.
- Ecologically sustainable development.

During the design of a busway, all environmental commitments made to the applicable environmental standards shall be adhered to. Therefore, the Planner/Designer shall review the applicable environmental standards to ensure that there is a comprehensive understanding of information contained therein, including the recommendations and environmental requirements. In some cases, additional more detailed analysis may be required as a result of commitments made to the applicable environmental standards and/or more detailed review during the design of the busway.

12.2 THE ENVIRONMENTAL PLANNING AN DESIGN PROCESS

In general, the process to address the environmental impacts busway during its planning and design shall follow the same procedures and use the same guidelines and standards as required by the City of Winnipeg for new roads and road links. It shall be, therefore, the responsibility of the Planner/Designer to be familiar with the requirements of the City of Winnipeg in this regard.

Three key areas of potential environmental concern in busway planning and design that are not present on new road links and widenings are:

- The impact of station operations

- Vehicle emissions from a predominantly diesel and/or compressed natural gas powered fleet

- The noise levels due to the operation of a lower volume of larger vehicles than is the case for the normal mix of vehicles on a public road.

12.2.1 Station Impacts

In assessing the environmental impacts of busway station operations, the Planner/Designer shall consider the potential impacts of:

- The concentration of stopping and starting vehicles in terms of additional noise and emission impacts.
- Pedestrian concentrations.
- Informal park and ride and kiss and ride activities in the neighbourhoods surrounding the stations.
- Light pollution due to the station lighting requirements.

12.2.2 Vehicle Emissions

The Planner/Designer shall use the results of the transportation modelling for the busway to determine the predicted reduction in corridor level emissions due to the increase in transit use due to the busway. Winnipeg Transit shall be consulted to determine the expected powertrain mix of the buses using the busway and their emissions ratings.

If required by Winnipeg Transit, further analysis of the predicted air quality at specific locations shall be under taken using available computer models developed for this purpose in the United States. An example being CAL3QHC, an EPA-approved model for predicting pollutant concentrations near roadway intersections.

12.2.3 Noise Impacts

The Planner/Designer shall follow the City of Winnipeg's Noise Guidelines and Policies but shall also take account of the results of the noise prediction analysis and the actual before and after noise measurements made for the Ottawa Southeast Busway.

In Ottawa the noise prediction analysis[1] was undertaken in the late 1980s and based on the use of a computerized model known as ORNAMENT with buses being classified as medium trucks as required by the Ontario Ministry of the Environment. The analysis predicted that the sound exposures from the Southeast Transitway (Busway) alone would not exceed the 55 dBA outdoor (Leq_{16}) criterion at any of the locations analyzed. The maximum predicted difference between the future no-build ambient sound levels and the future build sound levels was expected to be no more than 3.7 dBA.

Before and after the start of operations noise measurements were made in October and November 1996[2]. The conclusions of the study were that the daytime Leq_{16} in the community adjacent to the Southeast Transitway for the period following the startup of transitway operations is lower than the Leq_{16} for the pre-startup period at all locations except one where the noise levels were approximately the same.

END OF CHAPTER

---

[1] Noise Impact Assessment Southeast Transitway, Valcoustics Canada Ltd, June 20, 1989

[2] Community Noise Levels Before and After Start of Operations, Morrison Hershfield, January 1997

CHAPTER 13

ELECTRICAL AND ITS

CHAPTER 13 - ELECTRICAL AND ITS

13.1 INTRODUCTION

The basic electrical and Intelligent Transportation System (ITS) requirements for a busway consist of busway lighting along its length, at station facilities and at intersections, platform lighting and provisions for telephones and two-way communications. Potential or site-specific enhancements of the electrical system include building services such as lighting, climate control, CCTV monitoring, emergency and hot-line telephones.

The applicable codes are:

- National Electrical Code.
- Manitoba Electrical Code.
- City of Winnipeg Electrical Bylaws

13.2 GENERAL REQUIREMENTS

13.2.1 Overview

The lighting, climate and communications systems in the busway stations require superior quality, durable, aesthetically pleasing components; capable of resisting abuse by vandals and the mechanised cleaning methods of Winnipeg Transit. High pressure washing equipment is used to clean the public areas; consequently, all electrical components in these areas must also be rated for wet locations. The station buildings, pathways and platforms are to be fully lit to the design standards.

The electricity/communication provider shall be involved in the design phase to ensure that the best power rate option is obtained. Additionally, enhanced provision requirements such as automated meter recorders that will promote the best power rate shall be established early in the design. An audit shall be undertaken prior to commissioning to confirm the best rate.

Some of the material contained in this Chapter is descriptive of requirements for future works and would only be installed when the busway stations become much more active and a growth program is initiated. These items are described because it is cost effective to include embedded or buried conduits for these future facilities in the stations at their time of construction.

Where possible details as to electrical and other facilities shall be specified in the architectural drawings rather than left to shop drawings so as to minimize the variance in wiring, cover plates, welds/bolts etc between stations.

13.2.2 Elementary Station Requirements

In their simplest form, stations will consist of single shelters on concrete platforms as shown on Drawing E-8. Pedestrian access across the busway is provided by links to an adjacent bridge over or under the busway or via a channelized at-grade crossing as shown on Drawing E-8. Where an at-grade crossing is provided initially, it may be intended that future consideration be given to the construction of elevators and stairway towers connected to an overhead pedestrian bridge.

The Designer shall ensure that the elementary station may be electrically expanded to include future elevators, lighting and HVAC for elevator towers where applicable as determined by Winnipeg Transit. The Designer shall also ensure that elementary station designs include embedded conduits and disconnecting means and transformer capacity to accommodate future features and systems which may be incorporated later in either the existing platform or an expanded station format. The future requirements of each station will be determined by Winnipeg Transit.

13.2.3 Future Requirements

The Designer shall review all stations with Winnipeg Transit to establish requirements for any future systems. These may include but may not be limited to the following:

- Fire Protection.
- Building Monitoring and Control System.
- Parking control devices.
- Automatic Vehicle Location System (AVLS).
- Real-Time Passenger Information Systems.
- Public Address system.
- CCTV Monitoring system.
- Video Information system.
- Automatic Passenger Counting machines.
- Fare vending machines.
- Wide Area Network (WAN) fibre optic communications system.
- Driver facilities (telephone, washroom, storage, etc.).

Conduit provisions for the above future systems normally consist of appropriately sized conduits (12 mm to 50 mm diameter) installed from the site of the device to the communications room or board or to the location of the future distribution panels and capped and left for future use. The Designer shall include such system conduits based on discussions with Winnipeg Transit.

The inclusion of an electrical engineer on the Project Team during design to address communications system provisions can facilitate their successful installation.

13.3 LIGHTING

13.3.1 General

Luminaire wattages are not a set standard but will vary according to the allowable fixture spacing to maintain the design horizontal illumination level at grade. Generally, roadway and platform lighting shall be controlled by 2 panels – Normal Lighting (NL) and Timed Lighting (TL). Station building lighting and some platform lights shall be controlled by a Security Lighting (SL) panel and a Timed Lighting (TL1) panel.

Service room lighting shall be fed from service panels.

"Normal" lighting is only controlled by the photoelectric controller (PEC); whereas, "timed" lighting is operated by PECs and timers during the normal operation of the Busway. "Security" lighting in the station area may be on 24 hour service or controlled by PECs depending on the area of service and ambient daytime levels. The Designer shall determine the areas to be lit by the security lighting circuit in order to provide a safe and secure area during non-operational hours. The normal lighting lanterns are approximately 20% of the roadway/platform lighting provisions, but the Designer shall examine each location and determine where security lighting would be most advantageous.

The minimum security lighting requirements shall be as follows:

- Shelter - 2 fixtures near entrance
- Stairways - luminaire at the entry, landing and exits
- Ticket Booths - 1 luminaire
- Open Platforms - 1 luminaire at each end or at 20 m max.

If CCTV security cameras are to be installed, the recommended minimum illuminance level at any point shall be 5 lux (using metal halide lamps) with particular attention to vertical components of the illumination to maximize contrast levels.

13.3.2 Criteria and Materials

The design criteria to be implemented in the lighting of the specific areas of the busway are listed below:

Busway Main Line

Extent of Lighting

The busway shall be fully illuminated over its full length or partially illuminated as determined to be appropriate by Winnipeg Transit.

Criteria

All lighting shall conform to Manitoba Hydro Standards.

Materials

Luminaires and poles shall conform to Manitoba Hydro Standards.

At-grade Pedestrian Crossings

Where at-grade pedestrian crossings are provided, they shall be illuminated to the following criteria:

- Average Maintained Illuminance Level = 75 lux
- Uniformity (Avg./Min.) $\leq$ 1.5:1

Bus Ramps and Station Approach Busway Lighting

All ramps and approach roads shall conform to the requirements of Manitoba Hydro and be fully illuminated over their full length.

- Average Maintained Illuminance Level = 20 lux
- Uniformity (Avg./Min.) ≤ 3:1

Median Lighting in Stations

All median lighting in stations shall conform to requirements and provide:

- Average Maintained Illuminance Level including a 3 m foot wide strip of platform = 20 lux
- Uniformity (Avg./Min.) ≤ 3:1

Station Platform Lighting

Platform lighting shall conform to Manitoba Hydro Standards. It shall be provided only in the vicinity of shelters and ticket/information areas since buses will stop only in front of shelters during night conditions and the remainder of the platform will serve a pathway function.

Platform lighting shall be designed to be a combination of that lighting provided from the median poles and that provided under the canopies of the shelters.

- Average Maintained Illuminance Level = 100 lux
- Uniformity (Avg./Min.) ≤ 3:1

Transition Lighting

As per the requirements of Manitoba Hydro.

Shelter and Ticket/Information Area Lighting

Shelter and ticket/information area lighting shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 100 lux
- Uniformity (Avg./Min.) ≤ 2.5:1

Station Building (Public Areas) Lighting

Public areas inside station buildings shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 150 lux
- Uniformity (Avg./Min.) ≤ 2.5:1

Stairwell Lighting

Stairwells shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 150 lux
- Uniformity (Avg./Min.) ≤ 2:1

Pedestrian Underpasses and Overpasses Lighting

Pedestrian underpass and overpasses shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 75 lux
- Uniformity (Avg./Min.) ≤ 2.5:1

Pathways in the Vicinity of Busways Lighting

Pathways in the vicinity of busways shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 20 lux
- Uniformity (Avg./Min.) ≤ 3:1

Service Rooms and Elevator Machine Rooms Lighting

Service Rooms shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 175 lux
- Uniformity (Avg./Min.) ≤ 4:1

Restroom Lighting

Toilets shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 175 lux
- Uniformity (Avg./Min.) ≤ 3:1

Supervisors' Room Lighting

Supervisors' rooms shall conform to the requirements the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 350 lux

- Uniformity (Avg./Min.) ≤ 2:1

Exit Lighting

Exit lighting shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws.

Elevator Pits and Rough Service Utility Area Lighting

Elevator pits and rough service utility areas shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 100 lux
- Luminaires: To Be Established By Winnipeg Transit

Parking Area Lighting

Parking areas shall conform to the requirements of the National Electrical Code as supplemented by the Manitoba Electrical code and City of Winnipeg Electrical Bylaws and provide:

- Average Maintained Illuminance Level = 20 lux (Parking Lot Adjacent to Station)
  =10 lux(Parking Lot Remote from Station)
- Uniformity (Avg./Min.) ≤ 4:1

Note: Minimum illuminance level of 5 lux at any point is required if CCTV's are to be installed.

13.4 BASIC ELECTRICAL MATERIALS

13.4.1 General

All electrical equipment and material must be installed in accordance with the National Electrical Code as supplemented by the Manitoba Electrical Code and City of Winnipeg Electrical Bylaws including all Supplements and Bulletins and supplied in accordance with the applicable standards.

13.4.2 Conduits, Cable Trays, Wiring Enclosures

a) All conduits and fittings exposed in public areas shall be galvanised rigid steel with surface mount cast metal pull/junction boxes with appropriate conduit hubs. This exposed material shall be painted with semi-gloss exterior enamel, to match appropriate station colour schemes.

b) All shelters shall have minimum 30 mm diameter conduit or cable tray provisions for security lighting, timed lighting and communications. Each shelter shall have its own single runs of conduits back to the appropriate distribution panels (unless more than one conduit is necessary for circuit loading purposes). This enables the use of dedicated circuit breakers for each function for each structure which facilitates maintenance and replacement.

c) All cabletrays shall be CSA/UL approved, solid heavy duty galvanised steel or may be incorporated integrally with lighting/climate control equipment if approved for use as a wireway. Material to be painted as per a).

d) Embedded conduit shall be rigid PVC. Embedded junction/pull boxes shall be PVC, and cannot be used for lantern/ fixtures support.

e) All empty or unused conduits shall have a polypropylene pull string installed and identified with a durable tag as to destination of the conduit to facilitate future use.

13.4.3 Outlets, Switches

a) The standard outlet duplex receptacles used in service areas shall be of specification grade, whereas, those in an electrical room on the emergency circuits shall be hospital grade.

b) In public areas such as towers and shelters; the receptacles shall be tamperproof GFCI types, complete with a weatherproof cover.

c) Switches installed in the service areas shall be of specification grade.

13.4.4 Wiring

a) Conductors installed in conduits/ducts shall be of the following insulation types:

    i. THHN - installed above ground
    ii. THWN - installed underground
    iii. GTF - lantern wiring

b) All concealed wiring not embedded shall be armoured cable ACTHH or sealtite cable (wet or damp locations).

13.4.5 Vertical Conduit Enclosures

Vertical conduit enclosures shall be installed where required to cover and protect the vertical conduit feeds to the shelters (timed lighting, security lighting and communications). The enclosure shall be fabricated from a section of aluminium extrusion matching shapes, sizes and colours approved by the Architect and complete with access covers. The enclosure shall have the same finish as the shelter glazing mullions and shall be secured to the steel structure, or adjacent concrete, by a mounting bracket.

13.5 CONDUIT SYSTEMS

Reference shall also be made to Chapter 5, Section 5.7.

13.5.1 Duct Banks

a) All ducts crossing below roadways shall be encased with reinforced concrete.

b) Ducts may be directly buried in locations where the protection is not required in areas adjacent to a busway station, except as noted in d) below.

c) Lighting feeds for busway lighting poles outside the station platforms can be installed in 50 mm diameter polyethylene pipe (polypipe) provided that further mechanical protection is not required.

d) All ducts for telephone supply shall be concrete encased.

e) The following are typical duct usages to be incorporated in the provisions for the duct bank system - lighting, services, phone, communications, power distribution and high voltage supply (if required). Phone and low voltage communications duct systems including electrical pits shall be kept separate from other systems. High voltage supply to a transformer vault (if required) must be kept totally independent from any other system in accordance with local power authorities. Two 100 mm diameter ducts are required for the busway station interconnects and a future Wide Area Network (WAN) under hard surfaces - see Section 13.14.2.

13.5.2 Electrical Pits

a) Pits shall be sized to accommodate the physical requirements (minimum 1.2 m x 0.6 m x 1.5 m deep) shall be rated for highway traffic loading and shall be spaced according to established cable friction/pulling criteria.

b) Communications/phone pits shall be kept independent from other systems.

c) Pits may be used for combination systems - climate control, lighting, services etc., provided a satisfactory means of sectionalising the systems is incorporated. The method of separating the systems must be approved by the local Inspection department.

d) Drainage for each pit shall be provided to the nearest stormwater system, or if no alternative is available, to a granular/clear stone sump hole below the pit. All pit drains where drained to an outlet pipe shall be fitted with backwater check valves.

e) High voltage pits (where required), which cannot be gravity drained to the nearest stormwater pipe, must be connected to a sump pit with a pumping system to ensure that the pits remain dry.

f) Frames and covers for the pits shall be cast iron roadway standard, or local electrical power company high voltage pits type. Ladder rungs or steps shall comply with the respective City of Winnipeg Standards.

g) Underground pits shall be designed to withstand small vehicle loading and shall be complete with watertight covers.

13.6 SERVICE EQUIPMENT AND DISTRIBUTION

13.6.1 Service Transformer and Feeders

The service transformers shall be supplied in accordance with the electrical power suppliers' regulations regarding service. Based on past experience in several types of busway and transit stations, it is recommended that transformer sizing should allow for liberal expansion of the station loads.

The Designer shall allow loading for all known future facilities at any station and shall then make an allowance of an additional 25 % loading, rounded upwards to the next standard rating (kVA or A) for any transformers, main feeder cables, and distribution breaker enclosures and panelboards.

13.6.2 Service and Distribution

In order to reduce the amount of spare parts for maintenance purposes and facilitate product compatibility, the service and distribution equipment shall be supplied by an approved manufacturer.

a) Panelboards - 3 phase

- Lighting and Distribution
- Services
- Climate Control and Distribution

Size, voltage and main breaker (if required) of panelboards are dependent on distribution and loading requirements.

b) Disconnects - fusible or non-fusible, mechanical interlock, lockable, quick make, quick break, size as required.

c) Transformers - ventilated dry type floor mount and sized as required.

d) A power supply provision from the service panels shall be provided in each shelter and in various locations in the station building for maintenance use receptacles and for map cases as required by Winnipeg Transit. Separate circuits are required for map cases as well as receptacle feeds. Provision shall be made for additional future separate circuits.

13.7 LOW VOLTAGE SWITCHBOARDS

13.7.1 Materials

Low voltage power distribution may consist of low voltage switchboards or individual components depending on wall and floor spaces available. The size and distribution requirements shall be determined once an ultimate demand loading summaries have been calculated and co-ordinated with the local electrical power supplier to clarify the size of supply transformers required. Metering provisions must be co-ordinated with the local electrical power supplier.

13.7.2 Co-ordination Study

A short circuit analysis co-ordination study shall be done by the Designer or by the distribution equipment supplier. The study shall be supplied during the shop drawing process in order to confirm component compatibility.

13.8 SECONDARY GROUNDING

13.8.1 Ground Electrode System

The Designer shall carry out a study and calculations for each busway station, of soil resistivity and grounding electrodes required to give a desirable resistance to ground of 5Ω (10Ω maximum).

A grounding grid system shall be installed below, or adjacent to the electrical room. The grid system shall be connected to a metal watermain system where possible.

13.8.2 Continuous Ground Wire

All conduit systems shall have an internal ground wire installed between all equipment or structures.

13.8.3 Electrical Room/Cabinet Ground Bus

The electrical room/cabinet shall have a solid copper ground bus around the inside perimeter of the room connected to the grounding grid system. All electrical panels, service equipment, and cabletrays shall be connected to the ground bus and/or grounding system.

Where communications rooms or boards exist, all electronic and telephone equipment shall be grounded to a common bus in a star configuration. The common bus shall be connected to the main electrical ground at a single location only.

13.8.4 Structural Steel Grounding

The structural steel members in all shelters and pedestrian bridges must be grounded to the main grounding system.

13.8.5 Stray Current Provisions

Provisions shall be made for the appropriate isolation of bridge superstructures to accommodate any future LRT conversion.

13.9 CONTACTORS AND CONTROL

13.9.1 Contactors

The contactors used to control the various lighting panels/circuits shall be standardised.

13.9.2 Circuit Control

The control of the lighting panels/circuits shall be achieved by a station control system using Remote Control Units (RCU) and a combination of timers, thermostats, and Photoelectric Controllers (PECs).

All lighting panels should be energised by a relamp switch connected to either the control circuit or a digital input of the RCU to facilitate maintenance and relamping during the day.

13.10 FIRE PROTECTION SYSTEM

Due to the nature and function of a standard busway station, a fire protection system is normally limited to a monitoring function only. There is normally no requirement for a full fire alarm system. Rooms within a full station, such as the inspector's room, storage rooms, etc., are not considered to be accessible to the general public. During the design stage each station must be evaluated to determine the requirements for the fire protection system in accordance with the Fire Safety Plan as developed by Winnipeg Transit, local Fire Prevention Authorities and as required by local bylaws.

The system shall incorporate the following as minimum requirements:

- Smoke and heat detectors at the top and bottom of elevator hoistways.
- Electrical room heat detectors.
- Elevator machine room heat detector.
- Generator room heat detectors.

The fire protection panels should be fed from the low voltage switchboards with no means of disconnection except red coloured fusible disconnects immediately adjacent to the fire panels and clearly marked. The fire protection panels shall be connected to the input of dedicated control modules to indicate trouble or alarm status which can be monitored by Winnipeg Transit’s security control center.

The fire protection panels shall be specified such that, if required, the units could control smoke activated dampers and ventilation fans, or monitor sprinkler control systems.

Rooms in the stations, which may be considered as standard buildings by the local Fire Services, may have to be provided with sprinkler systems, smoke and heat detectors, pull-stations, hydrants, etc. as per the normal building and fire codes.

The fire protection requirements for the tunnel sections shall be addressed as follows:

- All aspects of tunnel fire protection shall be discussed with the local Fire Services’ office prior to design.
- Consideration shall be given to reversible direction air evacuation/charging fans which are controlled by smoke detection, heat detection and direction of wind at the time (via anemometer). The purpose of the fans would be to either evacuate smoke (if the alarm site was near the end of the tunnel) or introduce fresh air and force this air, along with the smoke, out either end of the tunnel (normally in the direction of the wind or towards the nearest end if the wind is light). Fan control shall be allowed at the fire control panel. For economy, the fans can be combined as part of the normal ventilation fans.
- Dense "water wall" sprinkler systems shall be considered for isolating sections of tunnel from smoke so that persons can leave the tunnel in a relatively easy manner. These systems must be co-ordinated with the fan controls and operable

from the fire control panel and be rated for winter operation because the tunnels will be unheated.

- Since there are no flammable building materials, the need for continuous sprinkler systems shall be closely examined with a view to eliminating the need if the fans and "water wall" sprinklers are used. The possible sources of smoke are vehicles on fire.
- There may be a Fire Service's requirement for fire hose cabinets.

13.11 EMERGENCY POWER SYSTEM

The standby power for busway stations will normally be provided by diesel or natural gas powered generators, or for small loads, by inverters. The level of service for station operations during power outages will dictate the size of the standby power system. Generally the normal operation of lighting, emergency systems and communications (panel "E") should be maintained for the duration of a power outage. Fuel tank capacities, where applicable, shall be adequate for a minimum of 6 hours running time. Inverters shall have a rated capacity of 90 minutes at the coldest design temperature. Future elevator operation is not considered to be an essential service and need not be supplied by standby power.

Since lighting is a substantial part of the emergency load, the Designer shall carefully consider the lighting circuit arrangements and connections as follows:

- Generally, every 6th lighting fixture in shelters or ticket areas, or sufficient fixtures provide the levels required by local codes, shall be on the emergency lighting panel along with any at-grade pedestrian crossing fixtures.
- Security lighting is that which is normally maintained during the hours of the night when the Busway is not operational; the fixtures connected shall include every 6th lighting fixture or one minimum per room area plus approximately 1/3 of the median-mounted roadway lights.
- Timed lighting is controlled by a timer through a contactor and is set to turn on just prior to the beginning of the morning rush hour (e.g. 5:30 a.m.) and turn off just after the end of operations for the night (e.g. 1:30 a.m.). This is usually the bulk of the lighting at a station.
- Normal lighting is that controlled only by photocontrol and overrides from the remote control. This would consist of lighting fixtures that are in the median-mounted area of the Busway and those under the shelter canopy that would stay on all night.

Due to the requirement for instantaneous switchover of power for remote monitoring units, other processors and critical lighting during outages, small UPS (Uninterruptible Power System) will be required.

For example there may be a situation where high intensity discharge lanterns are used for emergency lighting in critical areas and re-arcing of the lights may take 2 to 3 minutes after the units have been de-energized. Some computer control and emergency equipment require uninterrupted power supply and conditioned voltage for operation, as well as surge protection. Several small UPSs, sized appropriately, shall be used to fulfil this requirement.

13.12 CONTROLS AND INSTRUMENTATION

Certain building operation functions at the busway stations can be automatically controlled by either the host Central Processing Unit (CPU) at the control center or independently on location by a Remote Control Unit (RCU). The host and all connected control modules can communicate with each other. Operator interface can be accomplished at any control module of the RCU using the integral keypad or at the host CPU. The control modules may communicate to the host CPU via dedicated or leased telephone lines using two modems or a dedicated busway communications system. The RCU control modules monitor both analogue and digital inputs as well as controlling analogue (optional) and digital outputs. By using the input data and status from photoelectric controllers, thermistors, status contact points etc., the information may be processed to the control/monitor with such building functions as heating/ventilation, lighting, fire alarm panels, power outages, elevator alarm status etc. Software for the control modules has built-in time functions and all input points may be made alarmable at the host CPU for security acknowledgement. Prior to specifying a control system, the designer shall clarify the capacity of the CPU and co-ordinate the communications network. It should be noted that the modems used must be approved by the telephone company for the type of circuit currently employed by Winnipeg Transit. Winnipeg Transit shall determine the role they wish to play in operating the system.

This system will take time to define and bring into service so its design should be accorded a high priority during the design phase of the busway.

13.13 MECHANICAL SERVICE PROVISIONS

13.13.1 Elevators

a) All equipment and electrical installations installed within the elevator hoistway/pit and machine room must be solely for the operation of the elevator.

b) The fire alarm conduit for the hoistway heat detectors top and bottom shall be embedded in the hoistway walls.

c) Each hoistway pit and machine room shall have a GFIC duplex receptacle on an individual circuit. Lighting in these areas shall also be on a separate circuit.

d) The elevator shall have emergency audible/visual alarm beacons mounted outside the hoistway to be activated when the alarm buttons in the cars are depressed. This system is on the lighting circuits of the cars and can be reset with an operator’s key for the car light switches. The emergency alarm system shall be connected to the control module.

e) Additional communication wiring for remote-controlled intercom/telephone or PA systems in the cars and additional conduits from the elevator machine rooms to the station control modules shall be provided.

f) The elevator key switches shall be keyed alike for both car and hall buttons and shall match existing keys throughout the Busway.

The cab lighting shall be separately fused with its own disconnect switch.

13.13.2 Heating and Ventilation

Heating is typically required in any elevator machine rooms during winter months to prevent condensation and frost forming on control circuits and the hydraulic oil in the reservoir from becoming overly viscous. Self contained thermostatically controllable electric forced air heaters shall be provided for this purpose. Non-flammable insulation treatments shall be used to minimize the energy requirements of the heaters.

At other times of the year, the heat generated from pumps and the heated hydraulic oil, if the elevator is heavily used shall be dissipated through the provision of ventilation fans. The ventilation openings shall be capable of partial and full closure to allow the heaters to maintain acceptable temperatures.

Similar requirements apply to the communications equipment cabinet. Even in the winter it is likely that rack mounted communication equipment will need a fan to dissipate heat generated by some devices. Since it is difficult to isolate the communications components and connections from corrosive effects of de-icing salts, care shall be taken to minimize the chance for inside air to exchange with outside air.

Where passenger shelters are heated, they shall be designed minimize the amount of wind that can blow through the shelter when the heaters are in service and the heating system shall consist of radiant electrical heaters controlled by thermostats and motion sensors.

13.13.3 Heating Cables-Pipe Tracing

a) Rainwater leaders from roof drains shall be internally heat-traced by self-limiting type cables. The cable shall be thermostatically controlled by sensors connected to the drains.

b) External fire hose cabinets or siamese connections for fire protection shall have all joints and valves externally heat traced and insulated where potential freezing may occur.

13.14 PROVISIONS FOR ITS

13.14.1 Passenger Information System Displays

GPS, Tag and electronic sign-post systems for tracking bus locations in real time can also be used to drive various types of information displays in busway stations. The information can also be disseminated over the internet, via monitors in retail / office centers, on closed-circuit television, by telephone, over cellular (mobile) telephone, pagers, and other media.

At bus stops, the most common means of providing real-time passenger information is to display the anticipated time of arrival of the next bus on an illuminated sign. Signs may be elaborate or very simple, and can use LED, LCD, plasma, flip-disc, or other technologies. For a stop that hosts just one route, a simple “countdown to next bus” display is adequate; for a stop used by a variety of express and local routes, a multi-line display that details the next bus(es) on each route and their destinations, or the order of arrival of the next four or five buses may be needed.

It is particularly useful to have a multi-line display if buses tend to arrive in platoons or are so closely-spaced that passengers have a hard time picking up the route numbers of following buses. If passengers know the order of arrival they can move to an appropriate spot on the platform to board following buses rather than rushing back and forth to figure out which bus is theirs.

If the display is a countdown type (i.e. “Next Bus in 4 Minutes”) there is no need for a clock display as well; if the display shows the anticipated arrival time (i.e. Route 324 at 4:42) a system-synchronized clock display should also be provided.

Passenger information displays can take many forms, and can be attached to a pole at the stop, incorporated within a bus shelter, or be in a standalone kiosk.

The displays shall be located upstream of the stop and oriented towards the stop so that a waiting passenger can view the sign at the same time as seeing an approaching bus. Careful attention shall be paid to the requirements of visually impaired customers. The size, color, shape, and brightness of the information displays in all weather conditions (especially full sunlight) shall be tested in the field to the satisfaction of Winnipeg Transit before a commitment to a particular style or technology is made. Consideration shall be given to providing a supplementary audio loop for visually impaired users.

Displays should be enclosed in a protective case and located high, out of direct reach of vandals. Consideration shall be given to monitoring and videotaping the signs and stops via closed circuit television.

The signs may be turned off overnight, or preferably left on with a note to the effect that “Service Resumes at _ AM”. If turned off, supplementary heaters may be required to combat condensation in certain weather conditions.

13.14.2 Passenger Information Systems Communication Requirements

Passenger information signs are usually managed by a local controller, which is periodically updated by a central controller that draws information from the information system database. The refresh rate for new data to be sent to the signs is dependent on the rate at which information is being updated in the real time data base. Data may be transmitted to the local controller on a polled basis, or, on the basis that the information last sent is now superseded.

If the information to be transmitted is strictly text based, then a slow speed dial-up circuit (up to a 33.6kBaud serial data rate) may suffice for the link between the central and local controllers. The local controller may communicate with the signs using a serial data rate of perhaps 56kBaud, using a 4 wire RS-422, or a 2 wire RS-485 serial data protocol over-telephone type wiring.

Other information such as bitmapped graphics and digital audio files to drive hearing impaired inductive loops is more bandwidth intensive. When such information has to be transmitted frequently between the central and local controllers (rather than just being pulled from the local controller’s memory that is updated only in off peak times), the bandwidth available from a dial up line will not be sufficient. In these situations, the communications may have to be optimized to fit within the available bandwidth, or higher speed links need to be established.

Ethernet is usually used where higher speed links are needed. While Ethernet is not strictly deterministic in the manner in which it delivers information, it is usually fast enough that the devices and users in this process do not notice the difference, or are not affected by the delay that a reasonably loaded network segment would introduce. Ethernet in a busway environment typically is delivered over fibre optic links, since the fibre is usually needed to support the transport links for CCTV information, and the incremental cost of adding the Ethernet is very low, compared to providing via a separate transport link.

13.14.3 Busway Control Centre

General

The Busway Control Centre shall have the following responsibilities:

- To monitor the performance of the buses on the busway to some pre-determined schedule and headway standards.
- To determine the corrective action or actions required to correct any non-compliant performance.
- To communicate such corrective action to the bus operator(s) in question and request the necessary service corrections.
- To monitor the performance of the requested service correction.
- To display to the public the current status of the service and any predicted changes.
- To answer the emergency phone and to respond as required to any emergency situations.
- To provide current service status information to the information phone service.
- To operate the facilities management systems.

The Busway Control Centre will have many communications requirements to facilitate its intended function and assist in providing a service to the public. A schematic representation of the communication flows and paths is illustrated in Figure 13.14A

13.14.4 Field Equipment

Various different sorts of field equipment will be required in and around the bus station areas. The field equipment will provide raw data to the Control Centre that requires processing, and return data and control signals to the field equipment for display and / or appropriate actions. A brief description of the field equipment sub-systems follows.

The Public Address (PA) system provides the busway passenger with up-to-date traveller information and any emergency information as deemed necessary. The PA system shall be used to give the traveller confirmation of information received in other forms, and is a necessity for the use of the busway by the visually impaired traveller.

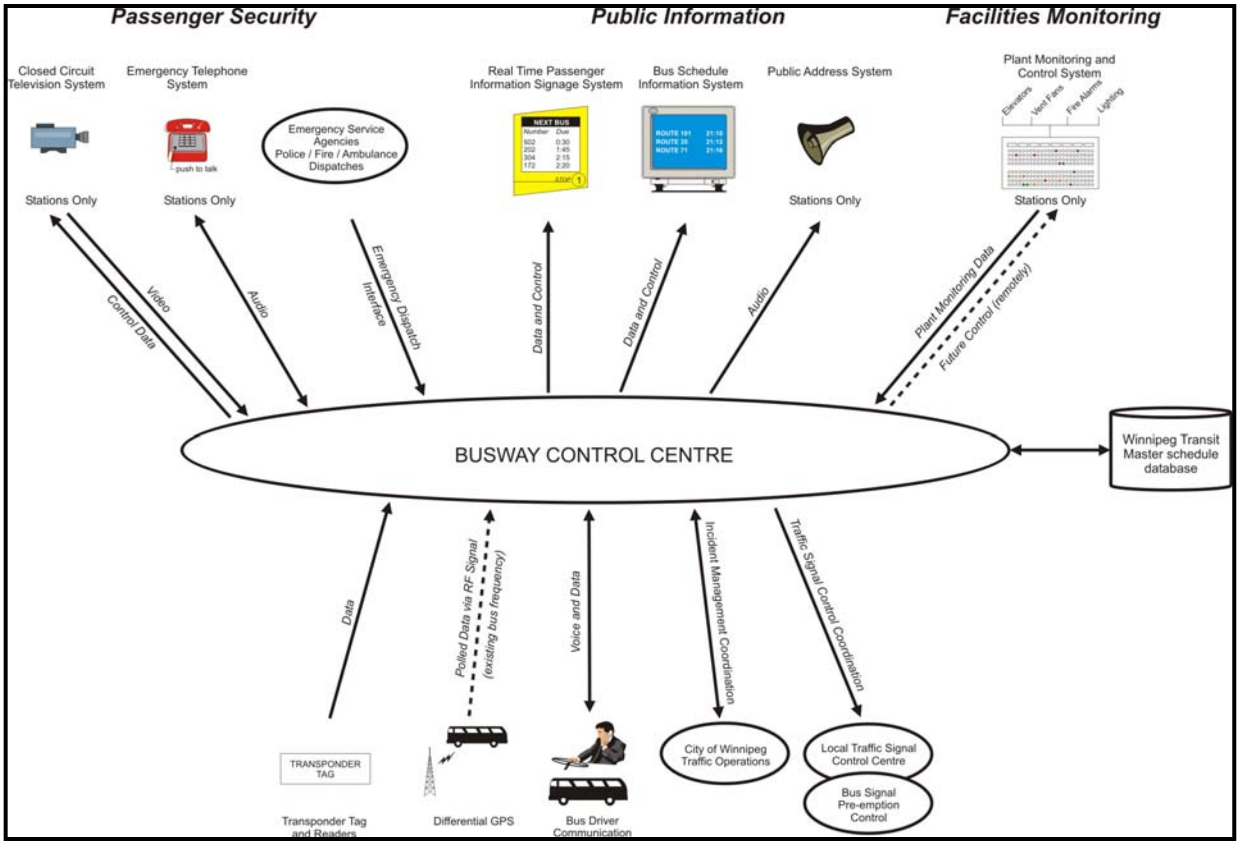
Closed Circuit Television (CCTV) monitoring shall be provided to permit complete video coverage of the public areas in each station.

Live video image transmission shall be provided as slow scan operation is not a viable surveillance alternative within the busway station areas. Actual hands-on control of the camera function shall remain with the Busway Control Centre. Candidate recipients of video images include the control centre operators, emergency services, and media.

The Emergency Telephone System shall provide an emergency interface between the travelling public and various external agencies via the Busway Control Centre.

The automated Plant Monitoring and Control System shall incorporate certain station physical plant functions which can be automatically controlled by either a host central processing unit (CPU) at the Busway Control Centre or independently on site by a remote control unit (RCU). The host and all connected control modules shall have the ability to communicate with each other.

Figure 13.14A – Busway Control Centre Communication Flows



Operator interface shall be accommodated at any control module of the RCU via keypad or at the host CPU located at the Busway Control Centre. The RCU control modules will require the ability to monitor and control both analogue and digital inputs and outputs. By using the input data and status from photoelectric controllers, thermistors, status contact point etc., the information can be processed for control / monitoring of such station functions as ventilation, lighting, fire alarm panels, power outages, lift alarm status, etc.

13.15 PROVISIONS FOR MISCELLANEOUS EQUIPMENT

13.15.1 Station Equipment

All provisions indicated in this section must be co-ordinated with Winnipeg Transit and/or the telephone utility.

a) The telephone utility - location and requirements of incoming service lines.

b) Internal phone system - emergency, information and pay phones in the station buildings, elevators, pedestrian bridges, tunnels and shelters. Electrical provision for a lit "Emergency Phone" sign to be provided above each emergency phone.

c) Advertising signs and map-cases - location and power supply requirements from the service panels.

d) Cable and power needs should be identified for integrated ticketing to ensure that cables can be tapped into.

END OF CHAPTER

CHAPTER 14

MECHANICAL

CHAPTER 14 - MECHANICAL

14.1 INTRODUCTION

The mechanical design requirements for busway stations include: elevators; ventilation and air conditioning in specific areas; drainage and plumbing for roofs, floors and service areas; potable water supply; fire hydrants where required; limited fire protection systems and in special cases irrigation systems.

Many of the above mentioned systems will not be installed in the initial phase of the busway stations but the Designer should assure that provisions for future work are installed or that the future work is feasible both physically and economically. The information in this chapter is presented as though such features are to be installed so that Designers may fully appreciate the mechanical aspects of large busway stations.

14.2 ELEVATORS

14.2.1 General

If the overall station configuration is such that passengers are required to move from one elevation to another, an efficient means of vertical transportation must be provided. This section of the manual outlines the various design considerations applicable when an elevator rather than a ramp is being considered for a typical busway station.

14.2.2 Applicable Codes and Regulations

The Designer shall comply with all relevant codes and regulations applicable to mechanical work and in particular the National Building Code as supplemented by the Manitoba Building Code and City of Winnipeg Bylaws.

14.2.3 Structural Design Considerations

a) Provide standard elevator shaft dimensions for 1100 kg capacity elevator.

b) Ensure that the structural design makes provisions for windows on each floor to coincide with glazing in the elevator car. This may not be as critical if a half-glazed elevator hoistway is being used. The purpose of this glazing is to afford a high degree of visibility and maximize security.

c) Make provisions for a separate elevator machine room preferably at the lowest floor being served and adjacent to or within 10 metres of the elevator hoistway. No equipment other than that required for the operation of the elevator shall be installed in this room. The floor area required for this room will depend on the elevator equipment being specified but it shall not be less than 3m by 3 m.

d) Make provisions for a sump pit in the elevator machine room to drain the elevator shaft pit. This sump pit is connected directly into the sanitary sewer system.

e) The elevator pit floor should be designed to withstand an impact load of 6800 kg in addition to all the dead and live loads.

f) If the machine room is lower than the general outside grades around the station, provide a 150 mm high step over kerb in front of the elevator machine room door.

14.2.4 Mechanical Design Considerations

a) Provide a floor drain in the elevator sump pit connected directly to a sump well outside the pit. The drain from the sump well to the sewer shall have a back water check valve and be trapped and vented as required by applicable codes and regulations.

b) Provide adequate ventilation to ensure the temperature of the machine room does not exceed 30^{o}C. The intake louvers and exhaust fans should be custom designed to suit the room size and be screened and corrosion resistant.

c) Ensure that no conduit or piping other than that required for the operation or security of the elevator is installed in the elevator shaft.

d) If gravity drainage of the sump pit in the elevator machine room is not possible, provide a pump to discharge into the sanitary sewer.

14.2.5 Electrical Design Considerations

a) Provide embedded conduit and install heat detectors in the top and bottom of the elevator shaft. Specific equipment is detailed under the Electrical chapter. These heat detectors are connected to the fire alarm panel in the station electrical room, which is monitored by Winnipeg Transit's Busway Control Centre.

b) Install a switch controlled light and convenience outlet in the elevator pit.

c) Provide appropriate conduit from the "Communication Boards" in the main electrical room to the elevator machine room such that an emergency telephone can be installed in the elevator car.

d) Ensure that all elevator machine rooms are adequately lit and that one fixture is on the emergency lighting circuit. Specific equipment is detailed in Chapter 13.

e) Ensure that lockable fused disconnects or circuit breakers provisions are made under the electrical design for the following equipment:

- elevator controller
- elevator car light/emergency beacon

The specific equipment is detailed in Chapter 13.

f) Provide embedded conduit so that the emergency call button in the elevator can be wired up to an audible flashing beacon which is mounted in a location on the exterior of the building, visible from a security patrol vehicle. The flashing beacon should be installed under the electrical part of the contract. Equipment is specified in Chapter 13.

g) Provide a high water level alarm for the pump in the elevator machine room sump pit, which is tied into the Central Monitoring System.

14.2.6 Architectural Design Considerations

a) Provide a self locking, 3/4 hr. fire rated door with minimum dimensions of 900 mm x 2150 mm for access to the elevator machine room. This door may be fitted with a transom louver for ventilation. If the elevator machinery is not located in a separate room, it shall be separated from all other room functions by a steel mesh partition fitted with a self-closing, self-locking gate.

b) Ensure that the space between the rough concrete opening and the stainless steel frame around the elevator door is finished off.

14.2.7 Miscellaneous Design Considerations

a) Provide elevator pit ladders under a separate portion of the contract.

b) Provide an elevator hoist beam capable of handling loads up to 1100 kg.

c) Ensure that the drilling of the elevator jack holes is provided for under a separate portion of the contract. For a 1100 kg capacity elevator the minimum hole diameter should be 500 mm. The requirement for a casing in the hole will be as recommended by the geotechnical consultant. The depth of the elevator jack hole is dependent upon the number of floors served and will be determined when the Station configuration is finalised.

14.2.8 Specific Elevator Features and Operating Details

General

For the purpose of standardisation, all designs should be based on the same car series. Where vertical transportation of floor cleaning machines is required, elevators shall be provided with load capacity of 1100 kg and door width of 1 m.

Elevator Criteria

- Load 1100 kg.
- Car speed: 0.6 m/sec.
- Operation: Simplex collective.
- Control: resistance automatic self-levelling.
- Travel: dependent on station design.
- Landings served: dependent on station design.
- Number of openings: dependent on station design.
- Opening size: 2.5 m by 1.9 m for 1100 kg.; headspace for elevator beam and pit below to be 1.5 m minimum depth within shaft.
- Type of car and hoistway for 1100 kg elevator = 2500 mm by 1900 mm custom design.
- Door operation: automatic, direct current powered.
- Door protection: locally available.

- Cab dimension: for 1100 kg elevator = 2150 mm by 1500 mm (3.3 m²) by 2400 mm height.
- Height to underside of car top: 2.3 m.
- Car and hall operating buttons: mechanical illuminated, supported by Braille identification.
- Maintenance: 2 year, 24 hour service.
- Key switches keyed to match existing throughout Busway system. Hall and car panel switches keyed alike.

Doors and Frames

Hoistway doors and frames and car doors shall be consistent throughout the system, particularly for sill and jamb details. Hoistway doors and frames are supported on a basic steel frame structure which attaches to the inside of the elevator shaft. Jambs and headers of stainless steel do not carry door loads.

Hoistway doors shall open preferably to one side. This requirement arises from the need to maintain similarity for physically challenged persons and in particular for those who are sight impaired. Glazing in hoistway doors is permitted but must conform to the current standard.

Elevator Stations

Car stations, hall stations and indicators should be consistent from one elevator to another including from station to station. Note that the hall stations and indicators are located on the door jamb on the open side of the door.

Accessibility Features

Features for persons with disabilities shall be provided.

14.2.9 Special Considerations

a) Elevators with glazed or partially glazed cars and hoistways are classified as "observation elevators" and shall comply with the appropriate standards.

b) No proprietary microprocessor - controlled elevator shall be accepted.

c) All metal, except stainless steel, in the elevator car and hoistway shall be epoxy-coated and moisture-protected following preparation of surfaces.

d) Emergency call buttons on elevators shall be low for accessibility, but not so low that people accidentally lean on them.

14.2.10 Escalators

In situations where the vertical height that passengers must ascend cannot easily be accommodated with a ramp and where large numbers of people must be moved within a short time period, the use of an escalator shall be considered in consultation with Winnipeg Transit.

14.3 HEATING, VENTILATION AND AIR CONDITIONING

14.3.1 Introduction

The typical Busway station will not normally require consideration of ventilation and air conditioning but at stations which include one or more of the following elements, however, such considerations shall apply.

- Tunnels - if the station is located below grade (ventilation only).
- Pedestrian Underpasses - if pedestrian movement under the busway is a requirement (ventilation only).
- Mechanical/Electrical Rooms.
- Supervisors' Rooms.
- Elevator Machine Rooms/Elevator Pits.
- Janitor Rooms.
- Drivers' Toilets.
- Staffed Ticket Sales Rooms.

14.3.2 Applicable Codes

The National Building Code as supplemented by the Manitoba Building Code and City of Winnipeg Bylaws.

14.3.3 Mechanical/Electrical Rooms

Heating

Electrical room dimensions will vary depending on station size and configuration; however the heating equipment shall be fan-forced electric unit heaters capable of maintaining room temperatures between 10^{o}C and 12^{o}C.

Ventilation

The main purpose of ventilation in the mechanical/electrical rooms is to limit the space temperature to a maximum of 25^{o}C. Intake louvers should be filtered and located remote from the busway environment where possible.

Air Conditioning

Air conditioning is not normally provided in these rooms, however if specialised computer equipment is installed to control the station lighting or other events, room temperature and humidity will have to be controlled. Provision for this should be made at the time of final design when the cooling requirements of the proposed equipment are known.

14.3.4 Supervisors' Rooms

Heating

Based on an insulated space of minimum dimension 3m x 3m possibly surrounded by totally unheated areas, sufficient heating capacity using fan forced thermostatically controlled electric heaters shall be provided to maintain the temperature between 20^{o}C and 22^{o}C.

Ventilation

Since these rooms are generally quite small and the doors are being opened frequently, natural ventilation occurs through the door. In the summer if additional fresh air is required, the fan mode of the air conditioner can be utilised.

Air Conditioning

The air conditioning equipment should be capable of maintaining the room at a maximum temperature of 23^{o}C. Minimum cooling capacity of 9,000 BTU/h with an air flow of 8.5m^{3}/min. shall be used. The unit shall be thermostatically controlled. The unit and controls shall be easily accessible for maintenance purposes.

14.3.5 Elevator Machine Rooms

Heating

Based on minimum room dimensions of 3.0m x 3.0m, sufficient heating capacity to maintain temperatures at 15^{o}C to 20^{o}C shall be provided. A minimum temperature of 10^{o} shall be maintained in the elevator pit.

Ventilation

Sufficient ventilation in the form of exhaust fans and filtered inlet louvers shall be provided to maintain the temperature of the elevator machine room below 30^{o}C.

Air Conditioning

Not applicable.

14.3.6 Janitor/Storage Rooms

General

The mechanical requirements for janitor/storage rooms will depend largely on the size of the room which is determined by the overall station function and size.

Heating

In all cases the janitors room must be heated by either a separate heating unit or be located within a generally heated area in the case of a mini station.

Ventilation

In the case of a major station, natural ventilation will occur under the door with an exhaust fan exhausting to the exterior. The exhaust fan shall be wired into the light switch such that it is operational when the light is on.

Air Conditioning

Not applicable.

14.3.7 Drivers' Washroom Facilities

Heating

Adequate heating shall be provided to maintain the temperature of 20°C to 22°C.

Ventilation

Exhaust fans exhausting to the exterior shall be provided in each toilet.

Air Conditioning

Not applicable.

14.3.8 Staffed Ticket Sales Areas

Heating

Based on an insulated space of minimum dimension 3.0m x 3.5m possibly surrounded by totally unheated areas, sufficient heating capacity using fan forced thermostatically controlled electric heaters shall be provided to maintain the temperature between 20°C and 22°C.

Ventilation

Since these rooms are generally quite small and the doors are being opened frequently, natural ventilation occurs through the door. In the summer if additional fresh air is required, the fan mode of the air conditioner can be utilised.

Air Conditioning

The air conditioning equipment shall be capable of maintaining the room at a maximum temperature of 23°C. Minimum cooling capacity of 9,000 BTU/h with an air flow of 8.5m^3/min shall be used. The unit shall be thermostatically controlled. The unit and controls shall be easily accessible for maintenance purposes.

14.4 DRAINAGE AND PLUMBING

14.4.1 General

Typical busway stations include some, or all, of the following components:

- Platforms and Shelters.

- Tunnels.
- Pedestrian Underpasses.
- Mechanical/Electrical Rooms.
- Supervisor's Room.
- Elevator machine rooms/Elevator pits.
- Janitor rooms.
- Drivers' toilet facilities.
- Pedestrian bridges.
- Towers/Info Center Structures.

14.4.2 Applicable Codes

The National Building Code as supplemented by the Manitoba Building Code and City of Winnipeg Bylaws.

14.4.3 Drainage

Tunnels

The drainage of any busway tunnel shall be designed under the roadway/structural works and shall be connected into the external stormwater pipe system.

Pedestrian Underpasses/Bridges

The drainage of any pedestrian underpass or bridge shall be achieved by designing the structural crossfalls and longitudinal grades to direct the water to perimeter floor drains. In a closed pedestrian underpass, the drains shall discharge into the sanitary sewer. In some jurisdictions, bridge deck drains may be permitted to discharge to the area below, provided they are not located over traffic lanes or passenger areas. The Designer shall confirm that this is permissible.

Electrical Rooms/Utility Rooms/Washrooms

All rooms or storage spaces shall be provided with floor drains with trap seal primers. In the case of electrical rooms or toilets, locations are dependent on the equipment installed in these areas.

14.4.4 Plumbing

Minimum Flow Rates and Pipe Sizes

As recommended by the National Building Code as supplemented by the Manitoba Building Code and City of Winnipeg Bylaws.

Janitors/Storage Rooms

Equipment

- Water Heater.
- Utility Sink.
- Faucet.

Note that station cleaning will be done using mobile pressure washing equipment and there is no requirement for large hose connections, etc. at the stations.

Drivers Washroom Facilities

Equipment

- Restroom
  2 required (1 female/1 male)
- Urinal
  1 required
- Lavatories
  2 required (1 female/1 male)
- Hot Water Heater
  1 required
- Drinking Fountain
  1 required (in foyer area)
- Soap Dispensers
  2 required (1 female/1 male)
- Paper Towel Dispenser
  2 required (1 female/1 male)
- Coat Hooks
  2 required (1 female/1 male)
- Napkin Disposals
  1 required
- Mirrors
  2 required (1 female/1 male)
- Shelves
  2 required (1 female/1 male)

Towers/Lobbies

To facilitate floor maintenance operations, a foot grille system shall be installed at all exterior doorways. The foot grille recesses shall be drained with floor drains, connected into the sanitary system. The drainage of all roofs is achieved by installing rainwater piping, discharging into the stormwater pipes in accordance with applicable Codes.

14.5 FIRE PROTECTION

The station construction, of concrete, steel and glass, is essentially non-combustible and the anticipated fire loading of the shelters and rooms within the stations will be low. Consequently, the anticipated fire severity is slight and the buildings will provide a high degree of fire safety.

The use of a full fire protection system (i.e. sprinklers, fire hose cabinets, pull stations, etc.) is not normally a requirement in the design of busway stations. If however, the station is integrated into a commercial complex or is located underground, the requirements for fire protection according to the local fire protection codes must be met.

Hydrant protection is required at stations so that all areas of the stations are within 90 m of a hydrant. Hydrant positions shall be to the approval of the local Fire Department. All mechanical/electrical rooms and elevator machine rooms must be provided with fire extinguishers of appropriate size and type.

In tunnels, smoke evacuation/air charging fans may be required as part of the fire protection scheme. These fans shall be reversible and shall be used as the normal ventilation fans. Fan control may use smoke detection, heat detection and anemometer input. Wall hydrants may be required. Refer to Chapter 13, Section 13.10 for co-ordination with the electrical aspects of fire protection.

14.6 IRRIGATION

Irrigation systems will not normally be included in the design of a busway station. In special cases where it is recommended by a landscape architect, approval by Winnipeg Transit will be required.

END OF CHAPTER

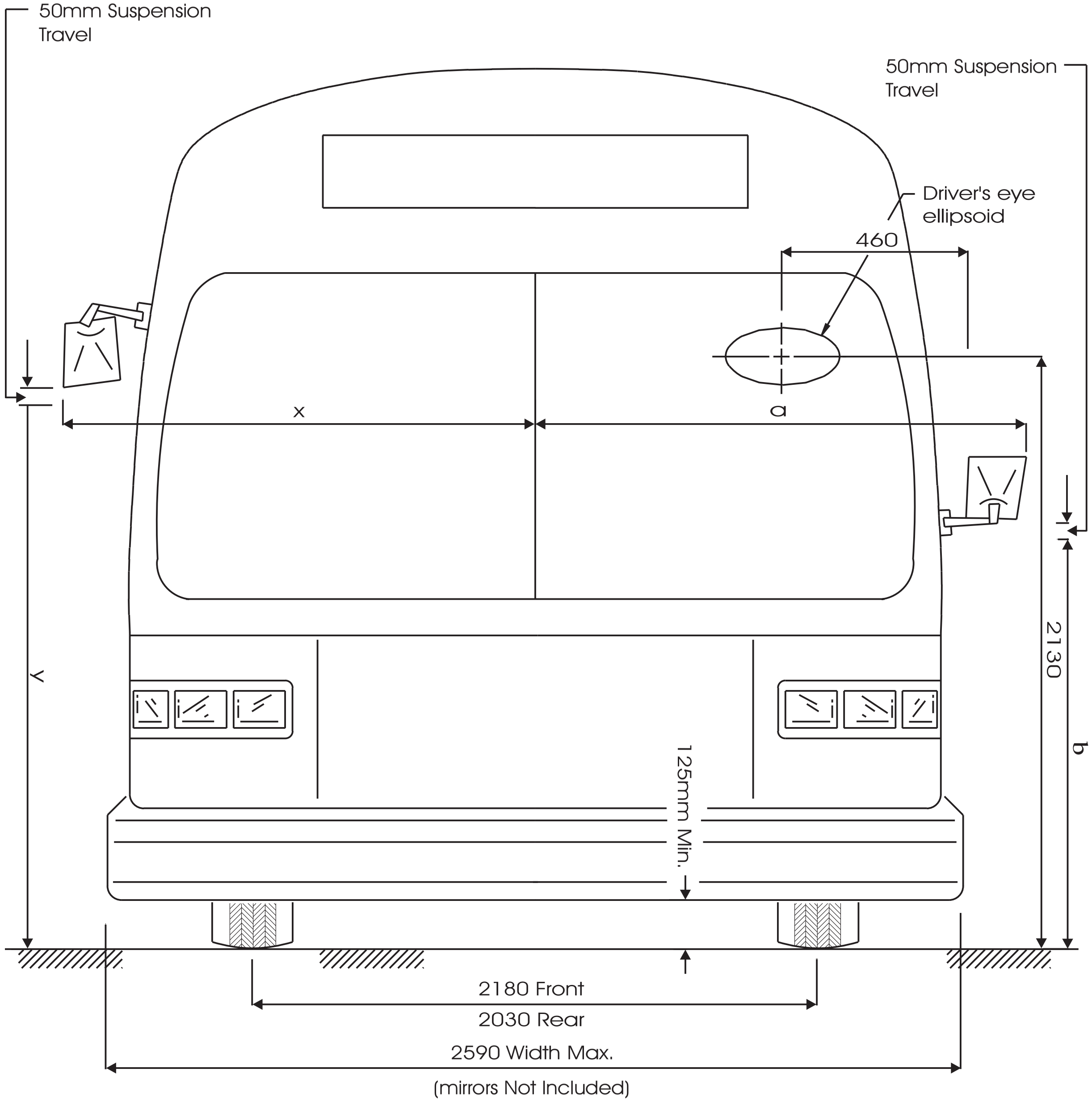
DRAWINGS

DRAWINGS

The typical drawings shown in this section are for the guidance of engineering staff during the planning, environmental impact, preliminary and detailed design.

Category	**No.**	**Title**
Design Vehicle	A-1	Typical Bus Dimensions
Design Vehicle	A-2	Design Bus Dimensions
Design Vehicle	A-3	Design Bus Turning Radius
Design Vehicle	A-4	Swept Area Diagram – Turning 90°
Design Vehicle	A-5	Swept Area Diagram – Turning 180°
Design Vehicle	A-6	Swept Area Diagram – Turning 360°
Design Vehicle	A-7	Swept Area Diagram – Straight 90°
Design Vehicle	A-8	Swept Area Diagram – Straight 180°
Design Vehicle	A-9	Swept Area Diagram – Straight 360°
Busway Sections	B-1	Unguided Busway - Closed Drainage - Shallow Fill
Busway Sections	B-2	Unguided Busway - Closed Drainage - Retained Fill
Busway Sections	B-3	Unguided Busway - Closed Drainage – Retained/Open Cut
Busway Sections	B-4	Unguided Busway - Open Drainage - Shallow Fill
Busway Sections	B-5	Guided Busway - Closed Drainage - Shallow Fill
Busway Sections	B-6	Guided Busway - Closed Drainage - Retained Fill
Busway Sections	B-7	Guided Busway - Closed Drainage – Retained/Open Cut
Busway Sections	B-8	Busway/Arterial Lane Barriers
Busway Sections	B-9	Controlled Access Highway Shoulder Bus Lane
Busway Details	C-1	Locations for Auxiliary Works
Busway Details	C-2	Guided Busway Transition Sections
Busway Details	C-3	Guided Busway Pedestrian Crossing
Access Ramps	D-1	Ramp - Closed Drainage - Cut and Fill Sections (Earth)
Access Ramps	D-2	Ramp – Open Drainage - Cut and Fill Sections (Earth)
Access Ramps	D-3	Ramp/Busway - Turning Lane Arrangements
Busway Stations	E-1	Unguided Busway - Low Volume Station
Busway Stations	E-2	Unguided Busway - Medium Volume Station
Busway Stations	E-3	Unguided Busway - High Volume Station
Busway Stations	E-4	Guided Busway - Low Volume Station
Busway Stations	E-5	Guided Busway - High Volume Station
Busway Stations	E-6	Station Median Aluminium Pedestrian Barrier
Busway Stations	E-7	Station Platform Clearances
Busway Stations	E-8	Typical Station Platform Layout
Busway Structures	F-1	Unguided Busway Bridge Cross-Section
Busway Structures	F-2	Unguided Busway Underground Structure Sections
Busway Structures	F-3	Guided Busway Bridge Cross-Section
Busway Structures	F-4	Guided Busway Underground Structure Sections
Busway Structures	F-5	Busway Construction Clearances
Busway Structures	F-6	Busway Overpass Clearances – Future LRT
Busway Structures	F-7	Busway Bridge Loadings – Future LRT
Busway Structures	F-8	Busway Bridge Deck Special Arrangements – Future LRT

	Standard	Articulated
Height	**mm**	**mm**
Front	3010	3050
Rear	2870	2870
Ground to floor	370	410
Weight	**kg**	**kg**
Front	4025	3900
Middle	-	5050
Rear	8370	9900
Total	12395	18850



Mirror Clearances

Curb Side	Street Side
x = 1600	a = 1550
y = 1980	b = 1520

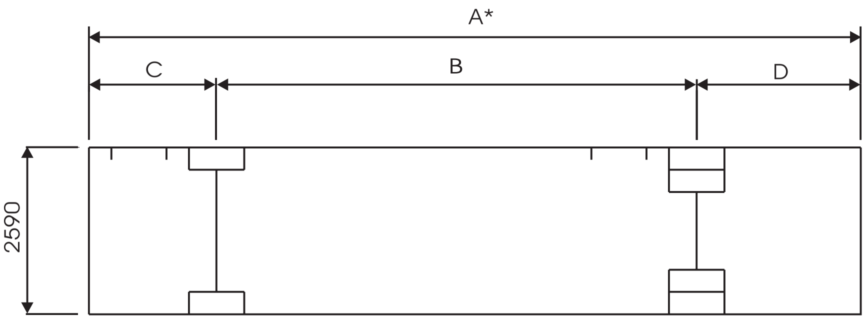
Notes: Dimensions are based on New Flyer Buses.
Dimensions Under Development.

City of Winnipeg Transit System

TYPICAL BUS DIMENSIONS

BUSWAY PLANNING AND DESIGN MANUAL

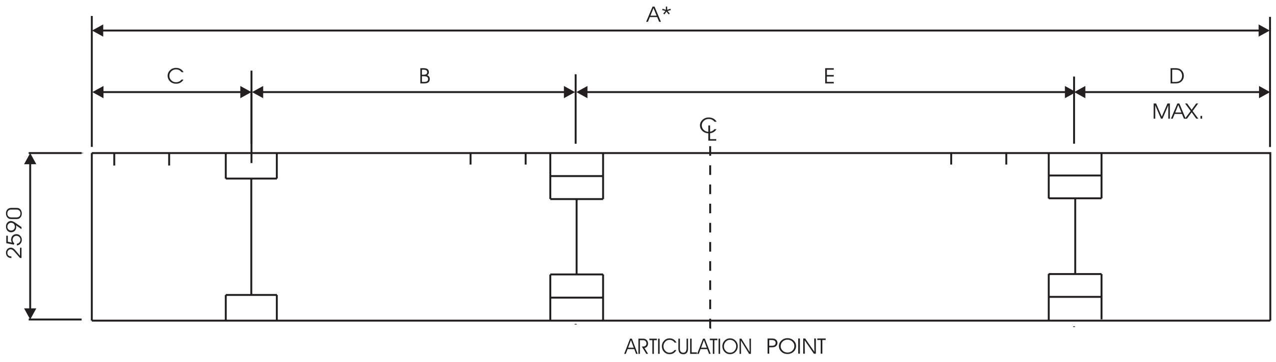
Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	A-1



* Length over bumpers.

TURNING RADIUS = 12790
STANDARD BUS PLAN

	A	B	C	D
MAX.	12500	7430	2130	2940



TURNING RADIUS = 13770
ARTICULATED BUS PLAN

	A	B	C	D	E
MAX.	18500	5780	2130	2900	7690

Notes : Dimensions are based on New Flyer Buses.

CITY OF WINNIPEG TRANSIT SYSTEM

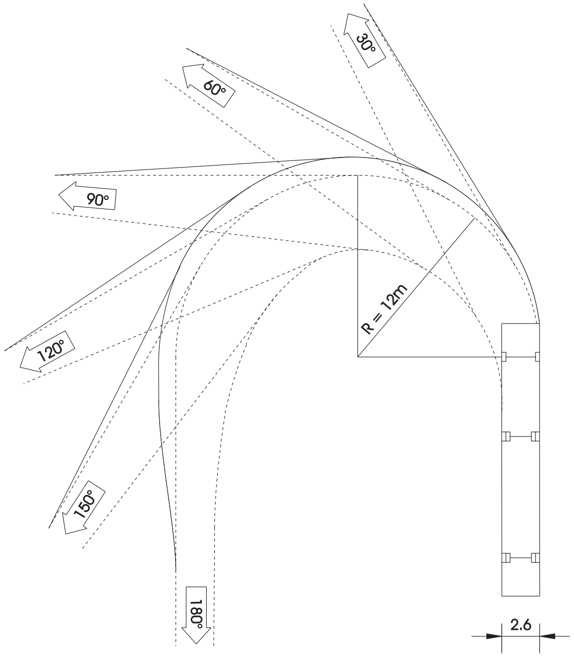
DESIGN BUS DIMENSIONS

BUSWAY PLANNING AND DESIGN MANUAL

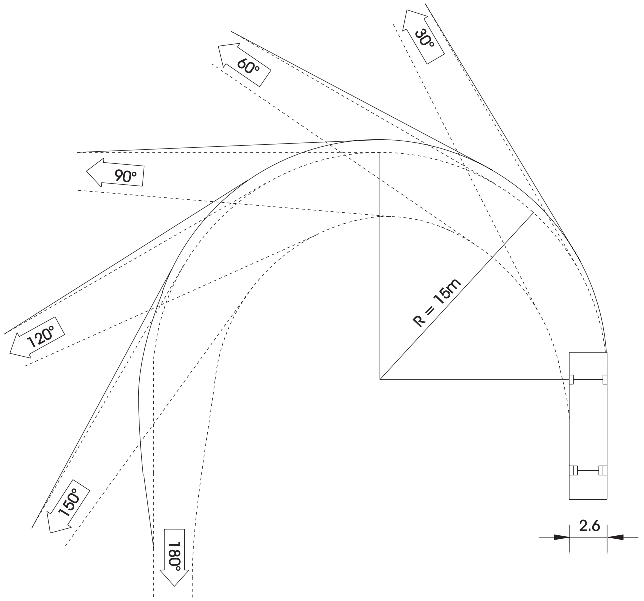
Date
Sept, 2004

Scale
N.T.S.

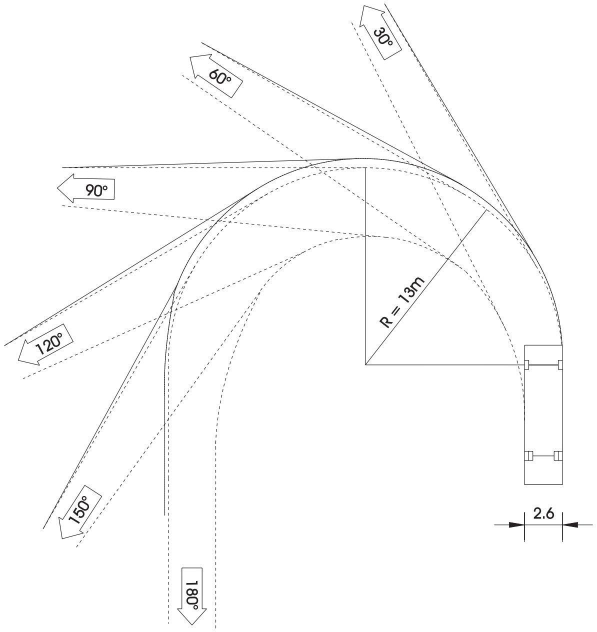
Dwg. No.
A-2



ARTICULATED BUS
R = 12m (MIN)
1:500



STANDARD BUS
R = 15m (MIN)
1:500



STANDARD BUS
R = 13m (MIN)
1:500

CITY OF WINNIPEG TRANSIT SYSTEM

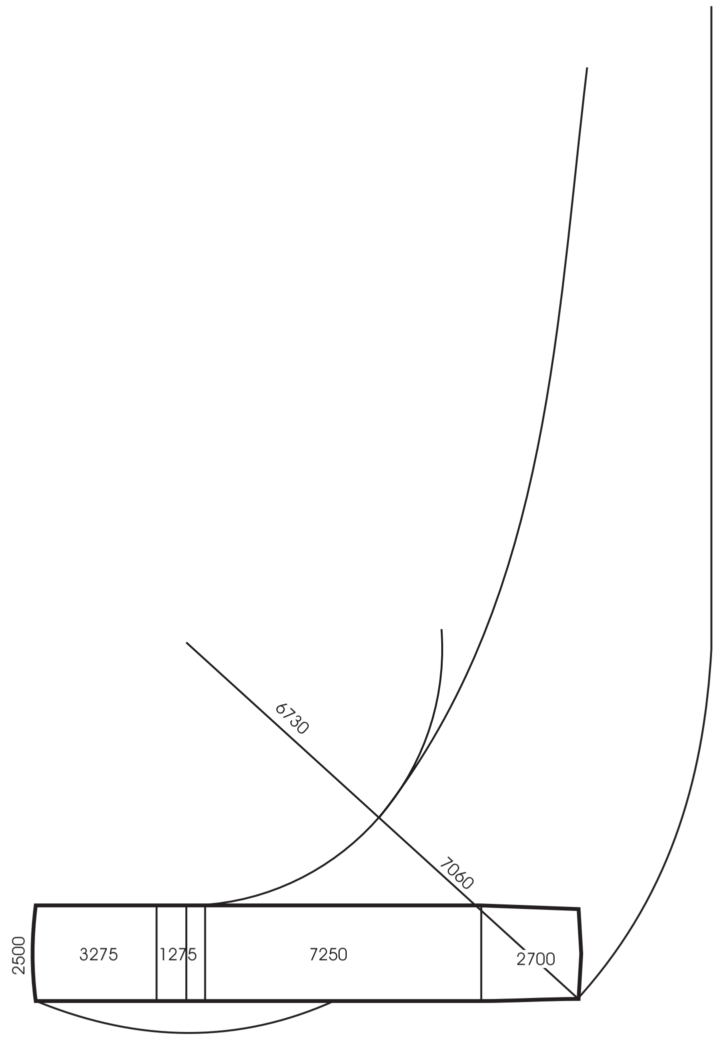
MINIMUM BUS TURNING RADII

BUSWAY PLANNING AND DESIGN MANUAL

Date
Sept, 2004

Scale
N.T.S.

Dwg. No.
A-3



TURNING (CIRCULAR) APPROACH

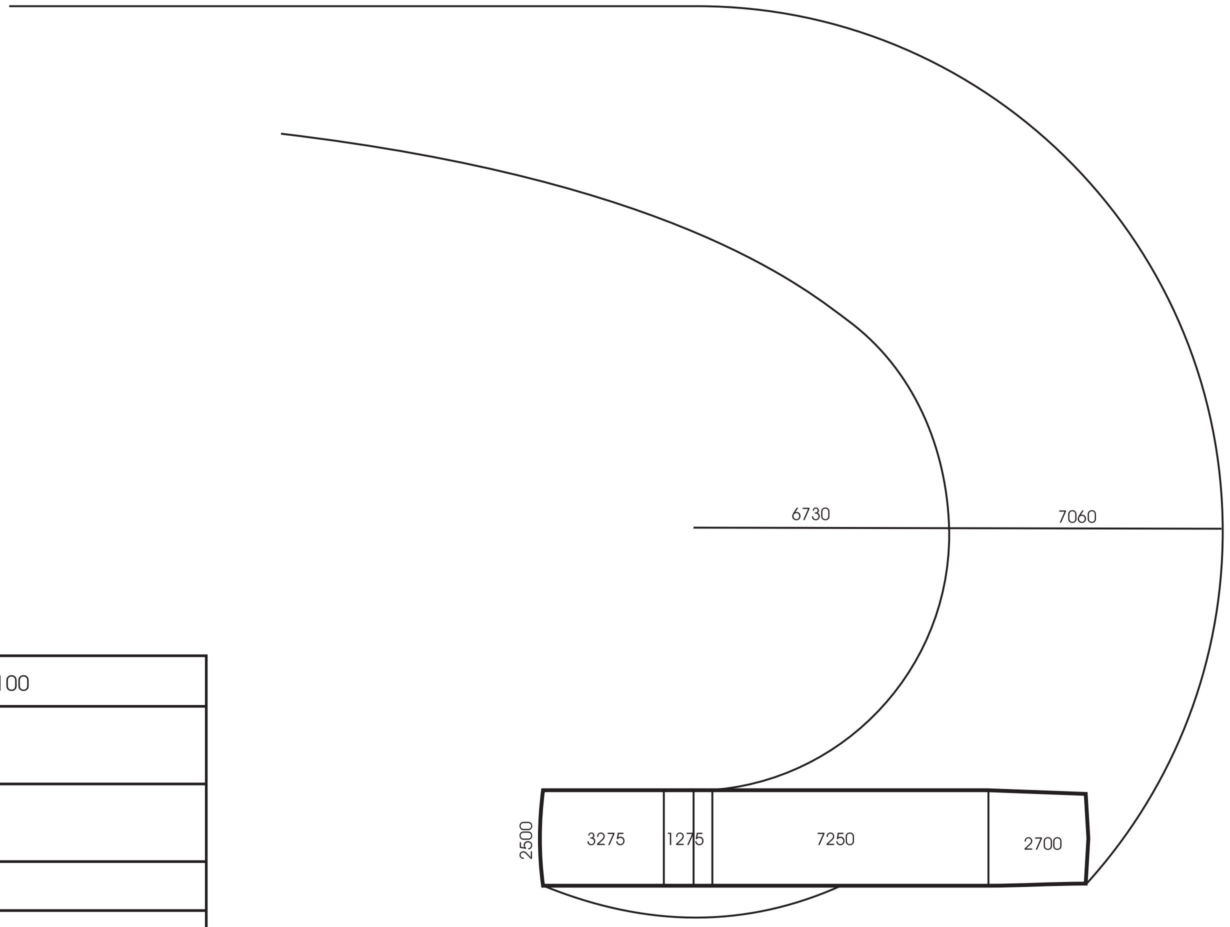
Bodywork corner shape	XF=YF=100
Overall length (bumper to bumper)	14.5 m
Turning diam. wall to wall (swept area - outer diam.)	27.57 m
Swept area - inner diam	13.45 m
Rear corner swing-out	0.8 m

CITY OF WINNIPEG TRANSIT SYSTEM

SWEPT AREA DIAGRAM - TURNING 90

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	A-4



TURNING (CIRCULAR) APPROACH

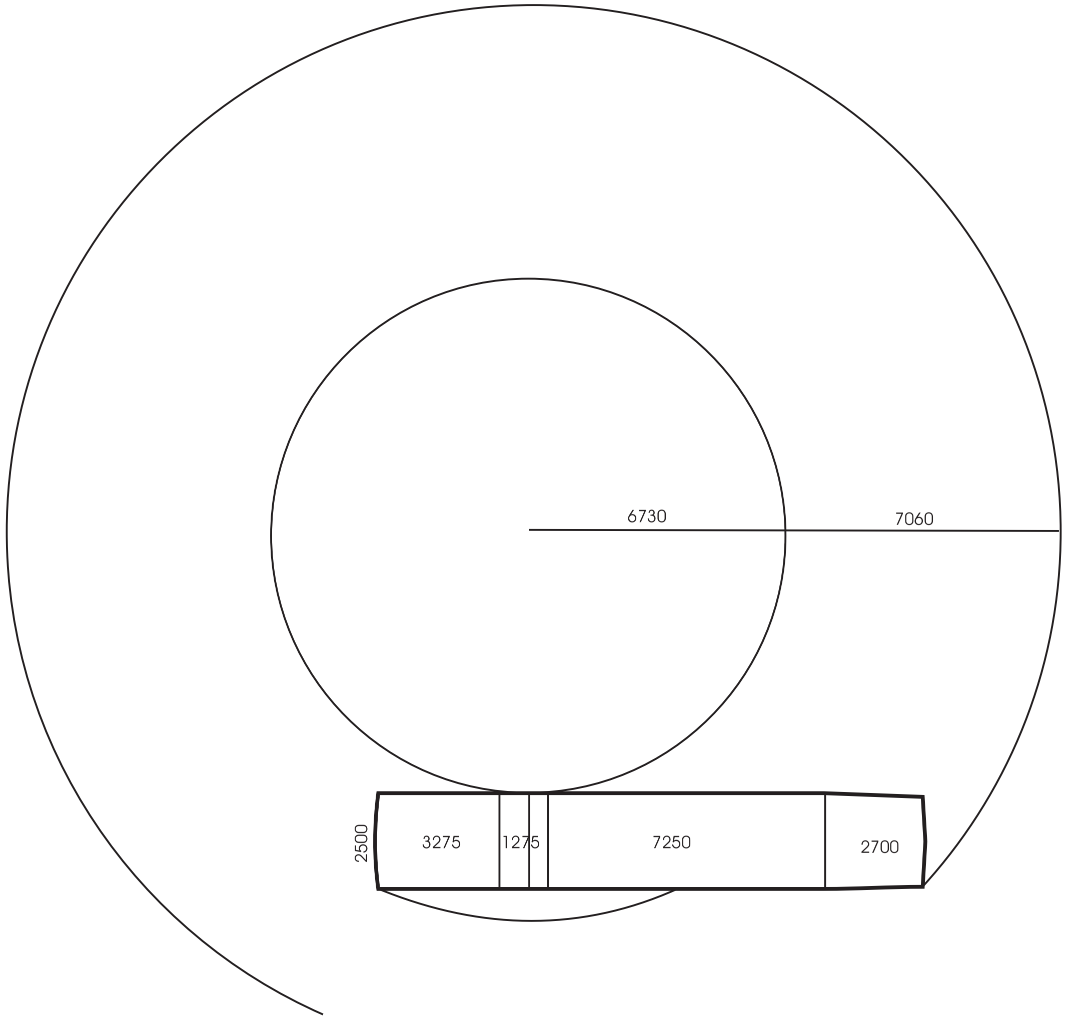
Bodywork corner shape	XF=YF=100
Overall length (bumper to bumper)	14.5 m
Turning diam. wall to wall (swept area - outer diam.)	27.57 m
Swept area - inner diam	13.45 m
Rear corner swing-out	0.8 m

CITY OF WINNIPEG TRANSIT SYSTEM

SWEPT AREA DIAGRAM - TURNING 180

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	A-5



TURNING (CIRCULAR) APPROACH

Bodywork corner shape	XF=YF=100
Overall length (bumper to bumper)	14.5 m
Turning diam. wall to wall (swept area - outer diam.)	27.57 m
Swept area - inner diam	13.45 m
Rear corner swing-out	0.8 m

CITY OF WINNIPEG TRANSIT SYSTEM

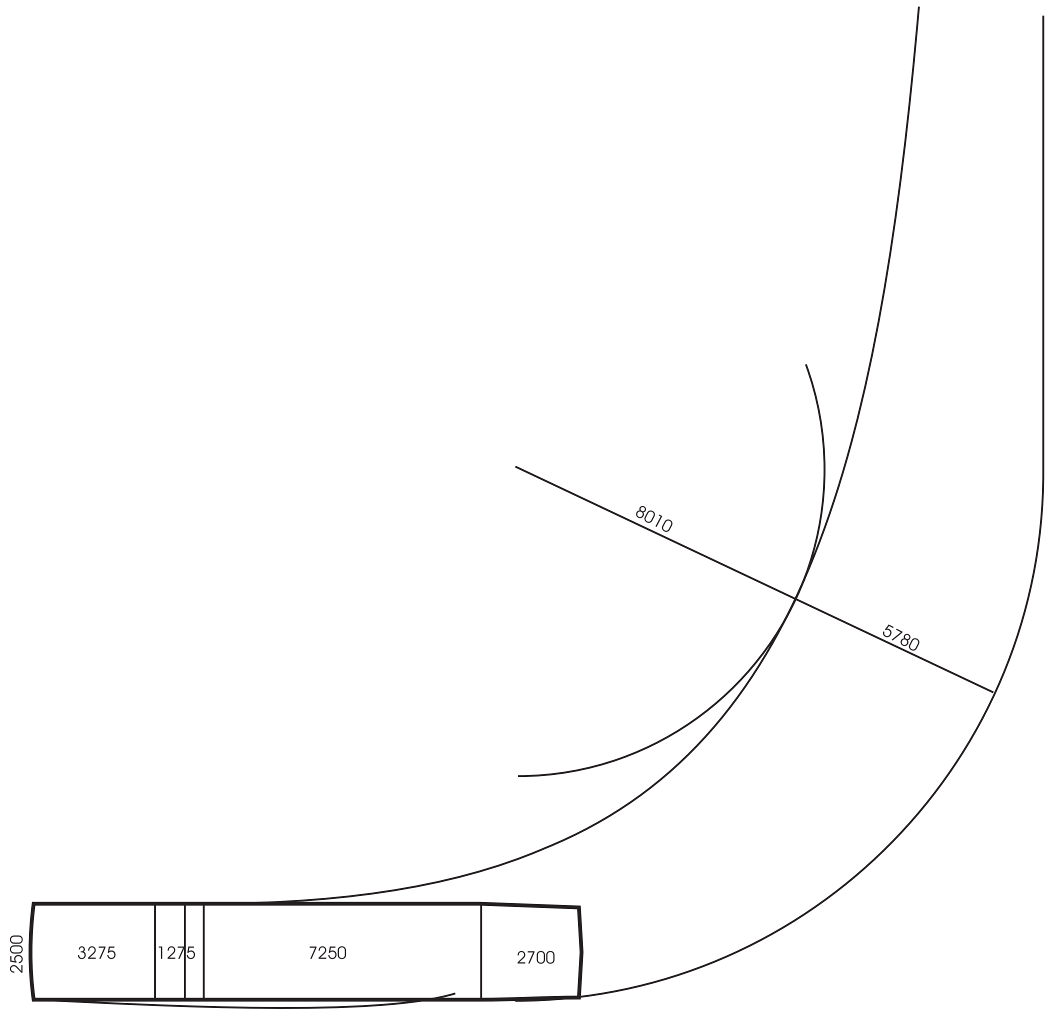
SWEPT AREA DIAGRAM - TURNING 360

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	A-6

STRAIGHT (TANGENTIAL) APPROACH

Bodywork corner shape	XF=YF=100
Overall length (bumper to bumper)	14.5 m
Turning diam. wall to wall (swept area - outer diam.)	27.57 m
Swept area - inner diam	16.02 m
Rear corner swing-out	0.22 m



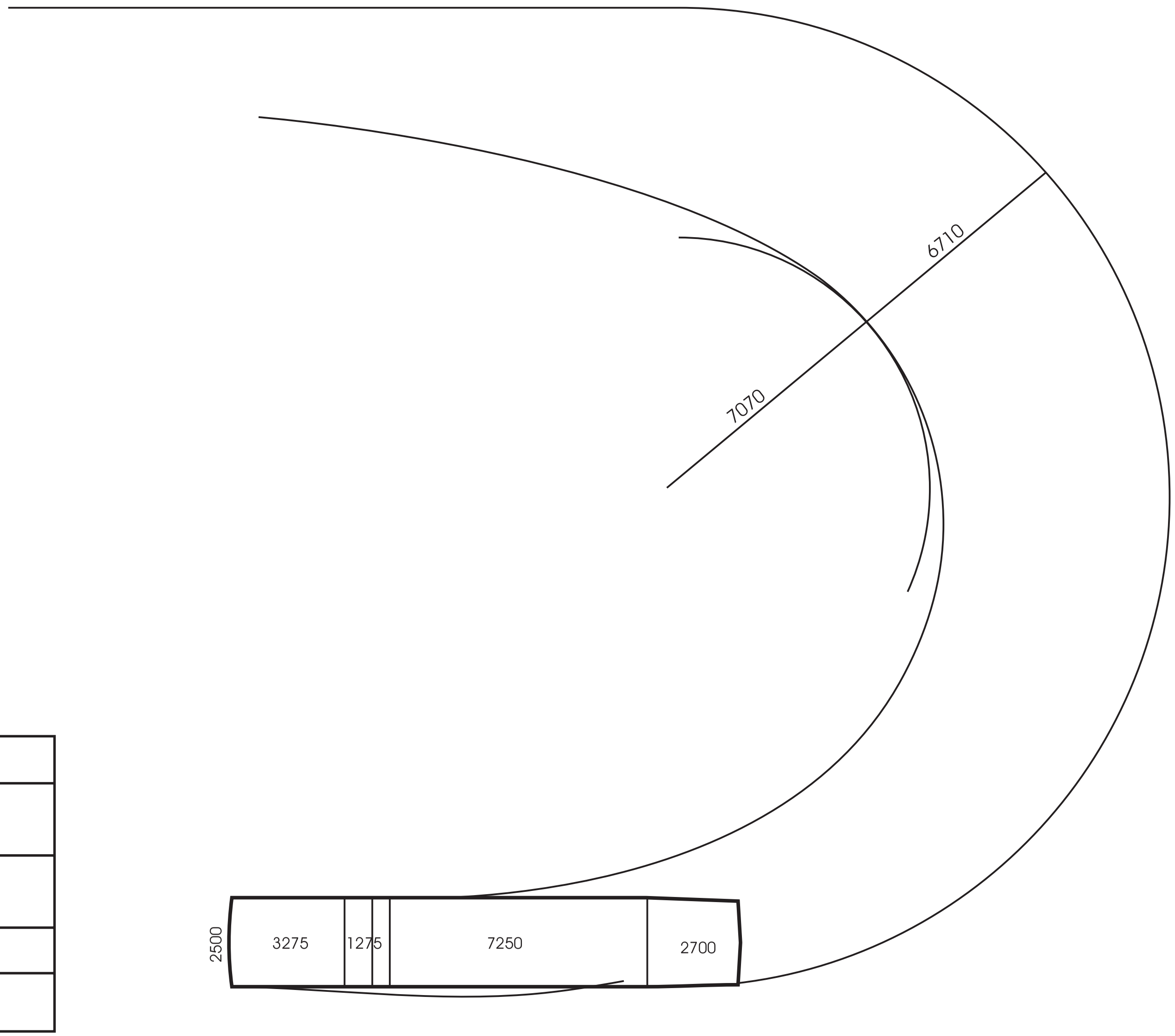
SWEPT AREA DIAGRAM - STRAIGHT 90

BUSWAY PLANNING AND DESIGN MANUAL

Date
Sept, 2004

Scale
N.T.S.

Dwg. No.
A-7



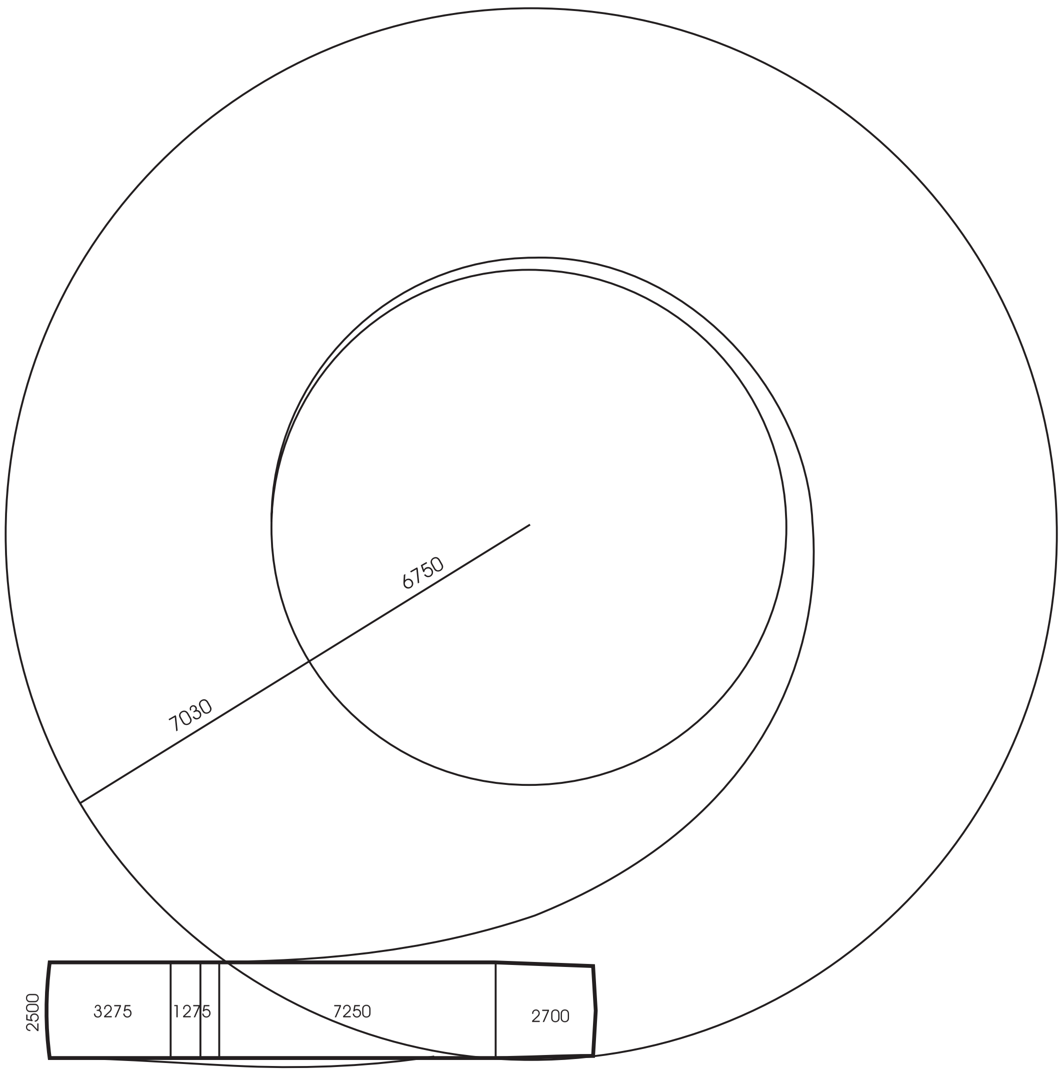
STRAIGHT (TANGENTIAL) APPROACH

Bodywork corner shape	XF=YF=100
Overall length (bumper to bumper)	14.5 m
Turning diam. wall to wall (swept area - outer diam.)	27.57 m
Swept area - inner diam	14.5 m
Rear corner swing-out	0.22 m

SWEPT AREA DIAGRAM - STRAIGHT 180

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	A-8



STRAIGHT (TANGENTIAL) APPROACH

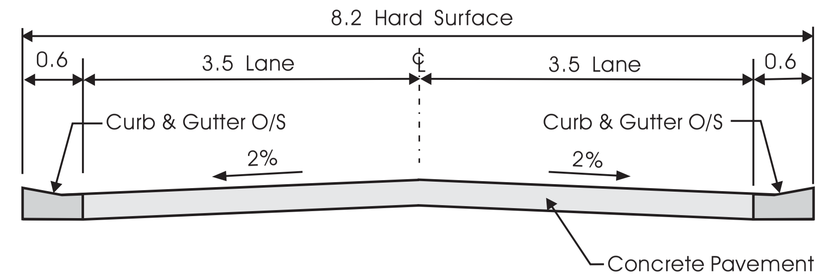
Bodywork corner shape	XF=YF=100
Overall length (bumper to bumper)	14.5 m
Turning diam. wall to wall (swept area - outer diam.)	27.57 m
Swept area - inner diam	13.51 m
Rear corner swing-out	0.22 m

CITY OF WINNIPEG TRANSIT SYSTEM

SWEPT AREA DIAGRAM - STRAIGHT 360

BUSWAY PLANNING AND DESIGN MANUAL

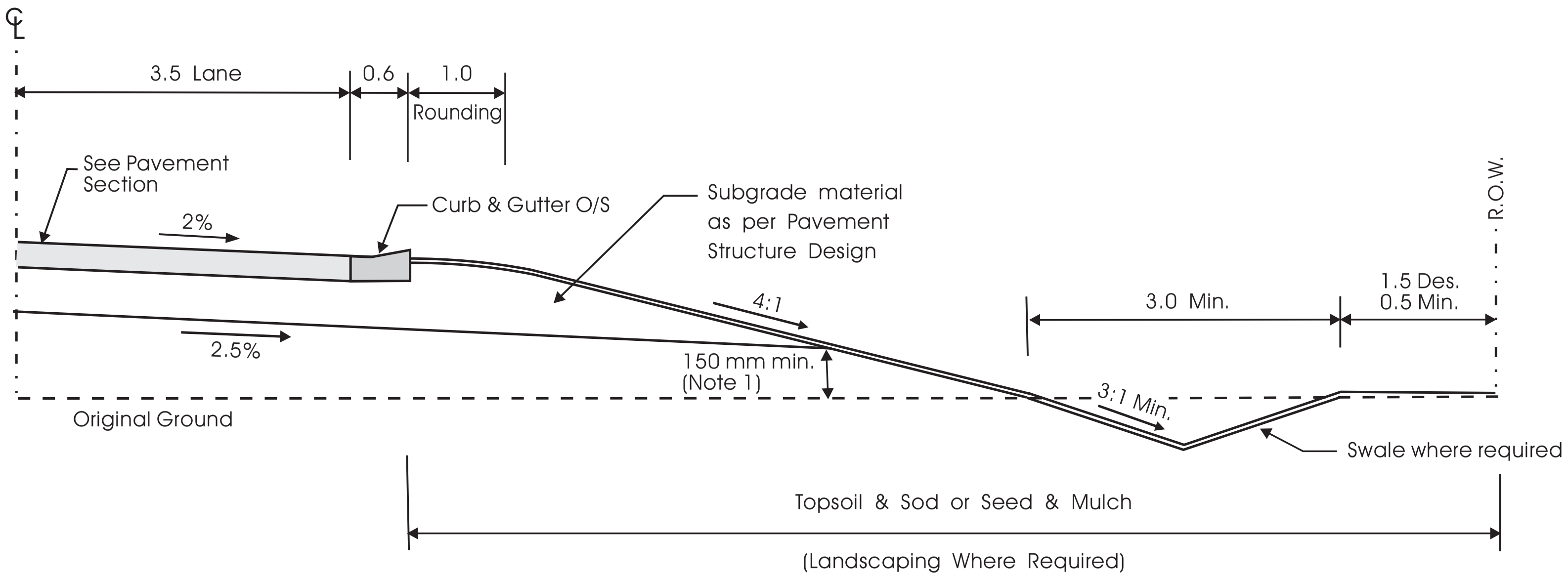
Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	A-9



Busway Pavement Section

Notes:

1. Where subgrade does not have 150mm clearance above original ground, use subdrain section as per Dwg. No. B-2.
2. Where right-of-way is restricted, use Dwg. No. B-3.



Shallow Fill Section Where Right-of-Way Allows

CITY OF WINNIPEG TRANSIT SYSTEM

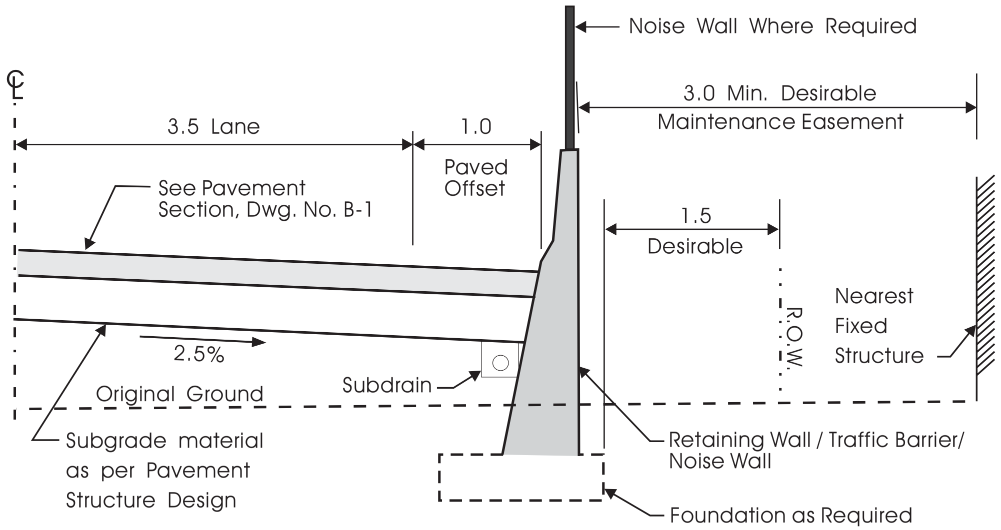
UNGUIDED BUSWAY - CLOSED DRAINAGE - SHALLOW FILL

BUSWAY PLANNING AND DESIGN MANUAL

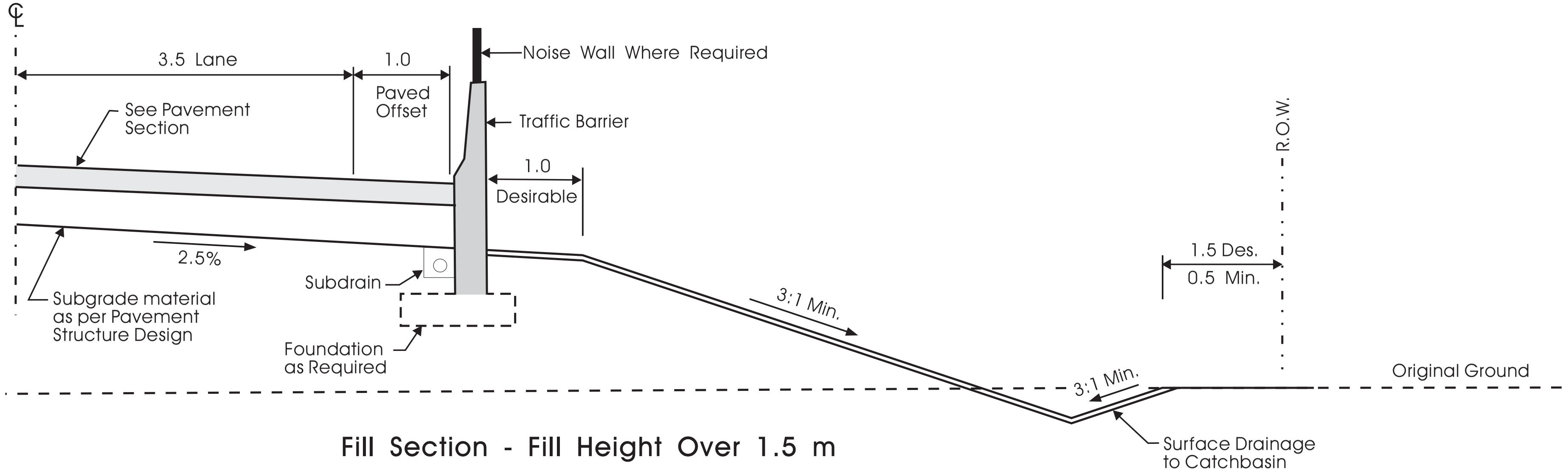
Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	B-1

NOTES:

1. For pavement section and shallow fills see Dwg. No. B-1.



Fill Section Where Right-of-Way is Restricted

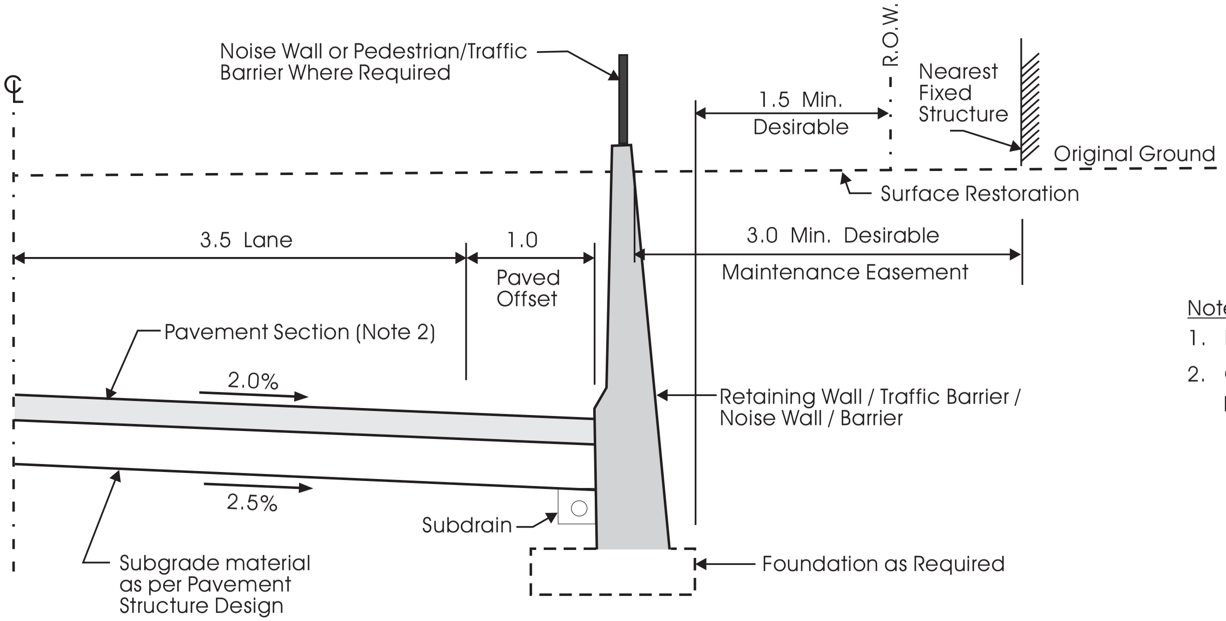


Fill Section - Fill Height Over 1.5 m

UNGUIDED BUSWAY - CLOSED DRAINAGE - RETAINED FILL

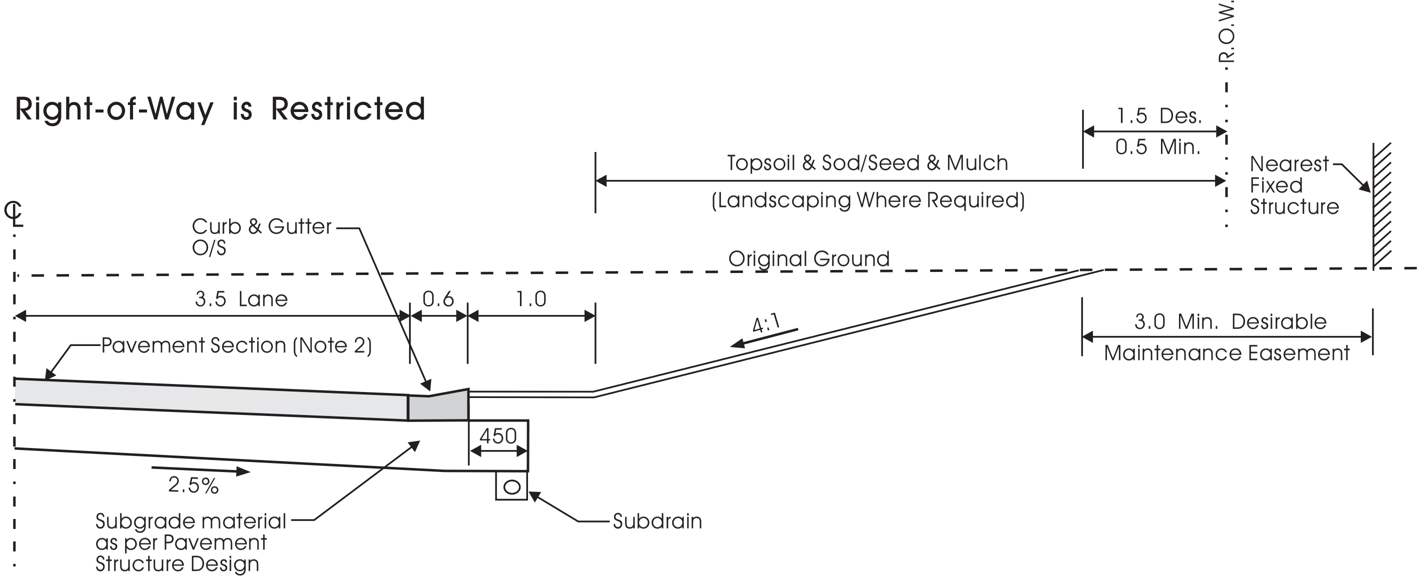
BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	B-2



Notes:
1. For pavement section and shallow fills see Dwg. No. B-1.
2. Catchment Table Drain depth as per Hydrology design. Table Drain may be eliminated where R.O.W. is restricted.

Cut Section Where Right-of-Way is Restricted

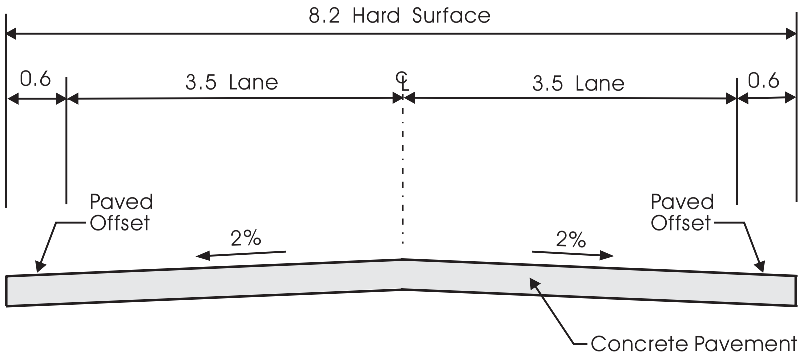


Cut Section - Cut Height Over 1.5 m

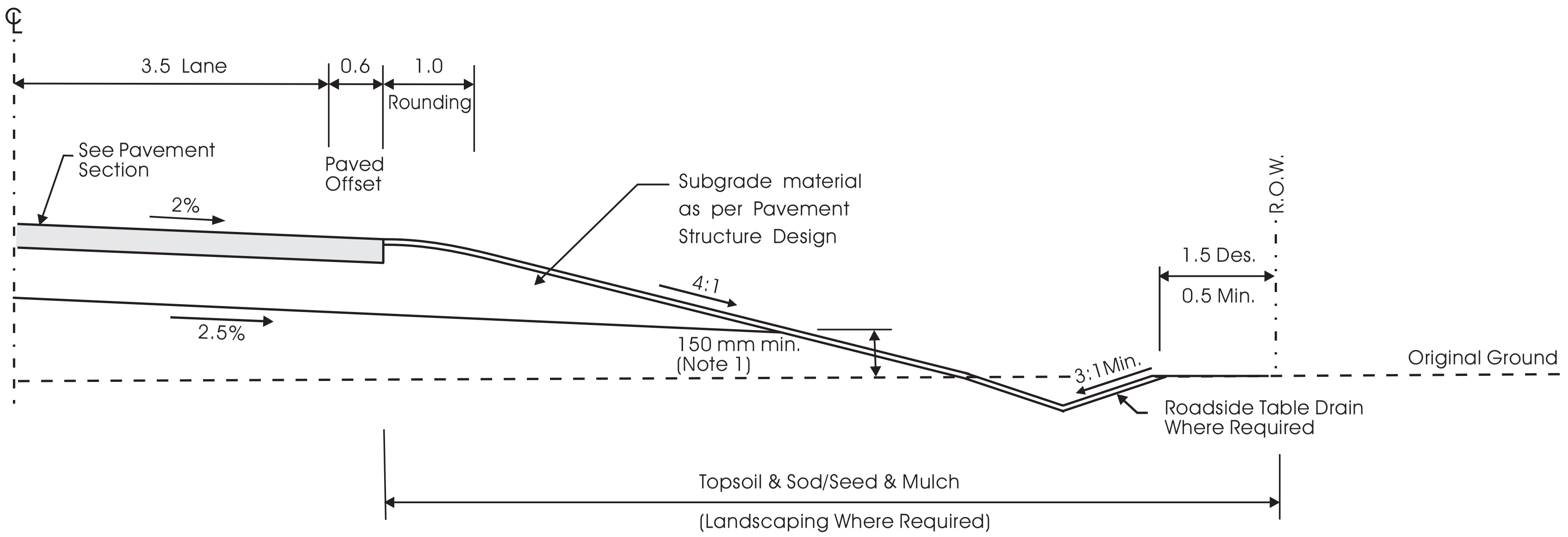
CITY OF WINNIPEG TRANSIT SYSTEM

UNGUIDED BUSWAY - CLOSED DRAINAGE - RETAINED/OPEN CUT

BUSWAY PLANNING AND DESIGN MANUAL	Date Sept, 2004	Scale N.T.S.	Dwg. No. B-3



Busway Pavement Section

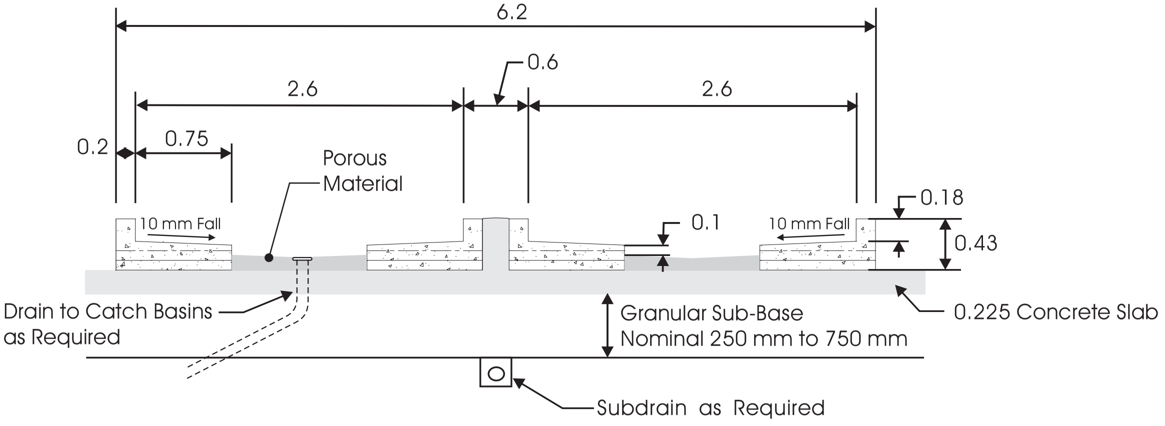


Shallow Fill Section Where Right-of-Way Allows

CITY OF WINNIPEG TRANSIT SYSTEM

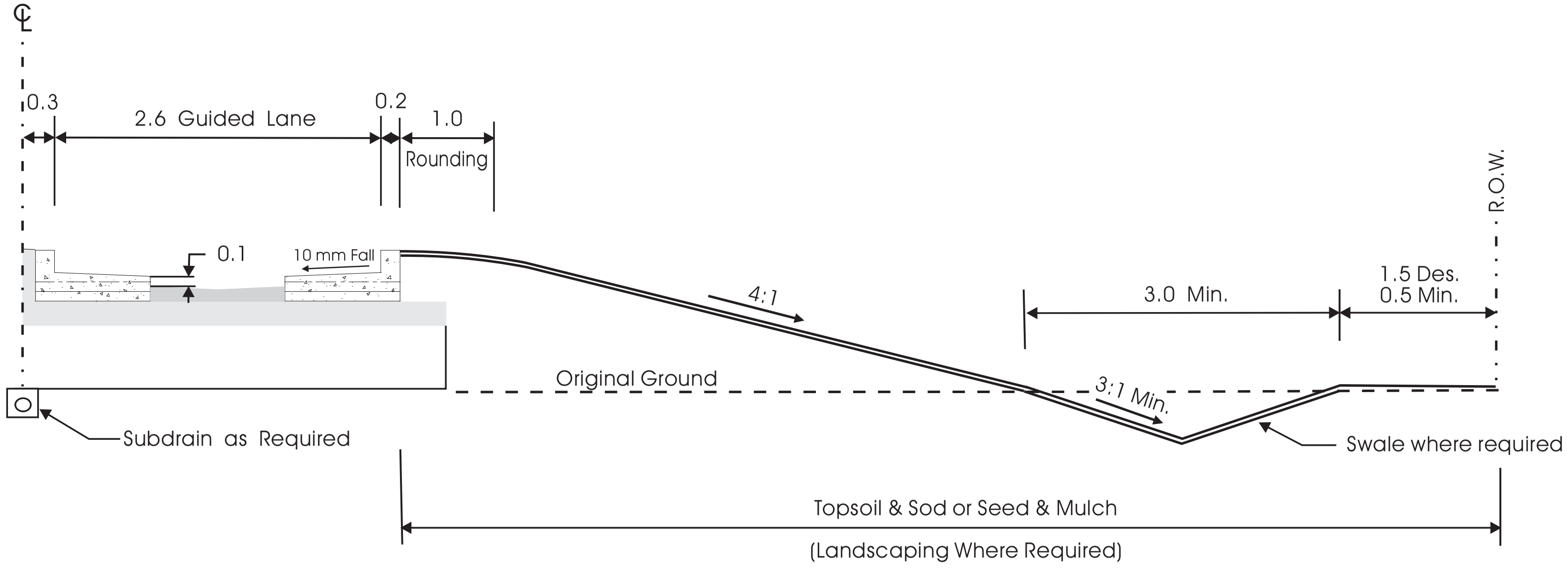
UNGUIDED BUSWAY - OPEN DRAINAGE - SHALLOW FILL

BUSWAY PLANNING AND DESIGN MANUAL	Date Sept, 2004	Scale N.T.S.	Dwg. No. B-4



Guided Busway Section

Notes:
1. Where subgrade does not have 150mm clearance above original ground, use sub-drain section as per Dwg. No. B-6.
2. Where right-of-way is restricted, use Dwg. No. B-7.



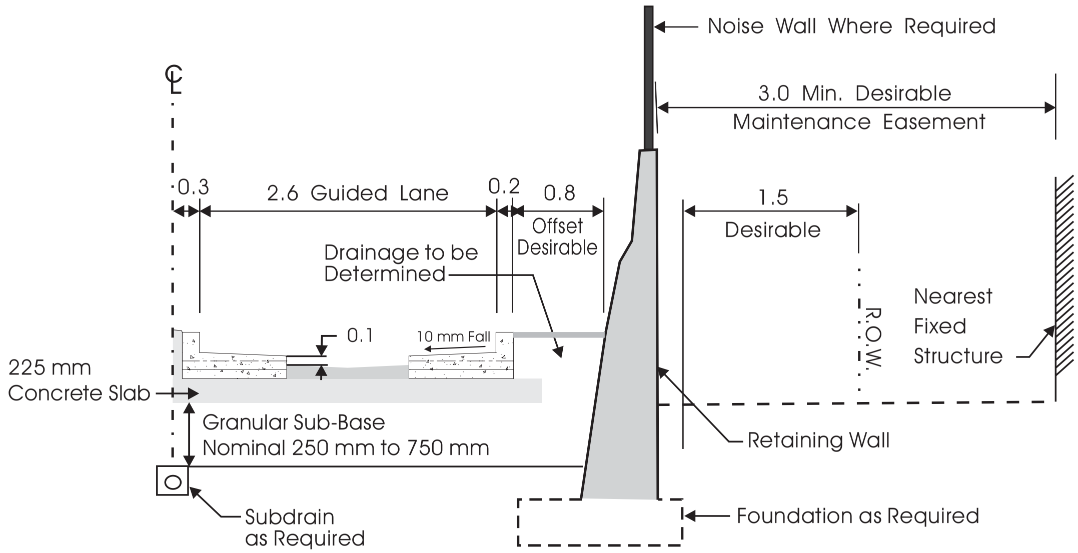
Shallow Fill Section Where Right-of-Way Allows

GUIDED BUSWAY - CLOSED DRAINAGE - SHALLOW FILL

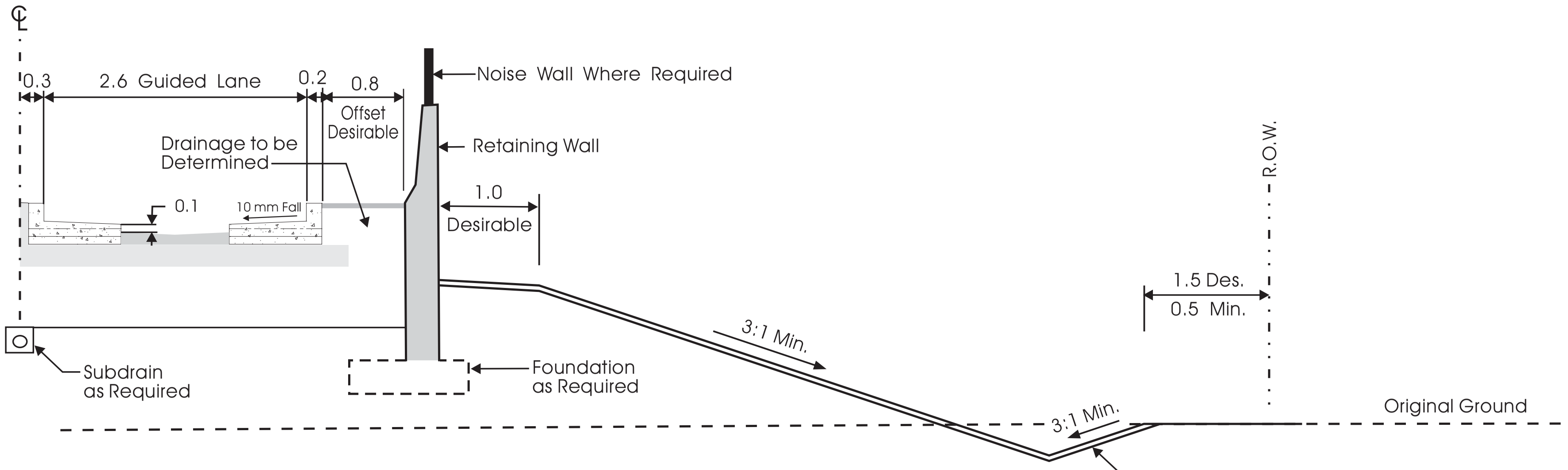
BUSWAY PLANNING AND DESIGN MANUAL	Date	Scale	Dwg. No.
	Sept, 2004	N.T.S.	B-5

NOTES:

1. For pavement section and shallow fills see Dwg. No. B-5.



Fill Section Where Right-of-Way is Restricted



Fill Section - Fill Height Over 1.5 m

CITY OF WINNIPEG TRANSIT SYSTEM

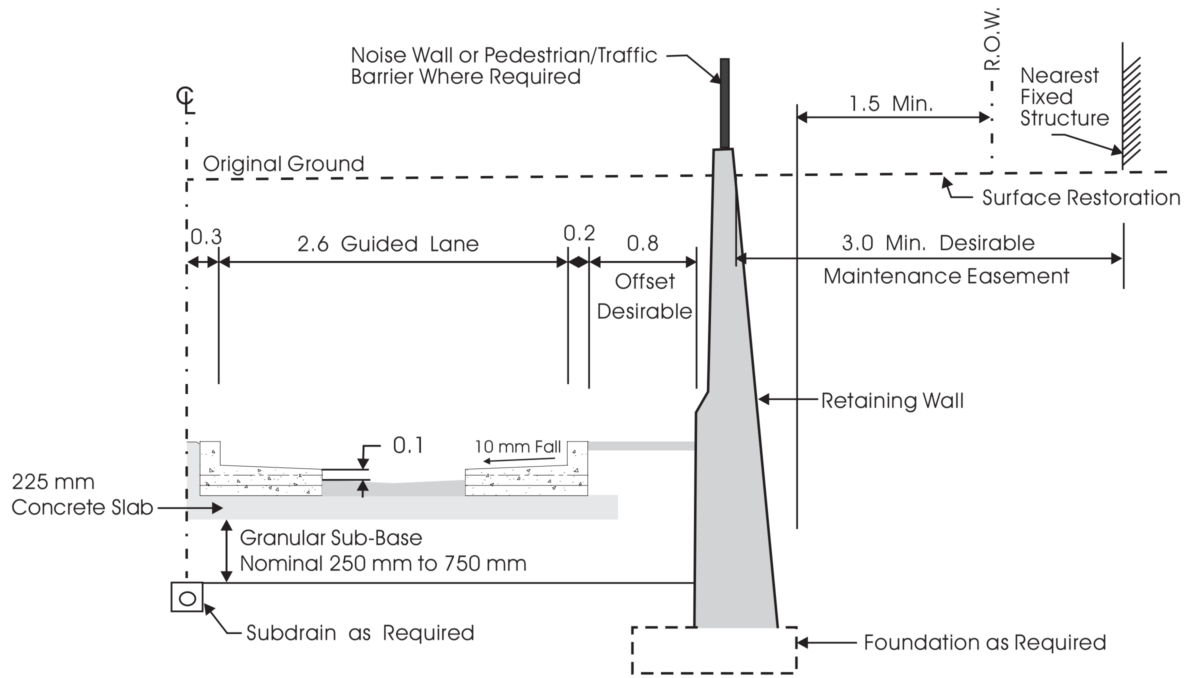
GUIDED BUSWAY - CLOSED DRAINAGE - RETAINED FILL

BUSWAY PLANNING AND DESIGN MANUAL

Date
Sept, 2004

Scale
N.T.S.

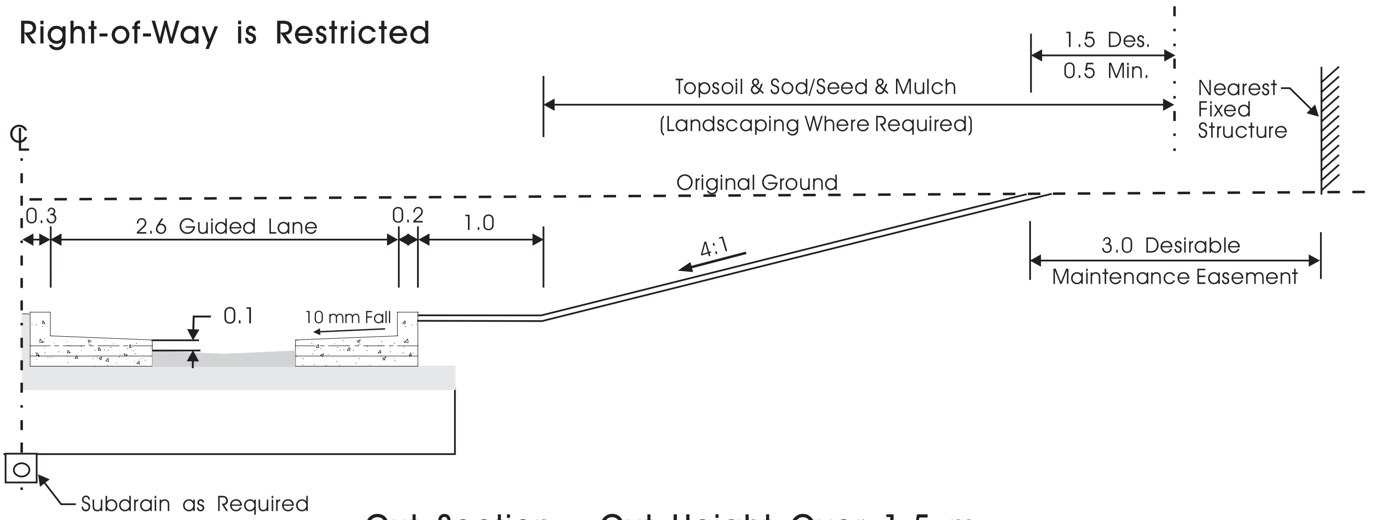
Dwg. No.
B-6



Cut Section Where Right-of-Way is Restricted

Notes:

1. For pavement section and shallow fills see Dwg. No. B-5.
2. Catchment Table Drain depth as per Hydrology design. Table Drain may be eliminated where R.O.W. is restricted.



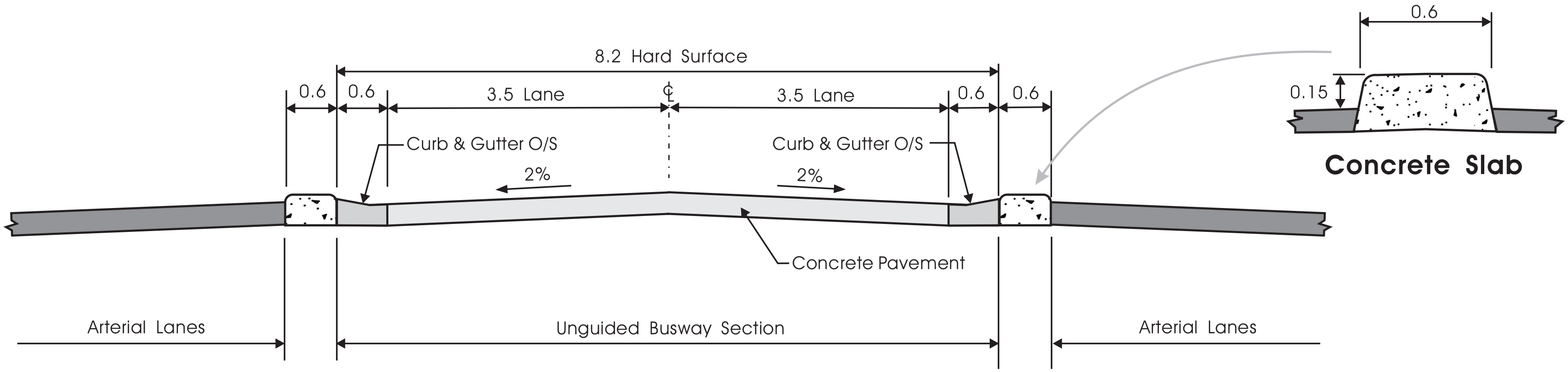
Cut Section - Cut Height Over 1.5 m

CITY OF WINNIPEG TRANSIT SYSTEM

GUIDED BUSWAY - CLOSED DRAINAGE - RETAINED/OPEN CUT

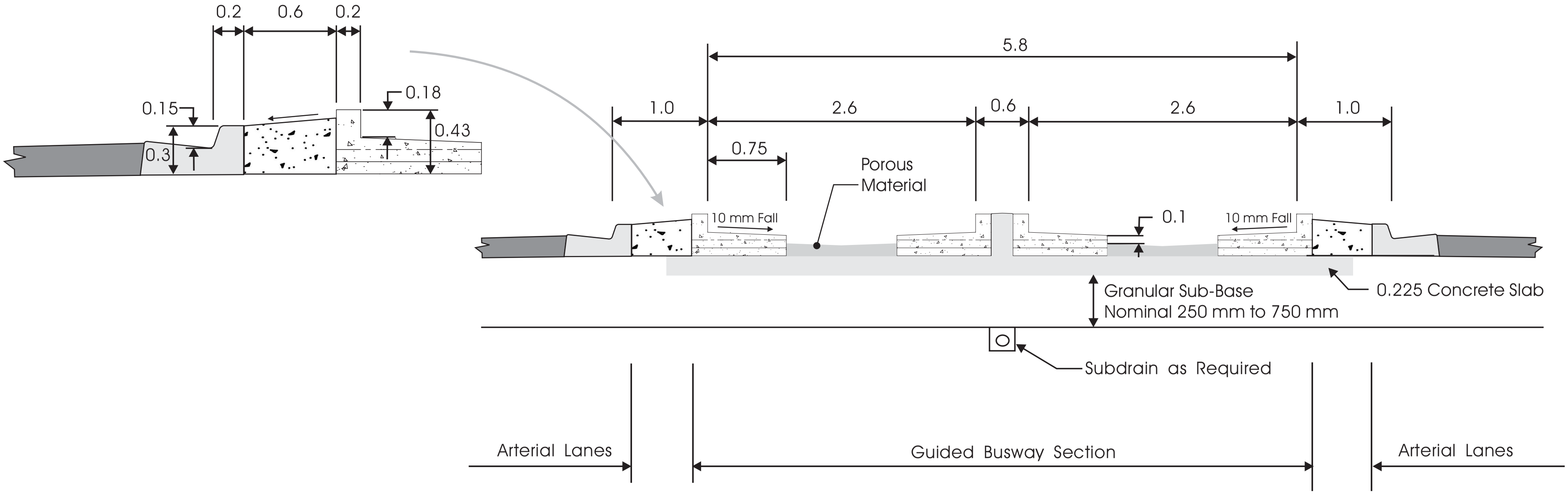
BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	B-7



Concrete Slab

Unguided Busway ection

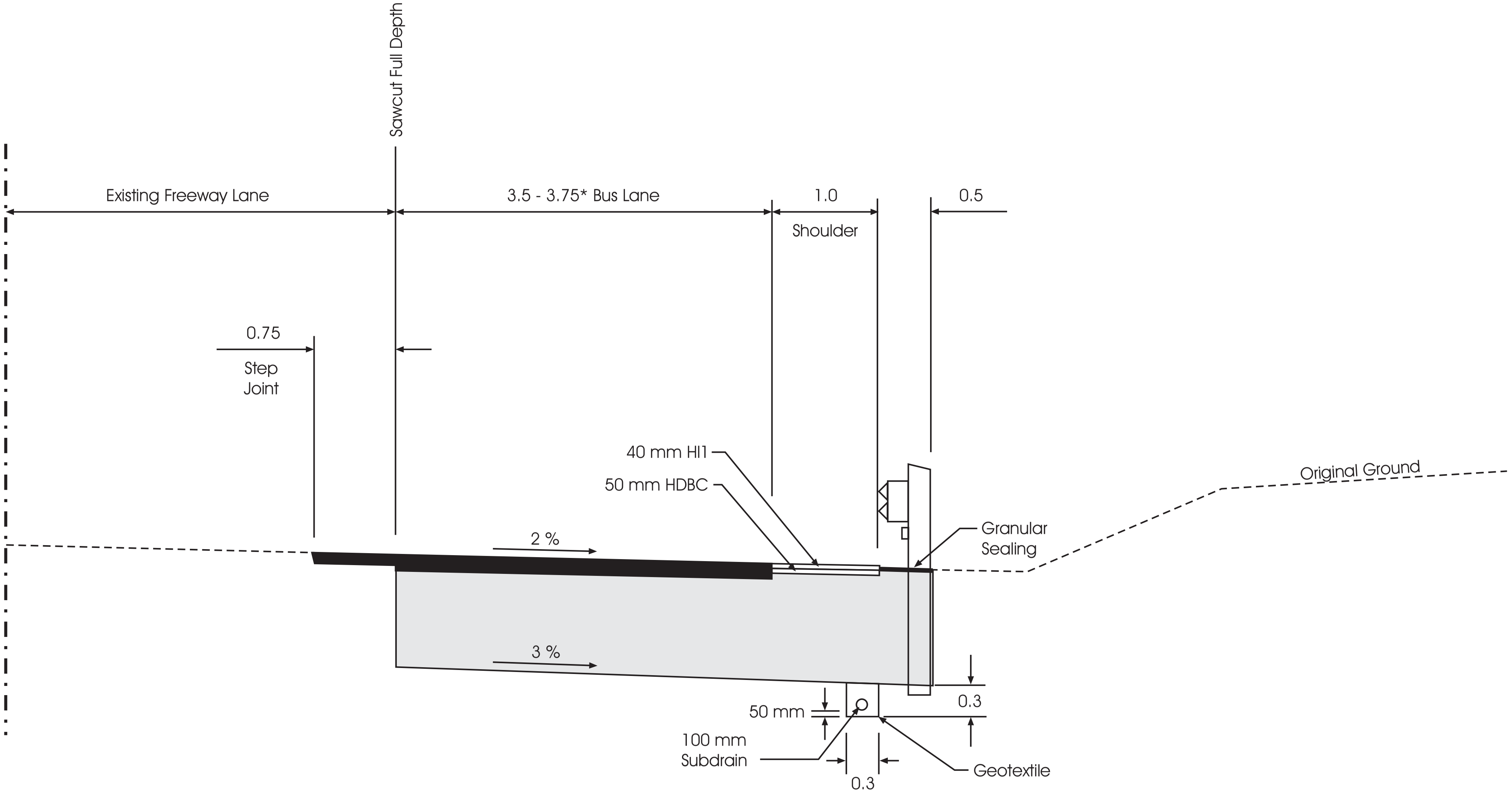


Guided Busway Section

CITY OF WINNIPEG TRANSIT SYSTEM

BUSWAY / ARTERIAL LANE BARRIERS

BUSWAY PLANNING AND DESIGN MANUAL	Date Sept, 2004	Scale N.T.S.	Dwg. No. B8



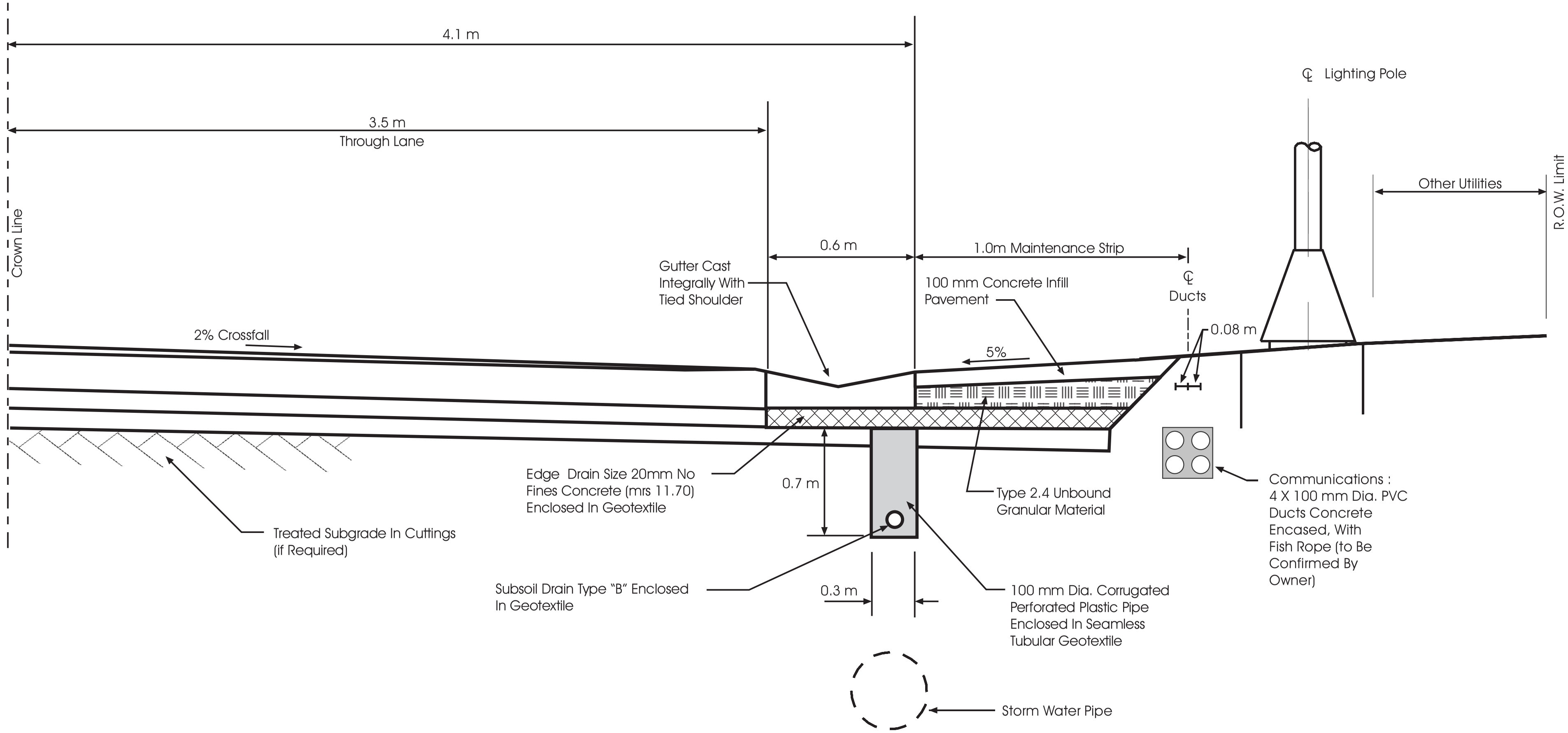
Typical Section - Guide Rail

* to suit local conditions.

CONTROLLED ACCESS HIGHWAY SHOULDER BUS LANE

BUSWAY PLANNING AND DESIGN MANUAL

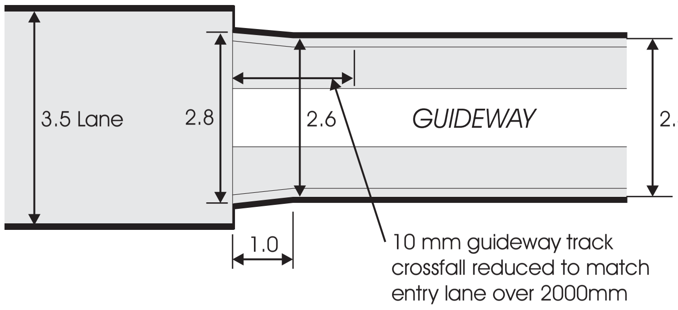
Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	B-9



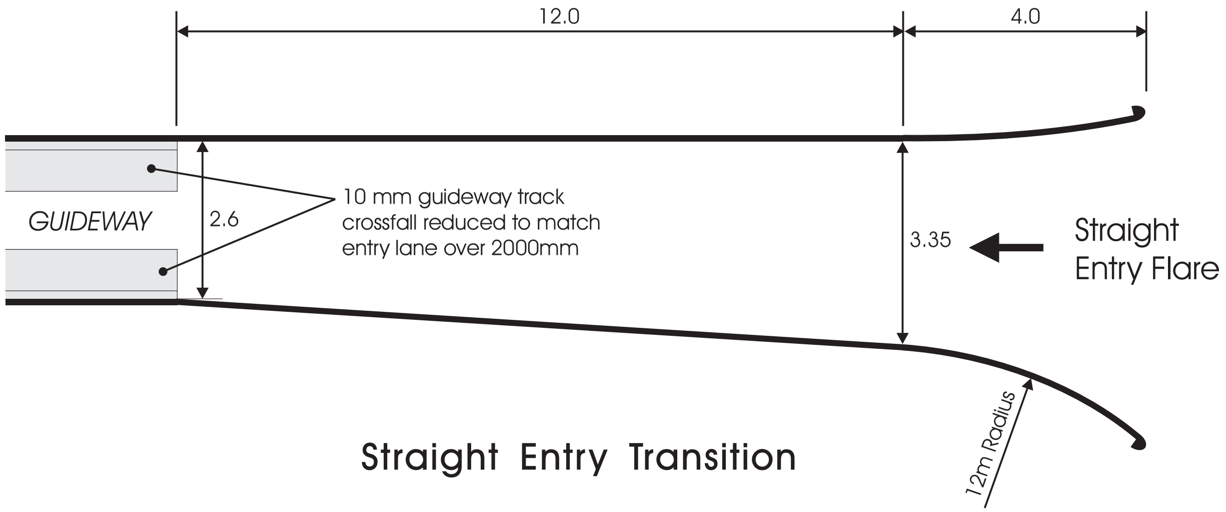
CITY OF WINNIPEG TRANSIT SYSTEM

LOCATIONS FOR AUXILIARY WORKS

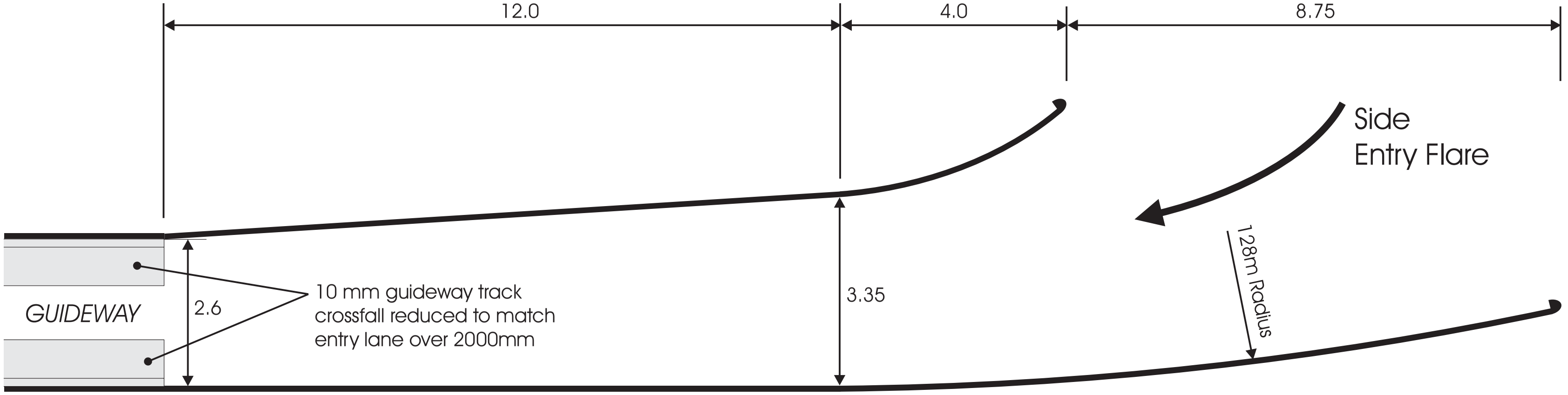
BUSWAY PLANNING AND DESIGN MANUAL	Date Sept, 2004	Scale N.T.S.	Dwg. No. C-1



Exit Transition



Straight Entry Transition



Side Entry Transition

GUIDED BUSWAY TRANSITION SECTIONS

CITY OF WINNIPEG TRANSIT SYSTEM

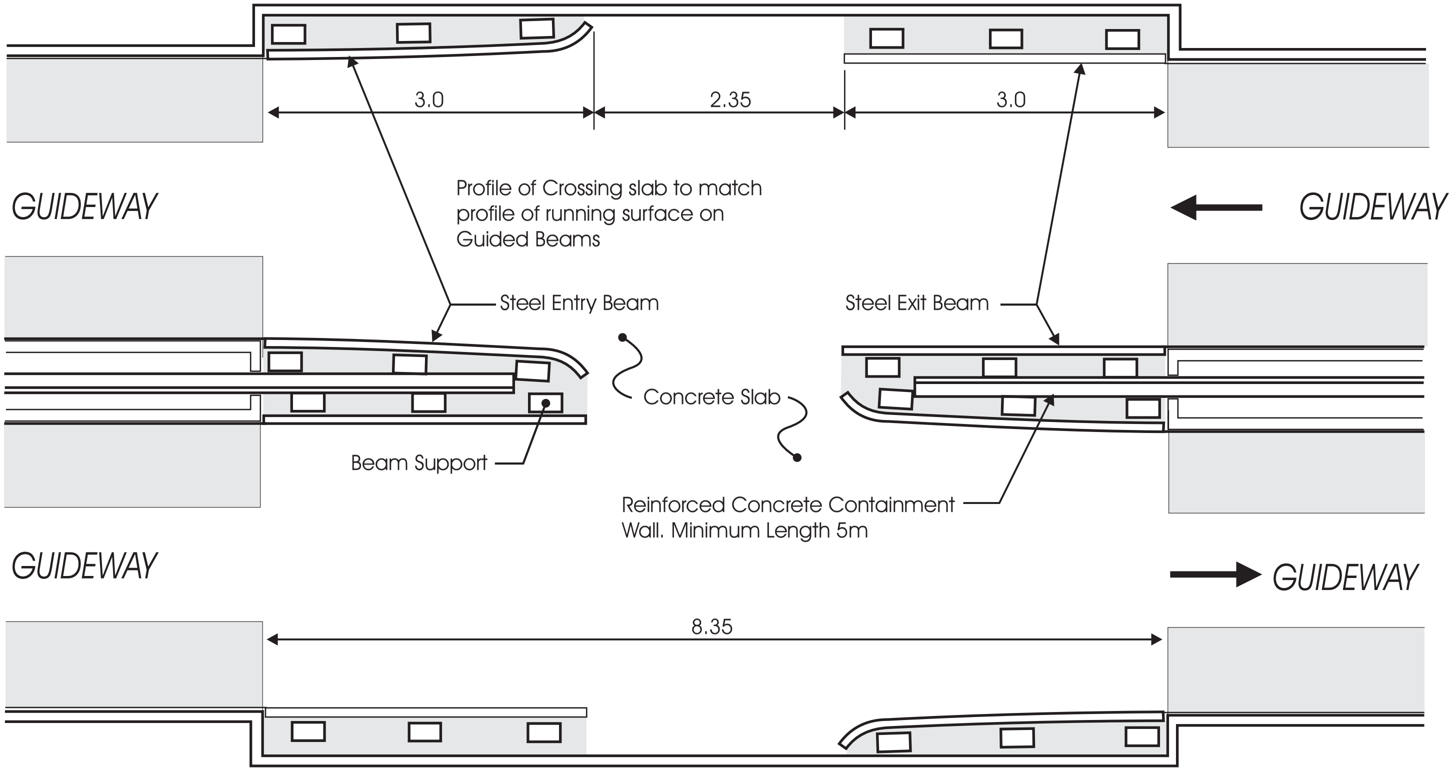
BUSWAY PLANNING AND DESIGN MANUAL

Date
Sept, 2004

Scale
N.T.S.

Dwg. No.
C-2

Curb Profile

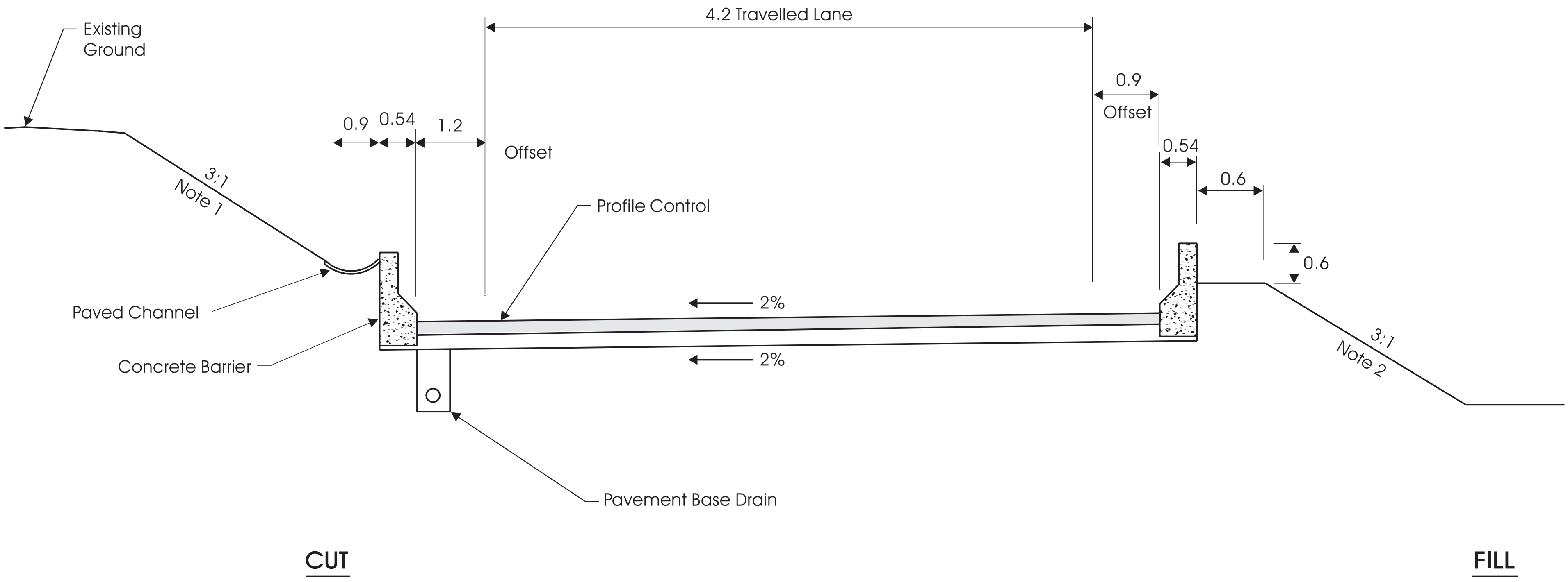


Pedestrian Crossing

GUIDED BUSWAY PEDESTRIAN CROSSING

BUSWAY PLANNING AND DESIGN MANUAL

Date Sept, 2004	Scale N.T.S.	Dwg. No. C-3



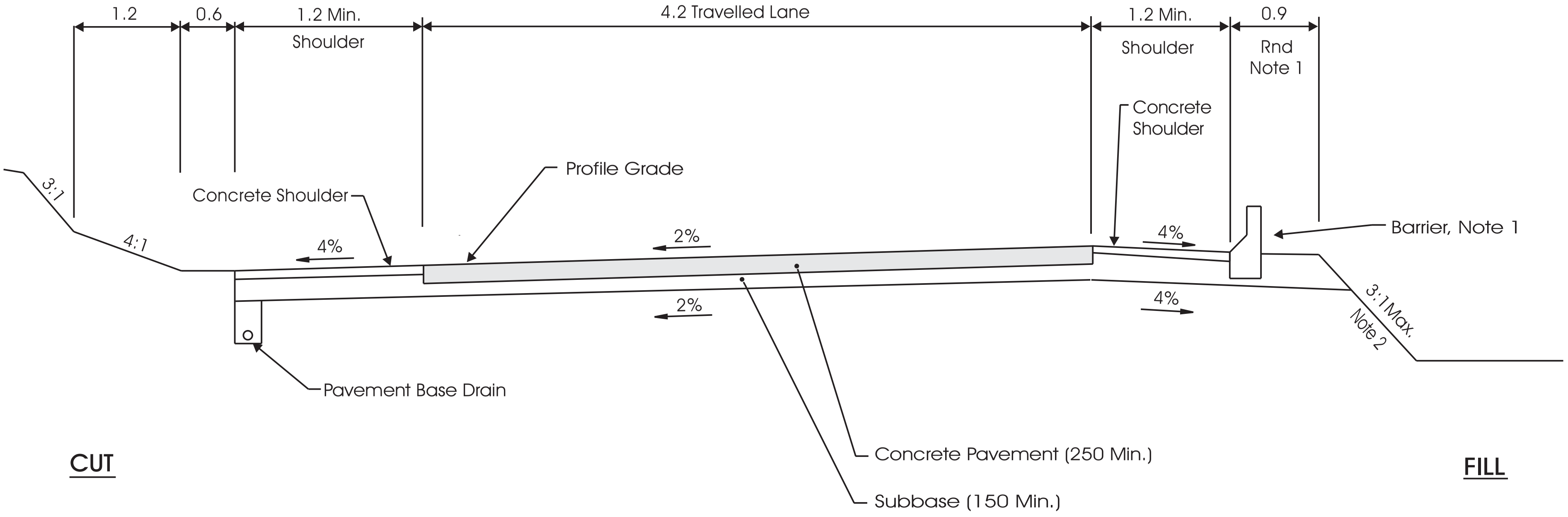
NOTE:

1. Refer to Dwg. No. B-6 for slope treatment.
2. Refer to Dwg. No. B-5 for slope treatment.

RAMP - CLOSED DRAINAGE - CUT AND FILL SECTIONS (EARTH)

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	D-1



Notes:

1. Where protection is required width of rounding shall be 1.0 from back of concrete barrier.
2. Refer to dwg. No. B2 for slope treatment.

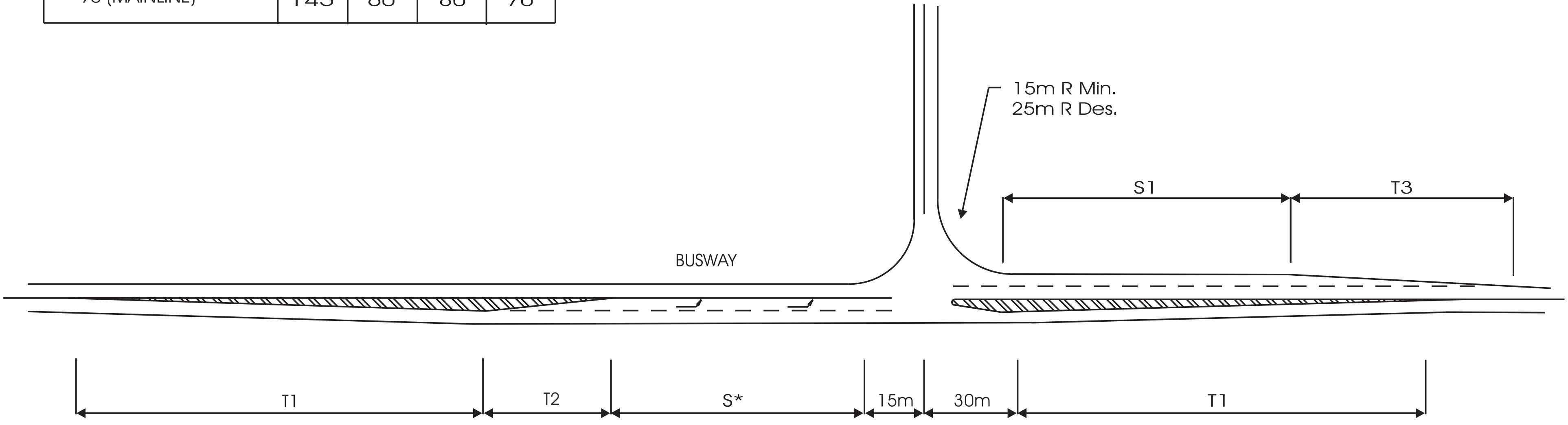
RAMP - OPEN DRAINAGE - CUT AND FILL SECTIONS (EARTH)

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	D-2

DESIRABLE LENGTHS

DESIGN SPEED km/h	T1 (m)	T2 (m)	T3 (m)	S1 (m)
60 (STATION AREA)	100	30	50	30
90 (MAINLINE)	145	60	80	70



$* \; S = \frac{NL}{100}$ WHERE N = VOLUME OF BUSES / HOUR TURNING
L = BUS LENGTH (20m)

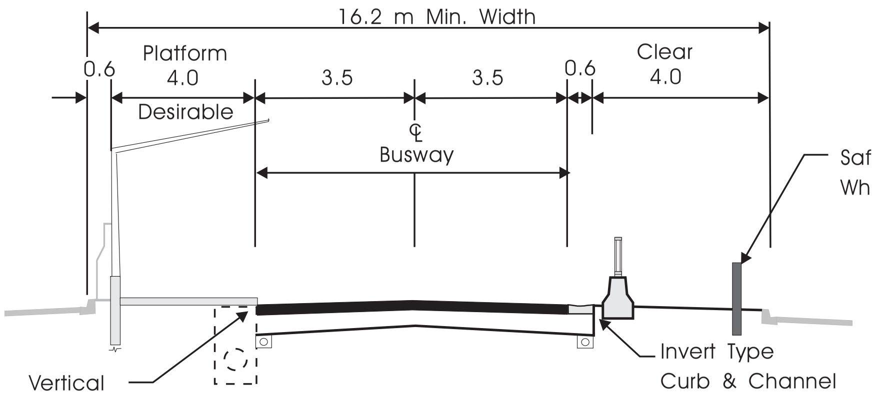
MINIMUM S = 75 m

CITY OF WINNIPEG TRANSIT SYSTEM

RAMP BUSWAY - TURNING LANE ARRANGEMENTS

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	D-3

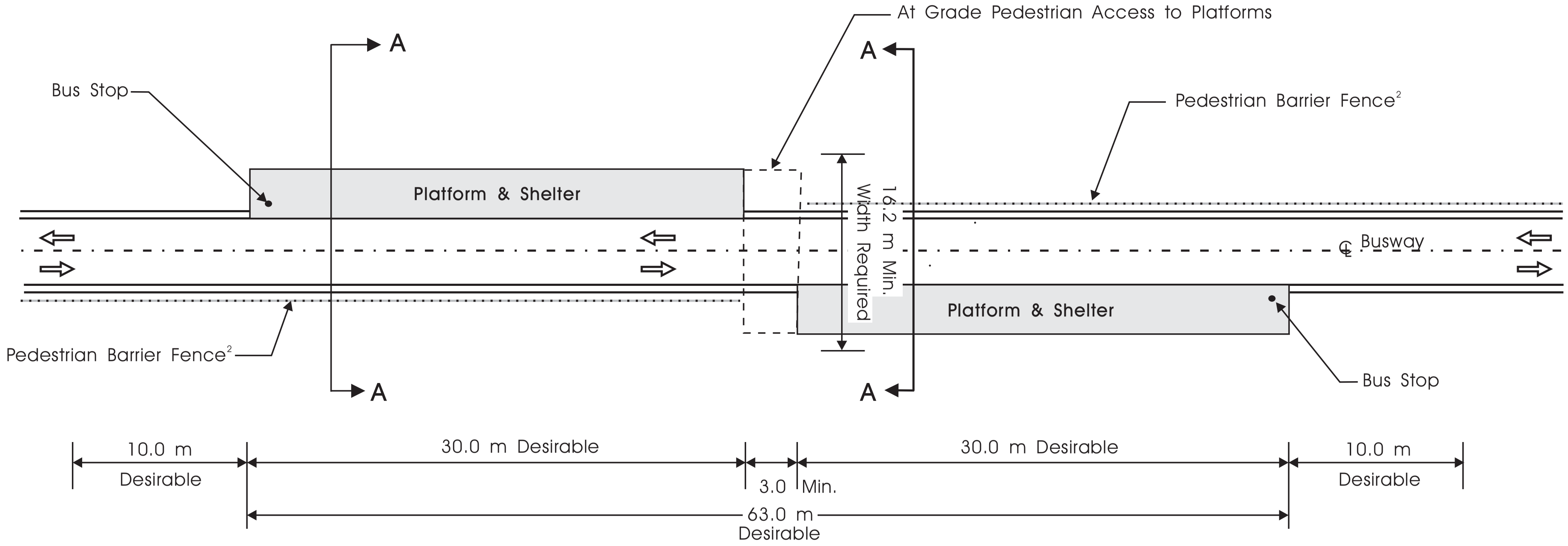


Section A-A

Notes :

1. If located in median or adjacent to roadway then safety barrier required.

2. For fence details see Dwg. No. E-6



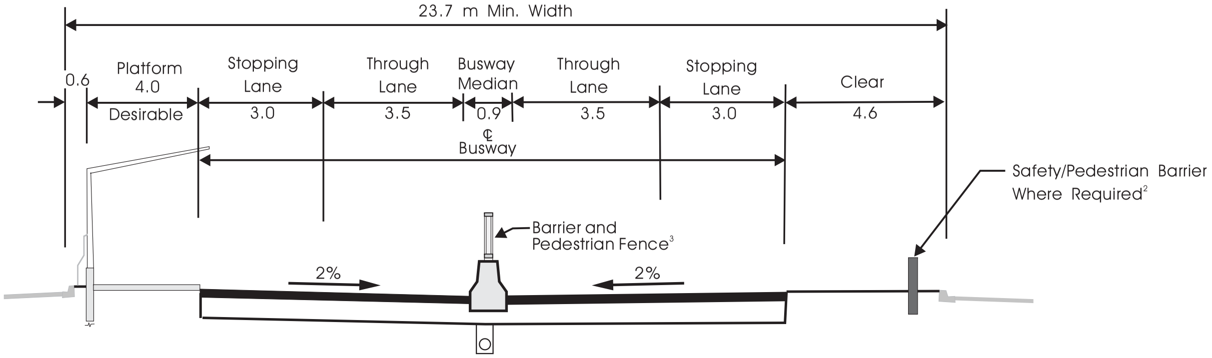
UNGUIDED BUSWAY - LOW VOLUME STATION

BUSWAY PLANNING AND DESIGN MANUAL

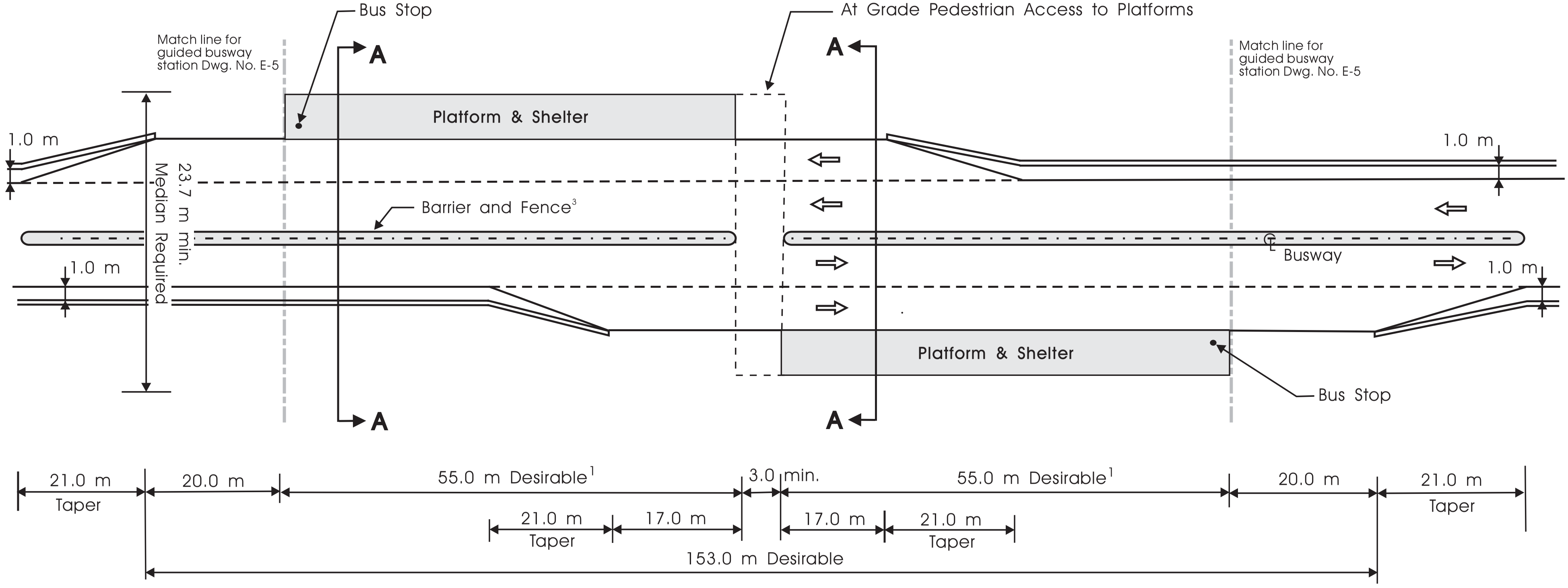
Date
Sept, 2004

Scale
N.T.S.

Dwg. No.
E-1



Section A-A



Notes :

1. Can vary between 30.0 m and 55.0 m
2. If located in median or adjacent to roadway then safety barrier required.
3. For fence details see Dwg. No. E-6

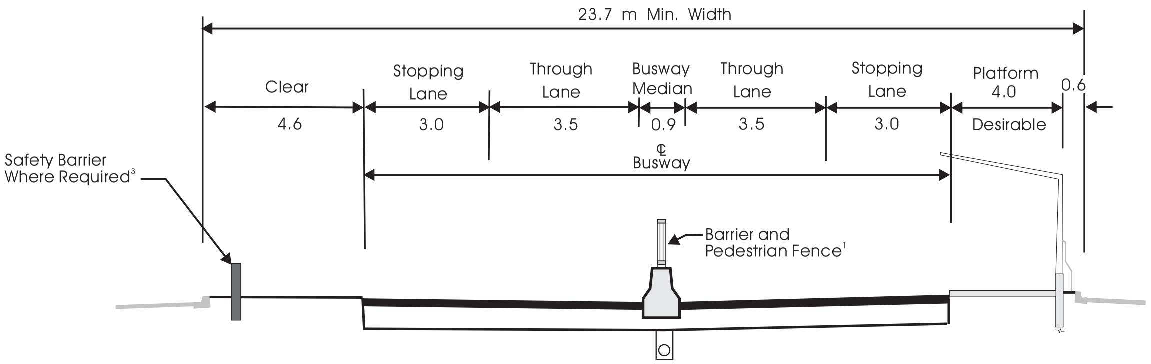
UNGUIDED BUSWAY - MEDIUM VOLUME STATION

BUSWAY PLANNING AND DESIGN MANUAL

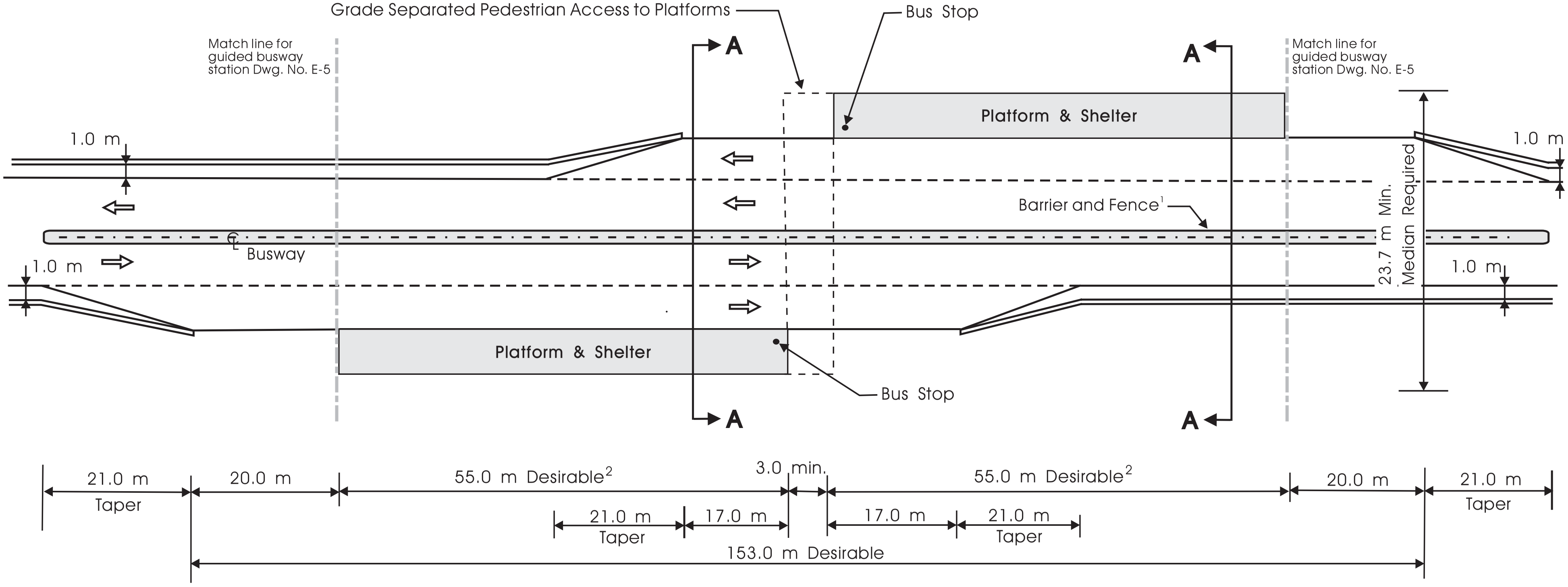
Date
Sept, 2004

Scale
N.T.S.

Dwg. No.
E-2



Section A-A



Notes :

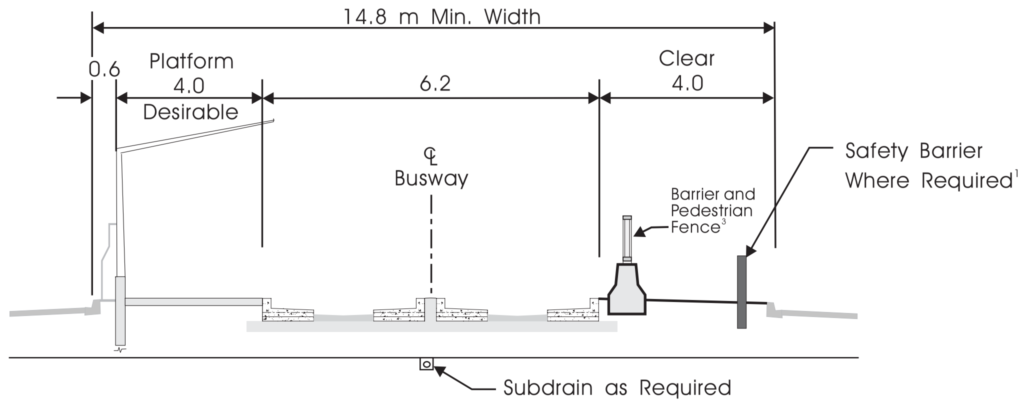
1. For fence details see Dwg. No. E-6.
2. Can vary between 30.0 m and 55.0 m
3. If located in median or adjacent to roadway then safety barrier required.

CITY OF WINNIPEG TRANSIT SYSTEM

UNGUIDED BUSWAY - HIGH VOLUME STATION

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	E-3



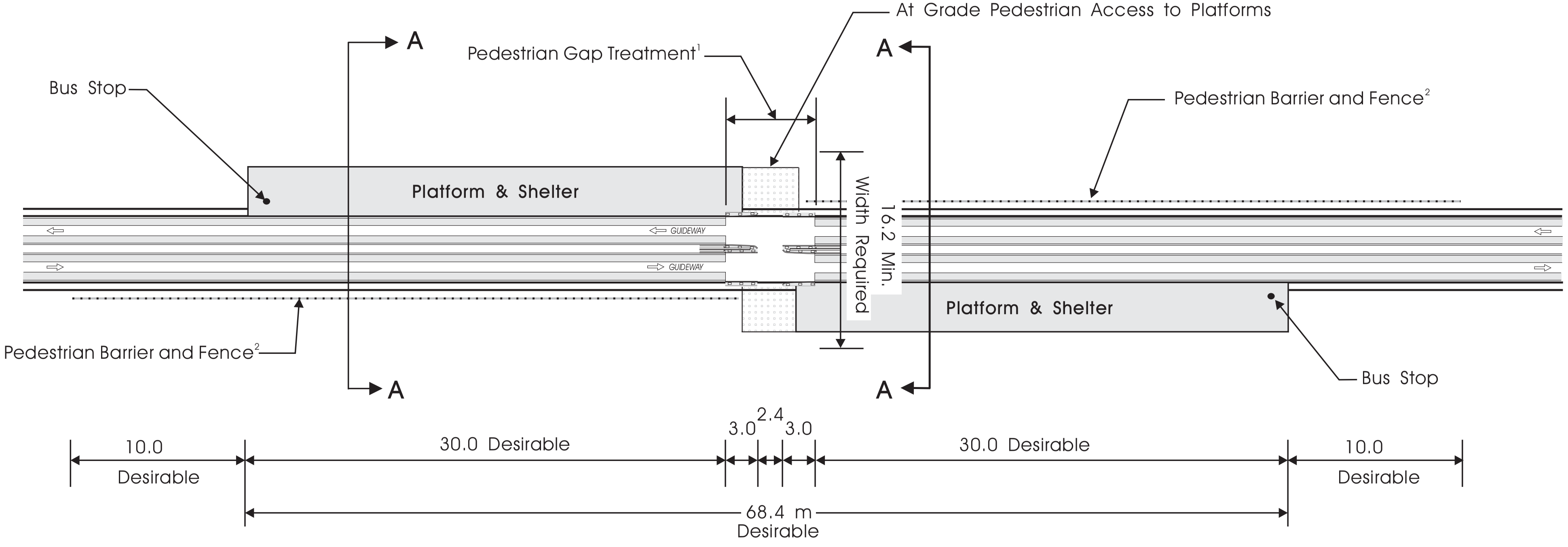
Section A-A

Notes :

1. See Dwg. No. C-3.

2. See Dwg. No. E-6.

3. If located in median or adjacent to roadway. Then safety barrier required.



ACT Planning &
Land Authority
Helping Canberra's future take shape.

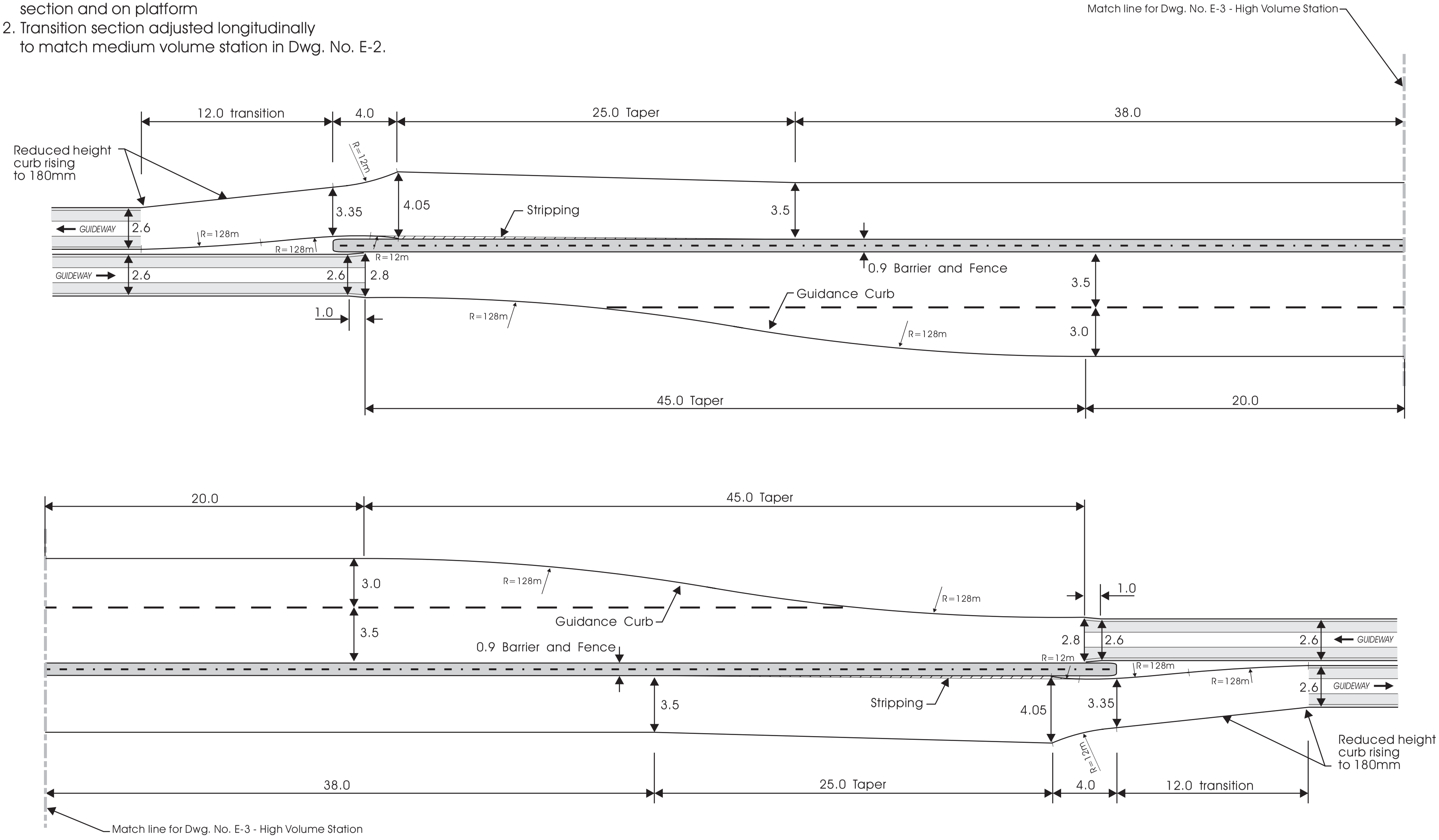
GUIDED BUSWAY - LOW VOLUME STATION

BUSWAY STATION DESIGN GUIDELINES

Date	Scale	DWG. NO.
November, 2004	N.T.S.	E-4

Notes :

1. Guidance curb continues through 45m taper and rises to 200mm in straight section and on platform
2. Transition section adjusted longitudinally to match medium volume station in Dwg. No. E-2.

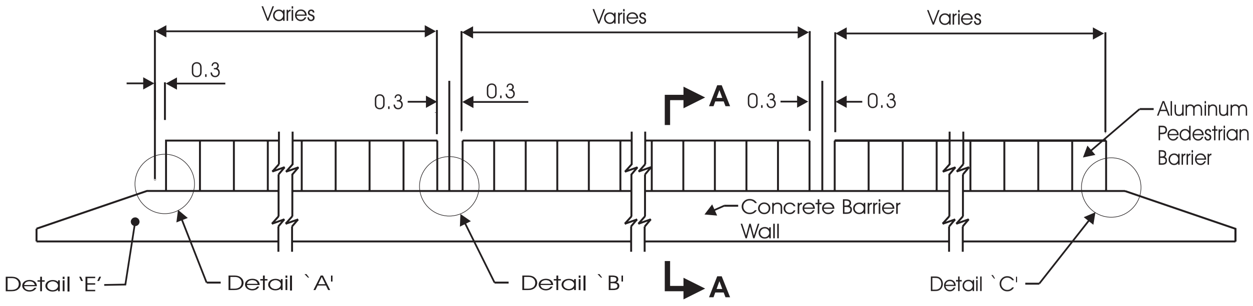


CITY OF WINNIPEG TRANSIT SYSTEM

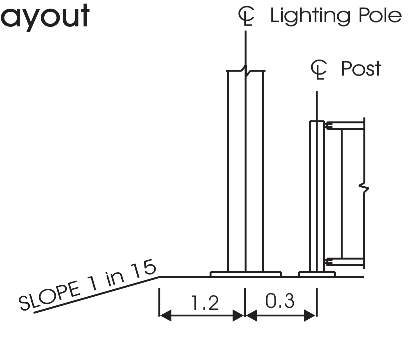
GUIDED BUSWAY - HIGH VOLUME STATION

BUSWAY PLANNING AND DESIGN MANUAL

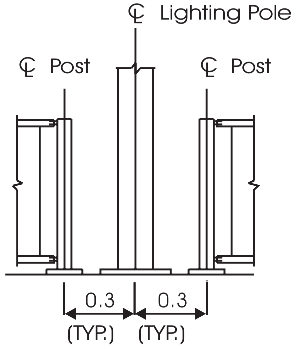
Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	E-5



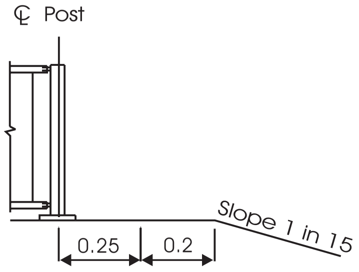
Pedestrian Barrier Layout
N.T.S.



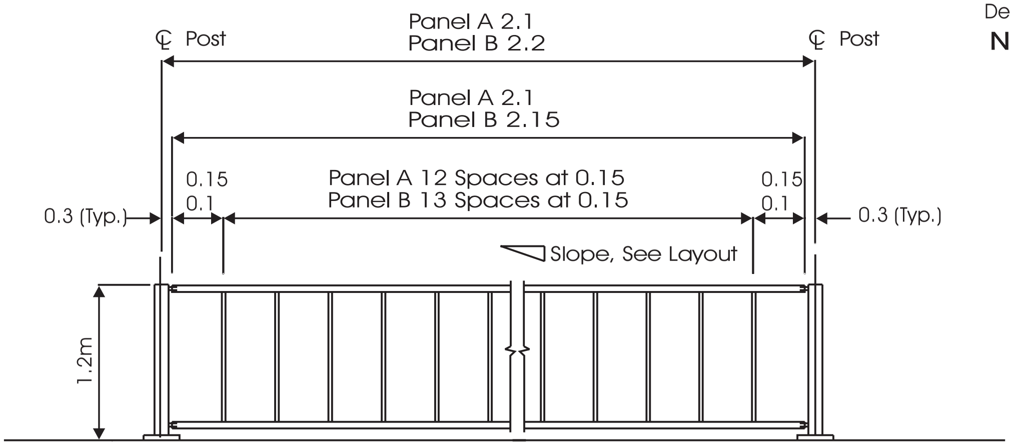
Detail **'A'**
N.T.S.



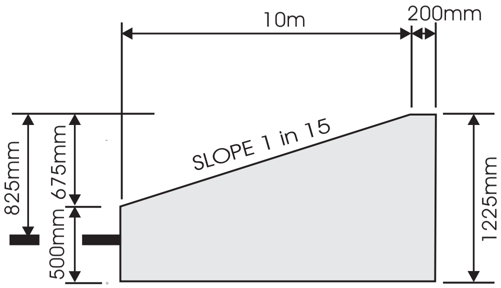
Detail **'B'**
N.T.S.



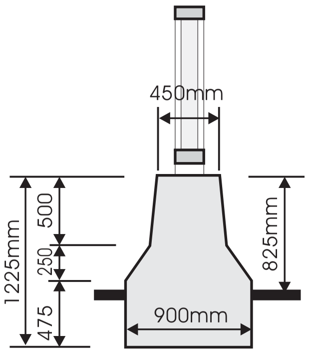
Detail **'C'**
N.T.S.



Intermediate Panel Detail
N.T.S.



Detail **'E'**
N.T.S.



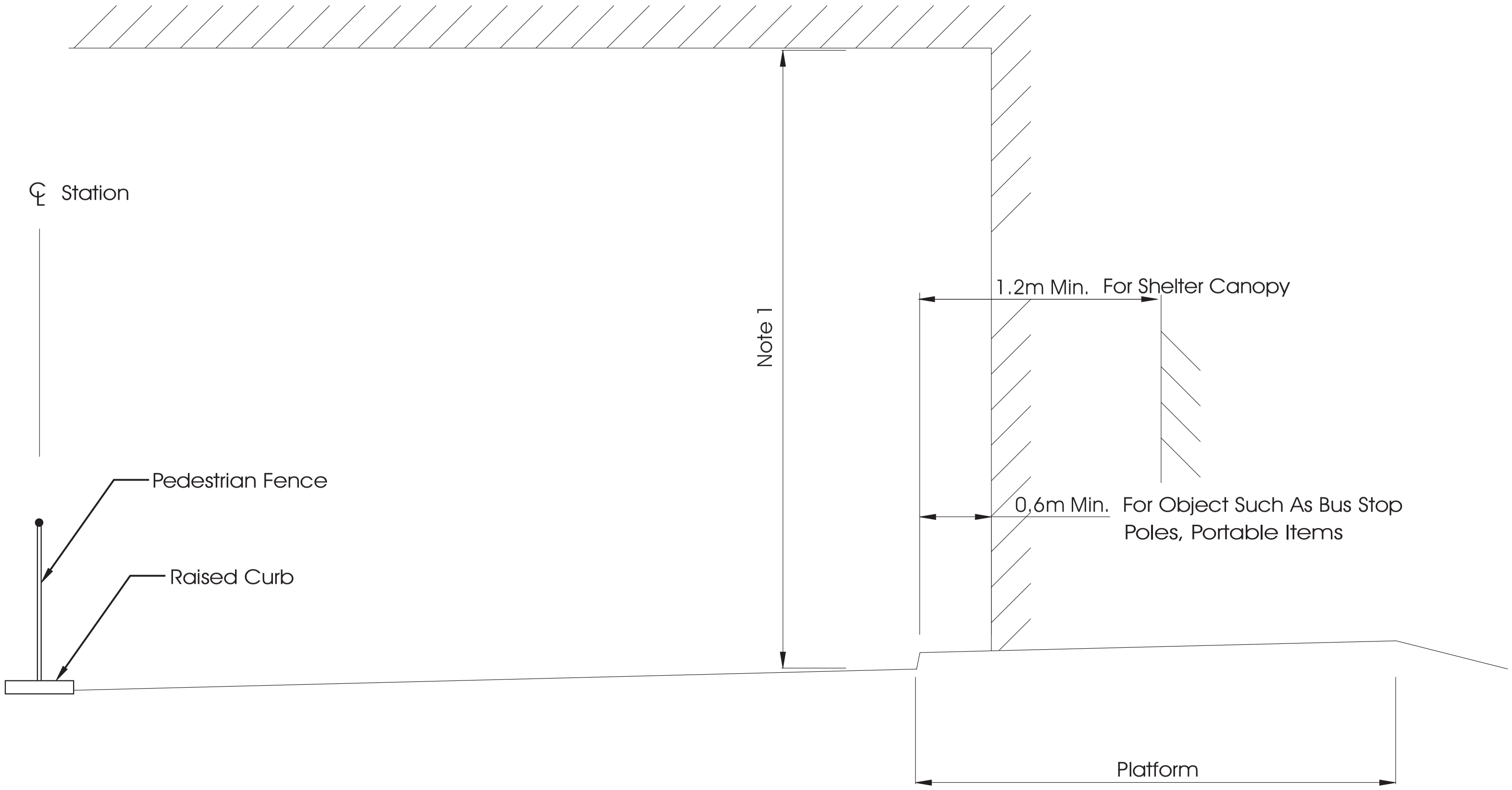
SECTION A-A
N.T.S.

Dimensions are in m unless otherwise indicated

CITY OF WINNIPEG TRANSIT SYSTEM

STATION MEDIAN ALUMINIUM PEDESTRIAN BARRIER

BUSWAY PLANNING AND DESIGN MANUAL	Date Sept, 2004	Scale N.T.S.	Dwg. No. E-6



Note:

1. Refer to Dwg. No. F2 and Table 3.2C

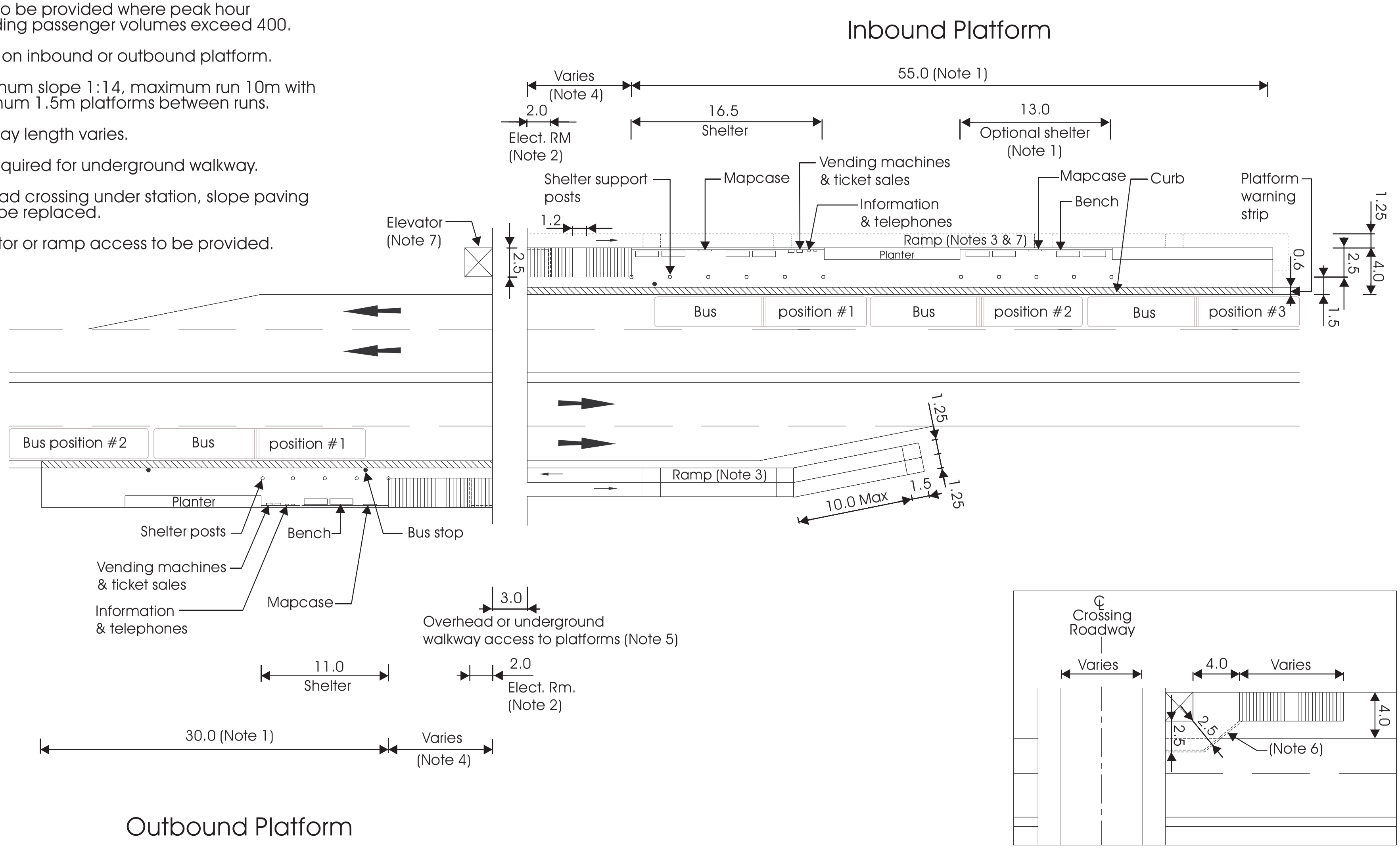
STATION PLATFORM CLEARANCES

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	E-7

Notes :

1. 55m to be provided where peak hour boarding passenger volumes exceed 400.
2. Either on inbound or outbound platform.
3. Maximum slope 1:14, maximum run 10m with minimum 1.5m platforms between runs.
4. Stairway length varies.
5. 6m required for underground walkway.
6. For road crossing under station, slope paving must be replaced.
7. Elevator or ramp access to be provided.



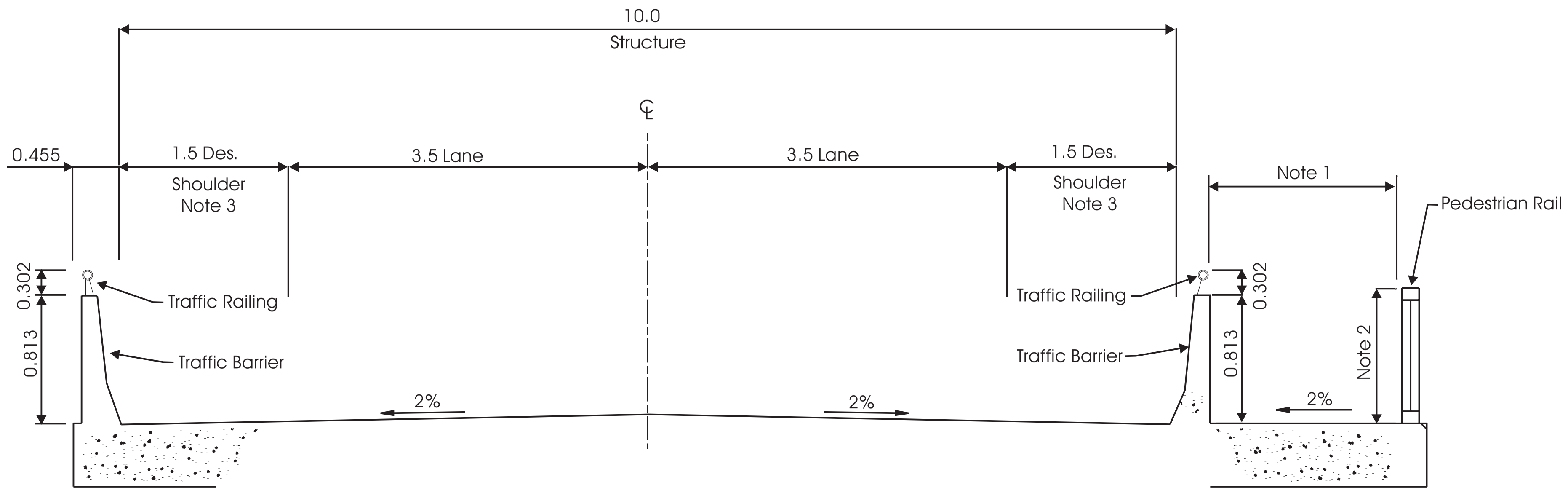
Typical Layout at
Station with Crossing Roadway

CITY OF WINNIPEG TRANSIT SYSTEM

TYPICAL STATION PLATFORM LAYOUT

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	E-8



Notes:

1. Where required, pedestrian or bikeway / pathway width shall be as follows

Walkway	2.0 Minimum
Bikeway / Pathway	3.0 Desirable 2.5 Minimum

2. Rail height shall be as follows:

Walkway	1.1 m
Bikeway / Pathway	1.2 m

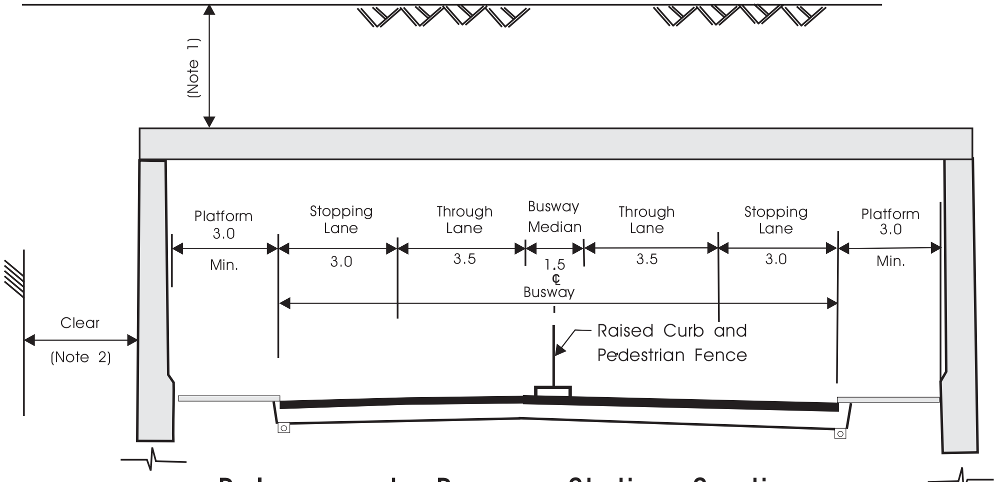
3. Shoulder may be reduced to 0.6 where restricted space applies.

CITY OF WINNIPEG TRANSIT SYSTEM

UNGUIDED BUSWAY BRIDGE CROSS-SECTION

BUSWAY PLANNING AND DESIGN MANUAL

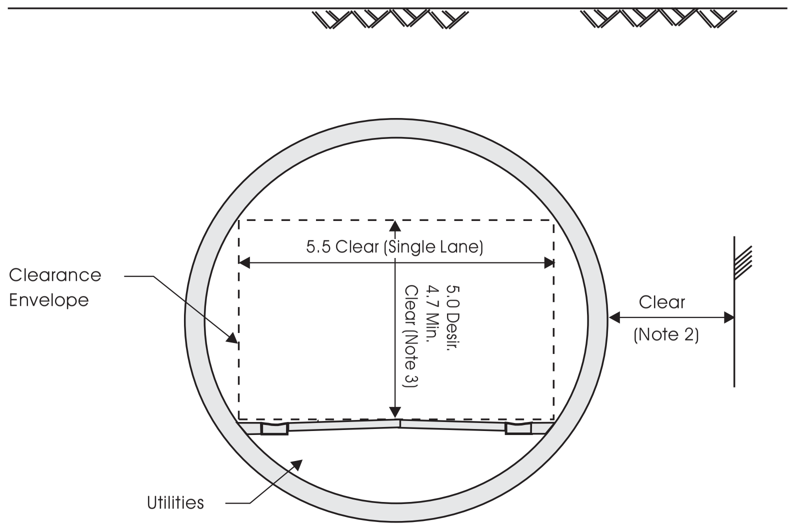
Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	F-1



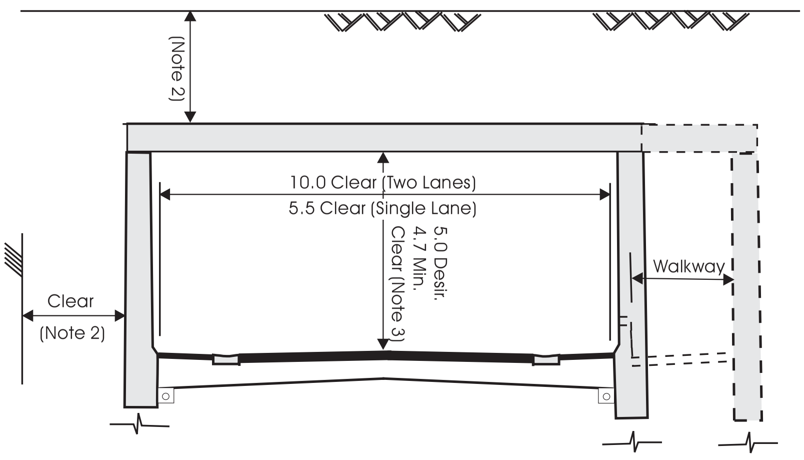
Below-grade Busway Station Section

Notes:

1. Clearance is for utilities. Greater cover may be required for Geotechnical reasons.
2. Clearance to other substantial structures requires extensive Geotechnical analysis.
3. Clearance is for buses only and does not include LRT requirements.



Tunnel Section



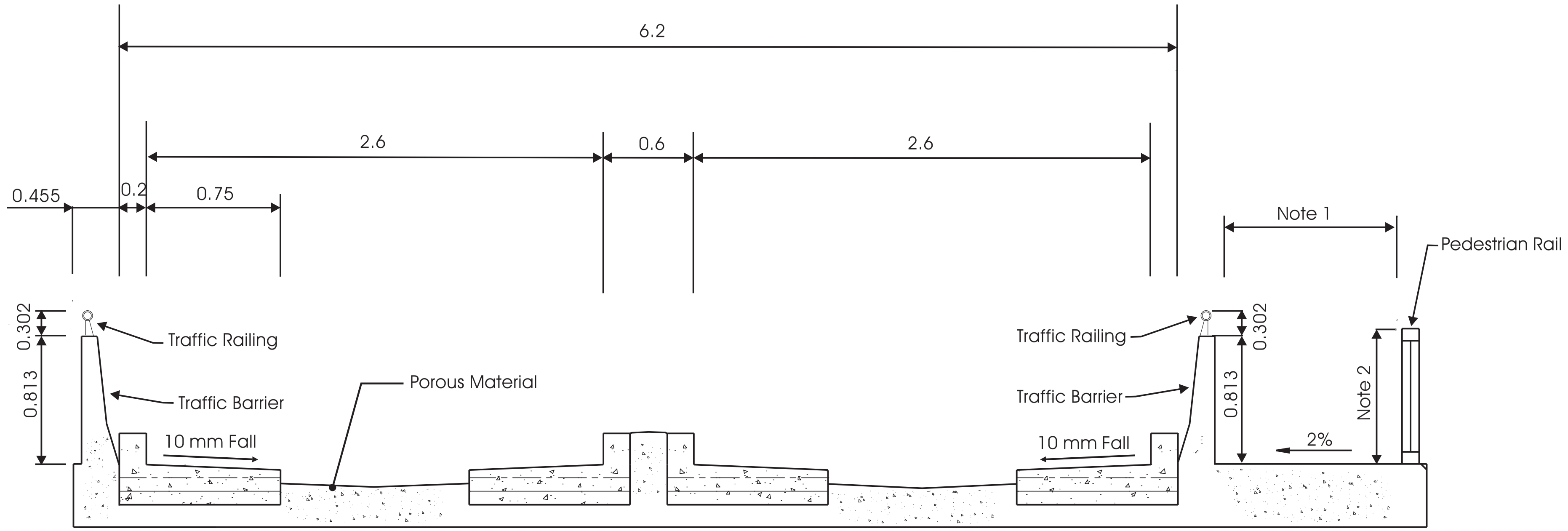
Cut & Cover Section

CITY OF WINNIPEG TRANSIT SYSTEM

UNGUIDED BUSWAY UNDERGROUND STRUCTURE SECTIONS

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	F-2



Notes:

1. Where required, pedestrian or bikeway / pathway width shall be as follows

Walkway	2.0 Minimum
Bikeway / Pathway	3.0 Desirable 2.5 Minimum

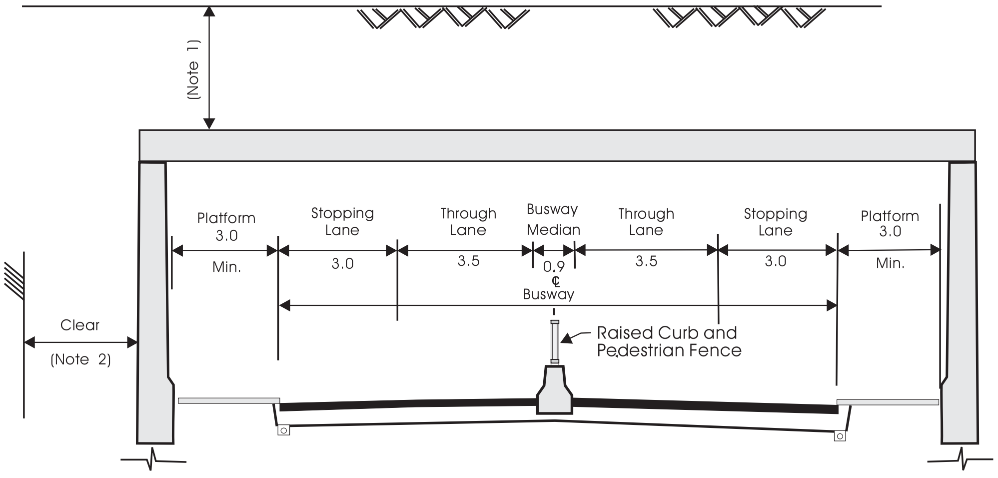
2. Rail height shall be as follows:

Walkway	1.1 m
Bikeway / Pathway	1.2 m

GUIDED BUSWAY BRIDGE CROSS-SECTION

BUSWAY PLANNING AND DESIGN MANUAL

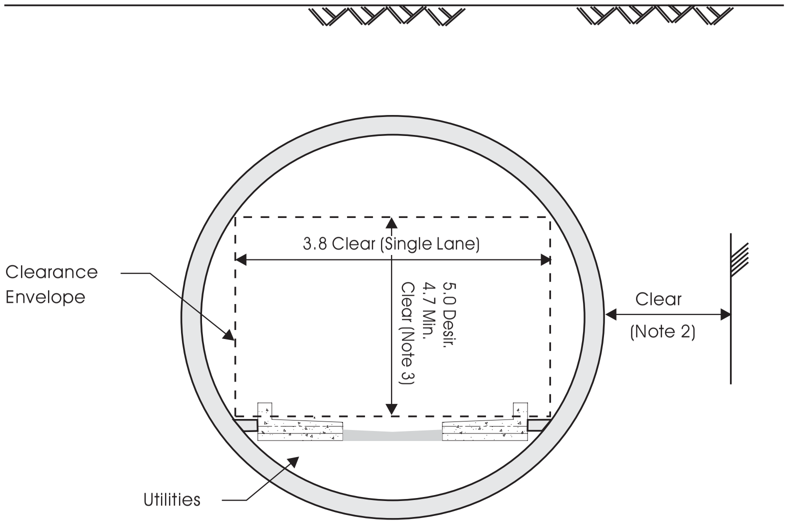
Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	F-3



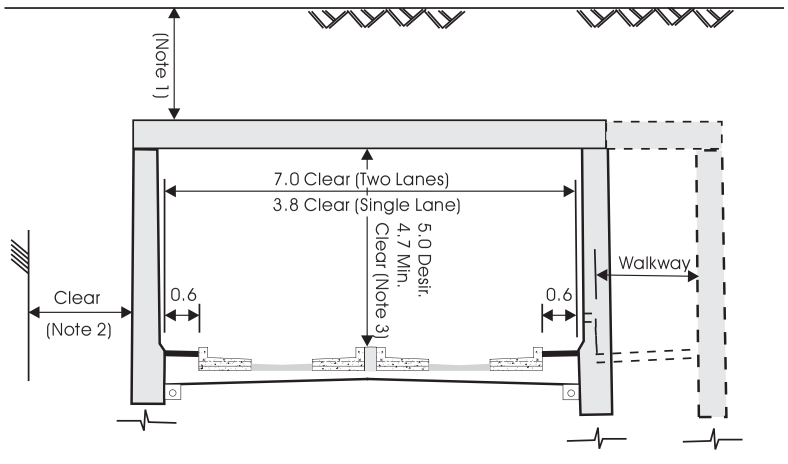
Below-grade High Volume Busway Station Section

Notes:

1. Clearance is for utilities. Greater cover may be required for Geotechnical reasons.
2. Clearance to other substantial structures requires extensive Geotechnical analysis.
3. Clearance is for buses only and does not include LRT requirements.



Tunnel Section

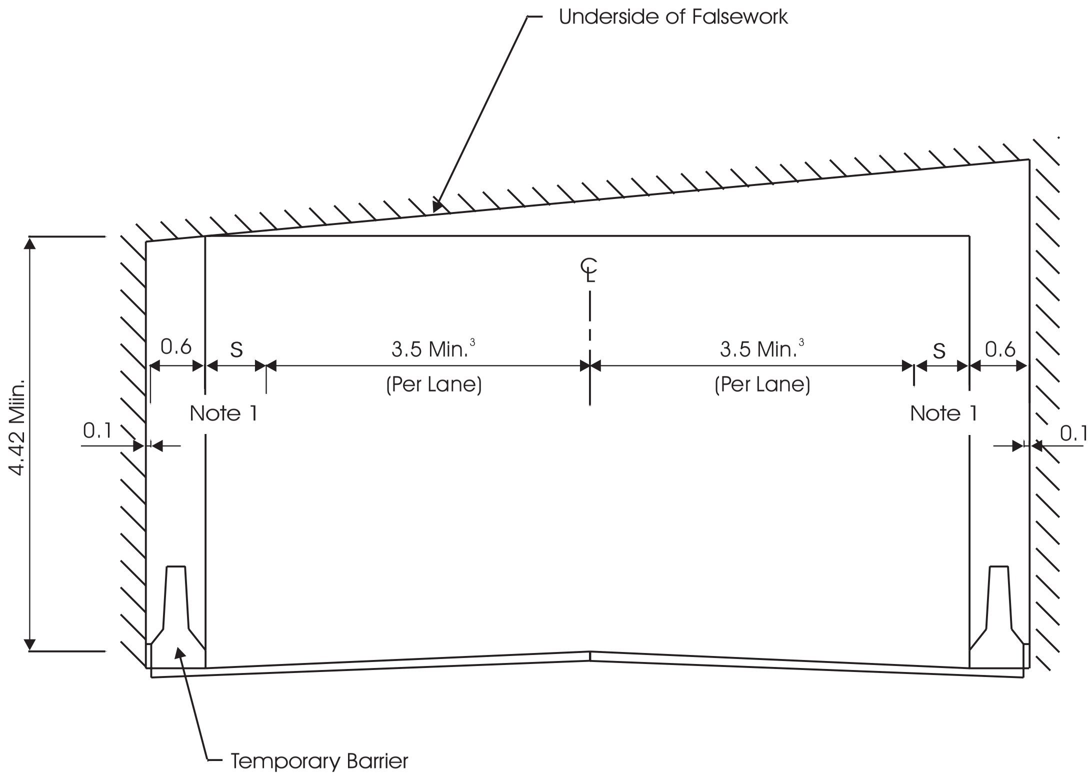


Cut & Cover Section

GUIDED BUSWAY UNDERGROUND STRUCTURE SECTIONS

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	F-4



Notes :

1. "S" shall be kept to an absolute Minimum. Consideration of the road alignment, class of road and required vehicle movements is imperative in determining "S".

   S = 0.5m minimum unless otherwise approved for unguided busways.
   For unguided busways S=0.0m minimum

2. Construction clearance over roadway shall conform to the requirements of the road controlling authority.
   Where no special requirements are imposed the minimum requirements of this standard shall apply.

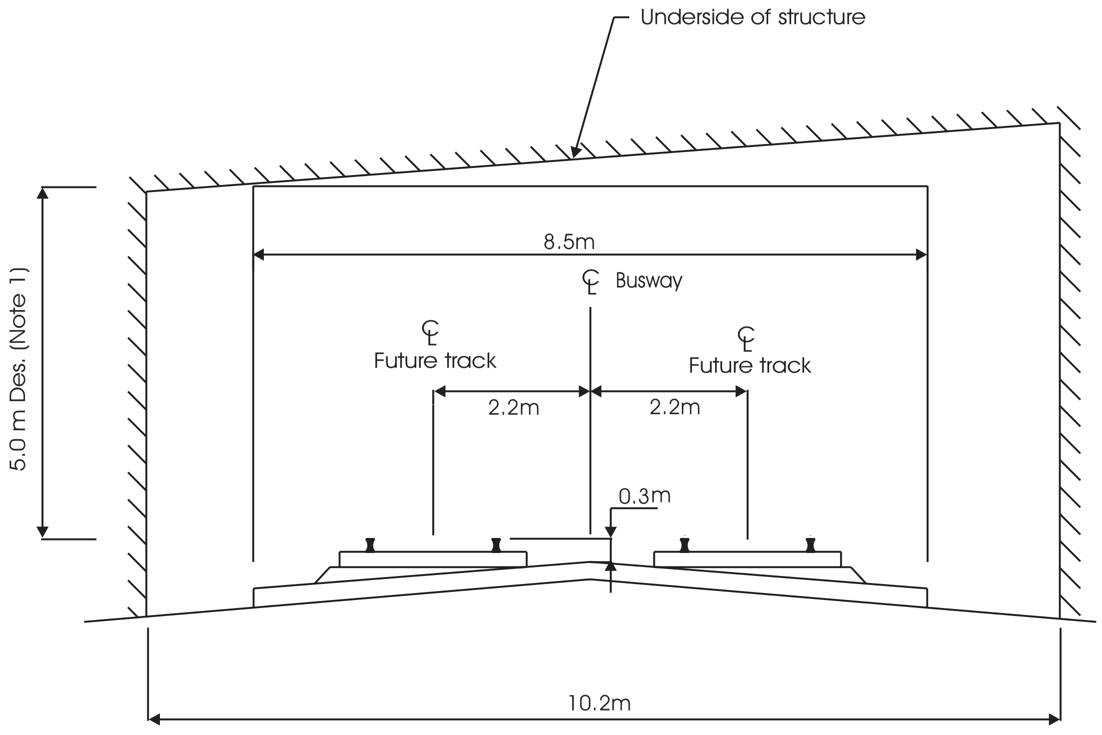
3. 3.1m for guided busways

CITY OF WINNIPEG TRANSIT SYSTEM

BUSWAY CONSTRUCTION CLEARANCES

BUSWAY PLANNING AND DESIGN MANUAL

Date	Scale	Dwg. No.
Sept, 2004	N.T.S.	F-5



Notes:

1. In specific locations where buses only will operate, the underpass clearance may be reduced to an absolute minimum of 4.7 m with permission by Winnipeg Transit

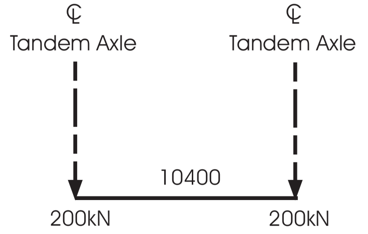
   Vertical clearance to underside of light pedestrian bridges shall be 5.5 m

2. Drawing shows future operation with LRT only. Where joint LRT/Busway operation may occur rails will be embedded in the concrete pavement. The desirable minimum clearance to the pavement shall be as shown in Table 3.2.b.

CITY OF WINNIPEG TRANSIT SYSTEM

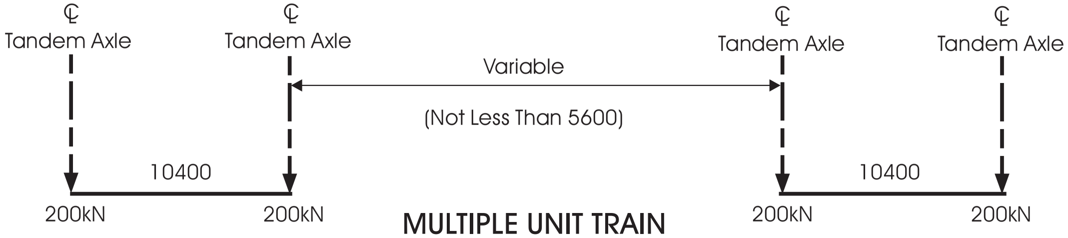
BUSWAY OVERPASS CLEARANCES - FUTURE LRT

BUSWAY PLANNING AND DESIGN MANUAL	Date Sept, 2004	Scale N.T.S.	Dwg. No. F-6



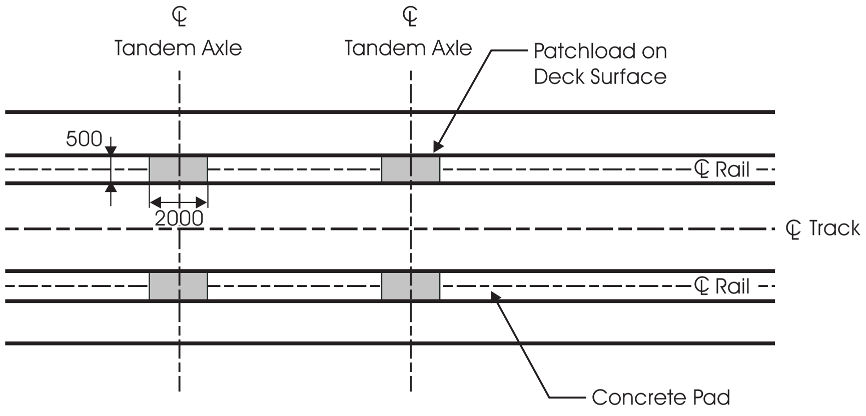
SINGLE UNIT

(VCW = kN)



MULTIPLE UNIT TRAIN

(No. OF UNITS - MAXIM. 6)



Notes :

1. Units shall be placed successively or spaced apart to produce maximum effects.
2. Patch load on top of deck allows for distribution through rail and concrete pad.
3. Rail loading shown are Vehicle Crush Weights (V.C.W)
4. For Serviceability Limit States Type 1 (Fatigue), use vehicle weight = 80% of V.C.W.
5. Vehicle Empty Weight (V.E.W.) = 75% of V.C.W.

CITY OF WINNIPEG TRANSIT SYSTEM

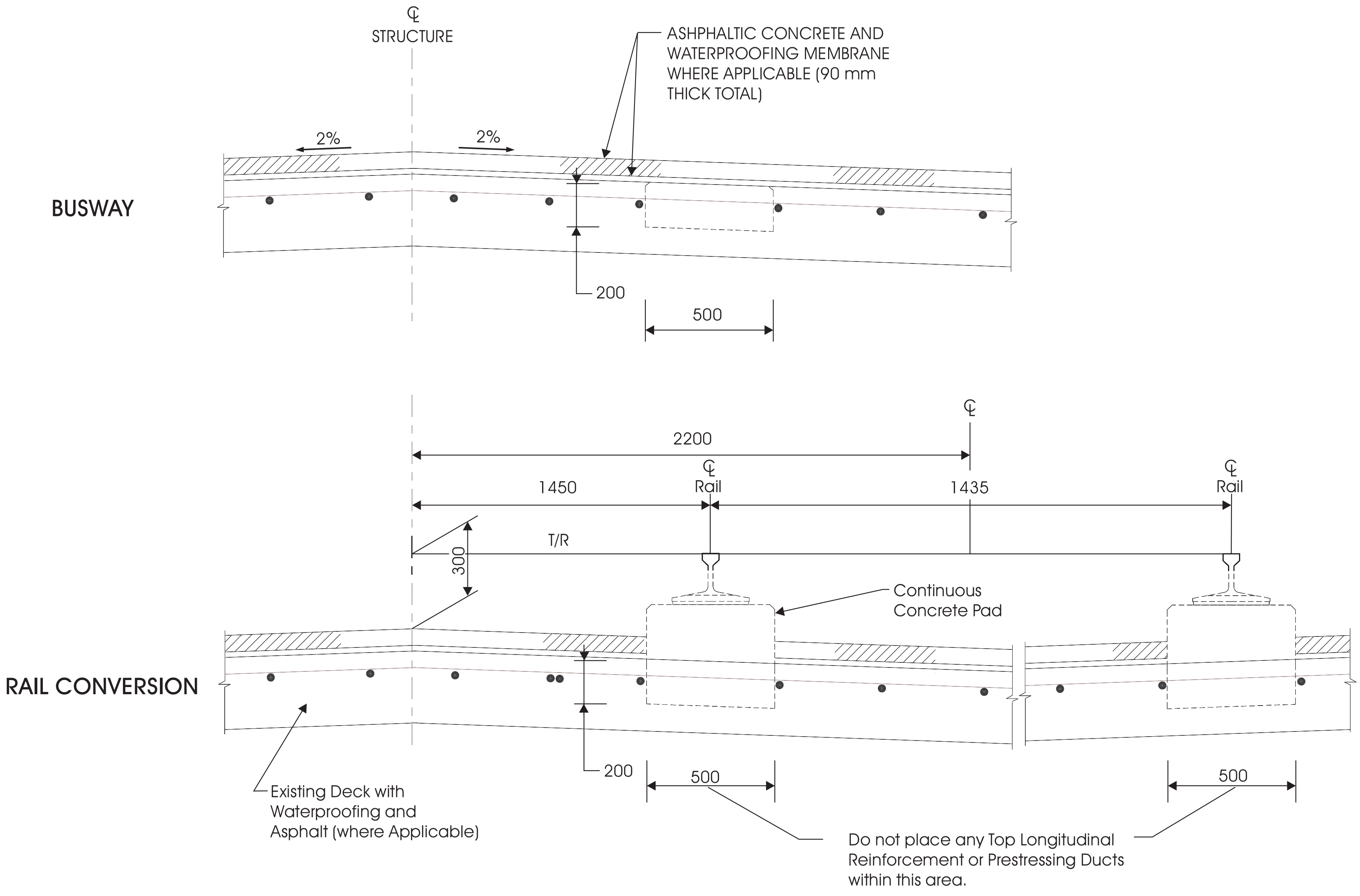
BUSWAY BRIDGE LOADINGS - FUTURE LRT

BUSWAY PLANNING AND DESIGN MANUAL

Date
Sept, 2004

Scale
N.T.S.

Dwg. No.
F-7



CITY OF WINNIPEG TRANSIT SYSTEM

BUSWAY BRIDGE DECK SPECIAL ARRANGEMENTS - FUTURE LRT

BUSWAY PLANNING AND DESIGN MANUAL	Date Sept, 2004	Scale N.T.S.	Dwg. No. F-8