MTO Design Supplement

For
TAC Geometric Design Guide (GDG) for Canadian Roads

Appendix 13

Work Zones

June 2023

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13.1 INTRODUCTION

This Chapter provides a general overview and best practices in designing construction work zones. The Chapter is not intended to be used as a stand-alone document when designing work zones. Designers should use the latest editions of the following manual and guidelines in conjunction with this chapter when planning and designing work zones:

- Ontario Traffic Manual (OTM) Book 7 – Temporary Conditions,
- Roadside Design Manual (RDM),
- TAC Geometric Design Guide (GDG), and
- MTO Design Supplement for TAC GDG

The guidance contained in this chapter is intended to directly guide work zone planning and design decisions associated with construction of highways in Ontario. In general, this chapter provides information for the road designer to develop a safe and well-conceived traffic control and staging plan through work zones including work zone options/techniques, and roadside environment. Specifically, this chapter provides geometric design details, characteristics, and physical infrastructure of roadways within work zones. In other words, this chapter is intended for use in conjunction with the *OTM Book 7, TAC GD*G along with *MTO Design Supplement* for *TAC GDG,* and the *RDM*, not as a substitute.

13.2 OBJECTIVES AND IMPACT CONSIDERATIONS

The fundamental objectives that designers should aim to achieve for their work zone designs are safety, mobility, and constructability. These objectives should be assessed throughout the planning and design stages of projects. These objectives aim to:

- Maximize the safety of all road users including construction workers.
- Maximize the mobility and accessibility on roadways during construction.

To achieve these objectives, an iterative process is required in the work zone design process and is based on impact assessments. The challenge for the work zone designer is to find the best balance between these key priorities. The end goal is to have an effective and efficient Traffic Staging Plan (TSP) that is constructable, while considering risks and appropriate cost in context of the temporary duration of each stage.

The designer should consult with the project team when considering the following factors for safety, mobility, and constructability:

- Project characteristics
- Travel and traffic characteristics
- Corridor, network, and community issues
- Design, procurement, and construction options
- Work zone design and safety issues
- TSP strategies
- Transportation operations strategies
- Public information strategies

The Federal Highway Administration (FHWA) guide *"Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects"* has a thorough discussion on assessing construction impacts, including a list of examples of useful information that may be gathered in consultation with the project team and stakeholders for use in the impact assessment. **Exhibit 13-A** provides an overview of various work zone impacts considerations.

Exhibit 13-A

Work Zone Impact Assessment

Project Characteristics	Project type Project size, extent, duration, and complexity Roadway classification Area type (urban, suburban, rural)
Travel and Traffic Characteristics	Traffic demand and volumes, including those for active transportation Seasonal and temporal variations in demand (hourly, daily, or weekly) Occurrence of special events Percentages of different vehicular volumes: Single-occupant, Multi-occupant; trucks; or buses) Type of traveller (commuter or tourist), freight corridor, transit corridor Public and private facility access issues Potential impacts of seasonal weather (snow or rain) Improvement in traffic operation produced greenhouse gases
Corridor, Network and Community Issues	Impacts of the project at both the corridor and network levels including parallel corridors, alternate routes, the transportation network, other modes of transportation, and impacts of other work zones in the vicinity of the project, either at the corridor level or the network level Impacts on nearby transportation infrastructure such as key intersections and interchanges, railroad crossings, public transit junctions, and other junctions in the transportation network Impacts on evacuation routes in the vicinity of critical transportation or other infrastructure Impacts on emergency services when there are no other alternative routes are available Impacts on affected public properties for recreational facilities and institutional Impacts of the project on affected private properties, including businesses and residences

Design, Procurement and Construction Options	Temporal alternatives for work performance such as season, month, day of week (weekend versus weekday), and time of day (night time versus day time, off-peak versus peak) Alternative lane closure strategies such as full closure, partial closure, crossovers, multiple lane closure, single lane closure, and impact of alternative transportation management strategies on lane-closure decisions Various design solutions address the durability and economy of maintenance of the roadway Alternative design solutions that impact decision-making on right-of-way acquisition, Alternative construction staging plans, and construction techniques and methodologies that may have varying types and severity of work zone impacts Alternative contracting methodologies such as design-build, etc. Accelerated construction techniques such as rapid bridge replacement prevent long-term queuing and resultant greenhouse gases produced
Work Zone Design and Safety Issues	Cross-sectional issues such as lane and shoulder widths availability Changes in elevation such as sudden transvers and edge pavement drops Longitudinal issues such as taper dimensions and stopping sight distance Horizontal and vertical sight distance Headlight glare from opposing traffic Project signing and advance warning Roadside devices and safety Work area separation, channelization, and protection (e.g., positive separation, barrels, cones, clear zone considerations, construction zone intrusion detection) Work area and worker delineation (visibility, retroreflective, etc.) Work site access and access points Visibility issues (e.g., night-time work lightning, fog) Curvature and gradient – vertical and horizontal Speed – posted and advisory speed limits, speed zone, etc. Work zone
Traffic Staging Plan Strategies	Traffic safety and capacity requirements Alternate route scenarios Potential impacts on other corridors, nearby intersections/interchanges etc. Project signing layout in combination with existing sign, lane closure types and strategies (full-closure, lane-width restrictions, crossovers, positive separation, etc.) Work zone and work configurations, Traffic safety and control checklists for developing a Transportation Management Plan

Traffic Operation Strategies	Deployment of ITS technologies for work zone traffic monitoring and management Provision of real-time traveler information to the public, including web-based information Application of transportation systems management (TSM) and corridor management strategies, including mitigation treatments for alternate routes (e.g., traffic signal timing adjustment on affected corridors), and alternate modes (e.g., public transit incentives etc. Coordination of various transportation management centers Conduct of mobility and safety reviews and audits Speed enforcement and management in work zones using police officers or cameras Traffic incident management plans for work zones Policies on work zone transportation management during emergencies (rain flooding etc.)
Public Information Strategies	Provision of project and work zone information prior to start of the work to make the public aware of the expected work zone impacts and the ministry's actions to mitigate the impacts Advice to public on commuter alternatives, such as information on routes and/or modes Provision of information on changing conditions on the project during implementation (e.g., changes in lane closure scenarios, construction staging, construction times, or alternate routing) Obtaining public input for the development of appropriate work zone impacts management strategies during the planning and design phases of the project; refinement of work zone management strategies during project implementation; and feedback on performance of the work zone and the project following the completion of the project Dissemination of information through brochures, pamphlets, and media sources including newspapers, television, radio channels, and web sites Public Information Centres, coordination and cooperation with affected public/private parties

Source: FHWA Work Zone Impacts Assessment: An Approach to Assess and Manage Work Zone Safety and Mobility Impacts of Road Projects

Construction sequence and operation is dependent on the assessed impacts which is linked with situational constraints. Situational constraints include factors relating to the physical space, the local environment, corridor mobility needs, prevailing traffic patterns, and the need to address specific safety concerns, such as safely accommodating all user types throughout the duration of the project. The level of detail on these assessments increases as the design progresses.

If a project is identified as "significant" in terms of road user safety, constructability, traffic operations and environmental constraint; more comprehensive plans identifying and assessing transportation operation and public information strategies may need to be developed and may result in a stand-alone work zone planning product.

13.3 TRANSPORTATION MANAGEMENT PLAN

The key concept of Transportation Management Plan (TMP) is the use of comprehensive and consolidated information relating to traffic management issues. Good work zone management principles for highway construction projects incorporate elements to ensure that traffic management issues are addressed proactively in the early stages of project planning and continuing through construction. The key issues are:

- road user and worker safety,
- information to road users,
- maintaining adequate level of service of traffic, and
- ability of enforcement by police.

Depending on the complexity of the project, a TMP may include information on strategies that will be deployed to improve the mutual safety of workers and the traveling public, or to provide ongoing communication and coordination with local residents through a public information campaign. For details, designers should refer to the *OTM Book 7.*

13.3.1 Traffic Staging Plan

Traffic Staging Plan (TSP) is a sub-set of the TMP and Traffic Control Plan (per *OTM Book 7*) which describes in detail how traffic movements (including all modes present in the vicinity of the project) should be maintained during each construction phase/stage of a project. The TSP should at a minimum include the following:

- plan-view layout drawings of temporary travelled ways,
- cross section of the roadway including cross slope,
- longitudinal profile of the temporary travelled ways,
- temporary Traffic Control Devices (TTCDs) including pavement markings, signs, and signals,
- temporary construction barriers and crash cushion/attenuators.

A properly developed TSP is a crucial piece of documentation wherein the designer communicates to the contractor the sequence for the project to be built and represents a significant part of the contract documents. A clear, detailed, and well-thought-out TSP can assist in a project being constructed safely and efficiently. However, a poorly written, incomplete, insufficiently detailed, or non-existent TSP frequently causes disagreements between the parties that result in delays, cost overruns, change orders, litigation, or questions of liability. Special attention is required during the design process on how the contractor will have access to and egress from the work site, including the delivery of materials, locations for storing and producing materials, timings of ingress and egress, and worker parking. On complex projects such as interchanges and lengthy projects, at least one useable worksite delivery location should be identified, including how delivery and haul trucks can safely accelerate and decelerate into and out of the traffic flow for each TSP. The designer's role in developing a suitable TSP requires professional knowledge and judgement both in design and constructability considering factors beyond a tunnel-vision focus. Factors that should be considered when developing TSP include:

- Ensuring that TSP will allow the contractor to construct the project to meet the contract quality requirements.
- Developing the necessary TSP by providing design instructions as concisely as possible to ensure there is sufficient clarity and unambiguity for the contractor to implement the TSP and contract administration staff to inspect the work.
- Showing sufficient detail in the plans and cross sections or notes to fit the construction project circumstances to provide safety and maintain traffic flow during the project. To accomplish this, the TSP may have components that range from merely referencing the application of appropriate *OTM Book 7* and *RDM* devices*, Ontario Provincial Standard Specifications (OPSS), Special Provisions (SP), Ontario Provincial Standard Drawings (OPSD)* and *Ministry of Transportation Drawings (MTOD)*, and finally to the incorporation of contract-specific design details.
- Providing a high degree of TSP and design consistency with other highway improvement projects with similar traffic characteristics to the project.
- Providing details of all TTCD and ensuring they are placed no sooner than required and removal of all such TTCD as soon as the work is completed.
- Allowing disruption to traffic flow only to the degree necessary to safely construct the project.

13.3.2 Constraints in Traffic Staging Plans

There may be a lot of obvious and hidden constraints that affect the development of TMP and TSP. The designer should consult with the regional Traffic, Maintenance, and Corridor staff when developing the TSP. The following constraints should be considered at a minimum:

- Adjacent Construction Projects
- Utilities,

- Property Acquisition
- Drainage
- Accessibility and Active Transportation
- Recreational Trails
- Transit
- Statutory Holidays and Events
- Environment, and
- Availability of Alternative Routes

The above list is not exhaustive. The Designer should investigate other constraints through discussion with the project team and reviewing previous records and design reports of the highway.

13.3.2.1 Adjacent Construction Projects

The designer should consider the adjoining construction projects limits in consultation with the project team when TMP and traffic staging is being planned. During construction, the contractor and contract administration staff should ensure that that construction operations are carried out without interfering with other adjoining projects/contracts. Coordination with and consideration of other project should start early in the design to resolve potential conflicts with adjoining projects ahead of time. This is especially critical and may be costly if the projects are under the control of another jurisdiction/municipality. If TSP is coordinated or completed for adjoining projects, detailed specific information must be included in the contract tender document to avoid potential delays, cost and the ministry becoming a constructor.

13.3.2.2 Utilities

Identifying and locating all overhead and underground utilities within the highway right-of-way or acquired right-of-way for a construction project should be accomplished during the development of the TMP and available to the designer developing the TSP. Location of utilities during preliminary design phase is essential to help minimize any overrun of resources and time. Identified utilities during design phase should be reconfirmed by the contractor in the very early stage of the project/contract to avoid any delays and change orders.

Where utility relocations and adjustments are not feasible prior to the commencement of construction operations and done concurrently with project construction operations, the utility work operations must be closely coordinated with construction operations. Coordination requirements should be set out clearly in the contract document, including any TSP that is needed for the utility company to follow and coordinate with the contractor. It is very important that any utility coordination required during construction is done such that the ministry does not become a constructor.

13.3.2.3 Property Acquisition

Acquiring additional property for the purpose of work zone/traffic staging is both time consuming and costly. The designer should make best and reasonable effort to keep the design within the existing right-of-way limits wherever possible and only resort to acquiring additional property (temporary or permanent interest) when necessary.

13.3.2.4 Drainage

Positive drainage should be provided during all stages of a contract. At the design stage, consideration to storm water and drainage management should be essential. Different options and their impacts should be analyzed; care should be taken to avoid or minimize impact on existing drainage; an example is filling or reducing their capacity for use as a temporary driving lane. Drainage impact when using temporary construction barriers should also be reviewed to ensure that storm water is adequately directed away from the driving lanes. For specific details designer should refer to the latest edition of ministry's *Highway Drainage Design Standards,* specifically Sections of *TW-2 Highway Drainage Management for Temporary Works* and *TW-1 Return Period of Design Storms for Temporary Works.*

13.3.2.5 Accessibility and Active Transportation

The TSP design should include accesses for local property owners. This may require constructing alternate facilities for pedestrians and bicyclists and should be in compliance with the Highway Traffic Act and the Accessibility for Ontarians with Disabilities Act, and all associated regulations under these Acts. Existing pedestrian sidewalks and paths should be kept continuous as much as possible. The alternate facilities should provide a smooth, firm, stable, slip-resistant, and continuous hard surface throughout the entire length of the temporary pedestrian facility. The designer should minimize abrupt changes in grade or terrain that could cause tripping or be a barrier to wheelchair use.

13.3.2.6 Recreational Trails

The designer should consider crossing and adjoining of any recreational trails within the work zone. If trails are seasonal such as snowmobile trail, the designer should ensure provisions are in place during appropriate seasons, including how continuity can be safely maintained. Stakeholders should be consulted, and proper signing should be in place.

13.3.2.7 Transit

The designer must consider how any transit stops within the work zone are impacted including provisions for safe ingress/egress, accessible access and short-term relocation impacts.

13.3.2.8 Statutory Holidays and Events

The designer should consider statutory holidays and any special events when developing TSP. The ministry's General Conditions of Contract doesn't allow contractors to perform construction operations on statutory holidays unless specially permitted otherwise by the ministry or contract administrator. The TSPs and construction operations should be optimally planned around these restricted periods to accommodate maximum volumes of traffic on available lanes before switching to a new traffic pattern.

Festivals and events that generate unusually high traffic volumes in the construction corridor may also dictate the type of construction staging concept that may or may not operate efficiently. Identifying when non-events will occur in the corridor may also be desirable for specifying when certain types of traffic strategies should occur to best accommodate certain types of work, for example, full road closure of roadway to install a major lateral storm water crossing or place overhead bridge beams.

13.3.2.9 Environment

The traffic staging designer should always consider environmental constraints such as fisheries in watercourses and their breeding periods, wildlife along both sides of highways, and Endangered Species Act. The designer should also be aware of the impacts of access roads or temporary staging areas built within the right-of-way; special attention should be given to known archaeological sites as it may need time to investigate and get required clearances, particularly within indigenous communities.

13.3.2.10 Availability of Alternate Routes

Availability of alternative routes is an important aspect and a constraint especially in rural, northern Ontario, and indigenous communities. The designer should consult the project team, municipality, Local Road Board and other stakeholders to assess the impacts at such locations. This will also severely impact access for emergency services.

13.4 PLANNING AND MITIGATION TECHNIQUES

Maintaining acceptable level of service for existing traffic during construction operations require a systematic transportation management planning and staging. For large and multi-year construction projects, the planning and analysis begins during the Transportation Management Plan (TMP) development and approval process. However, for less significant, smaller projects, the Traffic Staging Plan (TSP) may occur concurrently with the overall project design and without an early focus. In northern Ontario, TSP may not be required for less significant projects. However, regardless of when TMP planning occurs, it is a critical element in the overall planning and design of the projects. Alternative work zone techniques along with their impacts, mitigation, and cost should be evaluated at the same time and in conjunction with other planning and design factors. Impacts due to work zone planning may take the form of traffic congestion, interruption of economic activities, cost overruns, decreased constructability, adverse safety issues, disturbance of local traffic patterns including active transportation, environmental issues, and public complaints.

For projects where substantial traffic and safety impacts are anticipated, a larger planning and design effort is needed. Besides using conventional construction management techniques provided in this section, other traffic operation and public involvement strategies, such as traffic demand reduction measures, incident management, and advanced traveler information systems are useful and should be explored.

All construction projects require a strategy or set of strategies that will accommodate construction activities while maintaining acceptable traffic operation in terms of safety and capacity. The following strategies may be adopted as a stand alone or in combination:

- Use of shoulder,
- One lane, two-way operation,
- Lane constriction,
- Lane closure,
- Diversion,
- Median crossover,
- Detour,
- Intermittent closure,
- Full closure, and
- Innovative Strategies

These strategies are not necessarily separate, individual choices. In fact, some of them do not provide a complete and workable solution on their own. Some of the strategies are identified as mitigation strategies, meaning that they can be used to offset negative consequences for one or more of the other strategies. Different design strategies have their advantages and disadvantages, as summarized in **Exhibit13-B**, and described in successive sections. Designers should also refer to *OTM Book 7*.

13.4.1 Use of Shoulder

This strategy uses existing roadway width to compensate for the capacity lost by closing a permanent travelled lane. This strategy may be employed on divided multi-lane, undivided multi-lane and two-lane roadways. The shoulder may need to be widened and strengthened enough to accommodate the closed lane traffic and load. Full-width shoulders with the same pavement structure as the adjoining travelled lane can generally be used as a travelled lane at low cost. Bridges may have narrower shoulders than the approach roadways, which may determine or limit the feasibility of this strategy. Consequently, when a shoulder is used to carry traffic, the roadside hazards on that side will be closer to traffic. The existence, proximity, and nature of roadside feature e.g., bridge piers should be considered in assessing this strategy. Long use of this strategy may affect the performance of emergency vehicles (fire, ambulance, police) making use of shoulder for by-passing traffic. When using this option, the cross slope of the shoulder should be kept in mind, if the shoulder is being temporarily paved for this use, it should match the cross slope of the adjacent lane. When using the shoulder for work zone and if shoulder rumble strip exists, it should be paved. The shoulder rumble strips should be reinstated upon completion of work.

13.4.2 Alternating One-Way Operation

This strategy is used on two lane two-way roadways where one lane is fully closed for construction while traffic in both directions takes turns using a single travelled lane. Application of this strategy should generally be limited to low-volume, two-lane, two-way roads. This strategy is commonly used for bridge/culvert rehabilitation/replacement etc. If used for a longer duration, signal control should be used to coordinate the two directions of traffic. Long duration closures have significant impact on capacity and safety. As the length of the one-way segment increases, capacity is reduced. Also, construction operations may be impacted as they take place in close proximity to traffic operations. This strategy may also be used for short duration during daytime with flagging operations. A pilot vehicle may also be used to aid traffic operation.

Exhibit 13-B
Summary of Work Zone Strategies

Strategy	Summary	Advantages	Disadvantages
Use of shoulder	Shoulder converted into travelled lane	Low cost based on assessment of quality of existing shoulder	No room for disabled vehicles; debilitates shoulder pavement structure; cross slope and cross over may be problematic; less clear zone available.
Alternating one-way operation	Used primarily with two-lane facilities. Mitigates for full or intermittent closure of lanes.	Low cost and low non-transportation impacts; flexible, several variations available.	Requires stopping of traffic; reduces capacity and increases safety concerns.
Lane constriction	Narrowing travelled way width.	Maximizes number of travelled lanes.	May reduces capacity; increases safety concerns or road users and workers.
Lane closure	Closes one or more travelled lanes.	Maintains service; fairly low cost if temporary barriers are omitted.	Reduces capacity; may result in traffic being close to active work area.
Diversion	Provides a temporary roadway adjacent to construction.	Separates traffic from construction; reduced impact on traffic.	Cost may be substantial, especially if temporary grade separation of hydraulic structure is needed; additional right-of-way often required.
Median crossover	Maintains two-way traffic on one side of the roadway of a normally divided highway.	Separates traffic from construction; additional right-of-way not required.	Reduced capacity; lack of consistency with approach roadway; relatively costly; interchanges need special attention.
Detour	Reroutes traffic onto other existing facilities	Flexible; cost varies depending on improvements to detour route; in some cases, traffic plan needed.	Usually reduces capacity; service and infrastructure on existing roads may be degraded; may need agreement with another jurisdiction.
Intermittent closure	Stops traffic for a short period.	Flexible and low cost.	Useful for activities that can be completed in short time; requires stopping traffic.
Full road closure	Closes the facility to traffic for a limited duration	Separates traffic from construction.	Some form of mitigation is needed (detour, diversion etc.); potentially significant traffic impacts.

Adopted from NCHRP Report 581 (Design of Construction Work Zones on High-Speed Highways)

13.4.3 Lane Constriction

This strategy should be employed when maintaining travelled lane width less than desirable is preferred to other alternatives. The reduced lane width will bring the traffic in close proximity to construction operation and hence may create safety concerns for workers and motorists. Consideration of shoulder width reduction should be evaluated before using this strategy. The decision to use this strategy should be made after consideration has been given to the actual travelled way width, duration, length, traffic volume including truck percentage, and the cost associated with avoiding lane constriction. This strategy may directly impact the ability of the facility to accommodate large vehicles especially Long Combination Vehicles and oversize loads. The Commercial Safety and Compliance Office should be consulted when considering this option. In this strategy, reduction of posted speed should be considered.

13.4.4 Lane Closure

In this strategy, one or more lane and adjacent shoulders are closed to traffic. This strategy reduces existing capacity and increases the probability of queue formation and delay which may result in rear-end and side-swipes collisions. Based on traffic volume, drivers may have to reduce speed. Traffic impacts e.g., operating speeds, queue and delay should be assessed while considering the length of lane closure, grade, traffic volume including percentage of trucks. When lane closures are used for quick construction, short-duration, activity e.g., pavement resurfacing delineators or blocker trucks with truck mounted attenuators may be used. For longer duration work, Temporary Construction Barriers (TCB) either stationery or moveable may be used. The use of TCB may substantially increase the cost of implementation, reduces capacity but increases the safety of road users and construction workers. When TCBs are not required due to short duration closure, or on low volume roads, or during off-peak hours, this strategy has great flexibility for setting up and take-down procedures, refer to *OTM Book 7*.

This strategy is often used in conjunction with lane widening adjacent to an active traffic lane. It creates the potential for conflicting operations among construction equipment (e.g., compaction, demolition, deliveries and material placements), workers and roadway traffic. In addition to safety concerns, the constraints created by this strategy may affect the quality of construction.

13.4.5 Diversion

Diversion is a strategy where traffic in one or in both directions is carried by a temporary roadway bypass around the work zone and reconnected with the same highway at the end of the work zone. Diversions are sometimes used for bridge projects but are also used for other types of projects. When used in conjunction with bridge projects, a temporary bridge or culvert may also be needed. Unless a detour **(see Section 13.4.7)** is used to carry traffic. Diversions should be designed to accommodate the entire approach volume, including large and oversized vehicles. Selection of an appropriate construction zone design speed, as outlined in **Section 13.5.2,** is recommended. The capacity of the diversion should generally be close to or equal to that of the approach roadway to avoid substantial delay, queue formation, and rear-end collisions. The geometry of the diversion and associated Transportation Management Plan (TMP) should consider traffic characteristics on the approach roadway. Diversion involves construction of new temporary roads that can be costly. Major variables affecting cost include the length and width as well as design features e.g., barriers, earthwork, hydraulic structures, and surface/pavement. Diversion may also result in the need to acquire additional property interests and or have adverse impacts on the environment (e.g., historical, and archaeological sites, and endangered species). The impact of these factors on the project and schedule should be considered.

13.4.6 Median Crossover

Median crossover is employed to keep two-way traffic on a single roadway of a divided highway. The following are some features of this strategy:

- The number of lanes in both directions are reduced,
- At both ends of the work zone, traffic in one direction is routed across the median to the other side of the divided highway in the opposite-direction through a temporarily constructed crossover roadway, and
- Two-way traffic is maintained on one side of a divided highway while the roadway in the opposite direction is fully closed within the construction limits.

Generally, this strategy allows for the construction of the roadway while it’s fully closed to traffic, with minimal conflict between roadway traffic, equipment, workers, or onsite material movement. Median crossover is a long duration technique and involves a reduction in the number of travelled lanes and capacity. Traffic impact (e.g., speeds, queue and delays) should be assessed, micro-simulation may be carried out to ascertain the measurable effects on traffic.

During design, length of median crossover, roadway grades, illumination, traffic volume including percentage of truck traffic should be considered. If illumination doesn’t exist in pre-construction configuration, the designer should consider the need or warrant for illumination. If installing illumination is not cost effective, other options should be explored to enhance driver’s visibility within work zones. Existing access points (i.e., interchanges and intersections) may influence the location of median crossover. Design considerations include using barrier or other means to separate the lanes of opposing traffic, re-lapping of guide rail, additional end treatments, areas for enforcement and providing regular opportunities for disabled vehicles. Additionally, substantial grade differences between one roadway or within median topography can influence the feasibility and cost of temporary crossover roadway. **Exhibits 13-C1 and 13-C2** shows sample photos of an actual median crossover on *Highway 401* in *Eastern Region, Ontario*.

13.4.7 Detour

In this strategy, traffic in one or both directions is/are re-routed onto other existing lanes/roads/highways to avoid the work zone. Detoured vehicles may travel on existing, temporary or widened lanes/roads or a combination. This strategy compensates for the removal of existing travelled lanes from service. Detours should be carefully evaluated in terms of capacity, safety and pavement strength to ensure that they are capable of accommodating the volume and types of detoured vehicles.

Access to adjoining land (e.g., residents and businesses) on the closed roadway may be required. Public Information Centres (PIC) or other forms of communication may be used to disseminate information to stakeholders on the project. The additional length of trips using a detour is a cost to motorists in terms of time and money and should be evaluated before taking the decision. If traffic needs to be detoured to a road that is under a different jurisdiction, then an agreement and coordination with the jurisdiction should be considered early in the project.

Traffic operation and safety enhancements should be reviewed and addressed during design for proposed detour routes. If any improvement work is required to the detour as part of the contract, it should be properly investigated and incorporated into the design/contract.

Exhibits 13-C1 and 13-C2

Work Zone Median Crossover

Photos Taken from County Road 2/34 Looking West on Highway 401 at Raisin River

13.4.8 Intermittent/Rolling Closure

In intermittent or rolling closure, traffic in one or both directions is stopped for a relatively short duration to allow for construction operations. In non-emergency cases, this technique should only be used if the duration of closure and period of traffic impact is relatively short (i.e., less than 15 minutes during off-peak hours). This strategy alone is generally not adequate for an entire construction project; it is usually employed for specific operations e.g., setting bridge beams, conducting blast detonation, laying overhead utility cables, and moving large equipment etc.

13.4.9 Full Road Closure

In this strategy, traffic operations are removed or suspended in either one or both directions on a segment of roadway or ramp. When using this strategy, one or more supplemental strategies may be needed, with detours being the most common. The supplemental strategies may have other traffic impacts and should be evaluated during design. When full road closures are used on high volume facilities, alternative strategies (e.g., detour) usually cannot fully compensate for the capacity reduction.

Full road closure is desirable when unused capacity exist on roads running parallel to the closed roadway. This may be employed for bridge projects or other projects involving significant underground work within constrained right-of-ways, and projects that involve significant grade changes to existing alignment. The technique may be applied to any functional class of highways with any level of traffic volume. Stakeholder consultations, including with the general public should be done as part of the environmental assessment. When considering the use of this technique on high volume or limited access routes, significant advanced planning should be done during the TMP development, including enhanced public communication. The TMP should include a Traffic Staging Plan (TSP) component as well as a Public Information component. The TSP designer should ensure that any commitments made during the consultation process for the TMP development that affect the TSP plan are implemented as part of the design and contract package.

13.4.10 Innovative Strategies

The designer should consider innovative construction techniques for infrastructure especially for replacement of deep or large culverts, bridges, and embankment construction. These techniques can expedite construction resulting in less work zone traffic delays, convenience for traffic and cost effectiveness, congestion reduction, and has potential to reduce greenhouse gas emissions from traffic queuing.

Accelerated bridge construction can now be used to construct bridge superstructures away from the new road alignment and then rolling, launching, sliding, or lifting them into place. Replacing bridges within one work shift is now possible in lieu of using conventional construction that may take months or even years. Accelerating the completion of concrete joint repairs and slab replacement can also be accomplished by using prefabricated panel sections.

13.4.10.1 Prefabricated Bridge Elements and System

This technique beneficial for improving construction quality, reducing construction costs, as well as reducing work zone congestion. This technique saves lot of time of contractor and commuter traffic. In this technique the prefabricated bridge elements and systems, including prefabricated substructure elements such as footings, abutments, pier columns, retaining wall stems, and superstructure elements including partial and entire decks can be constructed offsite and brought to the project location ready to erect. Formwork erection, placing steel reinforcement and concrete, concrete curing time, and formwork removal can all be accomplished without inconveniencing traffic.

Mechanically stabilized earth and modular block retaining walls systems are prefabricated elements joined in different ways to create a wall system. This technique requires smaller right-of-way footprint for embankments; therefore, it usually accelerates construction time and thus reduce traffic congestion within the work zone.

13.4.10.2 Slide-in Bridge Construction

This technique allows a new bridge super structure to be built on temporary supports usually parallel to an existing bridge. During construction of the new structure, traffic continues uninterrupted on the existing bridge. When the new bridge is constructed and ready to be moved into place, the road is closed temporarily and traffic detoured, the existing structure is either demolished or removed, and the new structure is slide into place and tied into the approaches. Removal and transfer can often be accomplished within few days, which can greatly eliminate the disruption to traffic.

13.4.10.3 Leave In-place Formwork

Leave-in-place formwork technique is used when high traffic demand lanes needed to be closed in order to remove conventional formwork. These formworks are typically constructed of steel or other non-deteriorating material and after use become part of the structural element and left behind.

13.4.10.4 Rapid Embankment Construction

A chemically expanded polystyrene material is used as an embankment fill system. The expanded polystyrene blocks are placed behind a conventional abutment or around the piles of an integral abutment. Besides speeding embankment construction, the benefits of this system also include its lightweight (1-2 pounds per cubic foot), and the elimination or reduction of pre-load settlement times where required due to geotechnical conditions. Design considerations for this system include, but are not limited to, need for subbase layer below the pavement to distribute wheel loads; protection of the foam blocks from gasoline spills; system inappropriateness due to uplift forces where water table is above the bottom of the polystyrene blocks.

13.4.10.5 Precast Concrete Panel Pavement Systems

Installation of precast concrete pavement panels is an effective pavement rehabilitation technique of reducing work site construction time and traffic disruption. Removing and installing precast concrete panel pavement is often done during off-peak traffic periods, typically at night.

In this technique, prefabricated concrete panels are constructed offsite and transported to the work site on truck trailers for rapid replacement of deteriorated concrete pavement sections. The application of this technology includes repairing isolated concrete panels, intersection and ramp rehabilitation, urban street rehabilitation, and rehabilitation of longer mainline pavement sections. Actual removal and replacement can be accomplished by saw cutting the old concrete section, removing the old concrete, preparing the foundation by reshaping/grading the base, lifting the new panel into place, and filling joints with accelerated curing concrete material. The controlling factor before opening to traffic is the time required for the joint material to cure.

13.4.10.6 Trenchless Technologies

Trenchless technology is a form of underground construction for culvert and sewer installation that doesn't require open cut at ground level. If excavations are needed, they are much smaller in size compared to traditional open cut construction methods. Trenchless technology uses unique equipment and methods to install, rehabilitate or to replace underground infrastructure without causing disturbance to the ground above. It is a rapidly growing sector of construction valued for its convenience, safe installation methods, cost savings, and very minimal disruption to traffic. There are many methods and techniques available to avoid open cut for drainage. Designers are encouraged to refer the ministry's guides for trenchless technology.

13.5 DESIGN PRINCIPLES

Principles exist in the context of objectives and constraints. The principal objectives of highways are mobility and land access. Both mobility and land access functions are essential to community and personal vitality. A design objective specifically related to work zones is to minimize any reduction in the mobility and land access functions. Designs for highways in work zones are often more restricted than design for permanent roadways, since work zones must also accommodate construction operations and be closely aligned with the permanent road. The following basic principles should be considered when planning and designing a Traffic Staging Plan at the project level.

13.5.1 Safety of Road Users

Safety of all road users (motorists, pedestrians, cyclists, construction workers, etc.) should be the top priority and must be an integral part of each Traffic Staging Plan on any project. The objective is to provide maximum benefits at a minimum cost on an aggregate basis. Therefore, substantive safety is a principle, but not the sole consideration in the design of work zones.

The designer should use the same basic safety principles for work zones that govern the design of permanent roadways and roadsides.

13.5.2 Design Speed

Vehicle speeds through work zones are an important factor affecting the safety and mobility of road users and highway workers. The goal should be to route traffic through the work zone in a manner comparable to normal highway situations. The impact on traffic movement should be kept as minimal as possible. The design speed within work zones should desirably be the same as that of adjacent highway sections outside of the work zone. However, this may not be the case in all situations; designers should select a design speed that is justified based on prevalent constraints and safety of all road users. If reduction in design speed is proposed; it should be well documented with rationales and approved by the Responsible Manager of Engineering Program Delivery. Comparatively, work zone design speed in rural areas should generally be higher than work zone design speed in urban areas of similar highway classification.

13.5.2.1 Speed Management Techniques

The intent of speed limit reduction and management in work zones is to promote safe and efficient traffic flow through work zones, as well as enhance the ability of traffic to safely react to highway work and disruptions in traffic flow. Speed limit reductions in work zones should only be used when necessary and should be relevant to the conditions or restrictive features that are present. Designers should also refer to the *OTM Book 7* for more details. Traffic control through work zones is a 24-hour requirement and speed monitoring should be done at frequent intervals throughout the duration of the operations. When restrictive geometrics and other features imply a speed limit reduction, driver notification should be provided through consistent, credible, and complementary information sources. Although static regulatory and advisory signage is a fundamental and important source of information, it should not be presumed as independently sufficient. The following are 3Es (Engineering, Education, and Enforcement) speed management techniques that can be employed to keep the traffic speed around the posted speed. There is no preference for using one technique over the other; multiple techniques can be employed in a work zone at any given time.

Engineering
Incorporating engineering techniques such as warning signs, advisory speeds, positive guidance, width restrictions, channelizing chicanes, and use of intelligent transportation system technologies can be used to slow traffic through a work zone. Portable variable message signs (PVMS) with built-in radar detectors may be used to alert drivers about their excessive speed but requires endorsement by the regional Pre-Contract Traffic Section. Overuse of PVMS may desensitize the motoring public and reduce their effectiveness. Other engineering techniques such as transverse rumble strips, and lane constriction may also reduce speed, but it may have other safety impacts which should be reviewed.

Education/Awareness
The news media and internet are resources available to inform the public of impending and/or existing work zones. Newspapers, radio announcements, and television reports, as well as the ministry's Ontario 511 (511on.ca) web page provide the public with useful Ontario traveller information. It is also equally important to educate and consult with the stakeholders.

Enforcement

Active police enforcement is the most effective measure to encourage motorist's compliance with posted regulatory speed limits and other traffic regulations within work zones. The need for police enforcement should be determined as early as possible during the project design phase. The coordination amongst ministry Construction / Regional Traffic staff, Contract Administrator, police, and contractor should be sought prior to any active enforcement within a work zone.

13.5.2.2 Reduction of Speed Limit

Speed limit reductions in work zones are most effective when drivers perceive the need to slow down, (whether through noticeable geometric or work-related constraints on traffic flow) and when there is regular active police enforcement of the work zone speed limit. A reduced speed selection may not be consistent with driver expectancy and will increase the operating speed differentials between upstream and start of work zone which may produce an increase in collisions. Traffic speed in work zones is generally lower, regardless of posted speed limit, when work zone conditions such as flagging, variable message signs, lane shifts, lane-width reduction, and enforcement exist.

A work zone traffic control plan should be designed to provide work zone geometric transition(s), sight distance, lane width, and superelevation that result in a recommended speed for the work zone that meets or exceeds the design speed, or the preconstruction posted speed limit plus 10 km/h. Where an advisory speed or a reduction in the regulatory speed limit is warranted within a work zone, the speed limit should not be reduced by more than 20 km/h below the preconstruction posted speed limit, unless an engineering study shows that the geometric conditions warrant a greater speed limit reduction. For more information, refer to the *OTM Book 7.*

Advisory or regulatory speed limit reductions in work zones is to be established, consistent with changes in the physical character of the work area. Advisory or regulatory speed limit reductions in work zones should be in effect only where conditions warrant the speed reduction within the work zone. In long work zones with several intermittent activity areas, where it has been determined that a regulatory speed limit reduction is necessary at each activity area, the preconstruction posted speed limit shall be restored between activity areas where they are separated by 3 km or greater.

Regulatory speed reductions in work zones should be selected by the designer during the design phase and the development of Transportation Management Plan. The advisory speed selection may be recommended by the Area Manager, Construction in consultation with the Contract Administrator and Pre-Contract Traffic Section during construction. The Manager of Engineering Program Delivery will be responsible for approving all work zone advisory speeds and reduced regulatory speed limits.

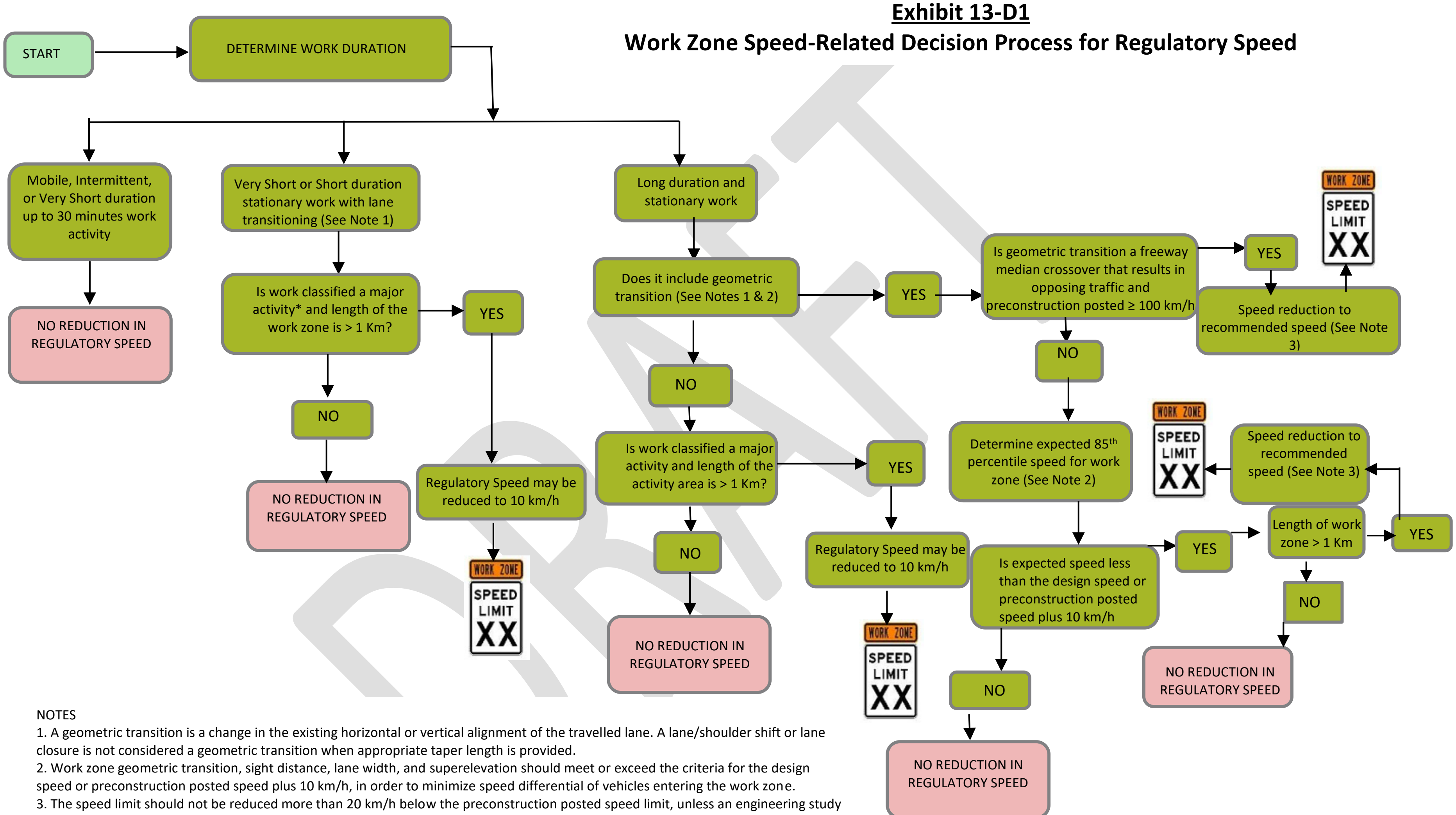
The duration of work is an important factor in deciding the reduce speed limit in work zones. According to *OTM Book 7*, the duration of work can be categorized in the following five types:

- Mobile Operations,
- Intermittent Duration,
- Very Short Duration,
- Short Duration, and
- Long Duration.

Designers should refer to *OTM Book 7* for details of duration or work zones.

The decision process in determining work zone regulatory and advisory speed is shown in **Exhibit 13-D1 and Exhibit 13-D2** respectively *(Inspired by the New York State Department of Transportation Engineering Instruction # 08-030 dated Sept 9, 2008)*. These exbibits should be read in conjunction with the guidance and table provided in the *OTM Book 7*.

Exhibit 13-D1
Work Zone Speed-Related Decision Process for Regulatory Speed

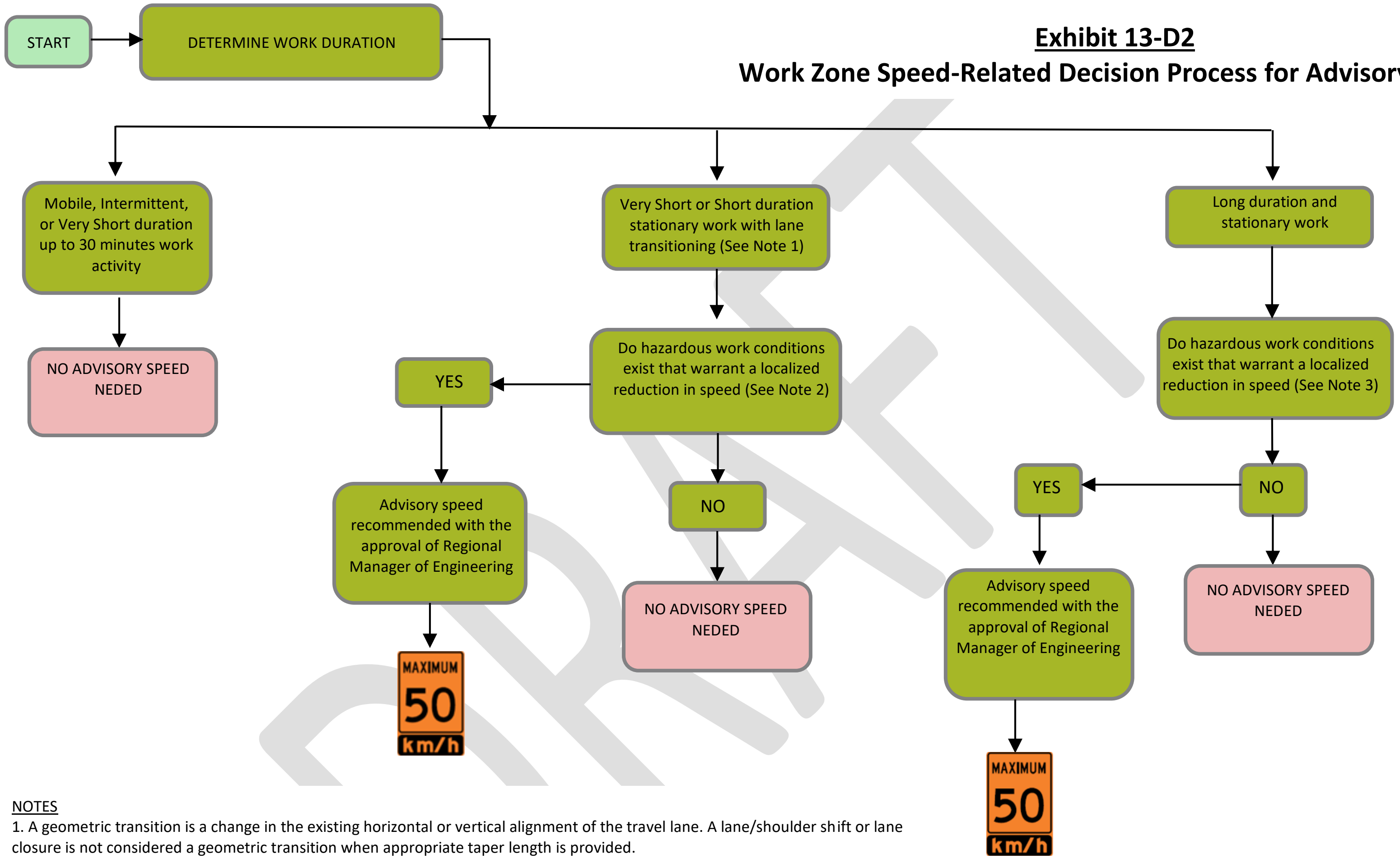


NOTES

1. A geometric transition is a change in the existing horizontal or vertical alignment of the travelled lane. A lane/shoulder shift or lane closure is not considered a geometric transition when appropriate taper length is provided.
2. Work zone geometric transition, sight distance, lane width, and superelevation should meet or exceed the criteria for the design speed or preconstruction posted speed plus 10 km/h, in order to minimize speed differential of vehicles entering the work zone.
3. The speed limit should not be reduced more than 20 km/h below the preconstruction posted speed limit, unless an engineering study shows that the geometric conditions warrant a greater speed limit reduction. The Regional Manager of Engineering will be responsible for approving all work zone advisory speed and reduced regulatory speed limits.

* A “Major Activity” means: Work on a fully controlled access highway with preconstruction posted speed limit ≥ 100 km/h and workers are not protected by temporary construction barrier

Exhibit 13-D2
Work Zone Speed-Related Decision Process for Advisory Speed



NOTES

1. A geometric transition is a change in the existing horizontal or vertical alignment of the travel lane. A lane/shoulder shift or lane closure is not considered a geometric transition when appropriate taper length is provided.
2. Hazardous conditions include: Narrow lanes, Bumps, Grooved pavement, Low or no shoulders, Edge drop-offs, Poor roadway surface, Insufficient sight distance, Geometric constraints, and Exposed workers adjacent to traffic lane.
3 All of hazardous conditions in Note 2 and the lateral offset from the face of barrier to the travel way < 0.6 m.

13.5.3 Design Consistency

The designer should provide design consistency that meets driver expectations and that avoids unexpected geometric and roadside conditions/features. Work zone designs should conform to the reasonable expectations of drivers based on their previous experience of highways with similar functional classification. Information sources, including the roadway and associated traffic control devices, should provide positive guidance and be presented in a consistent manner. Design consistency is also applying to speed management.

13.5.4 Primacy

Primacy is a principle used by the driver for prioritization of the information received from various sources (e.g., traffic control devices, geometry, traffic, and terrain). Driving through work zones often present challenges to the drivers with load of information compared to permanent roads. Under the principle of primacy, safety-critical and other important information should be clearly, conspicuously, and prominently presented to drivers. This should be considered during planning and design phases to make sure that the sign layouts will fit in the available area and to avoid information overload to the drivers.

13.5.5 Sight Distances

The following four types of sight distances exist but all of them may not be required for every work zone:

- Stopping,
- Passing,
- Intersection, and
- Decision,

Each of these sight distances may be applicable to work zones, although providing passing sight distance in work zones is not a priority. Extended approaching sight distance within work zones is desirable from safety and operation perspective. However, minimum stopping sight distances must be provided based on the design speed of work zone under wet conditions.

The driver eye height of 1080 mm and the object heights from zero to 600 mm are recommended depending on the object and location on the highway alignment (*see Chapter 2 of TAC GHG)*.

Intersection sight distance should be provided at intersections while decision sight distance should be considered at locations where competing information is provided to the driver such as at intersections and interchanges.

13.5.6 Roadway Surface

Driving surface characteristics, especially roughness and friction have an influence on motorist comfort and tire-road interaction. For a multi-year construction contract, the designer should consider the pavement surface that traffic will be running on and for what duration when developing the TSP. For instance, the frictional properties of asphalt binder course may not be appropriate over winter period. Unpaved roads are not desirable; however, traffic exposure should be considered in design decisions. Unpaved roads of low traffic volume < 500 veh/day for a short duration (maximum 5 days) may be considered for work zones. Surface treated roads of <1500 veh/day may be considered for work zones for up to 30 days. Surface treated roads may be slippery/icy at times when temperature changes rapidly. Designers should consider the local environmental conditions and effect on nearby residents when considering unpaved and surface treated roadways for work zones. If traffic is to be staged on a milled surface, the surface should be cleared of all debris and loose material. Milled surfaces are not very safe for cyclists, motorcyclists and pedestrians because of the rough grooved surface and potential for loose debris.

Unpaved surfaces greatly restrict the types of temporary construction barrier that can be used and barriers crash-tested for use on compacted gravel typically have relatively large working widths, see **Section 13.9 – Roadside Design**. This should be taken into account when considering the use of unpaved roads for construction staging. Steel beam guide rail may be used on a temporary basis to perform the same function as a temporary construction barrier. The designer should also consider the potential impacts to the surface course from the temporary construction barrier. It is possible that road surface may get damaged with the use of new heavier Type X barrier and require repair when changing the sequence of traffic staging.

13.6 DESIGN CONTROLS

Design controls are given attributes for the design and are beyond the control of the highway designer when designing the highway. These attributes influence the design process, solution, and design criteria. These attributes include:

- Human Factors,
- Design Vehicle,
- Land Use,
- Highway Classification and Driver's Expectation,
- Scope of Work

13.6.1 Human Factors

Physiological and psychological characteristics/behavior and limitations of human beings (road users) in a given set of highway environments are termed as human factors. A high workload in driving means having a demanding driving task such as processing a great amount of information coming from the roadside (e.g., excessive amount of traffic signs). The driver workload depends on conditions defined by:

- Road: predictability of the road environment (signs, pavement marking, and design) and expectation by the driver.
- Vehicle: vehicle workload especially commercial and manual transmissions or those with less safety features.
- Driver: for a novice driver all aspects of the driving task may be demanding especially distraction because of mobile phone, radio, children, eating and drinking etc.

Human factors play an important role in work zone design because of the changing environment and driver expectation. The designer should consider human factors in a complex work zone where driver workload is heavy, and information sources are competing in a short travel time. Human factor study could enhance safety of all road users and may be cost effective to conduct on complex work zones.

13.6.2 Design Vehicle

Vehicle characteristics and performance capabilities affect geometric design elements. The designer should select the design vehicle based on the guidance provided in *Chapter 2, Chapter 9* *of TAC GDG* and *Appendix 2 and Appendix 9* of this *Design Supplement*. Design vehicle factors that directly or indirectly influence design elements include dimensions, height of operator's seat, weight-to-power ratio, acceleration, and deceleration capability, body roll angles, and cornering and turning stability. In work zones, geometry is often constrained. Several key decisions (e.g., minimum lane width and maximum grades) are strongly influenced by the selected design vehicle, traffic volume and composition. The designer must also consider and consult with the project team and stakeholder if the work zone is located on a Long Combination Vehicle (LCV) route.

13.6.3 Land Use

One of the basis of highway functional classification is the land use pattern where the highway is situated serving a community. Land use affects the design elements and design choices. Examples of land use include area type (e.g., rural or urban), terrain, density and type of adjacent land, natural and human-made environmental features, and community characteristics.

13.6.4 Highway Class and Driver's Expectation

Work zones are designed within the highway right-of-way. Traffic routinely using the facilities and traffic approaching the work zone may have expectations based on previous experience with a similar highway type. These expectations might include the operating speed, number and width of lanes, width of shoulder and type, location of decision points (sight lines), roadside environments, and access arrangements.

13.6.5 Scope of Work

Scope of construction is beyond the designer's discretion. Construction scope varies just from routine maintenance to a full roadway reconstruction or bridge replacement. Construction work has substantial influence on the time and space required for construction. The time and space requirements, in turn, affect work zone design.

13.7 GEOMETRIC DESIGN ELEMENTS

Work zones geometric design elements include:

- Horizontal alignment,
- Vertical alignment,
- Cross-sections, and
- Roadside slopes.

These elements should be designed using a balanced approach with consideration for cost, right-of-way acquisition, impacts and a finite period. The service life and safety of road users and construction workers of the facility is the key difference between permanent and temporary road design. Designers should consider and integrate permanent infrastructure elements (e.g., embankments, pavements, structures, and appurtenances) into work zone roadway alignments. Constructing and removing temporary infrastructure is justified when doing so is necessary to provide the desired levels of access, mobility, and safety. The design should avoid frequent and abrupt changes in roadway geometrics (e.g., lane narrowing, lane drops, transitions that require rapid maneuvers). It is desirable to keep a uniform design speed for the geometric elements through the entire work zone.

13.7.1 Horizontal Alignment and Superelevation Distribution

There are two general approaches and methods to establish a relationship between horizontal curvature and superelevation, and guidance on the use of both methods is provided in *Chapter 3 of TAC GDG-2017* along with *Appendix 3 of MTO's Design Supplement*.

The maximum superelevation rate for the design of work zones should be the same as for permanent roadways. The selection of a distribution method of superelevation '*e*' and friction '*f*' has no effect on the maximum values. The use of any distribution method will yield the same curvature *'R'* (i.e., minimum radius) for a specific speed *'V'* and limiting values of '*e*' and '*f*'.

For permanent roadways, Method 5 is desirable for the distribution of *'e'* and *'f'* (*Ref. Section 3.2 of Chapter 3 of TAC GDG-2017*). Superelevation roadway curves necessitates the need for superelevation transitions, which results in alignment and other (e.g., drainage) complications. For these reasons, it is common design practice to provide curves that are sufficiently flat to not require the introduction of superelevation.

In Method 2, superelevation is introduced only after the maximum allowable side friction has been achieved. When compared with Method 5, this approach typically results in no superelevation on flatter curves (i.e., maintaining the normal crown through the curve) and reduced rates of superelevation on most other curves. Since Method 2 relies more on friction and less on superelevation than Method 5, its use for establishing superelevation on work zone roadway curves may be appropriate. This is not an indication that Method 2 is the preferred or superior approach. Both methods may be used for designing temporary roadways in work zones. It is possible to have a negative superelevation which is the condition where a driving surface is sloped away from the centre of a horizontal curve. Negative superelevation is most common when the normal cross slope of an approach tangent road is retained on a horizontal curve. For example, a roadway curving to the left with a slope of 2 percent from left to right has a superelevation rate of negative 2 percent (-2%).

13.7.2 Vertical Alignment

Generally, a maximum grade criterion provided in *Chapter 3 of TAC GDG-2017 and Appendix 3 of MTO's Design Supplement* for permanent roadways should be applied in work zones. However, grades below the maximum are desirable. The potential effect of grade on operations and capacity should be considered. When minimum stopping sight distance design criteria are adopted for work zones, minimum vertical curve length criteria on that basis are appropriate. In this case, minimum crest and sag vertical curve lengths are determined from *Chapter 3 of TAC GDG-2017 and Appendix 3 of MTO's Design Supplement* should be applied. For sag vertical curve on illuminated roadways, comfort criteria may be adopted for determining minimum length, refer to *Chapter 3 and Appendix 3 of MTO's Design Supplement*. Work zone design speed should be used in all formulas.

13.7.3 Cross Section

Work zones' cross section (lane and shoulder) widths vary by traffic volume and highway type. The roadway may not be paved for low-speed (≤ 30 km/h) and very low volume (AADT ≤ 200) highways.

In general, reductions in the roadway cross section width through the work zones should be avoided wherever possible. However, this is often not practical given the constraints of the project. When determining lane and shoulder widths in work zones, consider the guidelines in the following subsections:

13.7.3.1 Divided Highways

For freeways and high-speed multilane highways, desirably use 3.75 m wide lanes. As a minimum, maintain a 3.50 m lane width with minimum 1.0 m wide right and left clear shoulder widths excluding temporary construction barrier. Under very restrictive urban conditions and on low-speed highways, a 3.25 m lane width may be considered.

13.7.3.2 Undivided Highways

For high-speed, undivided highways, maintain a 3.5 m lane width and for low-speed, undivided highways, a 3.25 m lane width. A minimum shoulder width of 1.0 m for high-speed and 0.5 m for low-speed highways should be maintained.

In most cases, it may be more desirable reducing the shoulder widths versus reducing the travelled lane width. However, shoulder width should not be less than the minimum and designers should consider including refuge areas for disabled vehicles.

13.7.3.3 Cross Slopes

Cross slopes for work zones should generally follow the guidance applicable to permanent roadways, including consideration of surface type, number of lanes, and environmental exposure factors e.g., rainfall and/or snow/ice. The design cross slope on tangent alignment should be 2.0 percent while for paved temporary travelled way resurfaces, 1.5 to 2.5 percent cross slope may be acceptable. For aggregate and treated surfaces, cross slopes may generally be 2.0 to 3.0 percent.

Shoulder cross slopes may be difficult to control because of width and material type. Generally, shoulder cross slopes should be greater than the cross slopes of the adjacent travelled way, particularly if the shoulder is unpaved. Shoulder cross slopes up to 8% may be provided. Where it is necessary to use the shoulder as a travelled lane in the work zone, the shoulder cross slope may create a problem on horizontal curves, i.e., the shoulder cross slope may need to be modified for superelevation based on designed superelevation. Consider one or more of the following options to mitigate this problem:

- rebuild the shoulder providing a cross slope equal to that of the adjacent travelled lane.
- install advisory speed, curve and chevron signs according to the *OTM Book 7* for the horizontal curve.
- install temporary transverse rumble strips according to the policy and guidance of Provincial Traffic Office.
- restrict large vehicles (e.g., trucks, buses) from using the temporary travelled lane especially turning lanes; and/or.
- detour large vehicles to other highways.

The above options are for general guidance, and no option takes precedence over the other. The designer may use one or more options according to the site conditions.

For superelevated temporary roadways, the maximum rollover (i.e., the algebraic difference of roadway and high-side shoulder slope) should be limited to 6 percent.

13.7.3.4 Pavement and Shoulder Edge Drop-Offs

A pavement or shoulder edge drop-off is a condition where there is a significant elevation change (uneven pavement) from one travelled lane to another, or between a travelled lane and the adjacent shoulder. This condition is known to be hazardous to motorists, particularly motorcycles, compact cars, and vehicles pulling trailers. This condition can be mitigated by installing warning signs according to *OTM Book 7*, increasing lateral distance to the drop-off (slope of edge drop-off), providing a transition, adding temporary asphalt to pad the drop-off, reducing speed, or installing a delineation or barrier. No options are preferred to the other; designer should decide based on work zone principles.

13.7.4 Roadside Slopes

Parallel slopes along a roadway perform two essential functions within the roadside environment:

- Foreslope (includes frontslopes and sideslopes in cut and fill sections respectively) provide structural support for the roadway, and

- in conjunction with backslopes (in cut) provide a transition between the roadway and original ground.

Slopes are typically described by the ratio of horizontal to vertical change in slope (e.g., a 4H:1V is a slope that changes 1 m vertically for every 4 m measured horizontally). Where practical, temporary cut and fill slopes to be designed according to the ministry's Roadside Design Manual (*RDM*). However, for work zones, 3H:1V foreslopes may be used where there is sufficient clear zone available at the bottom of the slope. The use of steeper foreslopes and installation of roadside barriers may be considered on a case-by-case basis. Refer to Section 13.8 for more information on roadside design and clear zones.

13.8 DESIGN OF WORK ZONES

This section addresses the design of work zone roadway elements for specific strategies used in setting up the work zone, including temporary roadway infrastructure and existing roadways that are geometrically altered within the work zone. Several work zone and maintenance strategies for very short and short durations *(Refer to OTM Book 7 for Duration of Work or Section 13.8.3),* including alternating one-way operation, full road closure, intermittent closure and lane/shoulder closure, may not require altering the geometric elements. These types of strategies require a Transportation Management Plan (TMP) which is identified in the *OTM Book 7* in the form of Typical Layouts (TL). **Exhibit 13-E** below identifies work zone and maintenance strategies for some of which the *OTM Book 7* provides direct and illustrated guidance through TL. When these strategies are adopted for long duration, geometric elements may need to be changed as discussed in the following subsequent sections.

Exhibit 13-E

Coverage of OTM Book 7 Guidance for various Work Zone Strategies

Work Zone Strategies	**OTM Book 7 Guidance**		
	Freeway	**Multilane non-freeway**	**Two-lane**
Use of shoulder	Yes *(3)*		
Alternating one-way operation	NA	NA	Yes
Lane constriction			Yes *(2)*
Lane closure	Yes	Yes	Yes
Diversion			Yes
Median crossover			NA
Detour			Yes
Intermittent closure			Yes
Full road closure	*(1)*	*(1)*	*(1)*
At-grade intersections	NA	Yes	Yes
Interchange ramp	Yes		NA

Yes Explicitly addressed in the OTM Book 7
NA Not Applicable
1 Full Road Closure
2 OTM Book 7 typical layouts provide for low volume roads and for short duration
3 Covered in conjunction with lane shift

13.8.1 Use of Shoulder/Lane Shift/Lane Closure

There are numerous variations of this strategy for various types of highways and work requirements. Shoulders may be used for all types of duration of work from mobile operation to long duration work *(Refer to OTM Book 7 for Duration of Work).* The use of shoulders in long duration may require placement of temporary construction barrier see **Section 13.9.4**.

There may be instances when the shoulder and adjacent lane are required for a work zone for a long duration. In this situation, design decisions may be required that should be implemented with the integration of a TMP and TSP.

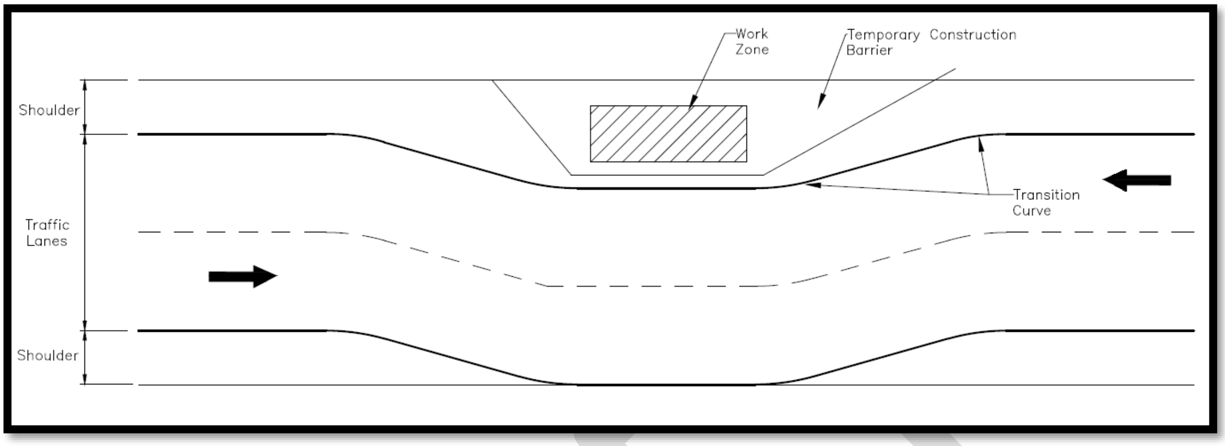
13.8.1.1Horizontal Alignment and Superelevation

The transitional path of traffic from the permanent travelled lane approaching the work zone (as a temporary travelled lane) is delineated by shifting traffic to the shoulder. Lateral shifting of traffic requires a pair of opposing direction horizontal transition curves. Transition curves should be with either simple spirals, reverse spirals, or simple curves. The use of reverse circular curves with or without spirals may be appropriate. The design speed of the work zone should be appropriate for the evaluation of superelevation and sight distance. The design of back-to-back curves should be sufficiently flat to not require superelevation. Where superelevation is needed, either Method 2 or Method 5 as outlined in **Section 13.7.1** should be applied. Where superelevation is provided, the alignment should provide for adequate transitions. In the case of superelevated reverse curves, an appropriate tangent between the curves is needed to avoid the tipping of design vehicle especially liquid cargo carrying vehicles. A common highway example is shown in **Exhibit 13-F**.

If the shoulder is on a horizontal curve, cross slope should be compared with the superelevation requirement. Maximum superelevation of up to 6% (0.06 m/m) may be applied as outlined in **Section 13.7.1**. It is desirable to provide a curve radius which is greater than the tabulated minimum radius for the work zone design speed and existing cross slope. In a situation when the shoulder cross slope does not coincide with the adjacent travelled lane, then the most comprehensive measure is to extend the cross slope of the adjacent travelled lane to the shoulder through pavement reconstruction or surface padding. Other potential mitigation measures may include speed advisories, detouring trucks and buses if required.

Exhibit 13-F

Use of Shoulder with a Lane Shift



13.8.1.2 Transition Tapers

Transition tapers may also be used for lane closures, lane width reductions, and lane shifts to safely maneuver traffic around the encroaching restriction. The formula for determining the taper lengths is shown in **Exhibit 13-G.**

Exhibit 13-G

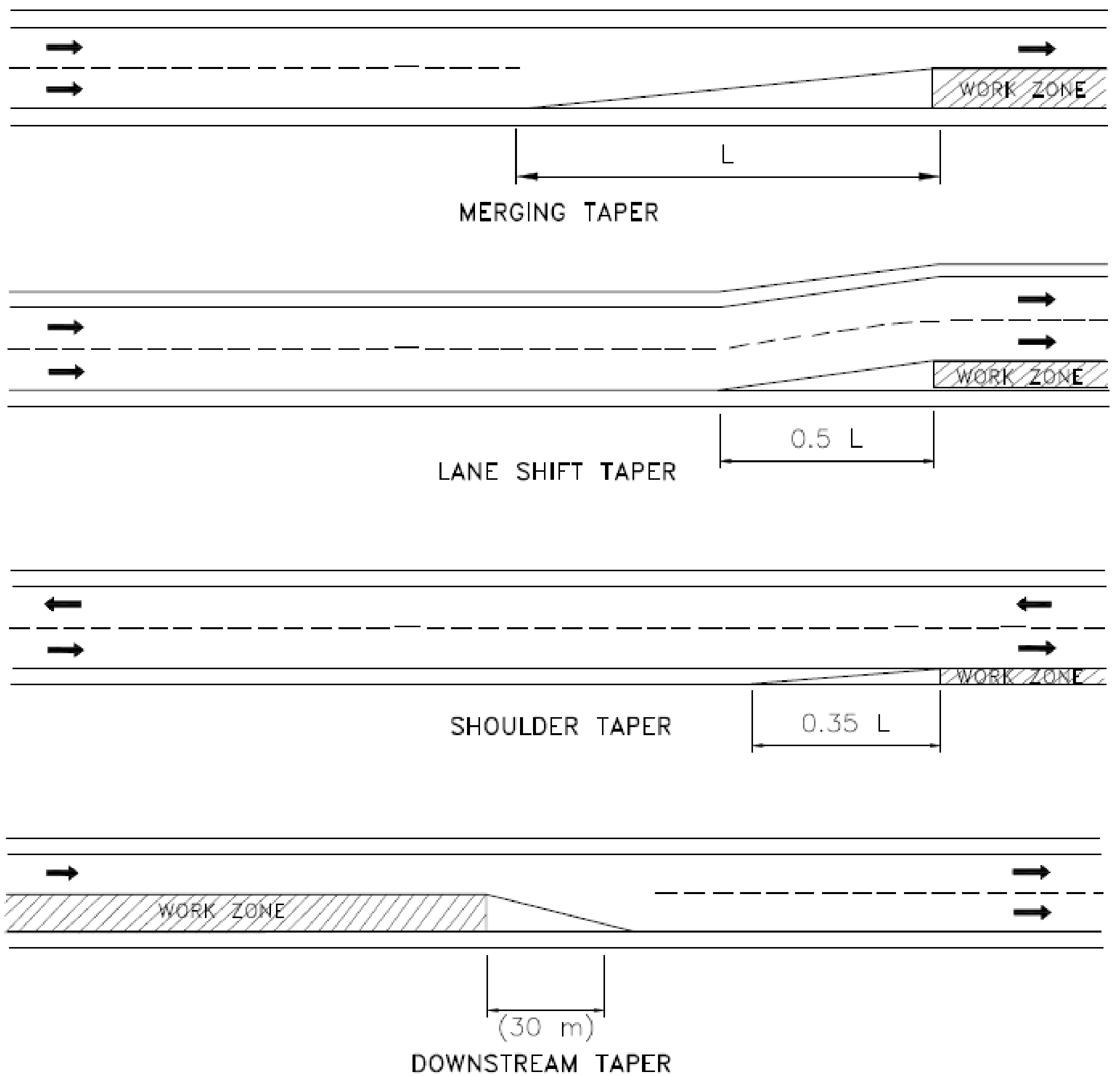
Formula for Determining Taper Length for Work Zones

Speed Limit (S) **Km/h**	**Taper Length (L)** **Meters**
60 or less	$L = WS^2/155$
70 or more	$L = WS/1.6$
L = Taper length in meters *W = Width of offset in meters* *S = posted speed limit, or off-peak 85th-percentile speed prior to work starting, or the anticipated operating speed in km/h*	

The criteria for taper length with illustration of the minimum taper lengths for various taper applications in work zones (e.g., lane closures, lane shifts etc.) is provided in **Exhibit 13-H**.

Exhibit 13-H

Taper Length Criteria for Work Zones



Type of Taper	Taper Length (L)
Merging Taper	Minimum 1L
Shifting Taper	Minimum 0.5L
Shoulder Taper	Minimum 0.35 L
Downstream Taper	30 m Per Lane

CRITERIA FOR TAPER LENGHT

13.8.1.3 Cross Section and Surface

When an existing shoulder is to be used as a travelled lane; it should be assessed for existing cross slope, pavement strength, and surface characteristics. It should meet or exceed the assumed friction values. The alignment design should be based on the assumed availability of certain minimum friction between vehicle tires and the roadway surface. Also, guidance for width of lane and shoulder is provided in **Section 13.7.3**.

If shoulder rumble strips exist, they should be removed and subsequently restored after use of the shoulder for traffic.

13.8.1.4 Drainage

The designer should refer to the latest edition of the ministry's *Highway Drainage Design Standards* Section *TW-2 Highway Drainage Management for Temporary Works.*

13.8.2 Alternating One-way Operation Using Traffic Signal Control

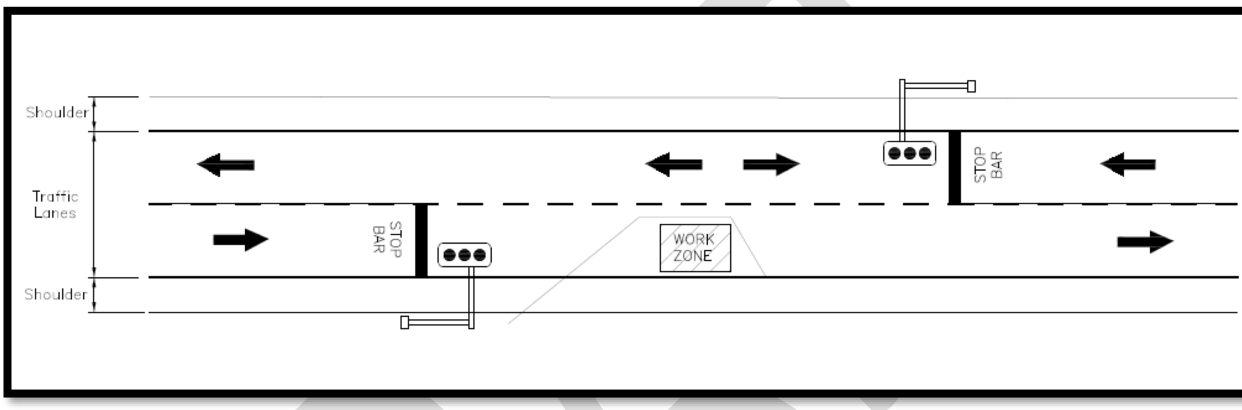
Alternating signalized one-way operation or one-lane two-way operation should be considered according to the policy of the provincial Traffic Office memorandum (PEM #2016-01 dated November 30, 2016) for two-lane two-way roadways. This strategy commonly applies for bridge major rehabilitation or bridge replacement. For short/long duration of construction, temporary signals should be installed with appropriate clearance intervals (amber time and all red interval) according to the guidance/policy from the provincial Traffic Office. The transition of traffic from one lane to the other lane should be smooth and can be achieved by providing a direct taper or an appropriate horizontal curve, see **Exhibit 13-G** for determining taper length and **Exhibit 13-H** for taper criteria with illustrations. The selection and design of the horizontal curves should be governed by the design speed, design vehicle, and sight distance. Desirably, provide decision sight distance to the signal head and stopping sight distance at stop blocks and queue ends as a minimum. The cross section should also include a 1.0 m clear shoulder on the right side of the travelled lane of shifted traffic. An illustration of this operation is provided in **Exhibit 13-I**.

13.8.3 Lane Constriction

It is desirable to maintain the approach road lane width through the work zone. However, desirable dimensions are not generally attainable due to various constraints. Therefore, this strategy inherently involves providing a design feature that is less desirable. Prior to considering lane constriction, use of shoulder should be considered. Designers should be aware that research indicated that reducing lane widths through work zone may increase crash rate, but the relationship between the magnitude of the reduction and the corresponding safety effect is not known. Vehicle operating speed and lateral position may be affected by roadside features.

Exhibit 13-I

Alternating One-way Operation on a Two-Lane Road Using Traffic Signal



Several factors should be considered in determining the minimum acceptable travelled lane width. These factors include:

- Traffic volumes including truck/commercial traffic volumes and oversize loads,
- Lateral constraints,
- Operating speed,
- Horizontal curvature,
- Roadside features,
- Duration of lane constriction,
- Divided and undivided roadways, and
- Number of lanes.

Travelled ways that result in travelled lane widths of 3.50 and 3.25 m are common in work zones considering above factors. Lane width of 3.0 m should be avoided in work zones at design speed ≥ 80 km/h. **Exhibit 13-J** and accompanying foot notes provides minimum travelled lane width considering factors mentioned above.

Travelled way widths that result in normal travelled lanes (see *Appendix 4 – Cross Section Elements*) with lateral offsets to constraining features are desirable. However, lane constrictions are less than ideal conditions that must sometimes be provided as a matter of practicality.

Lane constrictions are often used in conjunction with lane shifts, lane closure and shoulder closures. Guidance on TMP for each of these is provided in the *OTM Book 7*. With the application of constricted lane technique, the use of the TC-11 (Narrow Lanes sign) should be considered in coordination with other applicable Traffic Control Devices. Lateral constraint may also restrict sight distance along horizontal curvature, which should be reviewed.

13.8.4 Diversion

The diversion design is one where traffic in one or both directions is required to make a short diversion, within the highway right of way. The diversion design should reflect the service requirements and site constraints. Two-lane, two-way diversions are the most common type as illustrated in **Exhibit 13-K**. Typical application of Traffic Management Plan is provided in the *OTM Book 7*. Diversions are often used in conjunction with bridge and large culvert construction and/or replacement and may involve grade separation, which strongly influence the overall geometric design.

Exhibit 13-J

Minimum Travelled Lane Widths

		Travelled Lane Widths (m)			
	Facility Type	Undivided highway		Divided highway	
	Lanes per Direction	One	Two	One	Two
Travelled way Edge Condition	No constraint along travelled way edge	3.0[1]	6.0[2,3]	3.25	6.5[3]
	Constraint along one travelled way edge	3.25[1]	6.25[2,3]	3.5	7.0[3]
	Constraint along both travelled way edge	3.5[1]	6.5[2,3]	3.75	7.5[3]

Notes:

1. Values apply only when all the following conditions are met:

a. low volumes of traffic including commercial vehicles,

b. all curve radii equal or exceed 555 m, and

c. anticipated 85th percentile speeds are less than or equal to 80 km/h.

If any of these three conditions is not met, add 0.25 m to the base value.

2. Values apply only when all the following conditions are met:

a. roadways carrying moderate commercial traffic volumes, and

b. where all curve radii equal or exceed 555 m.

If either condition is not met, add 0.25 m to the base value.

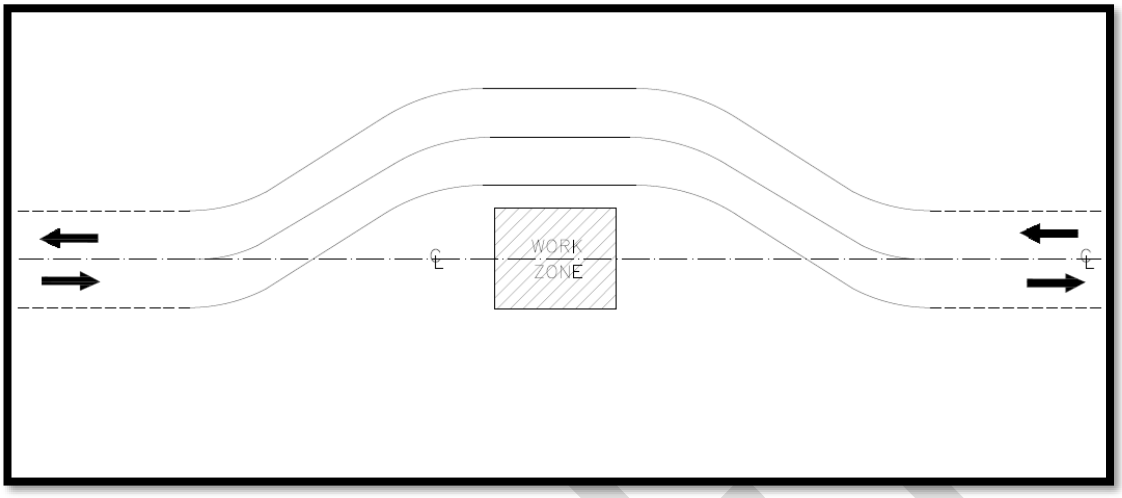
3. Values apply only to two-lane in one direction of travelled ways. For constricted two-way travelled ways, consider separation of opposing directions using additional travelled way width, and using channelizing devices, or traffic barrier.

How to use Exhibit 13-J: *The designer first considers the travelled way edge conditions. The 'lateral constraint' refers to the presence of a physical feature that results in 'shying away' at the edge of the travelled way. Temporary construction barriers are a common constraint feature. Next, identify the type of facility (undivided or divided) within the construction limits. Using this information and the number of travelled lanes through the work zone, determine the base (i.e., unadjusted) value within the appropriate cell. Superscripted numerals indicate the note numbers that should be referenced to determine appropriate adjustments, if any, to the base value. Values less than those obtained from this method may be appropriate for very low exposure (i.e., low traffic volume, low speed, short length of constricted lane segment, and short duration of operation).*

Source: NCHRP Report 581 (Design of Construction Work Zones on High-Speed Highways)

Exhibit 13-K

Typical Diversion Plan



13.8.4.1 Horizontal Alignment and Superelevation

Horizontal alignments of diversions commonly consist of a series of horizontal curves and may require vertical curves depending upon the profile. Sight distances should be reviewed for lateral obstructions and crest vertical curves. Refer to **Section 13.7.1** and **Section 13.8.1.1** for horizontal alignment and superelevation.

13.8.4.2 Vertical Alignment

Refer to **Section 13.7.2** for vertical alignment.

13.8.4.3 Cross Section

The typical cross section of diversions with normal crown and superelevated sections are illustrated in **Exhibit 13-L** and **Exhibit 13-M** respectively. The duration of service, construction cost, traffic volume and heavy traffic should be considered when design the cross section and the surface of the diversion. Desirably, diversion cross section should be the same as the approach roadway. However, this expectation is often not reasonable or practical. Recommended two-lane diversion travelled way and roadway widths are shown in **Exhibit 13-N**.

Exhibit 13-L

Typical Normal Crown Cross Section for Diversions

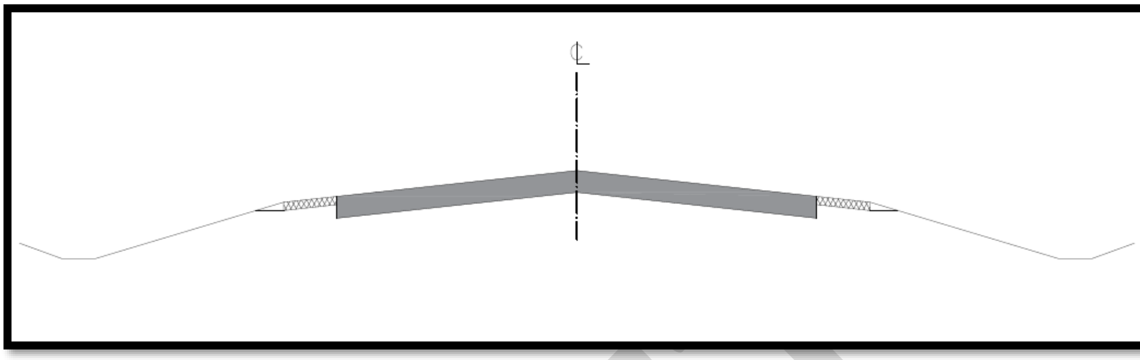
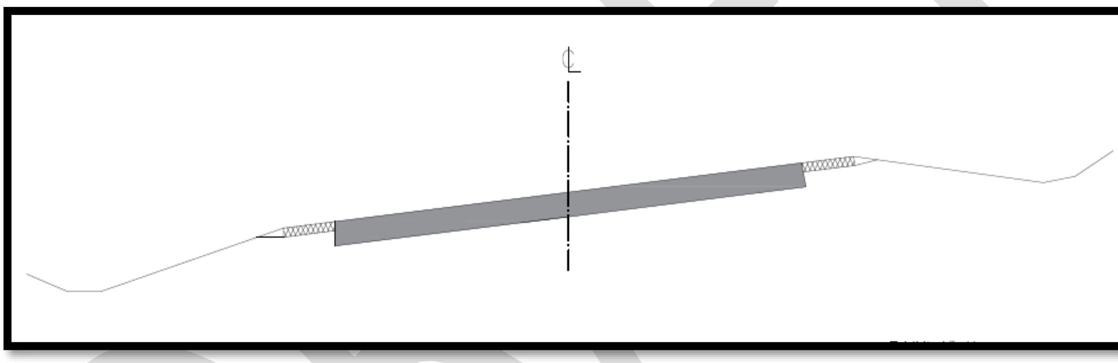


Exhibit 13-M

Typical Superelevated Cross Section for Diversions



Values greater than shown in **Exhibit 13-N**, up to those used for permanent roads of the same highway functional class, provide desirable service but the additional cost may not necessarily be justifiable.

Exhibit 13-N

Recommended Two-lane Diversion Travelled way and Roadway Widths

AADT	Travelled way Width (m)	Roadway Width (m)
< 1,000	6.5	7.5
1,000 – 3,000	6.5	8.5
> 3,000	7.0	11.0

Guidance provided in **Section 13.7.3** and **Section 13.6.3.3** for lane/shoulder width and cross slope respectively are applicable for diversions as well.

13.8.4.4 Drainage

The designer should refer to the latest edition of ministry's *Highway Drainage Design Standards* Sections *TW-2 Highway Drainage Management for Temporary Works.*

13.8.5 Median Crossover

A median crossover is the infrastructure temporarily constructed on a divided highway within the median between opposing travelled ways to connect one-side of the travelled way with the other to allow for two-way traffic. The core requirement in establishing the length and limits of a median crossover is to shift traffic from the portions of the highway that are to be reconstructed. Crossovers impose more constraint on drivers than the approach roadway. There is usually one one-way lane, which limits driver lane and speed choice. Additionally, cross-sectional arrangements often involve operation near barriers and provide reduced refuge opportunity for disabled vehicles. These factors increase driver anxiety and may require heightened vigilance. In recognition of these considerations, crossovers up to 15 km may be provided. However, it is desirable to have a maximum length of 8 km. Length is a function of traffic volume including commercial traffic. A careful traffic analysis should be done considering all factors to avoid unnecessary delays. Designer may also explore possibility of traffic analysis using micro-simulation to better understand the limits of median crossover. Median crossover should be sited to avoid:

- unnecessary proximity to bridge structures,
- substantial grade differences between one-way roadways,
- complex, sensitive, or formidable geologic features (e.g., rock outcrops or wetlands),
- interchange ramps. and
- other attributes including environmental that require extensive roadbed preparation.

Median crossovers are temporary roadways built to connect divided highways; it is a departure from the default path, being the permanent alignment through travelled lanes. Hence, driver familiarity and expectations are violated. From the driver's perspective, these temporary roadways are a nondiscretionary exit ramp from a mainline alignment. Although the movement is required for drivers, the combined and complementary use of geometry and TMP is needed to provide positive guidance for a distinctive departure from the permanent road alignment. The geometry should provide extended sight distance, a well-aligned and -delineated path, and a forgiving cross section.

Temporary construction barriers in conjunction with other Traffic Control Devices (channelizing devices, pavement markings, etc.) are used to delineate travelled paths and to separate opposing directions of travel in the areas where the permanent roadway carrying two-way traffic and temporary connecting roadway converge and diverge. The typical layouts for median crossovers are not available in the *OTM Book 7* and designers are encouraged to develop according to the principles of work zones discussed in the *OTM Book 7* and site-specific conditions. The designer may also take advantage of *Manual of Uniform Traffic Control Devices (MUTCD) of USA*; for an example, see **Exhibit 13-O**.

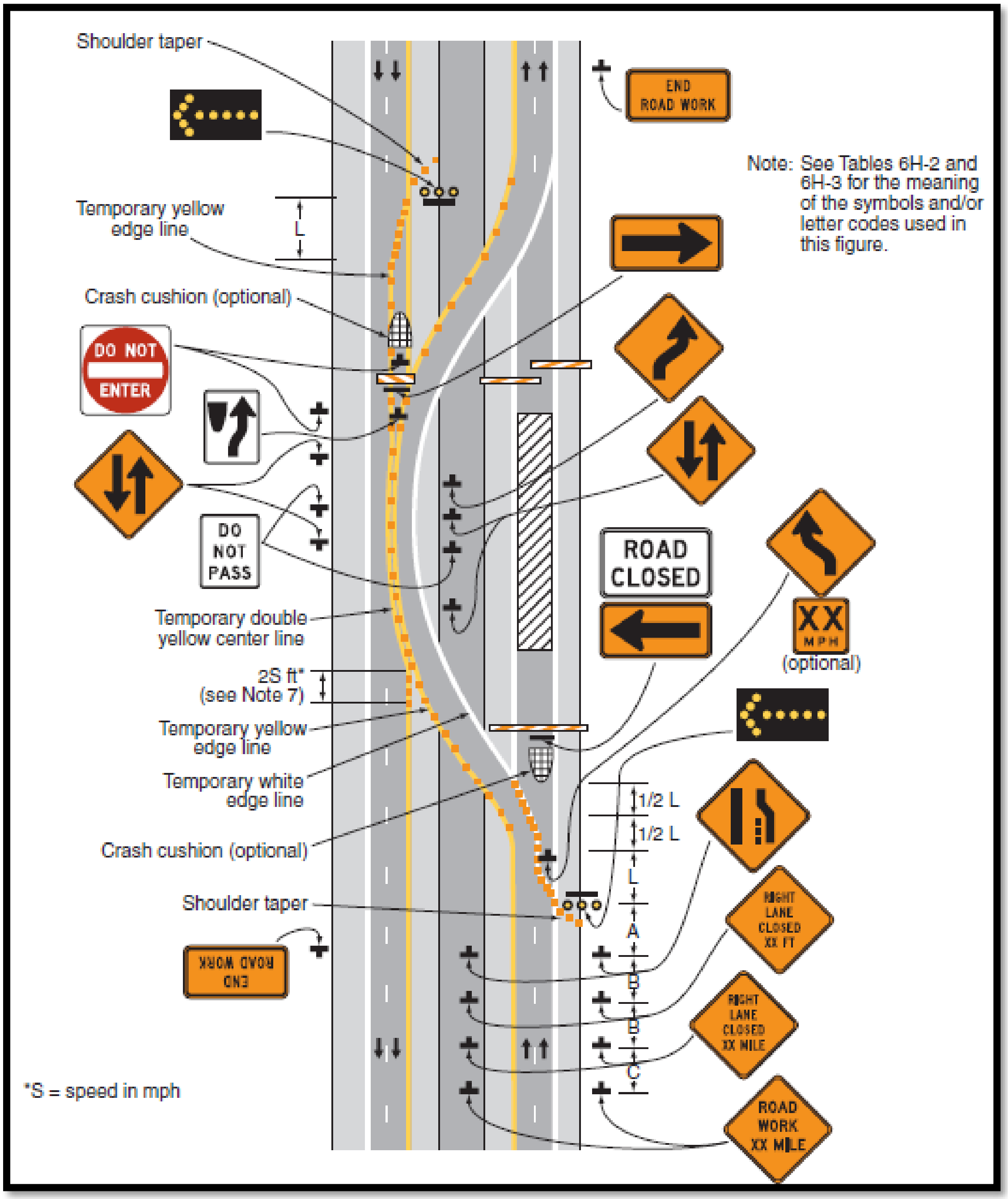
13.8.5.1 Horizontal Alignment and Superelevation

The horizontal geometry of median crossovers includes a series of horizontal and vertical curves. **Exhibit 13-P** schematically depicts a median crossover. The distance from the downstream end of the lane-closure taper to the beginning of the curve (distance ‘s’) should be in the range of 1.5 to 2 times the length of the taper provided in **Exhibit 13-G**. Higher values are desirable to provide separation between locations of driver decisions and associated manoeuvring.

If possible, the horizontal alignment should be flat enough to avoid the need for superelevation. The distribution of superelevation should be achieved by either Method 2 or Method 5 discussed in **Section 13.7.1** and **Section 13.8.1.1**.

Exhibit 13-O

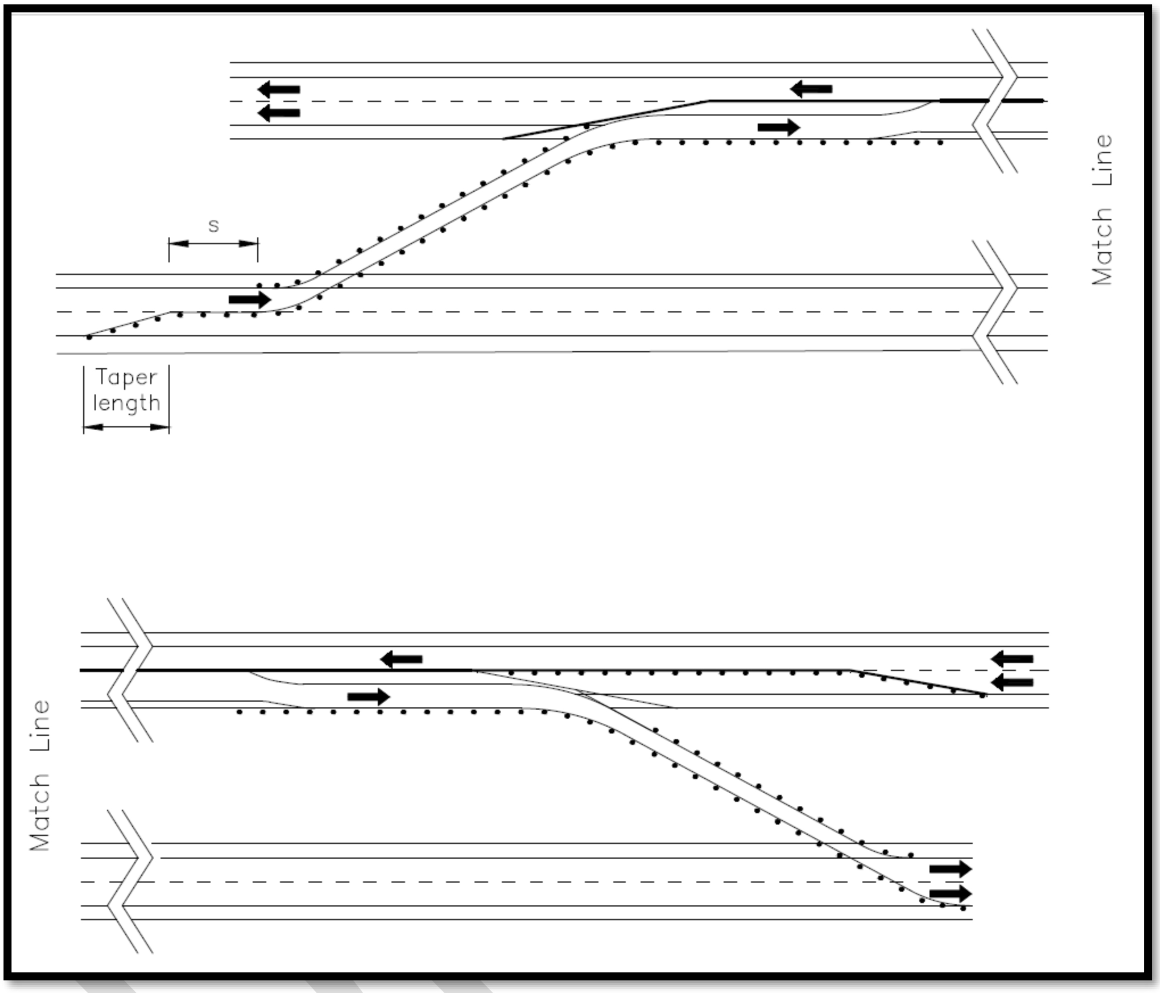
Median Crossover on a Freeway



Source: Manual of Uniform Traffic Control Devices, USA (2009 Edition, Updated 2017)

Exhibit 13-P

Horizontal Geometry for Median Crossover on Multi-lane/Freeway



13.8.5.2 Vertical Alignment

The effect of crest vertical curves and lateral sight obstructions should be reviewed. Refer to **Section 13.7.2** for vertical alignment for temporary roadways connecting the permanent roadways of a divided highway. The potential effect of grades on heavy vehicle performance and capacity should be considered.

13.8.5.3 Cross Section

Median crossovers may be two-lanes in one direction however, the most common is a single lane in one direction (two-lane two-way road) on four-lane divided highways. For a median crossover to facilitate a single travelled lane in each direction on a four-lane divided highway, the following cross section configurations may be used:

- Uniform traveled way cross slope where narrow median exists see **Exhibit 13-Q**, and
- Crowned in centre, where wide median exist see **Exhibit 13-R**.

Exhibit 13-Q

Typical Cross Section at Narrow Median for Multilane/Freeway for Median Crossover

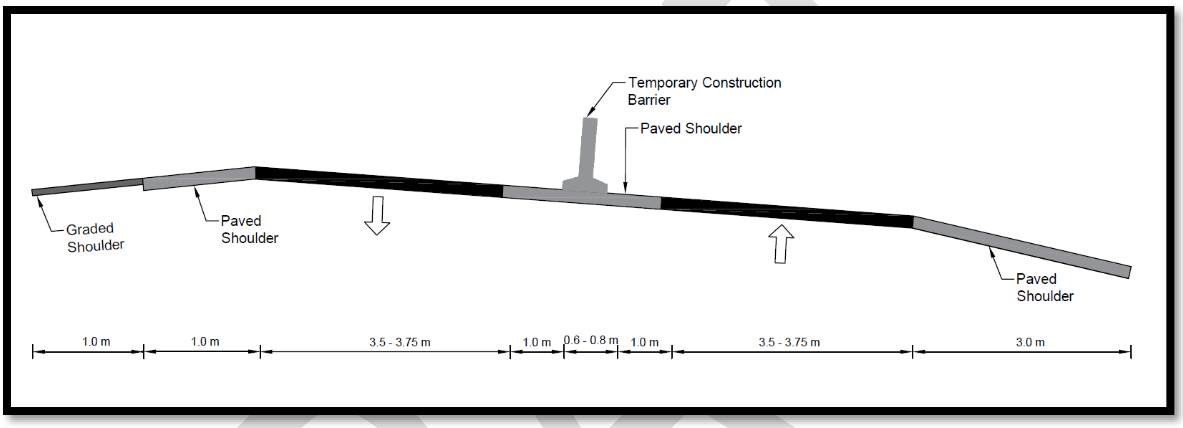
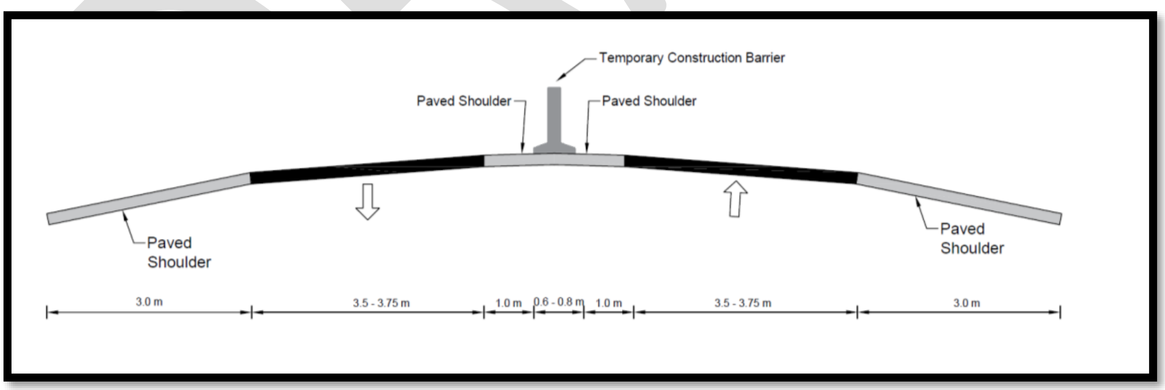


Exhibit 13-R

Typical Cross Section at Wide Median for Multilane/Freeway for Median Crossover



The travelled lane widths for a single lane in each direction range from 3.5 to 4.75 m, with 4.75 m being desirable. A wide cross section should be considered for a temporary roadway which carries high traffic volume, heavy vehicles, and high speed. Equal width shoulders are desirable.

Shoulders range in width from 0.5 to 3.0 m, with wider being desirable. For temporary roadways that will carry traffic only in one direction, a wide right shoulder should be provided to reinforce driver expectancy of the right shoulder for emergency stopping and refuge. A minimum of 2.0 m wide shoulder should be provided to accommodate a disabled vehicle. Equal-width shoulders may be provided for temporary roadways when the same roadway will be used for opposite-direction traffic at different time or in different traffic staging.

Temporary construction barrier or other appropriate delineation methods should be installed in median crossovers The permanent travelled way width available for use may not be sufficient to accommodate TCB and a left shoulder. The useful travelled way width is reduced by the barrier width footprint and its shy effect. The arrangement shown in **Exhibit 13-Q** and **Exhibit 13-R** should be used to provide adequate width for travelled lane and shoulders. In this arrangement a portion of shoulder needs to be included in travelled lane. When all or part of a shoulder is temporarily used as a travelled lane, certain complications may be encountered. Shoulder pavement structures may not be capable of supporting heavy vehicles and sustained traffic. Shoulder slopes may not be compatible with high-speed travelled because of superelevation requirements on horizontal curves. Therefore, when part of shoulder is to be used as travelled lane, it should meet the lane requirements in terms of cross slope and structural integrity.

For temporary roadways between the divided highways on high-speed highways, the travelled lane should be 3.5 m minimum wide. Shoulders 0.5 to 2.5 m wide on both sides are desirable. However, if this is not possible, then a wide right shoulder should be considered to reinforce the customary role and driver expectancy of the right shoulder as the location for emergency stopping and refuge. Additionally, emergency stops on the right side reduce potential conflicts with temporary barriers that are often located on the left side in the areas where temporary crossovers converge with and diverge from the one-way roadway carrying two-way traffic see **Exhibit 13-P**.

13.8.5.4 Cross Slope

A travelled way cross slope transition may be required between the permanent roadway and the temporary roadway. The direction, magnitude, and deflection from the temporary roadway to permanent one and vice versa are the key factors in cross slope transition and superelevation considerations. If the vertical profiles of the permanent and temporary roadways are such that a “break” in cross slope is required between the edge of pavement of the permanent and the temporary roadway, the effect of roll-over should be taken into consideration from an operational and safety point of view especially liquid cargo tipping over. The difference should desirably be 4% and not exceed 6%. For low-speed highways (≤ 70 km/h) it may be up to 8%.

13.8.5.5 Drainage

The designer should refer to the latest edition of ministry's *Highway Drainage Design Standards* Sections *TW-2 Highway Drainage Management for Temporary Works.*

13.8.6 Interchange Ramps

Design of ingress and egress to and from the construction site especially on high-speed highways involving interchanges is very important. It is equally necessary to maintain the existing access and exit points of traffic movements to reduce the negative impacts of traffic operations and in-line with the drivers' expectations. However, avoidance of these impacts should be weighed against the feasibility of providing adequate infrastructure for traffic to enter and exit the mainline facility. Temporary on-ramp and exit ramp are provided when sufficient space is available for speed change lane, (i.e., acceleration or deceleration), length, and the associated traffic control.

A temporary single-lane interchange ramp should have a travelled lane width of 4.5 m, with a 2.0 m right shoulder and minimum 0.5 m left shoulder. However, minor changes in cross-sectional arrangements may be appropriate for site specific conditions including traffic volume, commercial traffic, and duration of service.

13.8.6.1 Entrance Ramps

The feasibility of maintaining an entrance ramp during construction often hinges on providing an adequate combination of roadway geometry and traffic control to facilitate merging. Acceleration lanes enable entering traffic to increase speed while simultaneously selecting a gap in through-lane traffic. The basic principles and considerations associated with permanent entrance ramps pertain to temporary arrangements. Therefore, speed change lane lengths in work zones that meet the design criteria for permanent facilities are desirable. However, attaining these lane lengths is sometimes not practical. If desirable lane lengths are not feasible; the designer may use speed change lengths provided in **Exhibit 13-S**. This speed change lane may be installed either by direct taper or taper and parallel combination. Designing of direct taper is not desirable and may not be used as it violates driver's expectations and a focal point for collisions. If taper and parallel combination is used, taper may be 15 to 20% of the total of speed change lane length. In any case, sight distance must be considered, and the designer must provide the stopping sight distance. An illustration is provided in **Exhibit 13-T**.

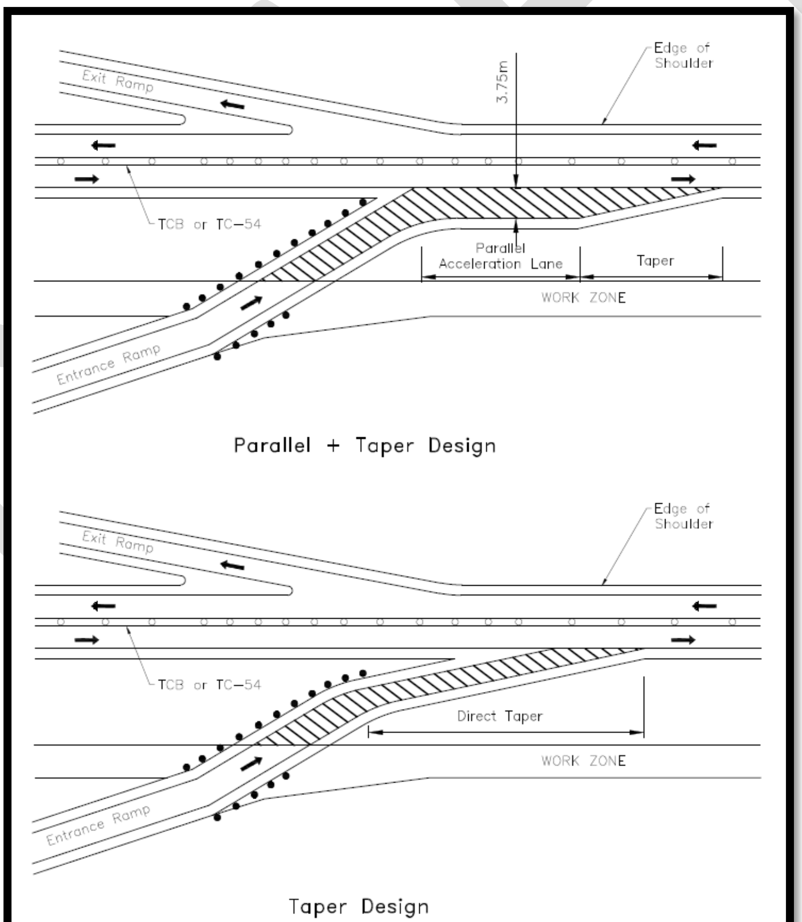
Exhibit 13-S

Length of Speed-Change Lane at Entrance Ramps

	Design Speed of Through Roadway (km/h)				
	90	100	110	120	130
Length of Speed Change Lane (m)	230	295	360	435	515

Exhibit 13-T

Temporary Interchange Entrance Ramps



13.8.6.2 Exit Ramps

Maintaining service on existing exit ramps is usually feasible for all work zone types. An adequate combination of roadway geometry and traffic control is needed to facilitate diverging from the mainline, negotiating the ramp, and meeting the operational requirements at the intersecting roadway (stop, yield, roundabout, and signal). Deceleration lanes enable exiting traffic to reduce speed after departing the mainline through lane and prior to encountering features that require lower speeds or stopping. The basic principles and considerations associated with permanent exit ramps pertain to temporary arrangements. Therefore, deceleration lanes in work zones that meet the design criteria for permanent facilities are desirable. It is desirable for exiting traffic to depart the through lanes at mainline speed and not reduce speed while occupying the mainline through lane. When this is not practical, the geometry of the ramp should be reviewed to determine if the ramp's length, horizontal alignment, and grade allow for gradual deceleration before reaching speed-critical features.

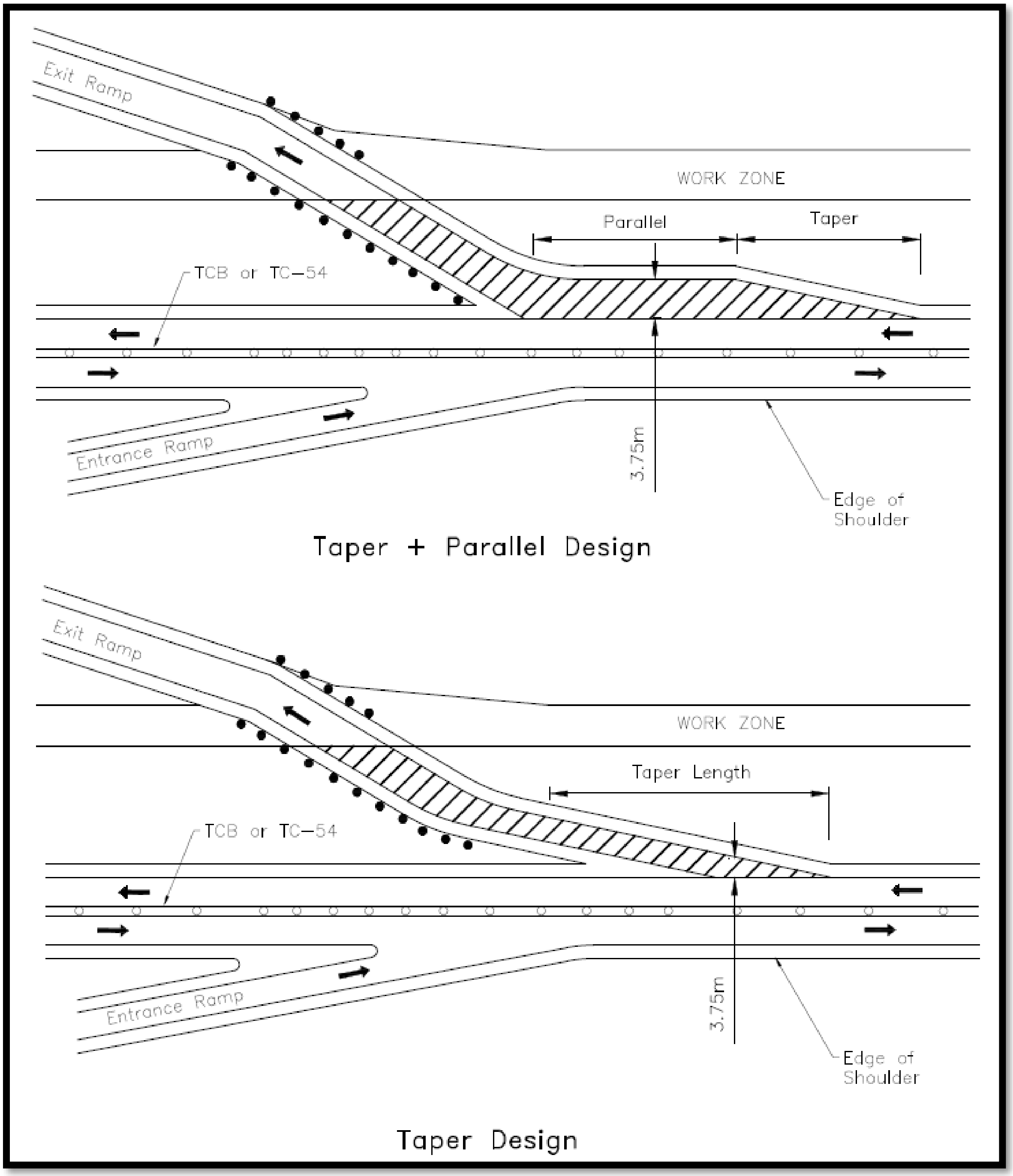
When using this arrangement, the minimum length of speed change lane (from start of taper to start of bull nose) are provided in **Exhibit 13-U**. The speed change lane design may either be direct taper or taper plus parallel. Designing of direct taper is not desirable and may not be used as it violates driver's expectations and a focal point for collisions. The speed change lane length includes the taper and parallel while taper may be 15% to 20% of the total length. The assumed speed at physical bull nose is 50 km/h. In any case the designer must consider the sight distance and must provide the stopping sight distance. **Exhibit 13-V** illustrates a temporary interchange exit ramp. This example has a parallel deceleration lane. This arrangement has some operational benefit, since a segment dedicated to deceleration is clearly visible to drivers on the freeway approaching the decision point and may reduce a tendency toward decelerating in the through travelled lane.

Exhibit 13-U
Length of Speed-Change Lane at Exit Ramps

	Design Speed of Through Roadway (km/h)			
	100	110	120	130
Length of Speed Change Lane (m)	240	270	300	330

Exhibit 13-V

Temporary Interchange Exit Ramps



13.9 ROADSIDE DESIGN

The roadside safety principles and procedures provided in the MTO's *Roadside Design Manual* (*RDM*) should be employed when designing all work zones. If there are any conflicts between the *RDM* and this chapter, the *RDM* shall take precedence. The foremost principle for roadside design in permanent roadways or in work zones is to provide a forgiving environment i.e., a roadside should be free of fixed objects and should have stable, flattened slopes that reduce the chances of severe collisions regardless of the reason for a vehicle leaving the roadway.

The practical guidance for a forgiving roadside concept is to provide a lateral area known as the 'clear zone' on the right side of an undivided highway and both sides for divided highways. The clear zone should be a traversable and unobstructed roadside area. However, clear zones could be obstructed and untraversable for a variety of reasons. If objects are located on the roadside, and especially within the desired clear zone, a series of alternative actions should be considered to reduce the likelihood of errant vehicles striking the objects. As mentioned in the *RDM*, the order of preference for addressing roadside obstacles is as follows:

1. Remove the obstacle,
2. Relocate the obstacle to a location where it is less likely to be struck,
3. Redesign the obstacle so that it can be safely traversed,
4. Reduce impact severity by using an appropriate breakaway device,
5. Shield the obstacle with a longitudinal barrier system or crash cushion for redirection,
6. Delineate the obstacle, if the above mitigation options are not appropriate; and
7. Reduce the posted speed.

Options 4 and 5 introduce the concept of crashworthiness. Where conditions require the presence of an obstacle or barrier near the travelled way, the obstacle or barrier should be designed to perform appropriately if struck.

Roadside safety concepts include forgiving roadside, clear zone, prioritized treatment of hazards, and crashworthiness and they are equally applied to work zones especially on high-speed highways. The work zone environment is different from the permanent roadway; equipment, materials, and workers are inherent to construction work zones. Depending on the setting, several of the prioritized roadside hazard treatments (e.g., removal or relocation) may not be a practical option.

The amount of traffic, speed and duration of construction work zones are the primary indicators of the probability of a collision in a work zone. Unlike the permanent roadway conditions, the duration of a construction work zone is definite. The shorter the duration of an observation period, the less likely it would be for 1, 2, or *n* vehicles to strike a roadside feature. Therefore, undesirable conditions that would warrant intervention on a permanent roadway may not be cost effective for a safety treatment in a work zone. Engineering judgement should be applied when evaluating roadside hazards in a temporary situation.

13.9.1 Clear Zones

A clear zone is a relatively flat lateral distance from the edge of the through travelled lane available for use by an errant vehicle before encountering non-breakaway obstacles or critical slopes. Standard clear zone widths are often unachievable everywhere to address traffic operations and constructability issues. Designers should assess whether to accept the increased safety risk with reduced clear zones, or provide mitigation strategies, such as using positive protection. On this basis, **Exhibit 13-W** is developed for work zone's clear zone that are less than those applied to permanent roadways.

The clear zone convention alone cannot be used to make all roadside design decisions. When a potentially hazardous roadside obstruction or non-traversable slope is located on the roadside, an analysis should be conducted that assesses the risk of vehicle collisions with the obstruction, estimates the severity of collisions with the obstruction, and determines the cost-effectiveness of one of the six prioritized treatments of the hazard.

13.9.2 Identification and Treatments of Work Zone Hazards

Since very limited data is available for work zone collisions. Therefore, designer should use their experience and judgement to identify hazardous features and the severity of the crashes involving construction workers, motorists, and pedestrians. The probability of a fatality for a pedestrian being struck by a vehicle travelling at 60 km/h is approximately 85 percent, for more details see Section 1.1.5 of Chapter 1 – Design Philosophy of *TAC GDG.* Besides workers, other roadside hazards that may be present in work zone roadside include but are not limited to:

- Construction equipment and materials,
- Excessive pavement edge and shoulder drop-offs,
- Severe roadside slopes,

- Existing permanent guardrail/construction barriers,
- Exposed ends of temporary construction barriers,
- Bridge piers,
- Bridge rails or parapet ends,
- Structure foundations (e.g., bridge falsework, sign foundations),
- Excavations and rock cuts,
- A gap in the median between dual bridges,
- Untreated guardrail ends in two-lane, two-way operations; and
- Other locations where construction will increase the potential hazards of existing conditions

Designer should use their experience and judgement to identify other potential hazards introduced by construction activities, work zone traffic staging plan and traffic controls. It is important to keep in mind that if traffic is rerouted via diversion or median crossover; this change may alter the separation between traffic and fixed features and may oppose traffic stream.

13.9.3 Traffic Protection

The purpose of the traffic protection devices is to contain and/or redirect errant vehicles and meet the crashworthiness evaluation criteria specified in the NCHRP Report 350 *"Recommended Procedures for the Safety Performance Evaluation of Highway Features"* and/or the *Manual for Assessing Safety Hardware* (MASH 2009 and 2016). MASH supersedes NCHRP Report 350, which superseded NCHRP Report 230 *"Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*" (1981). These devices include approved longitudinal barriers or Truck Mounted Attenuators (TMA) or Truck Trailer Mounted Attenuators (TTMA) also known as buffer vehicles. Traffic protection devices should be considered in work zone situations that place workers at increased risk from motorized traffic and where these devices offer the highest potential for increased safety for workers and road users.

The following policy adopted by the ministry, specified in the ministry's *Roadside Design Manual* (*RDM*), and reiterate here:
"On Provincial Highway Projects, only barrier systems, terminal systems, end treatments, transitions, crash cushions and small sign supports described in this manual (RDM) with active standards implemented in the Contract Preparation System should be used for new installations, unless otherwise authorized by the Highway Design Office".

Exhibit 13-W

Clear Zone Distances for Work Zone

Design Speed Km/h	AADT	Negative Foreslope (Fill) 6H:1V or Flatter	Negative Foreslope (Fill) 4H:1V to 5H:1V	Negative Foreslope (Fill) 3H:1V	Positive Foreslope 3H:1V	Positive Foreslope 4H:1V to 5H:1V	Positive Foreslope 6H:1V or Flatter
≥ 110	**≥ 6,000**	5.5- 6[a]	7- 8.5[a]	Use guidance for permanent roadway	4	4.5- 5	5- 5.5
	≥ 1,500	5- 5.5	6- 7.5[a]		3- 3.5	3.5- 4	4.5- 5
	≥ 750	4- 4.5	5- 6[a]		2.5- 3	3- 3.5	4
	< 750	3- 3.5	4- 4.5		2- 2.5	2.5- 3	3
100	**≥ 6,000**	4- 4.5	5- 6[a]		3- 3.5	4	4- 4.5
	≥ 1,500	4	4.5- 5.5		3	3- 3.5	4
	≥ 750	3- 3.5	4- 4.5		2- 2.5	3	3- 3.5
	< 750	2.5-3	3- 3.5		1.5- 2	2- 2.5	2- 2.5
70 to 90	**≥ 6,000**	4	4.5- 5.5		3	3.5- 4	4
	≥ 1,500	3- 3.5	4- 5		2.5- 3	3	3- 3.5
	≥ 750	3	3- 4		2- 2.5	2.5- 3	3
	< 750	2- 2.5	2.5- 3		1.5- 2	1.5- 2	2- 2.5
≤ 70	**≥ 6,000**	3	3- 3.5		3	3	3
	≥ 1,500	2.5- 3	3		2.5- 3	2.5- 3	2.5-3
	≥ 750	2- 2.5	2.5- 3		2- 2.5	2- 2.5	2- 2.5
	< 750	1.5- 2	1.5- 2		1.5- 2	1.5- 2	1.5- 2

a Clear zone may be limited to 5.5 m for practicality.

Notes:

- All distances measured from edge of travelled way.
- For clear zones, the AADT will be the total AADT on two-way roadways and the one-way AADT on one-way roadways. Traffic volumes will be expected traffic volumes through the work zone.
- The values for positive foreslope apply only to a section where the toe of the back slope is adjacent to the shoulder. For roadside ditches, use permanent roadway guidance.
- The design speed is the work zone design speed.
- It is not necessary to adjust the clear zone values for horizontal curvature.

Source: NCHRP Report 581 (Design of Construction Work Zones on High-Speed Highways)

Desirably, the designer should consider transportation management plan and traffic staging that do not require the use of traffic protection, while both minimizing the hazard exposure and maximizing the separation of workers and traffic. However, in many work zones, traffic protection is needed.

Traffic protection should be considered for the following conditions where construction and maintenance work are conducted with live traffic:

- Mobile/Intermittent or Very short duration,
- Short duration, and
- Long duration.

The designer should refer to the *OTM Book 7* for the definitions of durations of these operations.

13.9.3.1 Mobile Operations/Intermittent Duration or Very Short Duration

Work zones for a mobile and intermittent duration or very short duration operation may be accomplished using the following:

Multi-lane Highways
It may be accomplished using a stationary standard lane closure per *OTM Book 7.* The lane is closed using signing, arrow boards, and channelizing devices. If such a stationary standard lane closure is not used, then traffic protection devices e.g., TMA or TTMA should be used to close the lane in advance of the work zones. The use of additional signing would be dependent upon the posted speed limit, and the duration and length of the work, and should be in accordance with the *OTM Book 7.*

Two-lane, Two-way Highways
Lane closure for mobile and intermittent or very short duration operation on two-lane highways where one lane needs to be closed will require the use of a traffic protection device e.g., TMA or TTMA in advance of the work zone.

13.9.3.2 Short Duration

Traffic delineator devices will be required for stationary operations conducted under traffic in areas that offer no means of escape from motorized traffic (e.g., tunnels, bridges, bridge painting, narrow medians). For multi-lane and two-lane two-way highways, see additional guidance below regarding use of temporary longitudinal traffic barriers:

Multi-lane Highways
A work zone that occupies a location for Short Duration (SD) or requires multiple days/nights should use traffic delineators such as cones, barrels and temporary pavement markings.

Two-lane two-way Highways
A work zone that occupies a location for SD should use traffic delineators such as cones, barrels and temporary pavement marking.

13.9.3.3 Long Duration

Longer exposure of workers and highway users requires more positive guidance through a temporary condition in work zones.

Multi-lane Highways
The Long Duration (LD) work zone will require the use of temporary longitudinal construction barriers. Permanent signing and pavement markings which causes driver confusion should be removed and replaced with temporary signing and markings.

Two-lane Two-way Highways with work that occupies a location continuously for more than four days per stage consideration should be given for the use of temporary construction longitudinal traffic barriers.

For stationary operations on freeways longer than five days in duration, temporary construction barrier systems (TCBS) are required per Ontario Regulation 213/91, Section 67 under the OSHA. For minimal working widths, TCBS either do not deflect or have minimal deflection. TCBS are designed and crash tested for placement on paved surfaces.

13.9.4 Temporary Barrier Placement

Most of the time it is not practical to remove, redesign, or relocate potential work zone roadside hazards. Designers may have to decide which hazard to shield and which device (e.g., barrier type or crash cushion) is most appropriate. Factors and situations that are normally considered in making this decision include:

- Duration of construction activity,
- Traffic volumes and percentage of commercial/truck traffic,
- Nature of hazard,
- Length and depth of drop-offs,
- Work zone design speed, posted speed and anticipated operating speed,
- Highway functional classification,
- Length of hazard,
- Proximity of traffic to construction workers and equipment,
- Adverse geometrics ingress and egress requirements,
- Two-way traffic on one roadway of a divided highway,
- Right-of-way constraints such as property limits, environmental, utilities etc.,
- Drainage consideration,
- Pavement design consideration,
- Constructability consideration,
- Maintenance consideration,
- Transition areas at crossovers,
- Lane closures or lane transitions,
- Pinning barriers on bridge deck and causing damage to waterproofing layers.

13.9.4.1 Types of Barrier System

Temporary barrier systems are designed, and crash tested for use in construction work zones to provide physical separation between motorists and certain long term work zone operations. They are typically categorized based on material used for making the barrier. They are:

- Temporary precast concrete barrier systems,
- Temporary steel barrier systems, and
- Steel beam guide rail systems.

Precast temporary concrete barrier system and temporary steel barrier system are both categorized as Temporary Construction Barriers (TCB). Most TCBs are installed on paved surfaces and can be picked up and moved during construction for different construction stages. There are a few TCBs approved for installation on granular surfaces. In general, TCB should only be used in work zones in an approved as tested configuration. Steel beam guide rail systems can be installed temporarily through granular surfaces during construction and can be removed, salvaged, and reinstalled for different construction stages. Barrier systems may also be categorized based on their relative dynamic deflection upon impact. These are:

- Flexible,
- Semi-rigid, and
- Rigid.

Various approved barrier system details are provided in the ministry's *RDM*, *MTODs, SPs, OPSS, OPSD*, and *CDED* Manual. It is the designer's responsibility to select the appropriate barrier system for a particular work zone considering the factors mentioned above and the characteristics of the barrier system.

13.9.4.2 Shy Distance and Flare Rates

The distance between the edge of the driving lane and the inside edge of the barrier is known as the shy distance. Flare rate is a constant/uniform tapering of temporary barrier along the tapered alignment of the roadway. It is desirable to provide the recommended shy distance and flare rates through work zones according to the ministry's *RDM*. However, it may not be possible at every instance of work zones. The minimum shy distance and flare rates is provided in **Exhibit 13-X** and may be used for work zones.

<u>**Exhibit 13-X**</u>

Minimum Shy Distance and Flare Rates for Work Zones

Work Zone Design Speed km/h	Minimum Shy Distance m	Minimum Flare Rates
70 km/h and above	1.0	12:1
Less than 70 km/h	0.5	8:1

13.9.4.3 End Treatments

The blunt end of any barrier system is a hazard if it is located where it may be hit by an errant vehicle. It is more likely in cases of work zones where the shy distance of the barrier is compromised. It may cause environmental issue if the barrels filled with anti-freeze on bridge decks get hit and leak into the waterbody. The details of barrier system terminals and end treatments are provided in the ministry's *RDM* and should be followed for work zones.

13.9.5 Work Zone Layout

Where practical the designer should locate and design temporary roadside safety appurtenances based on the criteria provided in the ministry's *RDM* (e.g., deflection distance, length of need). However, it is sometimes not practical nor cost effective to meet these criteria for permanent installations due to the limited time traffic is exposed to construction hazards and the space constraints that are required during construction. The designer must evaluate the exposure time of the hazard in determining the need for installing a roadside safety appurtenance. The following offers several alternatives that should be considered in designing and locating temporary roadside safety appurtenances within work zones:

13.9.5.1 Clear Zone Offset

Applying the clear zone distances from the ministry's *RDM* to work zones is often impractical. Therefore, designer may use **Exhibit 13-W** work zone's clear zone distances. However, the potentially hazardous conditions typically found within work zones warrant the use of considerable judgment when applying these clear zone distances. Treat hazards within the work zone clear zone in the same manner as they would be in a conventional clear zone.

13.9.5.2 Length of Need

As with new installations, provide a sufficient distance of full-strength barrier prior to the hazard to minimize the potential for a vehicle to run behind the barrier and impact the hazard. There are standard MTODs and OPSDs that provide upstream and downstream length of need (e.g., *OPSD 911.232*) in conjunction with EAT (Energy Attenuator – Temporary) installations.

13.9.5.3 Flare Rates

Desirably, flare temporary traffic barrier terminals beyond the travelled way to a point outside of the work zone clear zone. **Exhibit 13-X** presents the desirable flare rates for barrier based on the selected work zone design speed. Use these flare rates unless documented extenuating circumstances render this impractical (e.g., stop conditions, driveways, intersections).

13.9.5.4 Openings

Avoid openings in the barriers. While there may be pressure from Contractors to have easy access to work areas, particularly bridge decks, this same open access can provide an unnecessary hazard to the public and workers alike.

Where openings are necessary, provide a ministry adopted and NCHRP Report 350 or MASH passed/approved end treatment at the barrier ends including delineation and proper signing.

13.9.6 Roadside Safety and Economics

If an obstruction or potential hazard in the work zone is identified, then designer should select the most appropriate treatment to mitigate the obstruction or hazard. The roadside safety decisions should be both practical and cost effective.

A benefit-cost analysis may be used to draw conclusion for various types of mitigating measures. The benefits usually refer to the reduced crash or societal costs as a result of decreases in the number and/or severity of crashes. The costs of implementing the action are the direct costs to the highway agency for initial installation, maintenance, and repair. If the ratio of the benefits to costs, determined by the following equation below, exceeds 1, then the benefits derived will be worthwhile of the investment over the analysis period. The benefit-cost ratio can be used to compare several different actions against each other and against the no-action option.

$$\text{B/C ratio } j\text{-}i = \frac{CC_i - CC_j}{DC_j - DC_i}$$

Where:

B/C ratio$_{j-i}$ = incremental benefit-cost ratio of alternative *'j'* to alternative *'i';*

CC_j, CC_i = crash or societal costs resulting from crashes under alternatives *'i'* and *'j'* (annualized over the analysis period); and

DC_j, DC_i = direct costs for alternatives *'j'* and *'i'* (annualized over the analysis period).

A benefit-cost ratio greater than 1 does not alone justify the implementation of a particular alternative. Conversely, a ratio less than 1 does not imply that no action should be taken. However, observing the ratios provides the designer with quantitative information to assist in making the best investment decision for safety and mobility needs.

The designer needs the following information to perform the benefit-cost analysis:

- Crash frequency prediction model under all proposed options,
- Crash severity model under all proposed options,
- Crash cost estimates by severity,
- Repair cost estimates by severity,
- Installation and maintenance costs for specified safety treatments, and
- A discount rate over the analysis period.

Designer should contact the Regional Traffic Office to obtain this information. If the appropriate information is attainable, benefit-cost analysis is a preferred method.

13.9.7 Additional Design Information

This section covers a few important work zone topics. These design topics include locations where drainage is an issue; lengthier work zone exists; and where police enforcement is needed.

13.9.7.1 Drainage

The purpose of the drainage design for work zones is to:

- Evacuate water rapidly from the travelled lanes and shoulders,
- Prevent pavement structure saturation,
- Avoid damage to properties including construction equipment,
- Maintain hydrologic systems traversed by the roadway, and
- Ensure safety of workers and road users.

The important element of work zone design related with drainage are to:

- Control erosion and sediment,
- Protect banks, and
- Storm water management

The designer should consider these basic design elements throughout the duration of construction, especially work related with bridges and culverts. If drainage design not considered, issues may arise that adversely impact the work schedule and may result in delaying the completion of the project. The designer should refer to the latest edition of ministry's *Highway Drainage Design Standards* Section *TW-2 Highway Drainage Management for Temporary Works.*

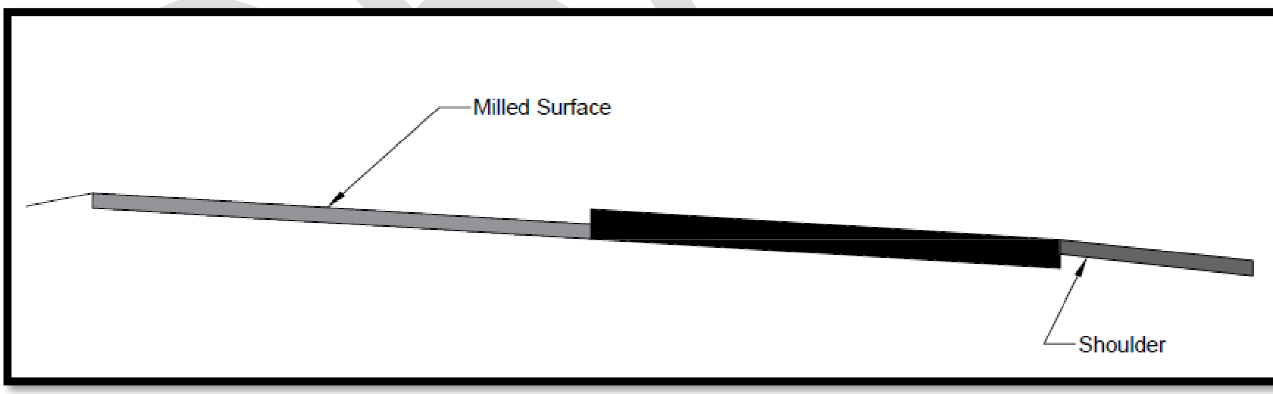
Drainage Issues

Designers should be mindful that many roadway features (e.g., shoulders, swales, and medians) are part of highway drainage conveyance systems. Several work zone types inherently alter the existing drainage system. For example, when the outside shoulder of a highway is used as a travelled lane, the potential for surface water encroachment into the temporary travelled lane is elevated. The following work zone drainage issues are common:

- Temporary infrastructure (e.g., temporary construction barrier, and curbs) may affect roadway drainage patterns, including spread into travelled lanes.
- Existing culverts may require extension to accommodate temporary roadways.
- Emergency turnouts may promote ponding.
- When a highway with two or more lanes sloped in the same direction is milled, surface water can be trapped, as shown in **Exhibit 13-Y**.

Exhibit 13-Y

Water Trapped by Milling in Work Zones



The analysis and design techniques provided in the ministry's drainage manuals and supplementary information in this section are the tools needed for providing work zone drainage. Anticipation of construction phase conditions and adaptation to dynamic construction and weather conditions are central to successful execution.

Design Storm Frequency

The objective of drainage design for work zones is to keep the driving surface well drained irrespective of the construction schedule at a particular location for continued and safe operations during adverse weather conditions. The measures used to provide for drainage of permanent roadways also apply to work zones; however, the relatively short life span of temporary roadways in construction work zones may result in a need for some modification. The Rational Equation (also known as the Rational Formula) is used in generally the same manner and with the same limitations as it is for permanent drainage structures. One difference relates to the selection of a design storm (i.e., design event). It would be unnecessary and costly if same recurrence interval is used for work zone as for permanent structures. The ministry's *Highway Drainage Design Standards* Section *TW-1 Return Period of Design Storms for Temporary Works* provide the return periods for bridges, culverts, diversion channels and diversion pipes and shown in **Exhibit 13-Z**.

Exhibit 13-Z

Design Storm Frequency for Work Zones

Minimum Minor Return Period For Temporary Drainage Works			
Duration of Construction	**Return Period (Years)**		
	Consequence*		
	Low	**Medium**	**High**
Less than 2 months	2	2	2
Up to 4 months	2	5	5
Up to 8 months	5	5	10
Up to 12 months	5	5	20
Up to 18 months	5	10	25
Greater than 18 months	10	10	25

** For consequence of failure or capacity exceeding definitions refer to the Highway Drainage Design Standards* Section *TW-1 Return Period of Design Storms for Temporary Works*

13.9.7.2 Emergency Shoulder Stoppage Areas

Shoulders are the traditional refuge for disabled vehicles. However, cross-sectional width is often compromised in work zones, resulting in the reduction or elimination of shoulders and travelled lanes. It may be necessary to install emergency shoulder stoppage areas intermittently through the work zone to mitigate cross-sectional width reductions. Factors considered in determining the necessity of providing the emergency shoulder stoppage areas are:

- Type of highway,
- Traffic volume,
- Vehicle mix,
- Design speed, and
- Length of road without a shoulder.

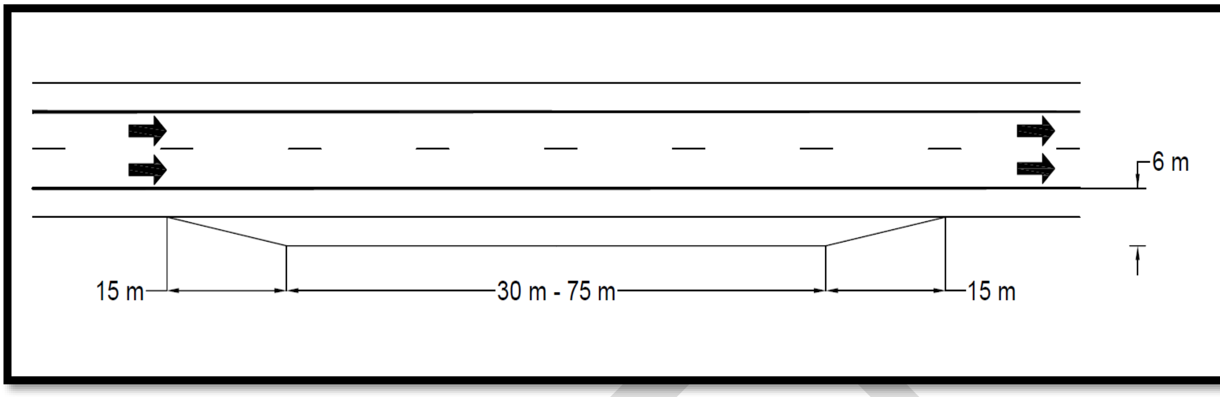
Stopping sight distance is an important consideration for site selection and design for emergency shoulder stoppage area. Exceeding desirable sight distance aids driver performance in resolving potential conflicts between traffic in the through lanes and traffic that is entering or exiting an emergency shoulder stoppage areas. With extended sight distance, drivers operating in the travelled lanes may be able to provide suitable gaps for entering vehicles by changing lanes or speed.

Emergency shoulder stoppage areas should be provided on flat, tangent sections of the roadway to maximize available sight distance, but this may not always be possible. Emergency shoulder stoppage areas should be avoided at or near the crest of vertical curves due to limited sight distance for approaching and exiting vehicles. If it is necessary, areas should be located well in advance of the crest curve to maximize available sight distance for approaching traffic.
Typical spacing ranges for emergency shoulder stoppages areas are from 0.8 to 1.6 km. Terrain and other context considerations (e.g., structure and slopes) often determine feasible locations and spacing. Emergency shoulder stoppage areas should be located on the right side of the travelled lanes. Left-side shoulder stoppage areas violate driver expectancy and should be avoided when possible. An example of emergency shoulder stoppage configuration is illustrated in **Exhibit 13-AA**.

Installation of advance construction guide signs improves the use and safety of emergency shoulder stoppage areas. By knowing the distance to a refuge, drivers experiencing emergencies can make informed decisions on the approach and exiting manoeuvres. Signing also provides other drivers with notice of potential exiting and merging traffic. Signing should indicate the distance to the emergency shoulder stoppage areas.

Exhibit 13-AA

Typical Example of Emergency Shoulder Stoppage Areas



13.9.7.3 Enforcement Pullover Areas

Visible law enforcement presence in work zone encourages motorist compliance with warning and regulatory signs and overall safe driver behaviour. However, effective enforcement may be hindered by the absence of paved shoulders or other locations where officers can safely position themselves and/or pull violators over.

Evaluating the Need

One or more enforcement pullover areas may be appropriate when the following conditions exist:

- To achieve compliance with traffic regulations such as reduced regulatory speeds, lane restrictions, and passing prohibitions etc., and
- There is no left or right shoulder for a distance of more than 5 km.

Enforcement pullover areas should be a supporting feature of an enforcement plan. The enforcement areas alone will yield no compliance benefits.

Design of Pullover Area

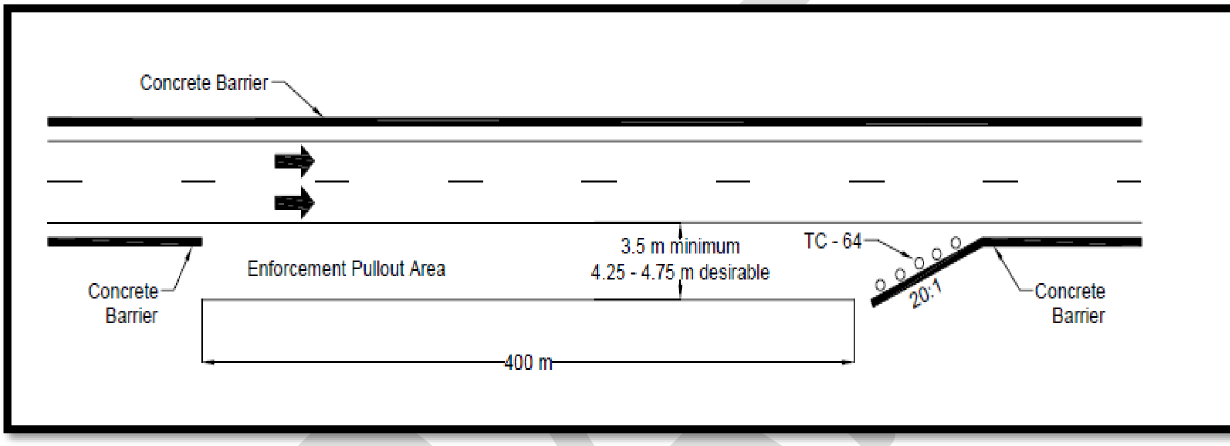
To be both safe and effective, enforcement pullover areas should be:

- Wide enough to allow the performance of enforcement activities,
- Long enough to afford safe entry and exit from the normal traffic stream, and
- Spaced so as to be effectively used by both motorists and enforcement vehicles.

An example enforcement pullover configuration is illustrated in **Exhibit 13-AB**. A minimum of 3.75 m width is recommended while 4.5 to 4.75 m widths are desirable. An enforcement pullover length of at least 400 m is recommended for 130 km/h design speed roadways. A spacing of approximately 5 km is a reasonable compromise between enforcement and contractor needs. Sight distance considerations for enforcement pullover areas are similar to those associated with emergency shoulder stoppage areas.

Exhibit 13-AB

Typical Example of Enforcement Pullover Area



13.9.7.4 Illumination

Conventional highway lighting that is present in pre-work zone conditions should be maintained during construction projects where possible. If individual lighting units are removed from service during construction, temporary units should be considered. Factors that should be considered are the vision and comfort of drivers and the ability of the workers to perform different types of tasks safely. For details, designer should also refer to Directive PLNG-B-05 – Ministry Policy for Highway Illumination and the *OTM Book 7.*

For new temporary roadways and intersections such as median crossover and traffic signal for single lane two-way operations, sufficient lighting should be installed to avoid any unexpected scenarios for drivers.

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