Guidelines

For Work Zone Designers




Designing for Incident Management

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15. Supplementary Notes This material is based on work supported by the Federal Highway Administration. This publication does not constitute a national standard, specification or regulation.			
16. Abstract Most State and many other transportation departments in the U.S. maintain roadway and/or work zone design manuals containing State specific regulations, policies, and design guidance for their designers and consultants to use. However, those manuals vary widely in the depth of coverage and the work zone design topics offered. National work zone design guidelines are lacking. This series of guidelines for work zone designers covers various work zone safety design topics for states, design manual decision makers, editors, and subject matter experts to develop or enhance their own guidance materials. "Guidelines for Work Zone Designers – Designing for Incident Management" provides guidance covering the topic of designing for incident management in work zones and is not intended to be a stand-alone document for designing work zone traffic control plans. State, county, local, and tribal transportation agency subject matter experts, should use this material as reference material to augment their own work zone design policies and guidance. The material in this guide was gathered from existing State design manuals, considered as best state-of-the-practice by the authors and worthy of sharing with other states, and from state-of-the-art work zone safety and traffic management research documents developed by the Transportation Research Board, the FHWA and other institutions.			
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0. Foreword

Designing highways, bridges, and other transportation infrastructure is both a science and an art. Good design requires careful balancing of a wide range of technical, social, financial, and environmental considerations, many of which affect road user safety. To guide staff and consultants on agency design policies, highway and bridge design manuals are issued by many State Departments of Transportation (DOTs). Design manuals are also issued by some county, municipal, and tribal transportation departments and by other highway agencies such as tollway authorities.

This document is part of a series of prototypical work zone design guidelines developed by the Traffic Operations and Safety Laboratory (TOPS Lab) at the University of Wisconsin through a grant provided by the Federal Highway Administration (FHWA). The documents in this series are not intended for use directly by designers. Instead, they are intended to serve as a framework to assist agency technical editors in preparing relevant sections of their design manuals. It is anticipated that the material in this document will be augmented with agency-specific policy and procedural information. Highway agencies should adapt and modify the information in this document based on their own operational experiences, traffic conditions, terrain, climate, organizational structures, risk management policies, legislation, and case law.

Guidance included in this document represents the authors' opinions of good practices. This document is not intended to serve as a national standard, policy, or regulation. Reference in this document to any specific commercial products, processes, or services, or the use of any trade, firm, or corporation name is for the information and convenience of the reader, and does not constitute endorsement, recommendation, or favoring by FHWA or the authors.

Two font colors are used in this document to assist agency design manual editors in adapting the prototypical guideline material for their state-specific guidelines:

Black color normal text identifies narrative, text, and other materials ready for consideration for incorporation into agency-specific guidelines, with relatively little revision.

Italicized purple color text identifies commentary material and other issues that are likely to need modification to reflect agency-specific policies, organizational structures, and choices, and require further considerations.

Note: Blue color is used to designate section heading numbers and titles in this Guide.

1. Introduction

Many types of traffic incidents can occur in work zones, ranging from relatively minor issues such as a vehicle with a mechanical breakdown to severe problems such as a truck crash (Figure 1). These types of crashes are compounded when hazardous material spills are involved. Job-site mishaps by contractors can also adversely affect traffic when construction equipment causes overhead powerlines to fall or hit and damage underground gas or electric transmission lines. This document is intended to help work zone designers develop physical accommodations, select operational techniques, and establish contractual provisions that:

- Reduce the risk of secondary incidents such as back-of-queue collisions.
- Reduce the traffic impacts of work zone incidents.
- Make it faster and easier for first responders (police, fire, and emergency medical services) to reach the scene and manage the situation.
- Make it easier to restore traffic flow promptly.

Figure 1. Lane-blocking incident at a freeway construction site.
Source: Wikimedia Commons/Oregon DOT

There are four general categories on types of incidents that can occur in a work zone:

- Vehicle malfunctions and traffic crashes involving road users.
- Worker illnesses, injuries, and other medical emergencies.
- Construction mishaps such as damage to overhead and underground utilities, fire, trench collapse, false work failures, or crane incidents.
- “Intrusions” by vehicles erroneously entering the work activity area.

All four categories of incidents have the potential to affect adversely traffic flow. For example, it is sometimes necessary to close traffic lanes so that emergency medical services personnel can reach an injured worker.

The strategies, tactics, and methods discussed in this document include:

- **Geometric design features** that make it easier to respond to incidents, prevent damaged or disabled vehicles from blocking traffic, and restore traffic flow.
- **Operational techniques and contractual arrangements** that make it possible to respond to work zone incidents more quickly or expedite restoration of damaged traffic control devices, highway facilities, and equipment.

Typically, the implementation of Work Zone Traffic Incident Management (WZ-TIM) infrastructure and strategies is done as part of the development of the project's Transportation Management Plan (TMP), [1], [2]. The results are then incorporated into relevant project documents such as the Temporary Traffic Control (TTC) plan *(also called a Maintenance of Traffic (MOT) plan in some States)*, contractual special provisions, and cost estimates. Preparing these documents during the design phase helps avoid cost overruns and other difficulties that can occur if WZ-TIM is not considered sufficiently before the construction contract has been awarded. Some of the goals of WZ-TIM are summarized in Table 1.

Table 1. Work Zone Traffic Incident Management (WZ-TIM) goals[2].

Work Zone Traffic Incident Management Goals	
• Reduce the amount to time required to detect and verify that an incident has occurred. • Expedite the arrival of appropriate response personnel and equipment. • Minimize the amount of roadway capacity lost due to the incident (and the presence of response personnel and equipment).	• Facilitate the management of response apparatus and personnel. • Reduce the amount of time required to clear the incident from the travel lanes. • Rapidly notify travelers upstream of the incident to encourage a reduction in traffic entering the incident area and to reduce driver dissatisfaction.

1.1. Hazards, Risk, and Collisions in Work Zones

In everyday speech, the words "hazard" and "risk" are often used interchangeably, but there is a technical difference: a "hazard" is a potentially dangerous situation, and "risk" is the probability that a person (such as a worker or road user) will encounter a hazard and suffer a casualty (injury or death). Work zone design decisions can increase or decrease the severity of hazards, and can raise or lower the risk level associated with these hazards.

To provide space for work operations it is often necessary to relax the usual roadway design standards temporarily. For example, one or more lanes might be closed, and the remaining lanes might be narrowed. It is sometimes necessary to shift lanes laterally to avoid partially completed work or other obstacles. The pavement surface might be rougher than usual, and sight distance might be reduced. Construction also introduces new hazards, such as collisions between fast-moving traffic and slow-moving work vehicles. The cognitive workload for drivers' increases: drums and other temporary traffic control devices increase the number of objects that drivers need to observe and mentally process as they try to identify traffic hazards. In addition, drivers sometimes get distracted looking at the roadwork when they should be paying attention to the road. The combined effect of all of these factors is that the number of crashes per distance travelled is higher in work zones than it is under non-construction conditions, for both freeways and other types of roads [3],[4],and [5]. The AASHTO Highway Safety Manual includes methods for quantifying these effects [6].

In 2013 an estimated 67,500 crashes occurred in work zones in the United States, resulting in 593 fatalities and nearly 48,000 injuries [7], [8]. Consequently, it is important for work zone designers to be prepare for the possibility of crashes. This includes eliminating hazards when possible and working to reduce the risk, severity, and traffic impacts of crashes.

All other things being equal, the likelihood of a crash increases roughly in proportion to the traffic volume, work duration, and physical length of the work zone [9]. Physical and contractual provisions to accommodate potential crashes are particularly important if the work zone is located in an area that will be difficult for first responders to reach, carries a high volume of high-speed traffic, or has severe reductions in traffic-handling capacity.

1.2. Traffic Effects of Work Zone Incidents

Traffic-Handling Capacity. Lane-blocking incidents that occur in work zones often have a disproportionate effect on traffic flow. Figure 2 compares (very roughly) the traffic handling capacity for a three-lane freeway under different operating conditions. Closing one lane for work operations takes away one-third of the driving space, but reduces the traffic-handling capacity of the roadway to about half of its pre-construction capacity. If an incident blocks one of the remaining lanes, the traffic throughput is reduced by about 75% compared to normal three-lane operations [10]. (The exact values depend on several factors; please refer to the current edition of the TRB Highway Capacity Manual for details).

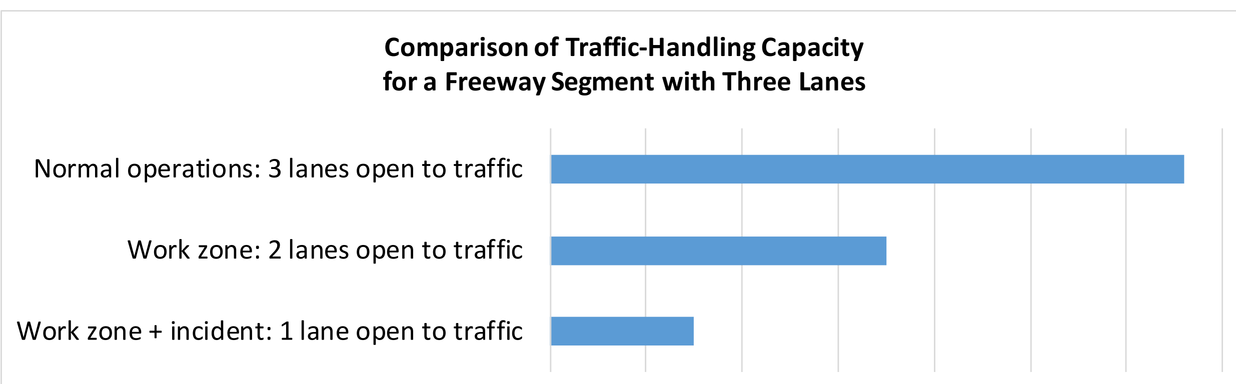


Figure 2. Comparison of traffic-handling capacity for a three-lane freeway segment under normal, work zone, and incident conditions.
Source: TOPS Lab

Secondary Crashes. When capacity is reduced by work zone incidents, traffic queues (back-ups) can form very rapidly, especially on freeways. Far too often, this results in a secondary crash at the back of the queue. The term "secondary crash" refers to a second (or subsequent) crash that occurs because of the original incident. They are a significant problem in terms of both frequency and severity. According to one estimate, secondary crashes account for 18% of all fatalities on freeways [11]. A particularly risky situation occurs when high-speed traffic unexpectedly encounters a line of slowed or stopped vehicles that is obscured by a curve or hill; the resulting high-speed rear-end crashes can be very severe.

1.3. The Safe System Approach

The Safe System approach is a relatively new way of thinking about the interaction of roads, road user behavior, vehicles, and speeds. It was developed in 2008 through a three-year cooperative effort by an international group of safety experts representing 22 countries. (The United States was represented by high-ranking officials from the Federal Highway Administration [FHWA], the Federal Motor Carrier Safety Administration [FMCSA], and the National Highway Traffic Safety Administration [NHTSA]). The goals of the Safe System Approach and Road to Zero (the U.S. national highway safety strategy) are the same: to create a roadway system that is increasingly free of death and serious injury.

Traffic crashes usually involve a chain of events that includes mistakes, mishaps, and sometimes misbehavior (Figure 3). Crashes can be prevented by breaking the chain before a mistake turns into a serious incident. Similarly, the consequences of a crash can be reduced by starting at the end of the chain and working backwards to identify opportunities to reduce its severity. Some of the techniques and strategies discussed in this document are intended to improve post-crash outcomes, for example by allowing Emergency Medical Services (EMS) to reach and treat crash victims more quickly. Others focus on the lower (gray) boxes in Figure 3, which address the traffic impacts of a crash, including secondary crashes.

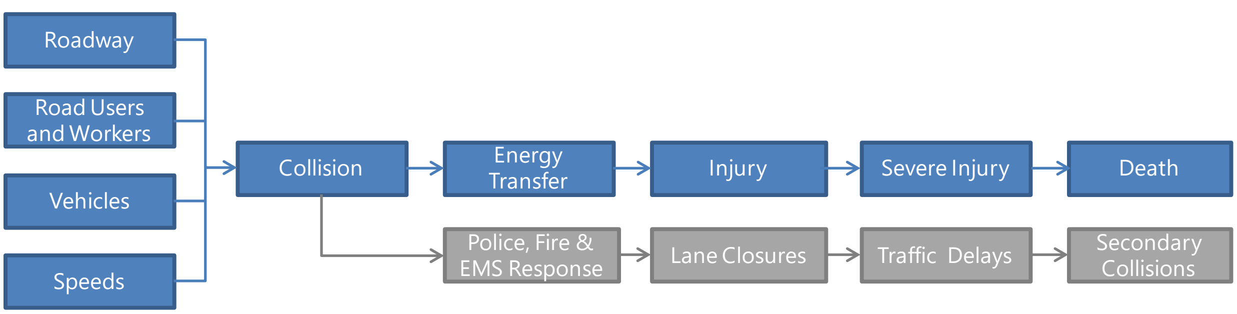


Figure 3. Causal chain for a fatal work zone collision.
Source: TOPS Lab

Implementing a Safe System in a work zone requires a coordinated effort between people and organizations. Designers play a pivotal role in this process. Decisions made during the design process determine the physical and contractual environment that will exist during construction. As a result, designers can help create a situation where first responders, the contractor, and the construction field engineering staff are able manage incidents quickly and effectively. For example, emergency response is sometimes hampered by lack of space and limited site access. When a designer successfully identifies ways to improve access and provide ample space for incident management, it can make response and recovery faster and easier, help protect the safety of first responders and road users, and diminish the risk of secondary collisions.

2. Back-of-Queue Protection

Traffic back-ups (queues) occur in many work zones (Figure 4). Protecting the back-of-queue is often one of the most important steps a designer can take to support work zone safety. Back-of-queue crashes occur when a vehicle moving at relatively high speed collides with one that has stopped or slowed due to congestion. Some work zone back-of-queue crashes occur because of congestion caused by lane closures; others are secondary collisions associated with earlier incidents. Back-of-queue protection is especially important when traffic back-ups are likely to occur in a location where drivers would not ordinarily expect congestion [12].

Figure 4. Back of Queue Traffic
Source: AAA Foundation for Traffic Safety

A number of circumstances contribute to back-of-queue crashes (individually or in combination). These causal factors include:

- A driver approaching the queue fails to notice it soon enough to avoid a collision.
- A driver approaching the queue vehicle misperceives the speed difference.
- An approaching driver cannot see the queue due to a visual obstruction such as a curve or hill.
- A queue forms too quickly for drivers to react appropriately.

Data compiled by the National Traffic Safety Administration (NTHSA) indicates that over the period from 2011 to 2013, front-to-rear collisions accounted for 19.5% of fatal crashes in U.S. work zones [13]. These types of work zone crashes are probably underreported in some States unless emphasis is given during law enforcement training that back-of-queue crashes caused by work zone related traffic back-ups, regardless of the location of work zone signs, are work zone crashes. In addition to fatalities, back of queue crashes are also a source of a significant number of work zone serious injuries, due to the potential for crashes to occur between vehicles traveling at a large difference in speed.

Back-of-queue crashes can be reduced by providing advance warning of the stopped/slowed traffic. The three main technical approaches to providing this warning are discussed in this chapter.

2.1. Advance Warning Distance and Sign Phrasing

Queue warning needs to be positioned far enough upstream to give drivers sufficient distance to comprehend the situation and begin braking before they reach the stopped/slowed traffic, but not so far upstream that drivers forget the warning. Although stopping distance depends on several factors such as traffic speed and pavement moisture, NCHRP Report 746 recommended that (for freeways) the warning should be positioned approximately ¼ mile upstream of the back-of-queue to allow ample stopping distance [14]. This means the warning will need to move upstream (against the direction of traffic) as the queue grows. The queue-warning vehicle or device must also be positioned so that it is not hidden by curves, hills, etc.

The signs/messages that provide advance warning of traffic queues typically use one of the following phrases:

- BE PREPARED TO STOP (MUTCD W3-4)
- SLOW TRAFFIC AHEAD (MUTCD W23-1)
- STOPPED TRAFFIC AHEAD

2.2. Vehicle-Based Back-of-Queue Warning

Vehicle-based warning systems consist of one or more vehicles that are deployed upstream of the back-of-queue. Each vehicle is equipped with signs and/or flashing lights to alert approaching drivers to the changed condition. Two types of vehicles have been used for this purpose:

- **Law Enforcement Vehicles** can be used to provide queue warning by positioning the vehicle upstream of the back-of-queue with its lights flashing. In some jurisdictions the officer is positioned contraflow (facing oncoming traffic) on the roadway shoulder; this allows the officer to roll forward as the queue grows. An important disadvantage of the use of law enforcement for queue warning is that the officer is not available for other duties. Depending on the number of personnel available at the time of the incident, there could be a significant time delay between the formation of the queue and the arrival of the queue-warning officer.
- **Queue Warning Vehicles** are specially marked vehicles, usually operated by highway agency employees or a contractor. Like law enforcement vehicles, they can be positioned facing oncoming traffic to make it easier for the operator to reposition the vehicle as a queue grows. Electronic displays or double-sided fold-down signs combined with flashing amber lights draw attention to the queue-warning message (Figure 5).

a. Quick response vehicle (with traffic flow)

b. Extended duration vehicle with truck-mounted attenuator (with traffic flow)
Source: Tennessee DOT

Figure 5. Queue Warning Vehicles

2.3. Queue Warning Signs

Queue warning signs are fixed or portable signs positioned at the roadside to warn drivers as they approach stopped or slowed traffic. Both static and electronic signs are used for this purpose. The activation of queue warning signs can be manual or remotely actuated. In the manual configuration, a person must drive to each sign to deploy it. In a remote control configuration, each sign is equipped with remote telecommunications that are used to activate an electronic message or actuate a motor to uncover a pre-lettered panel.

The choice between manual and remote control operation should be based on a site-specific consideration of cost, the anticipated number of activations over the project duration, and the likelihood that very rapid deployment of the message would be necessary. At some sites, a mixture of manual and remote control signs is appropriate, with remote control signs close to the work area (where queues are likely to begin forming) and manually activated signs further upstream (which would be manually deployed if the queues become unusually long).

At least three types of signs are used for queue warning purposes:

- **Roll-Up Signs.** Vinyl-coated fabric temporary mesh signs can be set up quickly without tools (Figure 6). The primary advantage is portability: several signs and their bases can be carried in a typical automobile trunk. As a result, they are easy to reposition as traffic queues change. Roll-up signs have some practical disadvantages: their conspicuity is often limited due to relatively small size, they can be partially obscured by vegetation due to low mounting height, they can blow over in heavy winds due to lightweight, and they are easily stolen. Although vinyl signs with ASTM Type VI

Figure 6 Mock Roll-Up Road Closed Sign
Source: Leif Skoogfors/FEMA

microprismatic sheeting are retroreflective, frequent inspection is recommended due to limited service life.

- **Hinged Fixed Signs** are typically post-mounted wood or metal signs with a horizontally or vertically hinged panel that can be unfolded to reveal an incident management message (Figure 7). They are usually larger and more conspicuous than portable signs and are generally more economical than electronic signs. Since the sign locations are fixed, it is typically necessary to install a series of queue warning signs that can be opened and closed as the queue length changes. Hinged signs can be equipped with motors to allow remote actuation.

Figure 7. Hinged Sign
Photo Simulation

- **Portable Changeable Message Signs (PCMS)** are usually trailer-mounted (Figure 8). They are typically large and conspicuous. Although they can be moved, repositioning the signs during an incident is often impractical due to timing, equipment availability, and traffic constraints. As discussed in Section 3.7, PCMS are relatively expensive and are generally not tested for crashworthiness. Many newer PCMS models can be equipped with telecommunications to allow remote activation of incident management messages.

Figure 8. Portable Changeable Message Sign
Source: WalterBaxter/Geograph

2.4. Automated Queue Warning Systems

Automated queue warning systems consist of a series of speed sensors and electronically actuated signs (Figure 9 through Figure 11). If the speeds observed near a sensor fall below a pre-determined threshold, the corresponding upstream sign is activated. In freeway applications, the distance between the sensor and its upstream sign is typically one-half to 1 mile.

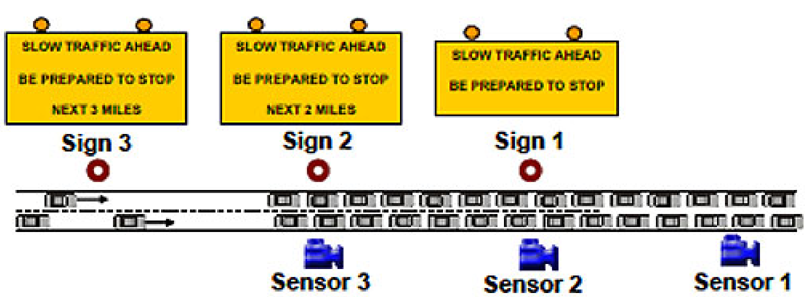


Figure 9. Conceptual diagram for Automated Back-of-Queue Warning System.
Source: FHWA ITS ePrimer

Figure 10. Back-of-Queue Warning System
(PCMS based)
Source: Minnesota DOT

Figure 11. Back-of-Queue Warning System
(beacon flashing light & static sign)
Source: John Shaw

Automated Queue Warning Systems are increasingly popular, especially for long-term work zones in areas with high traffic volume. When specifying such a system, the designer should begin with a clear idea about whether the primary purpose of the system is to warn drivers about congestion caused by lane closures, incidents, or both. This distinction is necessary because a lane closure combined with an incident could result in queues that extend well beyond the first upstream warning sign that would be used for a construction-closures-only system. In some cases, it could be appropriate to automate the detection of "routine" queues caused by lane closures, while specifying manually activated queue warning signs or queue warning vehicles for use during incident-related queues that extend further upstream.

3. Geometric Design to Support Incident Management

This chapter discusses several work zone physical layout strategies that support work zone traffic incident management and expedite access to incident sites.

3.1. Allocating Roadway and Shoulder Space

Allocating Road Space. Many construction projects require re-allocating the existing road space, especially the available width. Designers frequently face trade-offs between keeping lanes open to traffic and providing working space for the contractor. Many freeway projects require space for temporary barriers. Non-freeway projects (especially projects on urban arterials) often require space for turning movements, pedestrians, bicyclists, bus stops, and access to businesses and other properties. Some urban projects also require space for temporary fencing to manage pedestrian traffic and keep bystanders out of the work area.

A frequently used solution to these conflicting demands is to convert roadway shoulders into temporary driving lanes. While this has a number of benefits, eliminating shoulders can have a substantial impact on incident management:

- Without shoulders, any damaged or disabled vehicle will block at least one lane.
- The absence of shoulders makes it difficult for first responders to reach the incident scene.
- Without shoulders there is no place to stage equipment that will be used during later stages of rescue and recovery, such as an ambulance that is waiting for a crash victim to be extricated, or a reserve firefighting vehicle carrying specialized equipment.

Some potential solutions are discussed below.

Narrow Shoulders. From an incident management perspective, it is highly preferable to maintain shoulder widths sufficient to accommodate first responders and their vehicles (e.g. an 8 to 10-foot shoulder). When this is not possible, even a narrow shoulder (perhaps 4 to 6 feet wide) can be helpful. Although vehicles in the travel lanes will be forced to squeeze over to let emergency vehicles through, the existence of a narrow shoulder delineates a path for emergency vehicles and provides at least part of the space required for storage of disabled vehicles and staging of emergency response equipment.

Intermittent Shoulders. Intermittent shoulder widening can also facilitate incident management. For example, in hilly terrain, there will be cut and fill sections, and there might be relatively level sections where a portion of the roadbed can be widened. This can provide a space where emergency vehicles can maneuver around a driver who fails to yield, where disabled vehicles can be moved out of traffic, and where emergency vehicles that will be used during a later stage of the response can wait without blocking travel lanes. Although this requires a reasonably firm surface that can support the weight of firefighting vehicles, the widened area does not always need to be paved.

Embankment Foreslopes. In some cases, first responders will attempt to drive on embankment foreslopes to reach an incident. The feasibility of this approach depends on the width of the fore slope (and any adjacent shoulder area); the slope of the embankment; the strength of the soil; and the absence of obstacles, such as barriers, posts, and columns. In some cases, designers can make this solution more feasible by altering the construction staging sequence—for example by advancing the demolition of an old bridge pier that would otherwise block the path.

Figure 12. Some firefighting vehicles are equipped with all-wheel drive for operation on unpaved terrain.
Source: WikiMedia Commons/Bradley Bormuth

If this strategy will be used, advance coordination with emergency response agencies is strongly recommended. For example, some fire departments have all-wheel-drive firefighting vehicles (Figure 12) that might need to be redeployed from a different part of their service area.

Other Options. When the solutions described above are not practical, designers and first responders should consider alternative strategies such as:

- Temporary moveable barrier gates to provide additional access points.
- Temporary access from side roads or overpasses.
- Reverse entry to incident sites, with responders driving the wrong way on the opposite side of the road.
- Minimizing the length and duration of shoulder closures during each stage of the work operation.
- Full closure of the roadway with all traffic diverted to another route (thus eliminating the possibility of a traffic incident in the work zone).

3.2. Unequal Lane Width Distribution to Increase Space for First Responders

Many work zone designers prefer to make all traffic lanes the same width, but this is not always optimal from an incident management perspective. Table 2 lists the typical widths for various types of vehicles sold in the United States. Commercial trucks are typically about 2 feet wider than the largest personal motor vehicles.

Table 2. Typical vehicle widths.

Vehicle Type	Width (excluding mirrors)	Reference
Mid-Size Car	6 feet	[15]
Full-Size SUV or Pick-Up	6 feet 8 inches	[16]
Intercity Bus	8½ feet	[17]
Tractor-Trailer	8½ feet *(9 feet in Hawaii)*	[17]

By using unequal widths and regulating lane use (e.g., allowing trucks only in the right lane), it is sometimes possible to provide a shoulder that is wide enough for emergency vehicles without reducing the total number of travel lanes that remain open. Figure 13 shows an example. In this case, the available footprint is 42 feet wide. With a 2-foot shy distance to the left barrier and three 11-foot wide driving lanes, only 7 feet is available for the right shoulder (too narrow for most fire engines). By using an unequal lane width distribution it is possible to maintain three lanes with a 2 foot shy distance to the barrier, two 10 foot lanes for automobiles, an 11 foot lane for mixed traffic (including trucks), and a 9 foot shoulder (just wide enough for a firefighting vehicle, or a disabled semi that folds its mirrors).

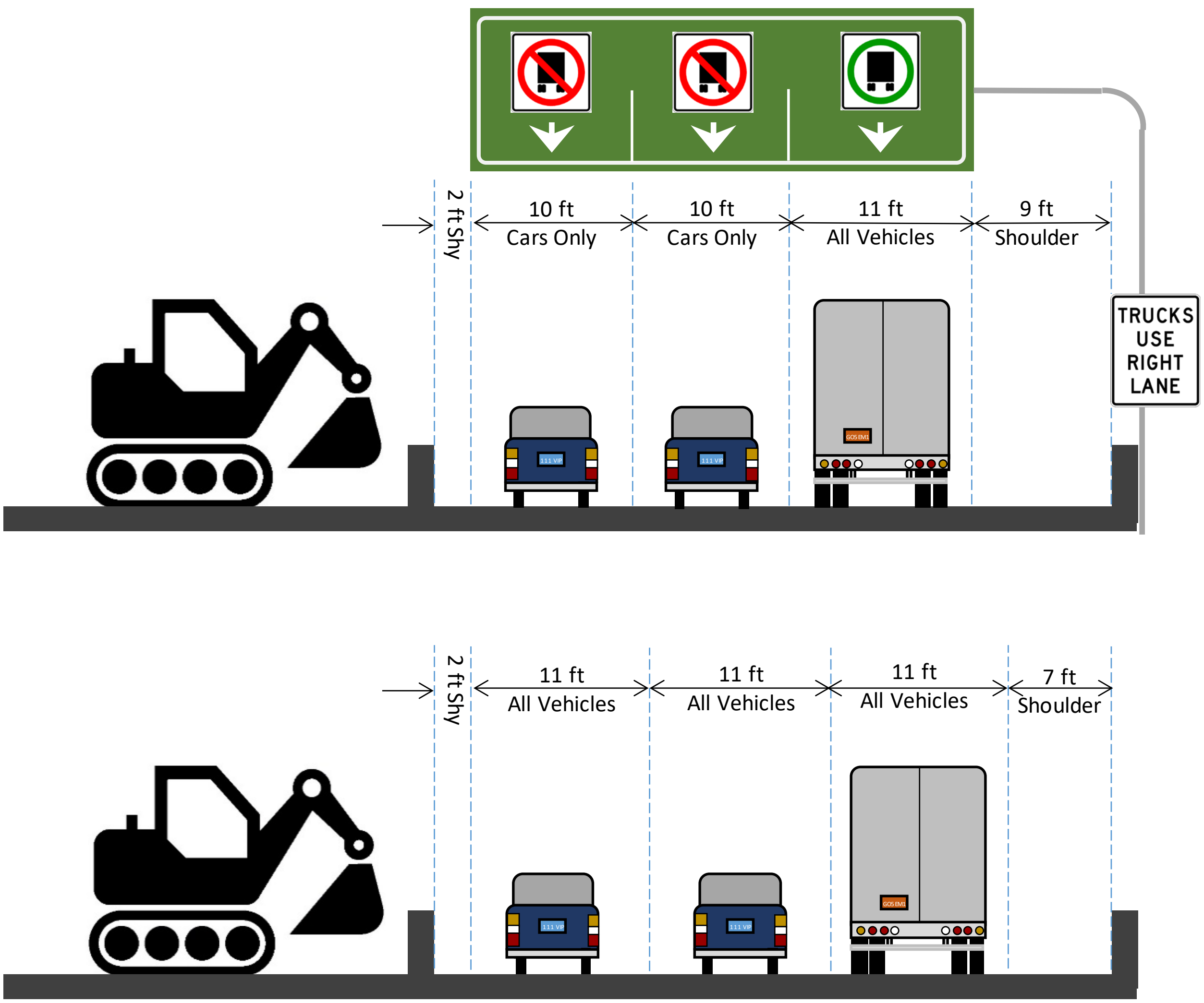


Figure 13. Comparison of unequal (top) and equal (bottom) lane width allocations and effect on emergency shoulder width for a site with 42 feet of available width.
Source: TOPS Lab

These configurations should be considered when the need for shoulder space to support incident management takes precedence over the simplicity of uniform lane widths. They can be an especially relevant solution if the segment is short or the duration of the unequal lane width condition will be brief. Other factors that affect the decision to use unequal lane widths include:

- Available roadway space.
- Traffic volumes, including truck volumes.
- Severity of the proposed width restrictions and length of the restricted section.
- Expected duration of the restriction.
- Roadway geometrics such as slope and curvature.
- Prevalence of over-width loads, state over-width load laws and permitting policies, and availability of alternate routes suitable for over-width loads.
- Cost of implementation.

In some cases, the combination of a wider lane for trucks and an adjacent wide shoulder can also make it possible to accommodate over-width loads that would otherwise need to be prohibited in the work zone.

Signage. Signage should be provided to warn drivers as they approach lane-use restrictions. Trucks and/or buses are permanently restricted from using specific lanes at numerous locations throughout the United States; examples include urban streets and toll plazas nationwide and all freeways in the State of Michigan. As a result, the Manual on Uniform Traffic Control Devices (MUTCD) [19] provides several relevant signs such as:

- TRUCKS USE RIGHT LANE (R4-5)
- TRUCK LANE XXX FEET (R4-6)
- STAY IN LANE (R4-9)
- TRUCK SPEED LIMIT (R2-2P)

As shown in Figure 13, the TRUCKS PERMITTED (R14-4) and TRUCKS PROHIBITED (R14-5) symbol signs can be used on overhead gantries to clarify lane use restrictions. A pictogram above each lane is used to indicate whether trucks are allowed (green circle) or prohibited (red slash).

3.3. Emergency Parking Areas

Emergency parking areas (Figure 14) are highly desirable when the shoulder width would otherwise be inadequate to accommodate emergency vehicles. These areas have many names including crash investigation sites, enforcement pads, lay-bys, pull-offs, pullouts, refuges, turnoffs, and turnouts. The MUTCD uses a term that is easy for drivers to understand: EMERGENCY PARKING ONLY (Figure 15). No matter which phrase is used, the idea is the same: to provide an area where

Figure 14. Short emergency parking area
Source: David Dixon/Geograph

emergency response vehicles can be staged or a damaged/disabled vehicle can be parked temporarily. In some cases, the widened area can also be used by law enforcement officers for conducting speed and other traffic enforcement duties.

Figure 15. MUTCD R8-4 sign

The availability of emergency parking helps reduce lane blockages caused by vehicles that experience mechanical problems such as overheating, tire damage, or insufficient fuel. Importantly, they reduce the need for drivers and tow truck operators to walk in live traffic lanes. Vehicles that are involved in minor collisions can be moved to emergency parking areas while the incident is investigated. In more severe incidents, emergency parking areas can be used to stage emergency vehicles that are being held in reserve or will be needed during a later stage of the response and recovery.

Parking time limits are often posted to discourage disabled vehicles from being left overnight; a two-hour maximum is used in several jurisdictions.

Typical candidates for this treatment are long-term freeway or expressway projects with narrow shoulders or full shoulder closures. Emergency parking areas are also recommended when two-way, two-lane operation will be used in combination with a central median barrier on what is ordinarily a divided highway, resulting in substandard shoulders for one or both travel directions [20].

Differing design objectives have resulted in two distinct approaches to the geometric design of emergency parking areas:
- One perspective assumes that most vehicles that use emergency parking will be mechanically impaired (running poorly, coasting, or being pushed by another vehicle), and thus will enter at reduced speed and will usually be hauled away by a tow truck equipped with flashing amber lights.
- The second perspective is that emergency parking areas should be long enough to provide acceleration and deceleration distances sufficient for ordinary vehicles to enter and exit freely at highway speeds.

Table 3 summarizes the resulting design differences. The subsequent text describes both options in more detail.

Table 3. Comparison of long and short emergency parking goals and design parameters.

Short Emergency Parking Pullouts	**Length:** 100 to 250 feet plus a total of 75 to 200 feet for entrance/exit tapers. **Spacing:** Irregular spacing of perhaps one-half to 2 miles based on site conditions. **Concept:** Vehicles with mechanical problems enter at reduced speed and are likely to be towed out. Severely damaged/disabled vehicles can be pushed in and towed out. Long enough to store one or more emergency response vehicles. Too short for pulling over violators.
Long Emergency Parking Pullouts (Enforcement Pads)	**Length:** 750 to 1320 feet plus approximately 300 feet for the exit taper. **Spacing:** One-half to 3 miles. **Concept:** Multi-functional. Vehicles with mechanical problems can enter and exit freely under their own power. Ample space for staging emergency response vehicles. Also provides a relatively safe location where law enforcement can intercept violators, with ample acceleration distance for police and violator to rejoin the traffic stream after a citation or warning has been issued.

Short emergency parking pullouts are occasionally used on two-lane rural highways and urban roadways, with pullout and taper lengths proportionate to the operating speed of the roadway. This treatment is particularly advantageous when a two-lane rural highway has narrow shoulders and high traffic volumes, as is often the case on main highways in coastal and mountainous areas.

3.3.1. General Design Considerations

Emergency parking areas should be located in tangent sections of the roadway, distant from locations with a large amount of lane-changing (Figure 16). There is a risk of unintentional vehicle entry by fatigued drivers if the emergency parking area is located on an outside curve. To deter mistaken entry, the area should be clearly marked with a regulatory sign with a message such as, EMERGENCY PARKING or EMERGENCY PARKING ONLY, and should not be located where it might be confused with an exit or additional lane. On undivided highways, emergency parking areas for opposing travel directions should be offset so that they are not used to make U-turns; an offset of 500 feet or more is recommended.

3.3.2. Short Emergency Parking Areas

In many cases, the construction of long emergency parking pullouts is not cost-effective due to project duration, right-of-way constraints, terrain, etc. To limit costs while still providing an area for emergency use, several agencies have developed standard detail drawings for short emergency parking pullouts. It is typically assumed that vehicles will enter these areas at relatively low speed (possibly with the assistance of a law enforcement or tow vehicle), and will leave very cautiously or with the assistance of an official vehicle or tow truck.

Figure 16. Short emergency parking area.
Source: Google Street View

Emergency parking areas developed under this design concept typically have parking area that is 100 to 250 feet long, which is adequate for a parking a disabled tractor-trailer or staging of one or more emergency response vehicles.

Deceleration taper lengths vary from 50 to 150 feet, and acceleration taper lengths vary from 25 to 150 feet.

The number and location of emergency parking areas is usually based on site conditions. Spacing on rural freeways is typically in the range of one-half mile (desirable) to two miles (maximum).

Various surfacing materials are used depending on the project duration, traffic volume, and similar factors; these range from well-compacted crushed aggregate to asphalt. Concrete pavement could be specified if the area will become a permanent part of the roadway infrastructure. The pavement thickness should be sufficient to support heavy vehicles. Cross slopes on the widened portion should match the existing shoulder cross slope. Placement locations are frequently based on drainage constraints, which should be accommodated.

Good operational design practice should be followed, including providing pavement marking edge delineation to enhance visibility of the parking area. Delineator posts should be provided at 25 to 40 foot intervals for night delineation.

Figure 17. Upstream guide sign examples.
Source: TOPS Lab

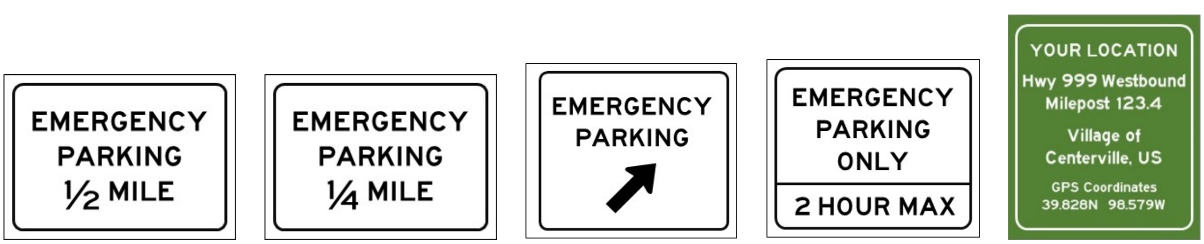


Figure 18. Recommended example signage for emergency parking areas.
Source: TOPS Lab

Advance guide signage examples (Figure 17) should be placed upstream of the beginning of the initial emergency parking area. Emergency regulation signing examples (Figure 18) should be placed beginning one-half mile upstream of each emergency parking area. Each area should also include a sign identifying its location to facilitate communication with first responders. In long work zones, motorist guide signs are sometimes placed near the upstream beginning of the work zone to notify drivers that emergency parking areas are available.

Example standard design drawings from Wisconsin DOT, Pennsylvania DOT, and New York DOT for short emergency parking areas are shown in Figure 19 through Figure 21.

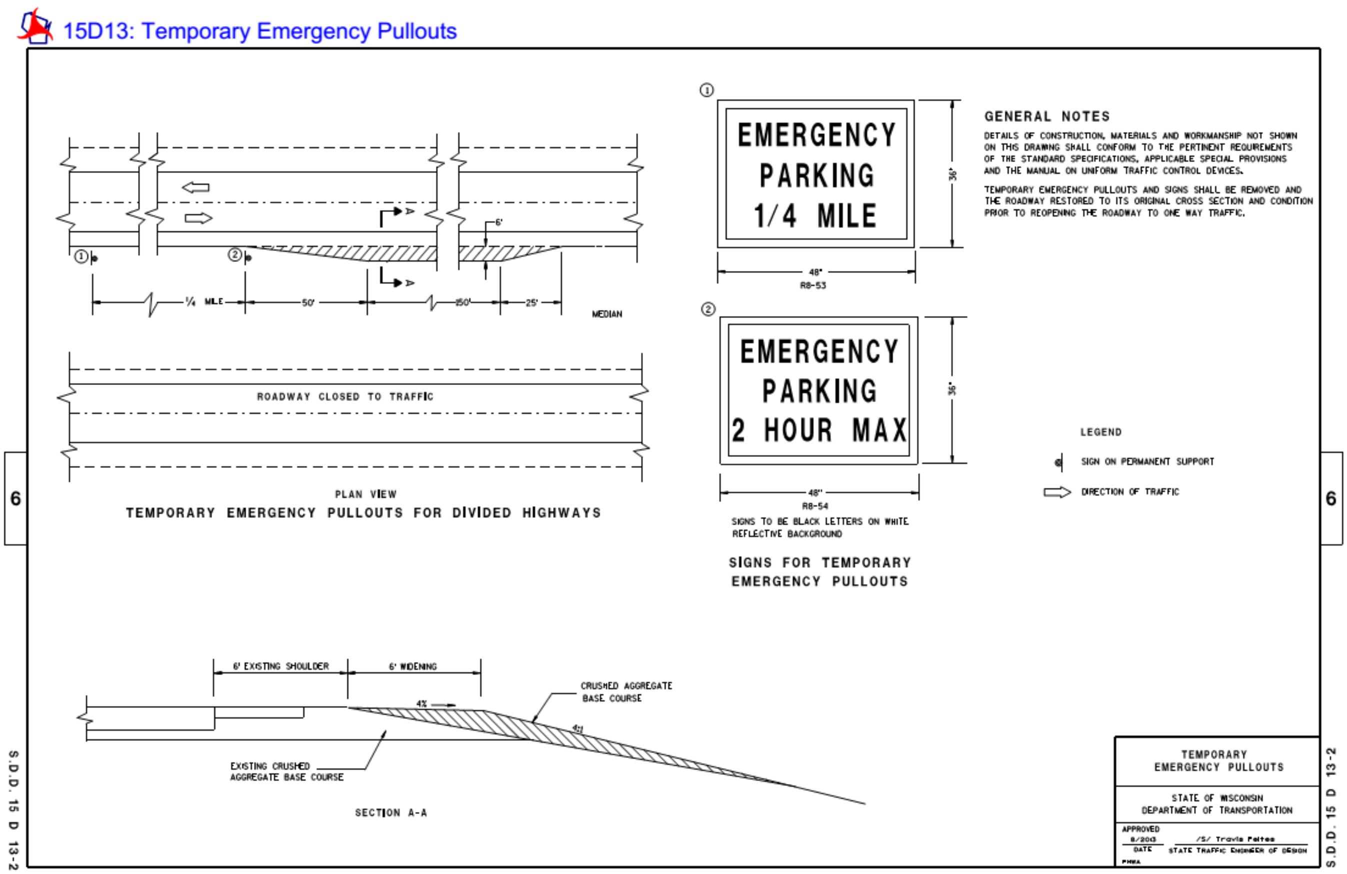


Figure 19. Wisconsin DOT Standard Detail Drawing for emergency parking areas.
Source: Wisconsin DOT Standard Detail Drawing 15-D-13-2.

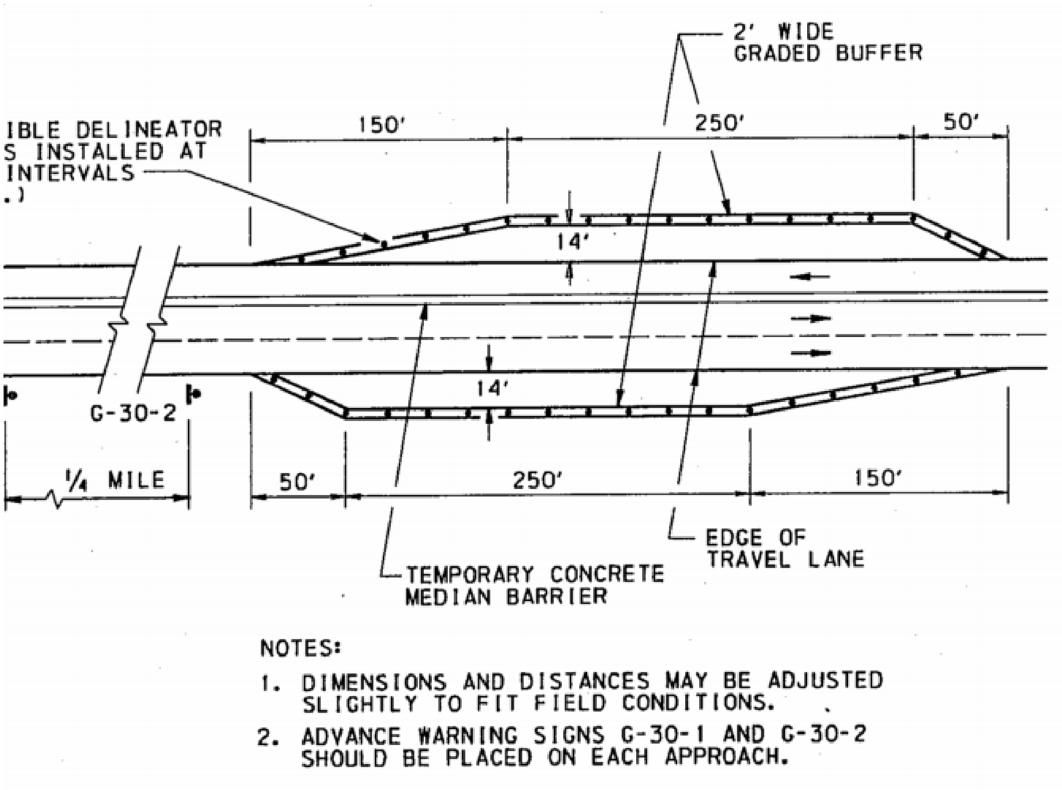


Figure 20. Pennsylvania DOT emergency parking design.
Source: PennDOT Traffic Engineering Manual (Publication 46) Exhibit 6-8

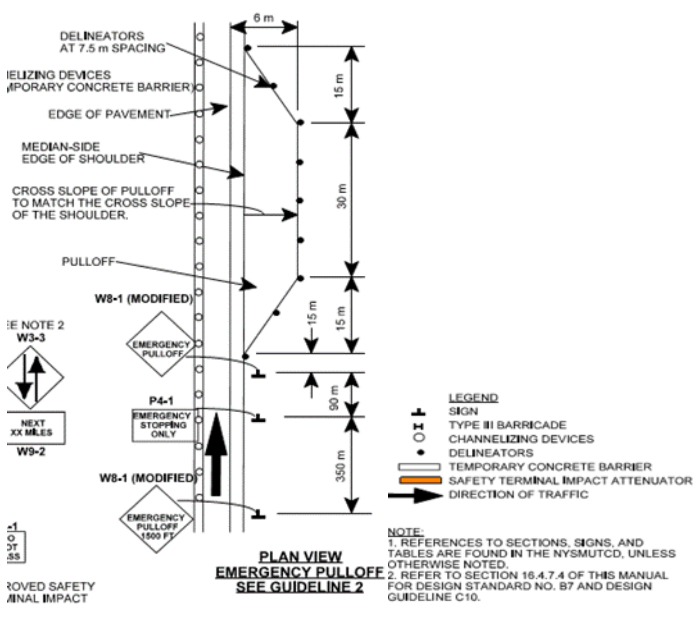


Figure 21. New York DOT emergency parking design.
Source: New York DOT Highway Design Manual Chapter 16

3.3.3. Long Emergency Parking Pullouts (Law Enforcement Pads)

Long emergency parking pullouts were originally developed in Texas to support speed limit enforcement in freeway work zones [21]. This resulted in a geometric design that provides length sufficient for law enforcement to pull over violators within the work zone (Figure 22). These pullout areas can also support incident management by providing space for emergency parking of disabled vehicles and staging of emergency response/recovery equipment.

Factors that potentially justify this strategy include:

- Work zones that require a shoulder closure or shoulder width reduction on both sides of the travelled way, extending continuously over several miles.
- Work zones that require a reduction in the regulatory speed limit (or the posting of other traffic regulations to assure worker and/or road user safety) which are expected to require significant enforcement efforts to achieve motorist compliance.

Law enforcement pullouts can only be effective if they are used. Therefore, if law enforcement is the primary motivating factor, appropriate institutional arrangements should be put in place to assure that sufficient enforcement resources will be deployed during construction.

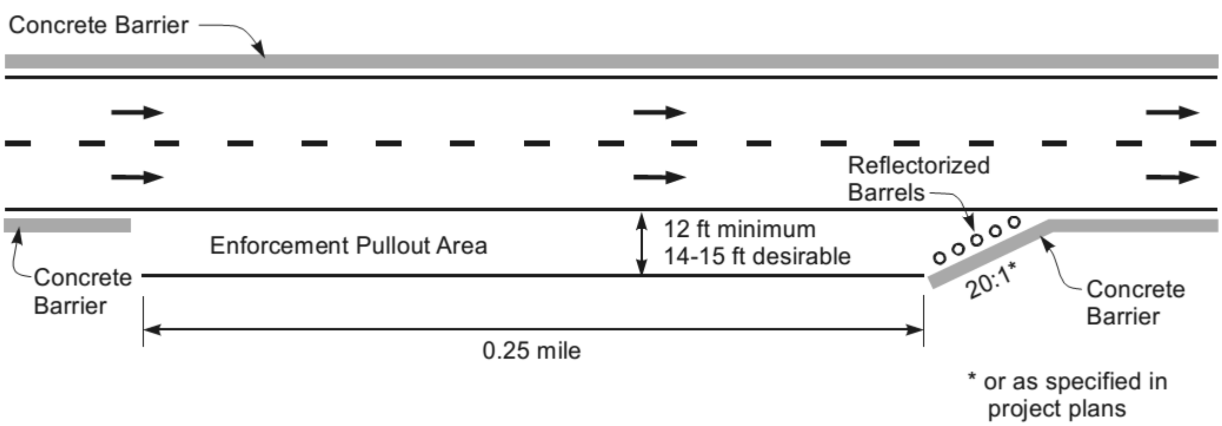


Figure 22. Recommended dimensions for long emergency parking pullouts.
Source: Texas A&M Transportation Institute, “Traffic Management and Enforcement Tools to Improve Work Zone Safety”

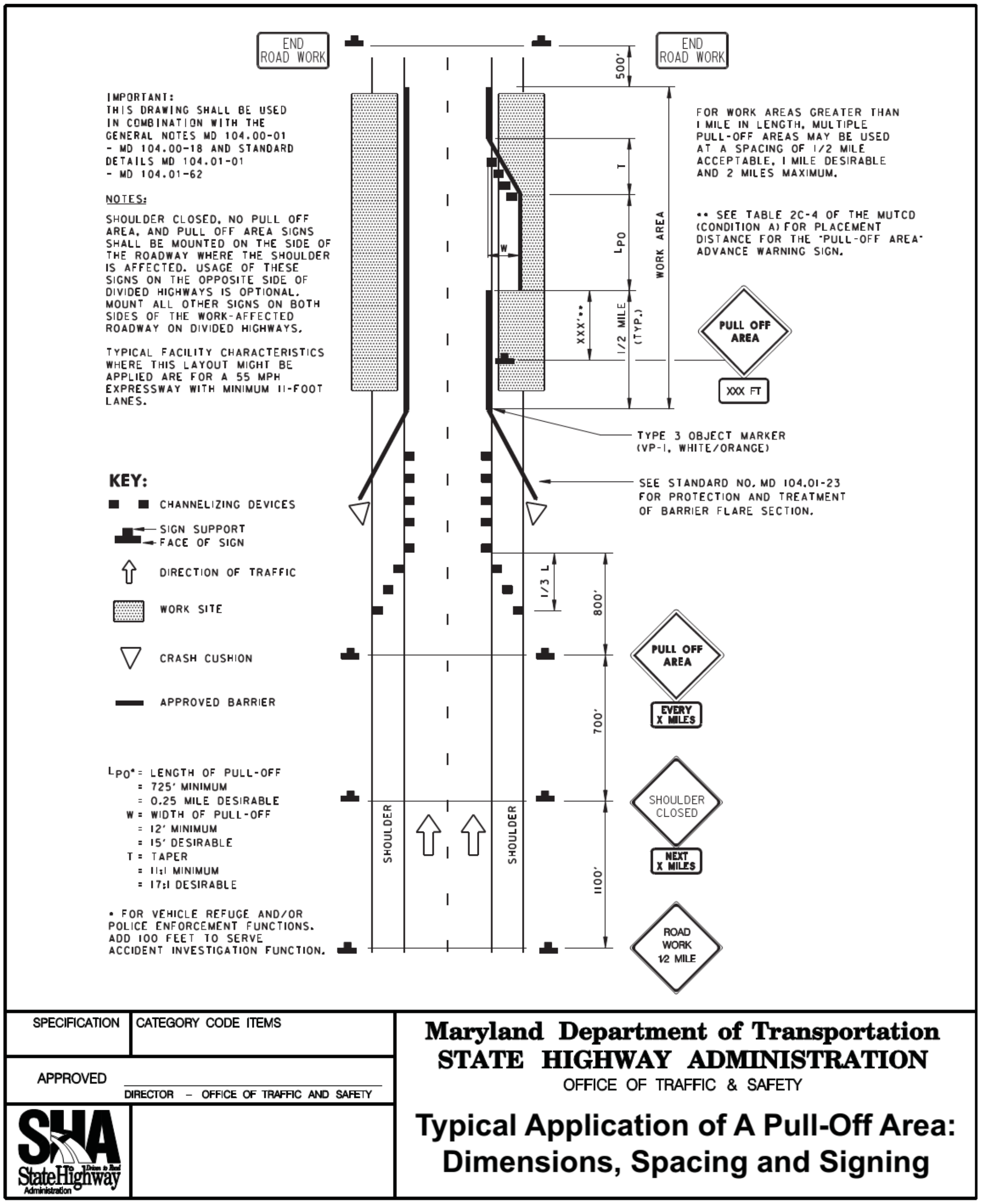


Figure 23. Maryland DOT design guidance for long emergency pullouts [22].
Source: Maryland DOT

Design details. As shown in Figure 22 (from Texas A&M Transportation Institute (TTI)) and Figure 23 (from Maryland DOT), long emergency parking pullouts typically have a minimum width of 12 feet and a preferred width of 14 to 15 feet. The desirable length of the main section of the pullout is 1320 feet (¼ mile), but no shorter than 750 feet. An acceleration taper is typically provided in the downstream end, but no upstream taper is used in the Maryland and TTI designs. They should be located on the right side of travelled way with a spacing of ½ to 3 miles [21].

Since the intended purpose is to allow high-speed entry and exit, the pavement surface should be asphalt with thickness adequate to support heavy vehicles. Cross slopes should match the existing shoulder cross slope. Temporary ditches to accommodate drainage should be included in the design. Good operational design practices should be followed, including pavement marking edge delineation to enhance visibility. Retroreflective delineator posts should be provided at intervals of 25 to 40 feet.

Research identified sight distances as the most critical element to achieve a satisfactory safety design, and the most difficult to address [21]. The research identified two key driving maneuvers that dictate the sight distance requirements:

- First, vehicles approaching the pullout area in the travel lane need to be able to stop safely if a vehicle in the pull-off area decides to return into the traffic stream. This sight distance requires drivers to detect, perceive, and if necessary, stop prior to reaching a vehicle that chooses to pull out of the area and into the travel lane. On roadways operating as a two-lane road with 55 mph or greater free-flow speeds, the stopping sight distance for approaching traffic will normally govern.
- Second, sight distance must be large enough to allow a vehicle in the pullout area to see traffic approaching in the adjacent travel lanes and correctly identify a gap large enough to allow them to pull into the travel lane. For roadways with free-flow operating speeds below 55 mph, this sight distance requirement will govern.

Table 4 lists the recommended upstream sight distances for various mainline operating speeds, based on research conducted by TTI [21]. It is important to note that these values are based on 0% grade. If there are significant positive or negative grades, the TTI research document should be reviewed for further guidance.

Table 4. Sight Distance Required Upstream from Beginning of Pull-off Area[21].

Required Sight Distance at 0% Grade						
		Two-Lanes			Four- or Six-Lanes	
Speed[1] (mph)	Analysis Method	Required Distance (ft)	Rounded Distance (ft)	Analysis Method	Required Distance (ft)	Rounded Distance (ft)
35	Critical Gap	318	325	Critical Gap	355	375
45	Critical Gap	409	425	Critical Gap	456	475
55	Critical Gap	501	525	Critical Gap	557	575
60	SSD	566	575	Critical Gap	607	625
65	SSD	644	650	Critical Gap	658	675
70	SSD	727	750	SSD	727	750
75	SSD	815	850	SSD	815	850

[1] Speed refers to the operating speed of the vehicles already traveling on the road. Speed of the vehicle pulling out into traffic is assumed to be 0 initially.

Source: Ullman, et al., Traffic Management and Enforcement Tools to Improve Work Zone Safety, page 70.

If the emergency parking areas are for motorist use (in addition to law enforcement), appropriate upstream advisory signs should be provided. TTI recommends the minimum distance between the signs and the pullout should be equal to the decision sight distance.

3.4. Alternate Routes for Incident Management

As the traffic volume, physical length, and duration of a construction project increase, so does the potential for an incident that results in a long-duration lane blockage. This in turn increases the need for alternative routes (Figure 24).

Many areas have developed permanent alternate route (detour) plans to facilitate traffic incident management, emergency evacuations, and similar situations. If alternate routes have already been established in the project area, they should be reviewed for applicability during construction; relevant plans can be incorporated into the incident management plan.

In some cases, detour routes established for nighttime full closures can double as daytime incident management routes.

Selection Criteria. If no detour or alternate plans have previously been vetted, plans should be developed for all relevant project stages and roadway segments. Parallel routes are often the first choice for alternate routes, but other factors should be examined when selecting routes. These include:

- Proximity to the main roadway.
- Length of the alternate route (compared to staying the main route).
- Ease of access to/from alternate route.
- Complexity of the alternate route (for example, does it require making turns at intersections that could be confusing for unfamiliar drivers).
- Land use along the alternate route, such as the intensity of commercial development, the potential for disruption to residential districts, schools, or hospitals, and any restrictions related to noise, air quality, etc. (In most cases, extra traffic is welcomed by the proprietors of retail businesses and considered a nuisance by occupants of residential properties).
- Existing safety record.
- Height, width, weight, and turning restrictions.
- Pavement and bridge condition.
- Existing traffic volume on the alternate route and capacity to handle additional traffic (especially at intersections).
- Traffic control features, such as signalized or stop-controlled intersections, railroad grade crossing warning systems, and speed limits.
- Existing ITS infrastructure such as traffic cameras, traffic flow sensors, and changeable message signs that gather information about travel conditions on the alternate route and provide feedback to road users.

- Effect on pedestrians, bicycles, and transit.
- Roadway ownership/jurisdiction.

In some cases, it is desirable to identify separate alternate routes for cars and heavy trucks. This can split up the traffic volume, and often allows cars to use a shorter route that might be unsuitable for trucks due to weight limits or sharp turns.

Signage. Careful attention should be given to signing alternate routes. For example, if there is a confusing intersection where drivers could easily turn the wrong way, additional signs should be provided to guide the lost drivers back to the alternate route. On long segments, extra signs are very helpful in reassuring drivers that they are still going in the correct direction.

Photo: WikiMedia Commons/ Mapsax

Source: WikiMedia Commons/Dough4872

Image: Google Street View

Figure 24. Alternate route signs.
Left: Michigan. Center: Pennsylvania. Right: Wisconsin.

On many projects, alternate route signing can be accomplished using static signs (Figure 25). For clarity in the traffic control plan and related bidding documents, the designer should identify which signs will be removed after construction and which will remain in place as part of permanent alternate route signing.

Alternate route signs are often most effective when used in combination with Portable Changeable Message Signs (PCMS) located in advance of the exits to the alternate route, which are activated in the event of an incident. Alternatively, large hinged signs (or hinged panels attached to existing permanent signs) can be used. Typically, these hinged signs are blank on the side that ordinarily faces traffic and can be flipped into position manually to display an incident management message (Figure 25).

Figure 25. Hinged signs.
Left: Construction focus. Right: Incident management focus.

Factors affecting the choice between PCMS and hinged signs include cost, the number of signs required, the project duration, the anticipated frequency and severity of incidents, and extent to which the signs can be positioned in locations where they would serve other functions when not being used for incident management (also see Section 3.7).

Cost-Effectiveness. Potential alternate routes often require some upgrades so that they can handle the diverted traffic. Examples include adding turn lanes to eliminate “choke points” at intersections, upgrading traffic signals, improving pedestrian management, widening shoulders, and in some cases strengthening pavements or bridges.

The cost-effectiveness of upgrades can be formally analyzed by comparing the costs of the upgrades to the benefits of the additional traffic-handling capacity and increased level of safety they provide, taking into account the probability of moderate, serious, and severe incidents affecting the main route. The analysis should also consider whether the upgrades will be used only temporarily, or will have lasting value after construction on the main route is completed. Typically, the analysis should be done based on the value to road users as a whole—not just the benefits to the agency that is funding the upgrades.

Passive vs Active Use of Alternate Routes. By itself, alternate route signing is a passive measure: some drivers start to use a marked alternate route on their own initiative if they observe slowed or stopped traffic on the main route. The effectiveness of this passive strategy mainly depends on how readily drivers understand the alternate route.

- Research indicates that the drivers most likely to use an alternate route are those who are already familiar with it and know how to reach their destination conveniently without returning to the main route [23]. Drivers who need to return to the main route are considerably less likely to use an alternate, especially if they are not familiar with the area.
- A passive alternate route might attract some unfamiliar drivers if it is visible from the main route, or if it appears to be convenient and very clearly marked. Ideally, unfamiliar drivers should be offered maps or diagrams illustrating the alternate route, turn-by-turn routing information, and information about where the alternate rejoins the main route

[24]. Project public information and outreach can potentially be used to help familiarize drivers with alternate routes in advance of the project.

When it is necessary to divert a large number of drivers, an alternate route will need to be "activated" to encourage (or require) its use. This could range from turning on PCMS or permanent electronic signs to emphasize the availability of the alternate, to using law enforcement vehicles to force all traffic to leave the main route.

Planning for Alternate Route Activation. Policies for the activation of alternate routes should be reviewed and discussed as part of the pre-construction planning process. The main issues are:

- Who will have the authority to initiate diversion plans (and de-activate them when the alternate route is no longer needed).
- How motorists will be notified or directed to divert.
- Who will provide staffing and equipment to implement the diversion.
- Whether any of these resources will be furnished by the contractor, and if so, how the contractor will be compensated.

Alternate route operation plans should be agreed jointly with first responders and jurisdictions along the route. "Game plans" should be vetted with emergency response agencies, and a chain of command activation/deactivation should be spelled out clearly prior to the start of the construction. After an alternate route is used, a debriefing or after-action review should be held to evaluate how well the plan worked and make any necessary refinements. Additional guidance about developing alternate routes can be found in FHWA's Alternate Route Handbook [25].

3.5. Ramp Closure Gates

When an incident occurs on a limited-access facility, the entrance ramps are often closed by law enforcement or other authorized personnel to prevent additional vehicles from entering the affected area. This reduces the number of vehicles that need to be managed at the incident site, helps prevent queueing and secondary crashes, and provides positive guidance to motorists who would otherwise enter the facility and encounter delays.

Figure 26. Permanent ramp gate (vertical type).
Source : Virginia DOT

Figure 27. Permanent ramp gate (horizontal type).
Source: Google Earth

Blocking motorist entry to ramps that do not have a gate typically requires a law enforcement officer and a suitable vehicle. The availability of ramp gates can help expedite ramp closures, freeing law enforcement resources for other duties.

If ramp gates are already in place, it is desirable to incorporate them into the work zone incident management plan. Installation of ramp gates should also be considered as an early-action item to prepare a site for construction.

Permanent ramp gates are available in both vertical (Figure 26) and horizontal (Figure 27) configurations. Type III barricades pre-positioned at entrance ramps can also serve this purpose on a temporary basis.

To notify drivers as they approach the closure, gates should be equipped with RAMP CLOSED or DO NOT ENTER regulatory signs that are visible to motor vehicle traffic only when the ramp is closed. It is also advisable to install hinged (flip-up) RAMP CLOSED signage on all approaches so that drivers do not inadvertently attempt to turn onto a closed ramp (Figure 28).

Figure 28. Hinged RAMP CLOSED sign at ramp gate (Canadian example).
Source: Google Earth

3.6. Temporary Traffic Control Device Caches

A cache (pronounced “cash”) is a location where useful items are stored. Establishing one or more caches of traffic cones, drums, or barricades in or near the work zone can be helpful in speeding up deployment of temporary traffic control for managing an incident. As shown in Figure 29, some agencies co-locate caches with emergency parking areas. To expedite deployment further, some agencies pre-load this equipment in a dedicated vehicle or trailer.

Figure 29. Emergency parking area with storage shed for emergency traffic control devices (permanent site).
Source: Steve Fareham/Geograph (retouched)

A typical cache could include:

- Channelizing devices such as drums, cones, vertical panels, or barricades. These devices are used for shifting traffic lanes or closing access during incident clearance.
- Temporary incident management signs described in the Manual on Uniform Traffic Control Devices [19]. As shown in Figure 30, the typical color for these devices is black on fluorescent pink, making them distinct from work zone traffic control signs.

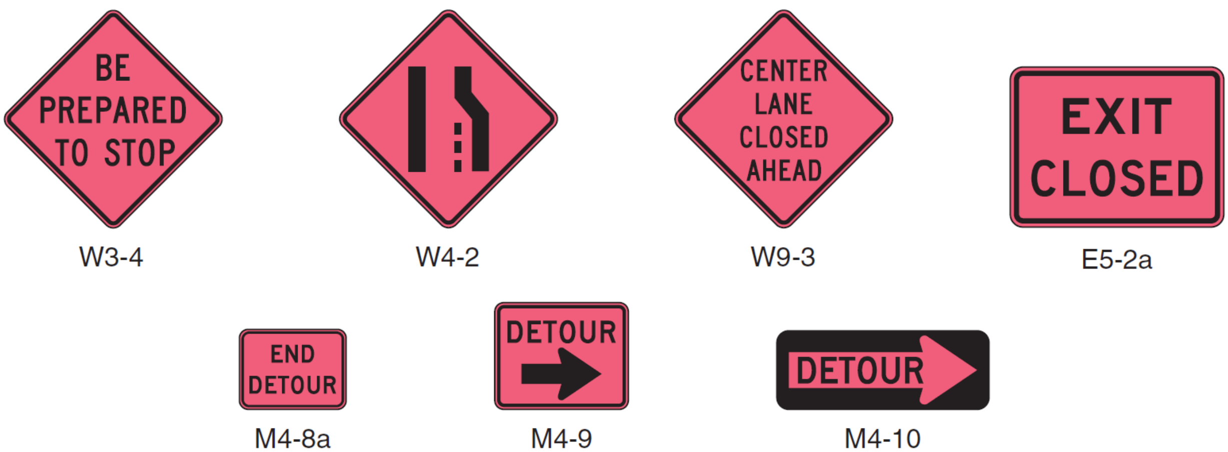


Figure 30. MUTCD Examples of traffic incident management area signs.
Source: MUTCD

The cache locations should be readily accessible to responders. Alternatively, a cache could be located upstream of the work zone to allow responders to pick up the materials before they encounter queued traffic.

Based on the project duration and site conditions, the designer will need to establish the location of each cache, how the materials will be stored (outside, under a pavilion, or in a shed), whether the cache will be fenced, and how authorized users will obtain access through any locked gates, doors, etc.

The cache location(s) should be shown on the traffic control plan. The number and type of devices in each cache, as well as the method of payment for providing and maintaining the caches, should be included in the traffic control plan specifications. An inventory control specification should be established to assure that caches are routinely checked to assure that all devices are present, MUTCD-compliant, and in satisfactory condition.

3.7. Use of Portable Changeable Message Signs (PCMS) and Hinged Signs for Incident Management

Portable Changeable Message Signs (PCMS) (Figure 31) and hinged signs (Figure 25 and Figure 28) are effective methods for providing special warnings and routing information to manage traffic incidents and resulting congestion, queuing, lane blockages, traffic diversions, etc. In some cases, signage used for construction-related messages can serve a dual purpose by displaying a second set of messages that are activated in the event of an incident.

PCMS are useful for situations where a sign must be repositioned frequently or its message often changes, but hinged signs are preferable from a crashworthiness perspective. PCMS often need to be positioned within the clear zone where they pose a potential crash hazard (Figure 32). Currently there is no testing protocol to assure that trailer-mounted PCMS are crashworthy. Hinged plywood, metal, or plastic signs can be post-mounted or installed on crashworthy temporary sign supports.

Figure 31. PCMS often need to be positioned in the roadway clear zone, where they pose a potential hazard to errant vehicles.
Source: WikiMedia Commons/Andrew Bossi

Figure 32. In March 2013 a motorist reportedly struck this device while driving through heavy fog on I-805 near San Diego, resulting in a multi-vehicle collision.
Source: Paul Anderegg - San Diego News Source

Several important issues should be examined and decisions provided in traffic incident management sign system design plans for construction zones:

- The advance placement of dedicated traffic incident management signs should be considered in the traffic control plan for each major work stage, especially for major/complex projects and projects where there is a high likelihood of incidents or construction-related delays that require rerouting traffic. Sign locations, types, and wording should be coordinated with the rest of the incident management plan, including the alternate routes that will be available and accessible during each construction stage.

Sign wording should be verified to assure that it is beneficial to motorists. The resulting wording and other design details should be included in the TMP's Traffic Operations Plan or Traffic Control Plan.

- To be effective, signs that suggest the use of an alternate route need to be located well upstream of the location where drivers make the corresponding route choice decision. To maximize the utilization of alternate routes, drivers should be given ample time to consider their route choice and ample space to maneuver into the lane where they will turn or exit.
- If a high level of compliance or a complicated message is required, it might be necessary repeat some of the information on a second sign.
- To avoid traffic congestion on the alternate routes, it might be necessary to use separate exits for cars and heavy trucks, or for traffic going to different cities. Additional signs might be required to provide information for each destination or vehicle category. For example:
    - Sign 1: LANES BLOCKED AHEAD, NORTON TRAFFIC USE HWY 111
    - Sign 2: LANES BLOCKED AHEAD, SUTTON TRAFFIC USE HWY 222
- In general, hinged signs are suitable for locations where there are two possible messages, either for incident or non-incident situations. If the site does not require a non-incident message, a blank panel in a non-conspicuous color (such as grey) should be displayed. For drivers familiar with a route, the appearance of a brightly colored sign where there was previously nothing noticeable can help draw attention to the unusual condition. In locations subject to vandalism, padlocks should be provided to deter unauthorized message changes.
- *In 2013, PCMS costs ranged from $12,000 to $20,000 [26]. According to FHWA's ITS Joint Program Office based on data from Vermont AOT, the estimated useful life of a PCMS is 7 years, with operation and maintenance costs estimated at $600/year.* The cost of hinged signs is significantly lower, generally comparable to a few days of PCMS rental. Therefore, cost estimates will be heavily influenced by the number of PCMS's are needed versus hinged signs.
- The primary advantage of PCMS is the ability to provide a multitude of situationally specific messages. Studies indicate that PCMS are an effective way to provide incident-related information to drivers, if the message is clear and easy to understand. Relevant messages should be pre-programmed into the sign, especially if it is not equipped with telecommunications that allow its message to be modified remotely in real-time.
- On high-speed roadways, PCMS messages should be limited to two sign phases or "screens". In general, the first screen describes the situation and the second screen indicates the action the driver should take. For Example:
    - TUNNEL CLOSED, USE ALT US 10
    - LANES BLOCKED AHEAD, USE ALTERNATE ROUTE

Some State, county, and local transportation agencies have their own fleet of PCMS, while others rely on contractor-supplied equipment. If the PCMS will be furnished and maintained by a contractor, the designer should assure that the project specifications appropriately describe the required hardware and software (including memory requirements for pre-programmed messages). Allowable methods of telecommunication with the sign should be specified if this feature is desired. The contractual provisions should include pre-construction testing of remote communication with each sign, especially if cellular or radio communication will be used in an area with questionable signal strength. A list of the messages to be preprogrammed into each sign should be supplied to the contractor, and a process established to verify that the messages are correct and can be deployed in a timely manner.

As discussed in more detail in Section 5, the organizational roles and responsibilities for the deployment of incident management signage (and post-incident restoration of normal signage) should be discussed in the TMP and other construction documents to assure clarity in the event of an incident.

3.8. First Responder Staging Areas

An incident—especially a major one—can require the services of numerous first responders and their vehicles at different times during the event. Since these vehicles and personnel may arrive from a variety of locations and not arrive at the incident scene in the order in which they are needed, having convenient staging locations for parking first responder vehicles is highly desirable. For example, a tow truck might reach the site while a crash victim is still being extricated from a damaged car. Extra response vehicles are often dispatched to the scene on a standby basis in case additional workers or specialized equipment are needed. In both cases, the emergency response vehicles need to be staged near the incident site until they are needed.

For the safety of first responders, construction crews, and the traveling public (and to minimize traffic disruption), it is desirable to pre-designate one or more areas near the work zone that can be used for incident staging. This strategy is especially relevant for long-term projects, projects in locations with severe physical space constraints, and projects in remote areas.

Staging areas serve the following functions:

- Providing a common area or “rally point” where responders can assemble.
- Providing a safe waiting area for responders and equipment not immediately needed at the incident scene.
- Providing an area where responders can take breaks and meals in case of a long-duration incident.
- Providing a safe work area for media reporting on the incident.

In some cases, staging areas double as crash investigation sites, allowing minor incidents to be investigated away from live traffic.

Staging areas should be identified in advance, and are potentially subject to change as construction progresses. They could be located adjacent to or outside of the work area, within the work area, or off the roadway. Adequate space must be provided for emergency response vehicles and investigation personnel; at minimum, there should be space for three vehicles.

- Ideally, staging areas serving limited-access facilities should be accessible from more than one location, for example, a main access from the freeway and a secondary gated access from a local street, minor highway, or haul road.

- If the staging area is located within the work area, it is desirable for it to be shielded from high-speed traffic by positive protection such as a concrete barrier.
- Screening devices should be considered to reduce the likelihood of "rubbernecking" and associated traffic congestion/delay.
- Appropriate MUTCD signing (e.g., Figure 33) should be provided to direct emergency responders and/or motorists to the staging site.

Figure 33. Staging Area Ahead Sign

3.9. Triage Areas

Triage is a preliminary medical examination performed during multi-casualty incidents to assess the severity of each victim's injuries and the urgency of treatment. Although "triage" comes from a French word meaning "three groups," most systems currently used in the United States divide patients into four or five categories, typically, those that require immediate treatment for life-threatening injuries, those with serious but non-life-threatening injuries, those with minor injuries, and those presumed dead. Medical resources, including ambulances, are allocated accordingly.

On major projects with a reasonable likelihood over the project duration of incidents that involve multiple road users or multiple construction workers, establishment of a pre-determined triage area should be considered (Figure 34). Examples of such projects could include work on a major bridge or tunnel where it could be difficult to find space for an impromptu triage area, projects at remote sites, and projects involving unusually hazardous site conditions or construction techniques.

Figure 34. Triage area under a highway overpass.
Photo: WikiMedia Commons/Win Henderson/FEMA

Figure 35. Medical helicopter landing zone.
Source: WikiMedia Commons/AlfvanBeem

3.10. Air Ambulance Landing Zones

Another strategy potentially relevant to remote, restricted-access, and high-risk sites is pre-establishment of one or more air ambulance medical helicopter Landing Zones (LZs) (Figure 35). The size of each LZ should be determined in coordination with local air ambulance operators; 100 x 100 feet is a typical preferred size [27]. LZs should have minimal slope, a clear approach from the air, and should be well separated from pedestrian and motor vehicle traffic, livestock, trees, buildings, overhead wires, and other obstructions. The GPS coordinates for each LZ should be determined and posted at the project site to facilitate communication with the air ambulance operator in case of an incident.

Ideally, the landing zone surface should be paved or sealed and swept regularly to minimize rotor wash (grit and debris stirred up by the aircraft's rotor). If this is not feasible, the LZ should be kept damp to minimize dust. Cones are the preferred means of delineating the LZ by day, and strobe lights are preferred at night. Floodlighting, if used, should be aimed away from the aircraft.

4. Managing Site Access

Many of the major construction projects implemented by State highway departments occur on freeways and other access-controlled facilities. On such projects, combinations of existing access controls, lane and shoulder width reductions, and high traffic volumes can make it quite difficult for first responders to reach an incident site promptly. Projects that involve multiple vertical levels (such as reconstruction of freeway-to-freeway interchanges) can pose special access challenges in the event of a traffic crash or worker illness/injury. Explaining the problem location to people who are not familiar with a multi-level site can also be challenging. This section discusses several methods for keeping highway work zones and work areas accessible to expedite incident response and recovery.

4.1. Fundamental Principle: Secondary Means of Egress

When developing work zone access plans, designers should consider an important question: If an incident blocks the usual path for entering or exiting the work zone, is there another way for first responders to get in and out?

The codes and regulations that govern the design of houses and buildings recognize that an incident (such as a fire) can block the usual way of entering and exiting a building (or a space within a building). As a result, the International Building Code and similar documents typically require at least two means of egress (except when the distance to an exit is short and the space has very few occupants). In buildings, doors and hallways are usually the primary means of egress, while windows and fire escapes are often the secondary means. Although these concepts have never been formally codified for work zones, the same principles should be applied:

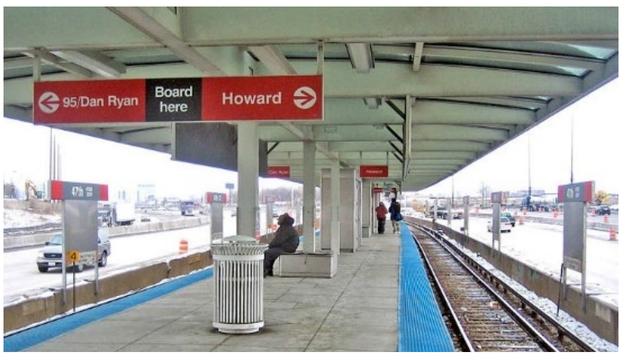
- It is highly desirable for responders to have more than one way of reaching a work zone incident.
- The secondary access does not need to be suitable for everyday use or high-speed traffic, but it does needs to be sufficient to allow responders to reach the site promptly.

Although site access is usually straightforward for streets and highways that have at-grade intersections, some project sites have unique characteristics that affect access (Figure 36). Examples include long or high bridges, tunnels, remote or mountainous sites, and roadways that run parallel to coastlines, rivers, or other terrain features that limit access from one or more directions. In areas with high levels of freight rail traffic, long trains can sometimes cut off access to an incident site for an extended duration.

Sometimes secondary access can be obtained by driving the wrong way on a divided highway or one-way facility. The feasibility of this approach varies depending on the physical and operational characteristics of the site, such as the required travel distance, terrain, permanent and temporary barriers, and traffic volume. Therefore, the feasibility of counter-directional access should be evaluated on a case-by-case basis, and other options should be considered if counter-directional access is difficult.

a. Major bridge.
Photo: WikiMedia Commons/Anthonymaw

b. Tunnel.
Photo: WikiMedia Commons/Ben Schumin



c. Freeway with electrified mass transit line in median.
Photo: WikiMedia Commons/Graham Garfield

d. Deep excavation.
Photo: US Army Corps of Engineers

Figure 36. Examples of work zones with severely restricted access.

4.2. Median Barrier Gates

Median barrier gates (Figure 37) are crashworthy barrier sections equipped with hinges, retractable wheels, and a locking mechanism. They are produced by at least two manufacturers. According to manufacturer claims, they can be opened or closed in about 2 minutes using manual power. Depending on the profile of the adjoining positive protection system, special transition sections might be required.

Figure 37. Median gate used for emergency vehicle access at a work zone.
Source: Barrier Systems, Inc.

Median gates can help provide alternate access points for incident management. They are particularly useful in situations such as:

- Sites where access from the opposite travel direction is desirable due to high traffic volumes or the length of the barrier run.
- Sites that have no shoulders, or where the shoulder width is too narrow for emergency vehicles.
- Sites requiring emergency access (or supplemental access) to work activity areas located behind a barrier.
- Sites where emergency access would otherwise be difficult due to construction operations at two or more vertical levels.
- Sites where there is a reasonable chance of an incident that blocks all available lanes and shoulders during the project.

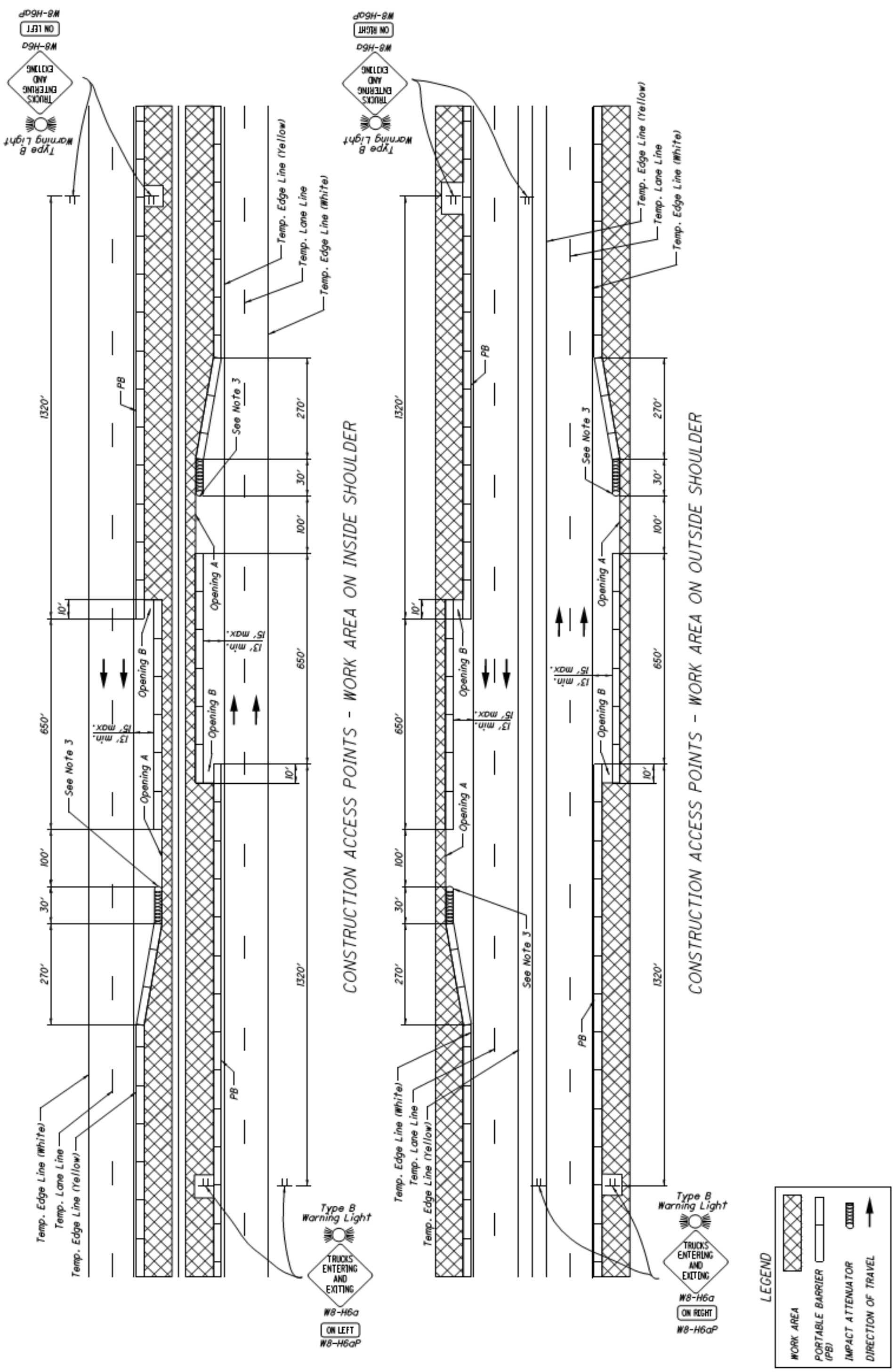
4.3. Use of Construction Access Points for Incident Management

Positive protection systems (temporary barriers) are frequently used to separate high-speed traffic from work operations. A challenging aspect of positive protection is how to accommodate emergency access in situations such as:

- A worker injury or construction incident that occurs behind the barrier.
- An errant vehicle that penetrates the positive protection system.

In many cases, access points provided for construction materials delivery and similar work operations can double as emergency access points for incidents that occur behind the barrier. *Ohio DOT's standard detail drawing for work area ingress/egress (Figure 38) is an example of a design that can be adapted for this purpose, if first responders are kept informed of work area access/egress locations as they change during construction.*

Sample guidance for establishing access points is provided in Figure 39.



NOTES:

1. It is intended that this drawing be used on freeways, expressways and multi-lane divided highways with original posted speed limits of 55 mph or greater to provide a safe means of interaction between project related vehicles and the traveling public by providing dedicated areas outside the traveled lanes for the deceleration and acceleration of project vehicles.

2. The surface materials used for the construction access point, including under the portable barrier and within the deceleration/acceleration lane, shall be firm and unyielding material as approved by the Engineer. The acceleration/deceleration lane shall be maintained in accordance with C&MS 614 and ensure that the surface material is not tracked out into the open lanes of traffic.

3. Impact attenuator and the last full section of PB adjacent to the impact attenuator shall be placed parallel to traffic. The impact attenuator shall be redirective, installed and anchored per the manufacturer's specifications and shall be an approved impact attenuator product which can be found on the Office of Roadway Engineering's website.

4. Sign spacing should be adjusted to avoid conflict with existing signs. Minimum spacing to existing signs shall be 200 feet for speeds of 45 mph or less and a minimum of 400 feet for speeds 50 mph or greater.

5. The construction access points shall be used in the following manner: Ingress shall be made by construction vehicles by changing lanes into the deceleration lane as early as possible, decelerating the construction vehicle using the deceleration lane, and then turning into Opening A to access the work area. Ensure that the construction vehicles entering Opening A are not swinging into open lanes of traffic when entering the work area. Egress from the work area shall be made by construction vehicles by leaving the work area via Opening B, accelerating the construction vehicle within the acceleration lane (using as much length of the acceleration lane as possible), and then merging into the adjacent lane of traffic.

6. Drums may be placed across Opening A and Opening B during periods when no active work is occurring (evenings, days, weekends, extended shutdowns, etc). If used, drums shall be consistently used across each Opening A and Opening B for each construction access point installed. Drums shall be spaced every 20 feet across the openings. When Openings A and B are open, the drums shall not be within the deceleration/acceleration lane for the construction access point.

7. All ingress and egress shall only occur at established construction access points including proper signing, acceleration and deceleration lane, and delineation.

8. Construction access point locations may be selected (or relocated from the location designed in the plans) by the Contractor with the approval of the Engineer. The locations shall be selected for good sight distance and avoiding locations just beyond sharp horizontal curves and crest vertical curves, on overhead structures, on upgrades, within ¼ mile in advance of an exit ramp or beyond an entrance ramp, etc. In the event that the Engineer determines that an access point does not function in a safe manner, he/she shall order it immediately closed at no cost to the State. Access points may be relocated subject to the approval of the Engineer, as necessary to accomplish construction activities.

9. All costs for relocation of portable barrier, installation, repair, replacement and removal of impact attenuators, grading for access drives and related costs shall be included in the lump sum bid for Item 614 Maintaining Traffic.

Figure 38. Ohio DOT standard detail drawing for work area access and egress (2015). Signature block and related drawing elements omitted.
Source: Ohio DOT Traffic SCD MT-103.10

Sample Guidance for Creating Construction Access Points

The traffic control plan shall address the need for construction access to the work zone. This is important for all work zones, but is a particularly critical issue on freeways, expressways, and multilane divided highways with original posted speed limits of 55 miles per hour or greater in order to provide a safe means of interaction between project-related vehicles and the traveling public by providing dedicated areas outside the traveled lanes for the deceleration and acceleration of project vehicles. The designer must address the question of how to get equipment and material into and out of the work zone safely. The following should be considered:

Type of work zones likely to create ingress/egress problems (e.g., median work spaces that will require vehicles to merge into and out of high-speed traffic, work activities that require frequent delivery of materials such as paving projects).

1. *Temporary acceleration and deceleration lanes for work vehicles should be provided.*
2. *The location of the construction access point should provide good sight distance for oncoming traffic while avoiding locations such as just beyond sharp horizontal curves and crest vertical curves, on overhead structures, on upgrades, within one-quarter mile in advance of an exit ramp or beyond an entrance ramp, etc.*
3. *In extreme conditions, lane closures may need to be considered.*
4. *Openings in barrier walls on multi-lane undivided highways, on multi-lane divided highways with original posted speed limits under 55 miles per hour, and on two-lane facilities shall be planned to ensure the ends are properly protected, and the barrier wall should not create sight distance issues.*
5. *Special warning signs may be necessary.*
6. *The use of Portable Changeable Message Signs may be considered.*

The number of construction access points shall be kept to a minimum with consideration given to relocating the construction access points during the project as necessary to accomplish construction activities.

Acceptable locations for openings in barrier walls on freeways, expressways, and multi-lane divided highways with original speed limits of 55 miles per hour or greater shall be designed into the plans and laid out as directed in Traffic SCD MT-103.10. See Section 641-28 for additional information on MT-103.10.

Figure 39. Sample Guidance for Creating Construction Access Points
Source: Ohio DOT Traffic Engineering Manual 640-9, Construction Access Points

Temporary access roads can be established (often at relatively low cost) to provide supplemental access points for work zones on freeways and other limited-access facilities (Figure 40). These temporary roads are often dual-purpose, providing construction access (or serving as a haul road) for the contractor and providing incident access for first responders. Temporary access roads are frequently the most practical way to reach incidents that occur behind a barrier wall, or to reach workers that are at a substantially higher or lower elevation than the adjoining roadway.

Figure 40. Permanent emergency and maintenance access on a high-speed facility (gated at entry).
Source: Google Earth

Typically, establishment of a temporary access road requires a temporary opening through the right-of-way fence. To minimize construction costs, the roads are generally built at locations that are relatively close to an existing street or secondary highway, at a site with favorable grade. Minor roadways that were severed by construction of the freeway are often good candidates for this treatment (Figure 41).

Figure 41. Severed local roads suitable for conversion to a temporary emergency access point.
Source: Google Earth

North Carolina DOT pioneered the use of temporary access roads that tie into freeway overpasses to provide access to the freeway median (Figure 42 and Figure 43) [28], [29]. This technique was originally developed to minimize haul distances and traffic impacts for a major freeway reconstruction project, and required temporarily removing part of the bridge parapet. This can potentially double as a method for providing work area emergency access to the work area or an emergency path to the freeway mainline.

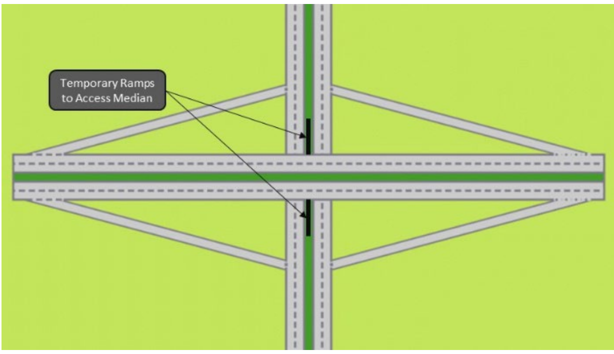


Figure 42. Temporary access to freeway median.
Source: WikiMedia Commons/Toto-tarou

Figure 43. Temporary ramp to freeway median.
Source: North Carolina DOT / Roadway Safety Consortium [29]

Adequate sight distance must be provided to assure that vehicles can safely enter the traffic stream. The maximum vertical grade for a temporary access road will differ depending on its intended use; steeper grades can generally be tolerated on roads intended to serve only as emergency access, compared to those that double as haul roads.

The appropriate surface treatment for a temporary access road varies depending upon its intended use, the project duration, and the type/weight of vehicles that will be authorized to use it. A compacted gravel surface is adequate in most cases.

In general, temporary access roads are gated and locked at the low speed (local road) side to assure that they are used only by first responders and other authorized personnel (Figure 44). Most agencies have an established process for controlled distribution of keys, which can be referenced in the TMP and other contractual documents.

Figure 44. Gated access to a freeway emergency access.
Source: WikiMedia Commons/Ruth Scharville

Figure 45. Mock-up drawing of entry sign with access code number.
Source: WikiMedia Commons/Ruth Scharville

Signage for temporary access roads should be based on a careful consideration of the design objectives. To deter unauthorized use, many transportation agencies prefer to keep the temporary access inconspicuous, but to some degree this conflicts with the objectives of emergency response agencies who will generally want to assure that the access point can be identified quickly by first responders. One potential solution is to use the WORK SITE ACCESS signage shown in Figure 45. Another possible solution is to assign the temporary road a mock street name such as "TR1" that can be coded into 911 dispatch systems, but will not have a meaning that is obvious to the public. Temporary access planning should be done early in the TMP process. *Although temporary, additional access points require administrative approvals based on established State and Federal access management policies. An example of the information that may be needed in the proposal includes description on the purpose of the request such as whether the intended use is only for emergency access or multi-purpose such as material delivery, exact location, available sight distances, proposed construction materials, and anticipated duration the temporary access will be needed. Methods for gating and controlling the access should also be addressed, particularly if the access is desired to remain in place beyond the construction project.*

4.4. Work Site Access Signage

Effective signage can support prompt emergency response in work zones and work activity areas. Signage identifying access and egress points helps assure that first responders go directly to the correct location. This helps avoid problems such as:

- Emergency vehicles arriving at the wrong location.
- Emergency vehicles overshooting the destination and having to double back to reach an incident site.
- Emergency vehicles attempting to use work area entrances that are unsuitable for wheeled traffic.
- Difficulty communicating about how to reach an injured worker on a job site with multiple access points or multiple vertical levels.

In many cases, these signs also provide information that is useful for truck drivers making materials deliveries to the work zone. This can help assure that deliveries arrive at the correct location, reducing the risk of traffic delays caused by misdirected trucks.

Figure 46 provides signage examples for a work zone that has one activity area with only one point of entry.

Figure 46. Sample guide signs for work zones with only one activity area entry.
Source: TOPS Lab

Major projects such as freeway-to-freeway interchanges often have multiple access points, and the most suitable points of entry could change as work progresses. Therefore, it is desirable to develop a signing system that construction staff and emergency responders can use and understand readily:

- Each access point should be given a unique identifier, which should be distinct from exit numbers or mile markers (for example, letters could be used instead of numbers).
- Secondary access points (from side roads, etc.) can also be given their own identifiers (Figure 47).
- To facilitate radio and cell phone communication in noisy work areas, consider using letter sequences that do not rhyme or sound alike (for example Q, R, S, T instead of B, C, D, E).

Figure 47. Sample guide signs for work zones with multiple activity area access points.
Source: TOPS Lab

Based on field experience and site conditions, additional signs may be provided to deter drivers from entering work activity areas (Figure 48).

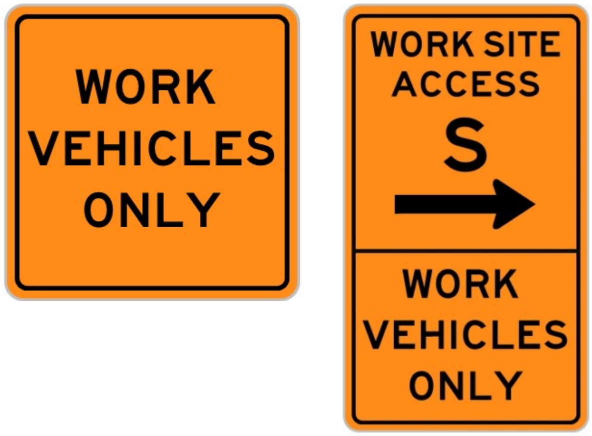


Figure 48. Sample guide signs to deter unintentional motorist entry into work activity areas.

Work site access signs for freeway projects are often affixed to temporary barriers. To assure appropriate vehicle dynamics in the event of a crash, signs should be attached only to the back (non-traffic) side of the barrier. If there is traffic running on both sides of the barrier, specialized sign mounting hardware is necessary to assure crashworthy performance. In most cases, the width of access guide signs into work zones will typically be limited to about 18 inches. On a square or rectangular back plate, the resulting letter height is relatively unobtrusive for ordinary traffic, but is usually adequate for a construction delivery driver or first responder who is actively looking for the sign.

Since points of entry often change as construction progresses, it is necessary to keep the signing plan updated throughout all stages of the project. Contractual provisions and operational procedures should be put in place to assure that first responders are kept informed at all times of the entry points that are suitable for use by emergency vehicles.

4.5. Wrong-Way Vehicles

Although wrong-way traffic is relatively rare on high-speed, limited-access facilities, the consequences of wrong-way entry can be severe. Each access point into the work zone should be reviewed to assure that it is laid out, signed, and marked in a manner that will deter unintentional wrong-way entry. Partial cloverleaf interchanges and locations with a history of wrong-way incidents should be given special attention, particularly if diverter islands normally used to discourage prohibited movements will be removed temporarily during construction. Where feasible, a turnaround space should be provided so that drivers who realize that they have made a mistake can safely resume correct-direction travel. Monitoring cameras and/or electronic wrong-way vehicle detection and warning systems should be considered in high-risk locations.

The majority of wrong-way crashes occur at night, often involving alcohol- or drug-impaired drivers [30]. In locations where there is a high risk of wrong-way entry at night, selective ramp closures using Type III barricades or similar devices could be considered.

Wrong-way traffic can also be problematic in urban street work zones, particularly if the project requires conversion of an existing one-way street to two-way operation, or reversal of the previous direction of a one-way street. Careful attention should be given to signing and marking at intersections. The use of centerline markings and directional arrows on the pavement is recommended (in addition to signage) when the new/temporary layout allows two-way operation on a street segment where drivers could previously drive legally on the left side of the street.

4.6. Repositioning Emergency Response Staff and Facilities

Some highway construction activities require closures that:

- Block access to an emergency management resource such as a police station, fire station, or ambulance station.
- Cut off or severely restrict emergency access to part of a community.
- Require detours that would result in unacceptably long emergency response times.

These situations vary greatly in terms of the duration of the blockage, the size of the affected area, the scope of the affected facility, and the difficulty of providing alternative emergency response resources. As a result, solutions need to be designed on a case-by-case basis. Typically, the benchmark for a successful solution is that the emergency response time is similar to the pre-construction response time.

Many situations can be resolved administratively through interagency mutual aid agreements. *This is perhaps most easily explained by an example:*

Mutual Aid – Fictitious Example (Figure 49):
Most of the Village of Summit Heights is located on the north side of the Brown River, but a small part of the community is south of the river. All of the community's fire stations are north of the river. During reconstruction of the Highway 999 bridge over the Brown River, about 500 Summit Heights residences located on the south side of the river will be inaccessible to the Summit Heights Fire Department.

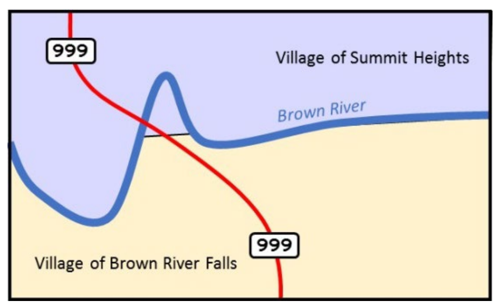


Figure 49. Example map of mutual aid communities
Source: TOPS Lab

At the suggestion of the project designer, the two communities reach an agreement to resolve this situation. During construction, six firefighters and two firefighting vehicles from Summit Heights will be based at the fire station in neighboring Brown River Falls. These personnel will be under the command of the Brown River Falls Emergency Services Department and will operate as an integrated part of the Brown River Falls emergency response team. All Brown River Falls personnel and the six Summit Heights personnel will respond to fires and other emergencies in both Brown River Falls and the affected section of Summit Heights. The six firefighters will remain on the Summit Heights payroll, and Summit Heights will fuel and maintain the two vehicles as usual. Thus, the agreement has no direct budgetary impact on either community.

In other cases, it might be necessary to reposition emergency service resources, even if the closure is only for relatively short periods. For example, a bridge closure in a community that is bisected by a river might require establishing a temporary operating location for emergency response staff and equipment on the distant side of the closure. Typically, the degree of permanence of the alternate facility should be proportionate to the closure duration. For a closure lasting a few hours, emergency response vehicles might be parked on the street with a temporary command center in a trailer. For a closure lasting several weeks, the vehicles and command center might be moved to a suitable space leased in a business park.

The initial planning for handling emergency responses should be made early in the TMP process by coordinating and communicating with emergency response agencies. The coordination should continue by refining the emergency response details throughout the entire TTC plan development to ensure legitimate needs and concerns are resolved.

4.7. ITS Infrastructure for Traffic Incident Management

Examples of ITS infrastructure that helps support work zone incident management include:

- Enhanced reference markers (mile posts).
- Traffic monitoring cameras.
- Traffic volume and speed detectors.
- Changeable Message Signs.

Existing traffic incident management infrastructure should be maintained and incorporated into work zone traffic control plans to the extent feasible. Where feasible, expansion of existing traffic monitoring and communication infrastructure should be considered as an early-action item to support work zone traffic incident management for larger projects.

Construction impacts on ITS infrastructure should be evaluated during the design process and appropriate temporary measures should be developed if necessary. For example, if the construction will sever critical ITS infrastructure such as primary communication cables, pre-installation of new cables along an alternate path or the temporary use of wireless communication links should be included in relevant project documents.

5. Contractual and Operational Provisions to Support Work Zone Traffic Incident Management (WZ-TIM)

This section discusses various contractual and operational strategies that can support Work Zone Traffic Incident Management (WZ-TIM) in combination with the infrastructure-based approaches described in the previous sections. During TMP development, these strategies should be integrated with other work zone management efforts such as demand management, corridor/network management, and enforcement [31]. Additional guidance on developing the overall Traffic Operations plan for a TMP can be found in Section 4.3 in the 2005 FHWA document, "Developing and Implementing Transportation Management Plan for Work Zones" [32].

The following list of questions may be used when developing WZ-TIM strategies.

- Will the project affect emergency response to this segment of highway?
- How easily can first responders reach incidents in the work zone?
- If an incident blocks the highway, is there another way for responders to reach the site?
- If an incident closes the highway in one or more directions, how will traffic be re-routed?
- Are there ways to minimize project impacts on first responders?
- Are there ways to enhance traffic incident clearance and safety?
- Is there equipment available that will improve emergency response and management during construction? Where will it be located?
- How will project construction staff and contractors coordinate with emergency responders?
- What arrangements will be in place to assure prompt towing of damaged/disabled vehicles?
- Will contractor personnel be on-call to assist emergency responders?
- Are existing coordination systems among first responders sufficient?

5.1. Inter-Agency Coordination

Planning for work zone traffic incident management should begin during the project design process and continue through the pre-construction and construction phases. The required amount of inter-agency coordination will vary depending on the complexity of the project, its physical location and physical characteristics, and the number of affected emergency response agencies.

There is no direct relationship between the dollar value of a construction contract and the importance of inter-agency coordination. Even a small project can have substantial effects on the ability to perform routine emergency responses if it interferes with access to public safety facilities such as police and fire stations, ambulance stations, and hospitals. A major concern are projects located on a roadway that are frequently used by first responders to access a freeway or other major route, or if it is located in an area that is difficult for first responders to reach in the event of an incident.

Getting Started. An important first step is to identify all emergency response agencies that are affected by the project. This is likely to include the police, fire, and ambulance services in the community where the project is located, and potentially in neighboring communities. Relevant towing operators and medical facilities should also be invited to participate in the inter-agency coordination process. Also, try to determine if the project is frequently used to transport hazardous materials in order to engage the material source or hazmat trucking carriers to identify their hazmat incident response companies. Local law enforcement agencies may be a good source for obtaining information about hazmat sources and trucking carriers using the project route.

In the United States, it is very common for emergency response agencies, especially law enforcement agencies, to have overlapping jurisdictions. For example, a single site could be served by the state police, county sheriff, and one or more local police departments. It is important to determine at the outset whether one agency will represent all law enforcement in the coordination process, or if each agency will be represented separately. In certain instances, there could also be a need for representation from special police forces, such as those serving larger railroads, mass transit systems, and airports.

The following list of steps may be used when developing WZ-TIM tactical and operational plans during TTC plan development. Each step should include identifying which jurisdictions and emergency response agencies are affected by the project.

- Identify access locations and plan alternate routes.
- Review project impacts on existing traffic monitoring and communications equipment, including electronic changeable message boards.
- Develop alternate route plans and installation of wayfinding signs on alternate routes.
- Consider feasibility of designing physical accommodations for incident management, such as enforcement pads, emergency pullouts, first responder staging and crash investigation sites, and emergency traffic control devices cashes.
- Consider the use of incident detection systems and supplemental electronic changeable message boards to disseminate information to drivers about work zone queues and mandatory and/or advisory alternate routes.
- Consider the use of contract dedicated towing services.
- Assure procedures are in place to notify and redirect oversize/overweight trucks during construction and administrative procedures to expedite incident response, clearance, and clean-up.
- Conduct meetings with emergency responder agencies to prepare, update, or review communication protocols, coordination procedures, inter-agency memos, mutual aid agreements, and contracts that will be used during the project construction.
- Prepare contact lists for use by contractors and project staff containing emergency responders contact information.
- Establish procedures to assure that contractors provide emergency responders with current project information on roadway closures and access locations.

- Conduct training and tabletop exercises using project plans to practice and clarify incident management procedures.

Coordination Meetings. Inter-agency coordination is generally the most effective if it includes face-to-face meetings augmented with communication through less formal channels. Each design project should be viewed as part of an overall long-term effort to improve work zone safety by building effective working relationships between the highway agency and the emergency response community.

At coordination meetings, designers should brief first responders (and other affected stakeholders) on the work that will be completed; the anticipated sequencing of roadway, lane, or ramp closures; and the access that will be available during each project stage. Drawings and maps are often a good catalyst for discussions about incident management during construction, including how responders will access the project site or bypass it to reach incidents that occur downstream. The primary and secondary access points that will exist during each project stage should be discussed in terms that are easily understood by the stakeholders. Physical accommodations for incident management (such as emergency parking turnouts and traffic control caches) should also be discussed.

It is vital for emergency response agencies to have an opportunity to review the draft traffic control plan, develop clear ideas about how they will manage any incidents that occur at the site, and provide feedback that the designer can use in finalizing the plan. A realistic deadline for comments should be established by mutual agreement. Recognizing that first responders are often very busy people who can be called away for emergency duties at a moment's notice, designers should be proactive in contacting first responders to solicit feedback if comments are not received before the agreed deadline.

Clarifying Roles & Responsibilities. Coordination meetings can provide opportunities to clarify and document the WZ-TIM roles and responsibilities for first responders, the transportation agency, and the contractor. Special attention should be given to differences between the work zone situation and TIM under ordinary (non-construction) circumstances. For example, a freeway ramp closure might cut off access for the fire department that normally responds to incidents in a certain stretch of the freeway, making it necessary for response to be provided by firefighters based in a different jurisdiction.

If necessary, mutual aid agreements and other inter-agency agreements should be updated to reflect the situations that will exist during construction. The roles and responsibilities for work zone incident management should also be described (in adequate detail) in the Traffic Operations section of the project's TMP.

Some examples of issues to be considered and resolved include:

- Which agency will be responsible for determining when to deploy incident management signage?

- Who has the authority to restore typical work zone traffic operations once an incident is cleared?
- Which agency will determine the content of any special messages that will be displayed on PCMS or other signs?
- What role will the contractor play (if any) in changing messages, setting up portable incident management signs, physically moving PCMS, or similar actions taken during an incident?

Follow-Up. The communication established between the designer and all affected emergency management stakeholders should continue as the project progresses from design through pre-construction and construction. Due to the potential for staffing turnover and leadership changes at emergency response agencies, designers should be prepared to recap previous briefings and summarize previous discussions and agreements. The designer should also assess the need for tabletop exercises or other training activities that could help assure effective response to incidents that occur in the work zone.

The designer should include contractual provisions to assure that in the post-letting phase, emergency response agencies are given real-time updates on closures and available access points, and any other commitments made to emergency management agencies are honored by the contractor and the agency's construction engineering representatives.

5.2. Emergency Response and Notification Plans

All contracts should include a requirement to develop an Emergency Response and Notification Plan. A key element of this plan is that someone (usually the contractor) will take responsibility for keeping contact lists updated throughout the construction phase. This includes 24-hour emergency contact lists with all means of communication that can reasonably be expected available during the project (landline phone, cell phone, SMS text, e-mail, fax, etc.). These lists should include all contractor, subcontractor, first responder, and highway agency representatives who potentially need to be contacted in case of an incident. Alternate contacts should also be included.

While e-mails and texts can often be sent directly to all representatives simultaneously, it is highly desirable to establish "phone trees" so that each person only has to telephone two to four other people if it is necessary to communicate by phone. Planning for multiple modes of communication can help assure that information is passed along in a timely manner if the incident causes a failure in one communications channel (for example, major freeway incidents sometimes result in an overload of the cellular phone network as drivers attempt to notify their families and business associates about the delay).

5.3. Contractor Involvement in WZ-TIM

Under ordinary (non-work zone) conditions, traffic incident management is usually handled by first-responders, often with the assistance of agency maintenance personnel for emergency repairs. While construction operations can make incident response and recovery more complicated than it is under ordinary conditions, the proximity of contractor personnel potentially provides equipment and human resources that can contribute to timely response and recovery.

The appropriate roles for contractor personnel will vary depending upon site conditions, the size and skill level of the workforce associated with the project, and the preferences of first responders and the highway agency. Some potential contractor roles include:

- Installing and maintaining signage and temporary traffic control caches that could be used for incident management.
- Patrolling the work zone to monitor traffic and report any incidents to first responders.
- Activating or repositioning incident management signs, including alternate route signage.
- Assisting with deployment of temporary traffic control devices for incident management.
- Closing entrance ramps, side streets, and driveways to limit traffic volume through the incident site.
- Providing back-of-queue protection.
- Providing towing services.
- Providing heavy equipment to move damaged/disabled vehicles out of the travelled way.
- Temporarily blocking stormwater inlets and other drainage structures to stop hazardous materials spills from contaminating waterways.
- Post-incident repair/replacement of damaged temporary traffic control devices.
- Post-incident repair/replacement of damaged highway infrastructure.

Potential contractor roles and responsibilities should be discussed with first responders as part of the overall TMP and incident management planning process. Appropriate contractor resources could be selected to augment those provided by first responders and the highway agency. For example, contractor personnel could be used to close freeway entrance ramps quickly in the event of an incident to reduce the burden on law enforcement resources.

Contractor roles, responsibilities, and expectations should be spelled out clearly in the contract documents and an appropriate basis of payment should be established (unless the contractor activity is part of overall project administration). For emergency assistance services of unknown type and quantity, the simplest and most flexible approach is often to have a set of time-and-material bid items that define hourly rates for each worker classification and equipment type.

If contractors will be involved in incident management, they should be prepared to coalesce into a unified command structure led by first responders. A qualified person should brief foremen, lead workers, and other relevant contractor personnel on the principles of Incident Command System (ICS). These principles are described in FHWA's Simplified Guide to the Incident Command System for Transportation Professionals and are very briefly summarized in Figure 50.

Core Principles of the Incident Command System (ICS)

- **Modular Organization:** The first arriving unit establishes command over the incident. The chain of command follows a top-down hierarchy. The overall organization expands and contracts as needed based on the conditions. As the response progresses, command is handed over to the agency or group that is best able to handle the overall coordination of that phase of the incident. For example, if law enforcement officers are the first to arrive at the scene but the most serious hazard is a fire, command is handed over to the fire services as soon as they arrive and are ready to take control.

- **Unity of Command:** Each individual participating in the operation reports to one (and only one) supervisor.

- **Span of Control:** Each supervisor oversees no less than 3 and no more than 7 individuals. Supervisors coordinate with one another, but do not get directly involved in front-line operations. Instead, supervisors allocate tasks to individuals based on their training and expertise.

- **Management by Objective:** Incidents are managed by aiming towards specific objectives. These objectives are ranked by priority, should be as specific as possible, must be attainable, and if possible given a working time-frame. Objectives are accomplished by first outlining strategies (general plans of action), then determining appropriate tactics (how the strategy will be executed) for the chosen strategy.

Figure 50. Core principles of the Incident Command System (ICS)

5.4. Quick Clearance Strategies

Steps that can be taken to minimize the time to clear an incident are often referred to as "quick clearance." Quick clearance is achieved by using policies and practices that can rapidly and safely remove temporary obstructions from the roadway. Quick clearance applies to all types of incidents and can range from vehicle disablement and non-hazardous spills to serious crashes. Many agencies use quick clearance policies and procedures as part of their routine traffic operations programs [33]. For projects where quick clearance is a paramount concern, these policies and procedures should be carried over, expanded, and incorporated into the construction project plan using contract specifications (Figure 51).

Traffic Monitoring Services

1. *Provide 24 hour per day continuous monitoring of traffic control devices and incident response for emergency situations on projects during complex traffic situations as defined in the contract documents. The contract documents will identify projects requiring monitoring with incident response. Ensure a vehicle and operator traverses the project throughout the entire traffic control zone at all times, except for refueling and short rest breaks no greater than 15 minutes in duration.*
2. *Furnish this work according to the contract documents any time that signs, barriers, barricades, or other traffic control devices are in place during complex traffic situations.*
3. *Provide a vehicle and operator for this work as follows:*
   - *a. Equipment.*
     - *1) Meet the following requirements:*
       - *a) 3/4 ton pickup truck or another similar vehicle.*
       - *b) Contractor's insignia on the vehicle.*
       - *c) Adequate weight and power and suitably equipped to move stalled automobiles or pickup trucks.*
       - *d) Equipped with an amber revolving light or amber strobe light visible in all directions and a cellular telephone or similar type of mobile phone.*
       - *e) Capable of carrying traffic signs, tools, traffic control devices, and other necessary equipment.*
     - *2) When used on projects where more than one lane in one direction is maintained at all times, ensure this vehicle is also be equipped with a Type C arrow panel mounted to be visible to traffic approaching from behind.*
   - *b. Operation.*
     - *1) Furnish an operator for the vehicle. Ensure the operator re-erects, repairs, or replaces defective devices immediately upon discovery.*
     - *2) Have the operator:*
       - *a) Be available to assist persons with vehicle problems and move automobiles, pickup trucks and other obstructions so as to keep all travel lanes and shoulders available for public traffic.*
       - *b) Continue assistance to motorists and involvement with obstructions until they are no longer an impediment to traffic and further assistance can be provided safely by others.*
       - *c) Assist motorists or remove obstructions promptly and safely when a vehicle or anything else is obstructing a travel lane or shoulder intended to be clear.*
       - *d) Summon further assistance if needed.*
       - *e) Keep a report of any events that restrict the normal traffic flow during complex operations, including responses to emergency situations, on forms provided by the Engineer. Provide the Engineer with a copy of this report daily.*
     - *3) During anticipated peak traffic times, the Engineer may direct the Contractor to provide additional monitoring personnel.*

Figure 51. Sample contractual provisions for traffic monitoring services.
Source: Iowa DOT Traffic Control Specifications Section 2558.01

5.4.1. Traffic Incident Monitoring and Response by Contractors

Contractor supplied traffic monitoring patrols are sometimes used to expedite incident response, especially on high-volume, high-speed facilities with severe capacity restrictions or other critical infrastructure such as major bridges and tunnels. The goal is to provide a faster incident response, especially to minor incidents, in order to try to prevent minor incidents from becoming larger and longer in duration. In addition to notifying first responders when an incident is observed, the patrol is sometimes also responsible for repositioning, repair, or replacement of damaged or displaced temporary traffic control devices; for pushing stalled vehicles out of the travelled way; or for providing roadside assistance to vehicles that experience minor mechanical problems. *Figure 52 provides excerpts of contractual language used by Iowa Department of Transportation to obtain such contractor-provided services.*

Basis of Payment for Monitoring with Incident Response

1. *Per calendar day for the number of calendar days used.*
2. *This payment is full compensation for:*
   - *Furnishing the necessary vehicle (including operation, maintenance, and supplies),*
   - *Furnishing the operator,*
   - *Documentation of any events that restrict the normal flow of traffic including responses to an emergency situation,*
   - *Re-erecting, repairing, or replacing traffic control devices,*
   - *Providing assistance to persons with vehicle problems,*
   - *Moving stalled vehicles, and*
   - *Summoning further assistance when needed.*
3. *Payment for the number of calendar days that additional personnel, such as for changeable message sign operation required by the Engineer, will be the contract unit price per calendar day. Payment is full compensation for furnishing the required personnel and necessary support vehicles.*

Figure 52. Sample contractual provisions for monitoring with incident response services.
Source: Iowa DOT Traffic Control Specifications Section 2528.05

5.4.2. Service Patrols (Tow Trucks) Dedicated to Work Zones

Service patrols (dedicated tow trucks) are an important quick clearance and crash prevention strategy (Figure 53). In addition to expediting response to traffic crashes, such patrols can reduce the risk of traffic back-ups and collisions that result from minor incidents. Typically, about 20% of calls handled by service patrols are to respond to a crash or to assist law enforcement, fire, or EMS personnel [34]. The remaining 80% of calls are usually for problems such as vehicles that are disabled by tire damage, run out of fuel, or have overheated. Prompt response to these everyday problems helps prevent secondary crashes that can occur when a driver strikes a disabled vehicle or hits a motorist who is in the roadway trying to fix a disabled vehicle. As a result, patrols play an important safety role even when they are handling relatively small problems.

Figure 53. Freeway Service Patrol vehicle and equipment.
Source: Hawaii DOT

The use of service patrols during a construction project requires careful consideration of several issues such as the desired hours of operation, staffing level, equipment specifications, and mode of operation. Potential modes of operation include:

- Stand-by mode which means parked in close proximity to the project or dedicated for sole benefit to the project.
- Constant patrolling mode.
- Combinations of patrol and stand-by mode, possibly varying by time of day based on expected traffic volume.

The geographical area covered by the patrol should include all areas where traffic queues (backups) caused by the construction are likely to occur. When planning the patrol area, the designer should also identify locations beyond the construction limits where patrol vehicles can turn around safely. On limited access facilities, it is generally safest to extend the patrol boundaries to a downstream interchange; patrols should only use turnarounds designed for maintenance vehicles in emergency situations. Turning around at interchanges also helps prevent the patrol vehicle from provoking congestion in the work zone.

If patrols will operate in stand-by mode for some or all the day, the designer should identify the preferred locations for patrol parking and access to the work zone. These locations should be identified in the traffic control plan since they could affect the contractor's construction staging plans. If infrastructure such as patrol parking pads or access driveways needs to be constructed by the contractor, construction time constraints should be identified in the contract special provisions.

The professionalism of service patrol operators affects both their effectiveness in responding to work zone incidents and the public's perception of the sponsoring agency. Screening and training requirements for patrol vehicle operators should be established accordingly.

Contractual arrangements for service patrols are an important consideration. In some jurisdictions, patrols are operated by the highway agency itself or by a law enforcement agency. In other jurisdictions, the work is contracted to the private sector, either through an agency procurement process or as a task within the construction contract. The following factors should be considered:

- If an existing service patrol arrangement is in place for routine incident management, modification or expansion of the existing contract is usually the most straightforward way to obtain the services required during construction.
- If no existing contractual arrangement is in place, the designer should allow ample time for procurement of stand-alone contracts.
- Patrol services are sometimes incorporated into the highway contractor's responsibilities. This approach is often expeditious, but might not be as cost effective as other options.
- The towing industry is often highly competitive, so it is important to assure that the criteria for determining service provider qualifications are logical and the selection process is transparent and fully compliant with all relevant state statutes.

5.5. Expedited Restoration of Temporary Traffic Control Devices

Work zone incidents often result in displacement or damage to temporary pavement markings, signs, barricades, drums, arrow boards, PCMS, and other TTC devices. This can occur because of an impact with an errant vehicle, or because of repositioning by first responders.

As part of the TMP process, the designer should determine whether the location and nature of the project makes it appropriate to establish a special expedited response time for replacement, repair, or repositioning of traffic control devices that are affected by an incident, especially incidents that involve law enforcement presence. *For example, the contractual special provisions might stipulate that the contractor must, "Provide equipment, forces, and materials to promptly restore traffic control devices or pavement markings damaged or disturbed by an incident within 2 hours of being notified." Although a two-hour timeframe is often selected, the timeframe needs to be set realistically based on site conditions.*

Regardless of the project, it is important that TTC devices are returned to their pre-incident condition and location before the incident scene is cleared by law enforcement. Therefore, first responders should be encouraged to coordinate with the contractor and the agency's construction engineering representative before they take it upon themselves to restore TTC devices to a previous position. The contractor and construction engineer should jointly conduct post-incident drive-throughs and walk-throughs to verify the presence, positioning, and integrity of all devices, including those used to manage pedestrian and bicycle traffic. Early notification can help ensure that the contractor can successfully mobilize personnel required to meet the requirement. Some projects on high-volume, high-speed, or high-risk routes also include a special provision requiring on-site contractor presence at all times.

Contractor compensation, if any, for expedited repositioning should be established based on the project's anticipated site conditions. While routine TTC device repositioning is usually non-compensable, expedited repositioning is potentially an extra-cost item due to the need to transport personnel quickly to the site, substitute higher-wage workers for those who would ordinarily take care of TTC maintenance, or complete the repair/replacement at a time when contractor personnel are ordinarily off-duty. Therefore, the contract should be specific on which replacement, repair, and repositioning services will or will not be paid as extra work under the contract.

5.6. Expedited Restoration of Temporary Barriers (Positive Protection)

Due to the need for specialized lifting equipment, the post-incident realignment or replacement of positive protection hardware (such as temporary portable concrete barrier) is usually treated separately from other TTC devices.

On large, high-volume projects where positive protection devices are used, a cache of replacement sections and other spare parts should be included in the specifications. The spares should be stored at an accessible location near the project site. The storage location should be identified on the traffic control plan if the designer has obtained appropriate easements or if a suitable location on public property is available. Alternatively, the project documents could include provisions requiring the contractor arrange for a suitable storage site; typically, the site will be subject to agency approval.

The timeframe for positive protection repairs should be specified in the contract. A typical mobilization for high volume, high speed freeway projects time specification is *one hour*. *Figure 54 and Figure 55 provide samples of two special provisions used by Wisconsin DOT to stipulate the availability of a "barrier installation specialist" to undertake emergency repairs at all times during the duration when barrier is used on the project. The Wisconsin DOT emergency repair standby time special provision requires the contractor to have temporary barrier lifting and hauling equipment and a specialist to operate the equipment on-site within one hour of notification, and requires spare barriers to be stored within the project limits. The emergency repair mobilization special provision is then used each time an emergency barrier repair is ordered, and is paid as a unit each time an emergency repair mobilization is successfully completed. In addition, two regular temporary portable concrete barrier bid items are also used: the first to pay for the specified amount of stockpiled spare barriers on the project, and the second is used to install the replacement barriers (both of these special provisions are paid per lineal foot of barrier).*

Standby Time Special Provision

This special provision describes providing equipment and labor that will be available at the project site, necessary to install temporary precast concrete barrier in emergency situations to replace or supplement previously installed temporary barrier, and in accordance to the pertinent provisions of Standard Specification 603 and the plan standard detail drawings.

Construction

Provide equipment at the project site that will be operational within one hour of notification by the engineer, the County Sheriff, or the State Patrol Region Headquarters, and that is capable to load, haul, unload, remove and place temporary precast concrete barrier that is in inventory on hand within the project limits. Provide a barrier wall lifting device that will be available for use by emergency services. Such equipment shall be stored within the project limits at all times when concrete barrier is in use within the project limits. Provide a qualified individual, designated as the Barrier Installation Specialist, who will be present at the project site within one hour of notification by the engineer, the County Sheriff, or the State Patrol Region Headquarters, and is capable of operating equipment and tools to load, haul, unload, remove and place temporary precast concrete barrier that is in inventory on hand within the project limits. The Barrier Installation Specialist shall be available, as outlined above, at all times when concrete barrier is in use within the project limits.

Provide additional individuals that will be present at the project site within three hours of notification by the Barrier Installation Specialist, who are capable of assisting the Barrier Installation Specialist to load, haul, unload, remove and place temporary precast concrete barrier.

Measurement

The department will measure Concrete Barrier Temporary Precast Emergency Repair Standby Time as a single lump sum unit of work, acceptably completed.

Payment

The department will pay for measured quantities at the contract unit price under the following bid item:

ITEM NUMBER	*DESCRIPTION*	*UNIT*
SPV.0105.04	*Concrete Barrier Temporary Precast Emergency Repair Standby Time*	*LS*

Payment is full compensation for furnishing all labor, tools, equipment, materials, and incidentals necessary to complete the contract work.

Concrete Barrier Temporary Installed and Concrete Barrier Temporary Emergency Repair Mobilization will be paid for separately.

Figure 54. Example of Special Provision for emergency replacement of concrete barrier.
Source: Wisconsin DOT.

Mobilization Special Provision

This special provision describes mobilization required for emergency repair of concrete barrier temporary. Extra barrier sections shall be available on site and will be paid for under the Concrete Barrier Temporary Precast Furnished item. Barrier sections requiring replacement will be paid for under the Concrete Barrier Temporary Precast Installed item.

Construction
Concrete Barrier Temporary Emergency Repair Mobilization shall be as requested by the engineer. The contractor shall respond to the request for Concrete Barrier Emergency Repair Mobilization within 1 hour.

Measurement
The department will measure Concrete Barrier Temporary Emergency Repair Mobilization as each individual mobilization, acceptably completed.

Payment
The department will pay for measured quantities at the contract unit price under the following bid item:

ITEM NUMBER	*DESCRIPTION*	*UNIT*
SPV.0060.20	*Concrete Barrier Temporary Emergency Repair Mobilization*	*Each*

Payment is full compensation for furnishing all work required under this item.

Figure 55. Example of Special Provision for mobilization of concrete barrier repair.
Source: Wisconsin DOT.

5.7. Post-Incident Reviews

Following major incidents, an "After Incident Review" should be conducted jointly by the highway agency and relevant emergency responder agencies. If the contractor's activities were relevant to the response, contractor representatives should also be invited to participate. The incident management special provisions of the contract should identify the contractor responsibilities to participate in this review, including allowing contractor input for potential traffic control plan modifications and requirements to make modifications as directed by the highway authority to the traffic control plan because of the After Incident Review.

After-incident reviews should include all relevant first responders, contractor, and agency personnel. The discussion should be moderated by a person who is good at encouraging frank, open discussion. It is important to discuss both the aspects of the response that were handled well and those which can be improved in the future.

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