Utility Work Zone Traffic Control

Guidelines

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Utility work zones are fundamentally different from most highway construction work zones. Utility work is often of a shorter duration and involves smaller crew sizes, which makes a traffic control plan such as that utilized in highway construction sometimes impractical. As utility service providers often need to work on or near roadways, utility work zones pose unique challenges to the health and safety of both motorists and workers.

This guideline document provides an introduction to utility work zone operations and presents recommendations for several important aspects of safety related to utility work, including the establishment of a safety culture in the organization, the use of uniform and consistent traffic control devices and systems, and the development of a set of typical temporary traffic control plans (TTCP) that are appropriate for specific types of work sites. As a part of the "Utility Work Zone Traffic Control Guidelines", twenty-seven typical TTCPs were developed based upon site-specific work site factors that include the work location, type of roadway, and the speed limit and traffic volume of the adjacent roadway. An accompanying automated software program has been developed to aid in the selection of an appropriate TTCP based upon site-specific conditions.

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1.0 Introduction and Background

Utility work zones pose unique challenges to the motorist as well as to the workers health and safety. Utility service providers such as the electric, gas, telephone and cable companies often need to work on or near roadways providing essential services to the public at large. Most of their work activities typically require less time as compared to roadway construction and maintenance activities and are generally completed in a timely manner. It is often impractical for a utility company to create detailed, site-specific work zone temporary traffic control plans for each and every work zone they visit in a typical day. The utility companies and their contractors, therefore, must follow policies, procedures and standards for work zone traffic control that incorporate desirable safety and mobility guidelines and standards and follow their intent to ensure the safety of the motorists and the workers in a utility work zone.

> *"The needs and control of all road users (motorists bicyclists, and pedestrians within the highway ...) through a TTC zone shall be an essential part of highway construction, utility work, maintenance operations, and the management of traffic incidents."*
>
> MUTCD Section 6C.01

The federal Manual on Uniform Traffic Control Devices (MUTCD) (1) contains the basic principles of design and the use of traffic control devices for all streets and highways. States can and do have modifications to the national MUTCD—for example Ohio has the Ohio MUTCD. Part 6 of the MUTCD contains the standards, guidance, options, and support information related to work zones. In work zones, temporary traffic control (TTC) is primarily used to enhance traffic safety and mobility. As stated in Part 6 of the MUTCD, "the primary function of temporary traffic control is to provide for the safe and efficient movement of vehicles, bicyclists, and pedestrians through or around temporary traffic control zones while reasonably protecting workers and equipment" (1). The MUTCD includes 'Typical Applications' for a variety of street and highway work zone situations commonly encountered by road users. These provide detailed schematics and depict examples of recommended advance traffic control warning signs, tapers for lane transitions, buffer spaces, temporary channelizing devices (such as cones, drums, traffic barriers), and pavement markings. However, the MUTCD does indicate that systematic procedures be used for establishing traffic control, which consider actual field conditions, as they may vary drastically from the condition illustrated in the 'typicals' with such conditions as: road configuration, location of work, work activity, duration of work, traffic volumes, and traffic speeds. In such cases, the MUTCD recommends that the 'typicals'/guidelines be applied/adjusted to actual situations and field conditions using proper judgment *(1)*. Sometimes, many professionals and regulatory agencies misinterpret the MUTCD's 'typicals' and think that they must be used exactly as presented in all circumstances.

The MUTCD (Part 6) provides comprehensive information related to roadway construction-related traffic control. The research that provides the background for the MUTCD rarely involves utility work zones. The manual, however, recognizes the transient nature of utility work and differentiates between the shorter duration of certain work activities by providing an amount of flexibility for the typical temporary traffic control for such situations. Work duration is a major factor in determining the number and types of devices used in temporary traffic control zones *(1)*.

Highway work zones often contain a sign at the beginning and end of the work zone informing drivers of the work zone boundaries. Utility work zones may not always contain these signs since they are shorter in duration and may be mobile. The MUTCD provides a definition of construction, maintenance and utility work zones stating that they may be identified by signs at the beginning and end of the work zones, but they may also be identified by providing rotating/oscillating lights or strobe lights mounted on the work vehicle. According to the MUTCD, "A work zone is an area of a highway with construction, maintenance, or utility work activities. A work zone is typically marked by signs, channelizing devices, barriers, pavement markings, and/or work vehicles. It extends from the first warning sign or high-intensity rotating, flashing, oscillating, or strobe lights on a vehicle to the END ROAD WORK sign or the last TTC device." *(1)*

The US Department of Transportation, Federal Highway Administration has established a 'Work Zone Safety and Mobility Rule' *(2)*, which is applicable to all state and local governments that receive highway funds. It supports a three-tiered approach to work zone mobility and safety, which includes an overall policy for management of work zone impacts, agency-level processes and procedures to implement the work zone policy, and project-level procedures to assess and manage work zone impacts. The first component of the Rule promotes the use of decision-making framework and targeted strategies to address a wide range of safety and mobility issues in work zones throughout the project development stages. The second component requires agencies to develop an agency-level work zone safety and mobility policy utilizing the work zone safety and operational data, personnel training, and process reviews to assess and manage the impacts of all project stages based on standard procedures adopted by the agency. The third component includes the identification of 'significant projects' and requires that the transportation management plans consist of a Temporary Traffic Control Plan, Transportation Operational Strategies and Public Information components. *(2)*

Utility work zones differ from typical highway construction and maintenance work zones. They are often shorter in duration and the extent of traffic control used is dependent on the work crew and their company's/agency's safety practices and their perception of risks. Long-term utility work is generally planned ahead of time and often requires a maintenance of traffic (MOT) plan approval by the appropriate road agency. Therefore, such a utility work zone adheres to national and local work zone traffic control standards and practices. Emergency utility work zones are events that are most often controlled by local law enforcement officials and could range from a shoulder closure to an entire roadway closure. Such emergency utility work can vary from a few minutes to several hours.

Utility work often involves the presence of work vehicles and equipment in the travel lanes of the roadway, on the shoulder, and/or within the right-of-way of active roads and highways. Although utility work is often less time-consuming than highway construction and maintenance activities, it still poses similar challenges to passing motorists and workers. The MUTCD provides general guidelines and some minimum standards for utility work zone traffic control, and it provides significant flexibility such that its requirements are applicable to the entire range of work zone situations. These requirements are often interpreted in many different ways by utility companies/contractors/road agencies, such that the resulting non-uniformity may lead to increased risks for both motorists and workers, as well as reduced mobility for the road users.

The guidelines included in this report focus on utility work zone activities that are conducted on a typical day (i.e., not long-term work, or emergency work) and mitigating safety challenges that are often present in these types of work zones. The guidelines have been developed to fill in the gaps that are found in existing relevant guidelines/standards and utility work zone traffic control practice, as well as to satisfy the needs that are identified through literature searches, current practice surveys, safety official interviews, information collected during utility work zone site visits and utility worker surveys.

2.0 Work Duration

As per the MUTCD guidelines (Section 6G.02), the "five categories of work duration and their time at a location shall be:

A. **Long-term stationary** is work that occupies a location more than 3 days
B. **Intermediate-term stationary** is work that occupies a location more than one daylight period up to 3 days, or nighttime work lasting more than 1 hour
C. **Short-term stationary** is daytime work that occupies a location for more than 1 hour within a single daylight period
D. **Short duration** is work that occupies a location up to 1 hour
E. **Mobile** is work that moves intermittently or continuously" *(1)*.

The MUTCD recognizes the nature of such work zones and states that "During short-duration work, **it often takes longer to set up and remove the TTC zone than to perform the work**. Workers face hazards in setting up and taking down the TTC zone. Also, since the work time is short, delays affecting road users are significantly increased when additional devices are installed and removed" *(1)*. It also presents that "Considering these factors, simplified control procedures may be warranted for short-duration work. A reduction in the number of devices may be offset by the use of other more dominant devices such as high-intensity rotating, flashing, oscillating, or strobe lights on work vehicles" *(1)*.

> *"During short-duration work, it often takes longer to set up and remove the TTC zone than to perform the work. Workers face hazards in setting up and taking down the TTC zone. Also, since the work time is short, delays affecting road users are significantly increased when additional devices are installed and removed."*
>
> MUTCD Section 6G.02

The traffic control plan for utility work may be determined based on the type of work being conducted, the type of roadway and the traffic characteristics on the adjacent roadway. In a study conducted in Michigan (3), field observations were performed to determine the various types of work conducted by utility companies and the amount of time needed to complete each job. It was found that the same type of utility work took different periods of time to complete at different locations based on field conditions. If a traffic control plan is setup for a 30-minute work zone, but the work ends up taking 90 minutes to complete, workers are not expected to adjust the traffic control plan halfway through the job. The plan should have been set-up for the type of work being performed so that when the work takes longer than expected, the proper traffic control will have already been in place. (3)

> *"There are safety concerns for the crew in setting up and taking down traffic control zones. Since the work time is short, the time during which road users are affected is significantly increased when additional devices are installed and removed. Considering these factors, it is generally held that simplified control procedures are warranted for short duration activities. Such short-comings may be offset by the use of other more dominant devices such as special lighting units on work vehicles"*
>
> Traffic Control on State Highways for Short Term Work Zones. Oregon Department of Transportation, revised 1998

Ullman, Finley & Trout(4)conducted a current practice survey of 17 state transportation agencies and also sought the opinions of a focus group of Texas DOT employees to identify variations in the definitions of mobile and short duration highway construction/maintenance operations among state DOTs and assess their procedures and plans used in short duration and mobile operations. The authors obtained responses for the current practice survey from 17 state DOTs. It was found from the survey that the definition of mobile operations did not vary dramatically among state DOTs who responded, which was 'work that moves intermittently or continuously'. The short duration operation definitions varied from work performed in less than 15 minutes (Oregon DOT) to work that lasts up to 12 hours (Maryland DOT). The Nevada DOT indicated that although their definition reads "work that occupies a location up to one hour", they acknowledge that the actual work categorized as 'short duration' could take several hours. The authors stated that "one interesting note made by several states is that the work encompassed by the definition of short duration maintenance can frequently take a shorter amount of time to complete than to set up and remove the appropriate traffic control devices" *(4)*. As per the state DOT responses, the type of work performed under the short duration category generally include guardrail

> *"Workers are reluctant to utilize extensive traffic control for work that only takes a few minutes to complete. In addition, the set up and removal of traffic control devices increases the workers' exposure to traffic."*
>
> B.R. Ullman M.D. Finley and N.D. Trout, Identification of Hazards Associated with Mobile and Short Duration Work Zones

work, lighting maintenance, paving operations, pothole patching, sign repair/installation and signal work.

This utility work zone guideline recognizes the issues related to interpretation of the work duration categories, however it provides standardized traffic control plans that are sensitive to the real-life characteristics of the roadways where the work is being performed.

3.0 Utiliity Work Zone Crashes and Risks

A study of a decade (1996 to 2005) of motor vehicle crashes reveals that there is an annual average of 942 fatalities recorded in work zones in the USA. These fatalities were categorized into construction, maintenance, utility and unknown type of work zones. The average annual number of fatalities in utility work zones was approximately 14 over this period.

The National Cooperative Highway Research Program Report 500 Volume 17 *(5)* used the data for 2003 from the Fatality Analysis Reporting System (FARS) database and concluded the following:

- More than half of the fatal work zone crashes occur during daytime hours.
- Fatal work zone crashes are twice as high during the week as compared to the weekend.
- Most fatal crashes occur during the summertime.
- Over half of the fatal work zone crashes involve single motor vehicles. *(5)*

In the National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment and Control Evaluation (FACE) Program *(6)*, investigations of fatal occupational injuries are conducted throughout the USA and recommendations for mitigation of such fatalities are provided. The work zone fatalities investigated are most prevalent in highway construction projects, however there are a few that involved utility/maintenance projects.

One such report describes the fatality of a utility worker resulting from a vehicle entering into the work zone. Recommendations for future prevention of such an incident were stated as: 1) "Analyze the work site including traffic patterns and plan the work zone before you begin working", 2) "Position work vehicles to create an obstacle to prevent oncoming traffic from hitting you", 3) "Minimize exposure to moving traffic" and 4) "Drivers should not engage in activities that distract them from driving or hinder driving performance" *(6)*. These reports include isolated fatal crash investigations and did not include any general countermeasures.

Ullman and Scriba *(7)* conducted an analysis to assess the extent to which work zone fatal crashes are underreported nationwide. This was done by estimating an 'expected' percentage of work zone fatalities (using the percentage for states that explicitly identify work zone crashes on their report forms) and comparing it with the actual number of reported fatalities.

The results of this analysis indicated an underreporting rate of nearly 10 percent for national work zone fatalities between the years 1998 and 2000 *(7)*.

Utilities such as electrical lines, telephone lines, gas lines, sewer and water systems are often located in various places within or outside the right-of-way based on the age of the

surrounding developments. Older cities typically have their water and sewer utilities placed underneath the roadway pavement, while in newer cities and towns these utilities are typically located beyond the roadway, underneath the sidewalk or shoulder adjacent to the roadway. The actual location of the work for a utility company can range from within the roadway, on the shoulder, outside the roadway, overhead, or underground. According to the study conducted in Michigan *(3)*, most utility work projects take place on or beyond curbed or uncurbed sidewalk/shoulder in urban areas, often on local roads and residential streets with low to moderate operating speeds. Additionally, the length of utility work zones is generally short and the utility work zones are often in localized areas and extend to the limited area on or around the roads and highways.

Since the exact duration of utility work cannot be predicted accurately in advance, the temporary traffic control should consider the safety risks associated with each utility work zone. Crash and injury risk is related to the variation in the outcomes that could occur over a specified period in a given situation. Therefore, the risk of utility work zone crash/injury/fatality is a function of various factors including:

- Traffic volume on the roadway
- Travel speed

- Lateral distance of the work area from the travel lanes
- Work duration – time to complete the work
- Sight distance and work area visibility
- Others

Therefore, all utility work must be performed in an expeditious manner. Time exposure in a work zone is critical to risk. Work zones which extend during nighttime hours are associated with higher risk as compared to daytime work. Risks associated with motor vehicle crashes can be described as pure risk. This means that if there is a crash, there is a chance of loss. However, if there is no crash, the motor vehicle owner or the utility work zone workers do not gain anything. This is an example of pure risk. On the other hand, when someone buys a lottery ticket or spends money in gaming in a casino, they are also taking a risk. In this case, they have a chance of loss and also a chance of gain. The chance of gain may be very small, still there is a chance. This makes gambling a speculative risk.

It is desirable to have stricter standards for situations that pose a higher risk. For example, a utility work zone near a freeway or a high speed and highly traveled arterial street has a higher risk as compared to lower volume and lower speed roadway. Therefore, the work zone traffic control treatment in low volume low speed roadway situations can be less intensive as compared to a high speed high volume roadway.

3.1 Crash Avoidance

The basic purpose of work zone temporary traffic control is to provide information regarding the impending danger associated with work in and around roads and highways to the passing motorist. Information about a work zone is provided through signs and other traffic control devices such as cones, drums, barriers, etc. As motorists recognize a work zone, they will probably take necessary evasive actions in order to avoid a traffic crash. Travel speeds are often reduced creating a lower speed zone in the work zone. It is often difficult to provide worker protection and motorist protection at the same level of risk. Therefore, early recognition by the motorist of a utility work zone in and around a roadway is desirable. Such early recognition is often enhanced if we observe the following:

1. Uniformity of treatment—means treating similar sites with similar traffic control devices that are easily identifiable to the passing motorist.

2. Making utility work zones conspicuous to the passing motorist - use of the color orange is very well known by the motoring public as an indicator of work zone and temporary traffic control devices. According to the MUTCD, the color of work zone traffic control devices is orange. A safe design of utility traffic control work zones is to make the signs, barricades, cones, drums, etc. as conspicuous as possible. When a work vehicle that has oscillating or strobe lights is used in a utility work zone for short duration work, it often performs the function of informing the passing motorist of what is required to maintain a safe work zone. Having a work vehicle that is orange and also has an operating oscillating/strobe lights enhances the conspicuity of the work zone.

3. Utility work zone treatments must consider driver expectancy. Drivers gather information from signs and traffic control devices as they pass through a work zone. In fact, they expect similar situations to be treated similarly. It is essential to make sure that driver expectancy is not violated.

4.0 Why is Uniformity Important?

Uniformity of temporary traffic control devices for their intended application is critical in eliciting an appropriate driver action from the motoring public. The use of uniform traffic control devices at work zones simplifies the tasks of the road user because they allow them to more easily recognize and understand the message. This, in turn, reduces the motorists' response times and improves their ability to take the desired driving action.

As per the MUTCD "uniformity assists road users, law enforcement officers, and traffic courts by giving everyone the same interpretation. Uniformity assists public highway officials through efficiency in installation, maintenance, and administration" *(1)*.

To be effective, a traffic control device should meet five basic requirements:

- Fulfill a need
- Command attention
- Convey a clear, simple meaning
- Command respect from road users
- Give adequate time for a proper response

The failure to recognize roadway hazards is a primary cause of traffic crashes, particularly those crashes occurring in utility work zones. Such failures may be due to a number of factors, including fatigue, drowsiness, in-vehicle distractions, or general inattention, and inadequate information provided to drivers. In order for motorists to safely navigate through utility work zones, they must be able to perceive the ongoing work activity and react accordingly, prior to reaching the work zone.

> *"Uniformity of devices simplifies the task of the road user because it aids in recognition and understanding, thereby reducing perception/reaction time."*
>
> MUTCD Section 1A.06

Traffic conditions and changes in the driving environment, such as increased congestion, narrower travel lanes and the presence of horizontal curvature , may prompt drivers to slow down prior to their perception of advanced warning signs. These visual cues are recognized by drivers due to prior driving experience in similar situations. Construction and maintenance work zones may provide such visual cues to motorists, even in the absence of advanced signage or lighting. In addition, the long duration of such work zones adds to the apriori expectancy of drivers who encounter the work zone frequently.

However, utility work zones may not be as evident to motorists since utility work typically occupies a smaller area, is of a shorter duration, and requires fewer personnel and equipment than normal roadway construction or maintenance work zones. The duration of eye fixation on objects within the roadway environment tends to decrease after repeated exposures to the same environment, meaning that regular drivers may be slower to perceive and react when encountering a new and unexpected utility work zone. Thus, it is imperative that utility work zones are clearly identified to the driver both in advance and throughout the work zone area.

While utility work is most frequent in urban areas, drivers tend to have much shorter durations of eye fixation and tend to focus on a wider cone of vision in these areas due to the increased number of visual distractions compared to rural environments. Further complicating matters is the fact that inexperienced drivers tend to have longer eye fixation durations than experienced drivers, particularly in potentially hazardous situations (8). Consequently, it is important to convey a clear, simple message alerting drivers to the approaching utility work zone so they can quickly discern and react to the message.

From an engineering standpoint, motorists may be aided in this process through advanced warning, which typically consists of some combination of signage, lighting, and vehicular design elements to inform motorists of impending utility work. In order to be effective, these warning devices must attract the attention of approaching drivers, alert them of the approaching work zone, and provide them with adequate information so the appropriate action can be taken.

Unfortunately, there is currently somewhat of a lack of **uniformity** among the work zone traffic control practices of utility companies and contractors, particularly in regard to traffic control devices and work vehicle design. There are few concise standards or guidelines and consequently, there is substantial variability within these operations from state to state. This nonuniformity may lead to confusion among motorists and increase the amount of time necessary to process the information and react accordingly. Frequently, drivers are not able to react quickly enough as they enter the work zone environment, making evasive maneuvers more difficult and crashes more likely.

The MUTCD provides guidance on the use of traffic control devices, worker clothing, and warning lights for utility work occurring on roadway shoulders, two lane roads, and multi-lane facilities. However, no specific guidance is provided pertaining to vehicle **conspicuity** in terms of vehicle color or retro-reflective markings on the vehicle.

4.1 Signage

Signs are a key element in alerting motorists to the presence of a utility work zone as drivers are better capable of detecting roadway hazards when prompted by appropriate signage. The MUTCD provides specific guidance on work zone signage, including sizes, location, and mounting height. Larger signs are more conspicuous than smaller signs and dynamic message signs are generally more conspicuous than conventional signage. Though the MUTCD provides guidance, there exists great variability in regard to sign placement, particularly in utility work zones.

The MUTCD requires that post-mounted signs installed on the roadside be no less than five feet above the ground or seven feet when pedestrian traffic or on street parking has the potential to interfere with sign visibility. However, utility work zones frequently mount traffic control signs on collapsible sign supports, a situation which requires a minimum mounting height of only one foot. Experienced drivers tend to fixate their eyes for a lesser amount of time while driving and have less vertical variance in their eye fixation locations than inexperienced drivers (8).

> *"Ground-mounted signs installed at the side of the road in rural areas shall be mounted at a height of at least 1.5 m (5 ft)..."*
>
> *"...where parking and/or bicycle or pedestrian movement is likely to occur, or where there are other obstructions to view, the distance between the bottom of the sign and the top of the near edge of the traveled way shall be at least 2.1 m (7 ft)."*
>
> *"Signs mounted on barricades, or other portable supports, shall be no less than 0.3 m (1 ft) above the traveled way."*
>
> MUTCD Section 6F.03

The drivers, however, generally focus on the roadway surface as they drive. Consequently, placing signage and other warning devices lower to the ground has the potential to produce a greater impact on the driving population. Thus, it is desirable to place the temporary signs as close to the ground as possible in utility work zones. It is recommended that signs be mounted on portable support at a minimum height of one foot above the traveled way where such mounting height is not inhibited by parked vehicles. However, when on-street parking or pedestrian traffic is present, post-mounted signs at a height of seven feet are appropriate.

In addition to placement, sign visibility is also affected by the properties and characteristics of the signs. The use of fluorescent orange microprismatic retro-reflective sign sheeting materials increase sign conspicuity and subsequent detection distances. Several states now exclusively use such sign sheeting materials for work zone traffic signs. Consequently, it is recommended that utility work zone signs follow these same guidelines with a planned transition target.

4.2 Vehicle Design

A driver's ability to detect and appropriately respond to a utility work zone vehicle is based on multiple factors. The passing motorists must visually detect the work vehicle far enough in advance so that, if necessary, appropriate action can be taken. To ensure an appropriate response, the driver must also recognize that the vehicle is a part of the work zone traffic control treatment, **especially for short duration work.**

Utility work zone vehicles must be visible to drivers during all periods in which utility work is performed. Thus, if both day and night operations are performed, then utility work zone vehicles must be visible during those times by passing motorists. During the day, visibility of a work zone vehicle is largely a function of the contrast between the color of the work vehicle and its surrounding background. However, at night, vehicle color becomes less of a factor as the vehicle's visibility is mostly provided by luminance contrast between the vehicle and background. This luminance contrast can be provided either by illumination from a light striking retro-reflective material affixed to the work zone vehicle. Mounted warning signs, rotating and strobe lights, retro-reflective tape, warning flags, and auxiliary headlamps are each utilized to various degrees by various agencies to increase the **conspicuity** of work zone vehicles.

4.3 Vehicle Warning Lights

The MUTCD provides no specific suggestions on the color or configuration of warning lights, although it has generally been accepted that construction, maintenance, and service vehicle equipment warning lights be limited to **the color amber**. All state road agencies use amber warning lights, though some supplement the amber lights with other colors, including blue, red, and white.

> *"Appropriately colored or marked vehicles with high-intensity rotating, flashing, oscillating, or strobe lights may be used in place of signs and channelizing devices for short-duration or mobile operations."*
>
> MUTCD Section 6G.02

The combination of blue and amber lights has been shown to imply a slightly greater sense of hazard to motorists than the amber light alone. The combination of blue and amber light has been found to increase the tendency of drivers braking and reducing speed in work zones. Driver brake usage was more frequent when the warning light configuration included red, amber, and blue lights. Regardless of the specific lighting configuration, any combination of the aforementioned colors provides a benefit over **an unlit vehicle**.

The level of conspicuity of amber lights falls between the blue and red lights in both daytime and nighttime viewing conditions. Under daylight conditions, red lights are more conspicuous than blue lights while the opposite is true under nighttime conditions. However, several states prohibit the use of blue and/or red lights for any non-emergency vehicles. The use of a particular color light for more than one type of application has the potential to create confusion among motorists as to what actions to take in a given situation. Given these issues, it may be appropriate to have uniformity among all utility work vehicles so that motorists are presented with a consistent standard regardless of the locale. Therefore, the use of **amber lights** is desirable for utility work zone vehicles.

In addition to the color of lights, there is also significant variability as to the type of lighting utilized on utility work vehicles, which may include combinations of strobe, rotating, flashing, arrow board, and light bar vehicle lighting systems. Appropriate utilization of such lighting systems is important as drivers commonly have problems accurately perceiving the location of the work vehicle.

Arrows and flashing lights are generally more effective than rotating lights at reducing inaccuracies in driver perception. A review of the existing utility work zone operations showed great variability in the type of emergency lights utilized by different utility companies and/or their contractors. Creating a standard, or set of acceptable standards, for lighting configurations would help to improve **driver expectancy** when encountering a utility work zone operation. Such standards would reduce driver confusion as past studies have shown work vehicles equipped with light bars to often be confused with those on moving vehicles, such as tow trucks. Rotating or strobe warning lights are strongly recommended for utility work zone operations while arrow panels are recommended **when work occupies a traffic lane**. A combination of two rotating beacons and a flashing light has shown to be most effective in field research, followed by a combination of two rotating beacons with an incandescent flasher.

In addition to the type of lighting, other characteristics, such as flash rate, the number of lights, mounting position, and light intensity vary substantially across utility work zones. Developing uniformity in these characteristics presents further opportunities for aiding motorists in the identification of utility work.

4.4 Retro-reflective Markings on Vehicles

Nearly every state transportation agency utilizes retro-reflective materials on work vehicles to enhance nighttime visibility although colors and material patterns vary. Most agencies apply these materials to large trucks, although they are also used on smaller vehicles by many agencies. In most cases, the retro-reflectivity is provided by affixing a highly durable retro-reflective tape approximately four to six inches in width on the sides and rear of the vehicle. A majority of state agencies use red and white striped tape, with some agencies

using additional colors including orange, yellow, blue, and green. A rear-end marking treatment using black diagonal stripes mounted on an orange background has been shown to be most effective, followed by a pattern of alternative orange and white reflectorized blocks along the perimeter of the back of the truck. These treatments are recommended for use on utility vehicles as they are capable of improving both daytime and nighttime vehicle **conspicuity**.

Vehicle markings and retro-reflectorization vary greatly between utility companies. Standards have been developed in other industries and have proven to be successful at improving conspicuity. To increase the conspicuity of work vehicles, particularly large trucks, the installation of red and white retro-reflective tape is recommended along the sides of the truck. The combination of red and white type is recommended as these colors are commonly associated with danger, such as in the context of railroad crossing gates. It is further recommended that vehicles be oriented such that the rear of the vehicle is perpendicular to approaching traffic where possible, with allowances for angles of up to a maximum of thirty degrees.

4.5 Vehicle Color

Vehicle color has been found to influence the frequency of motor vehicle traffic crash involvement during daylight hours. White vehicles have been shown to be significantly less likely to be crash-involved than vehicles of other colors, likely due to the relatively high contrast of white with most background colors in the roadway environment. Darker colors were found to have a higher risk of crash involvement, likely due to the lower color contrast of the vehicle with the background surroundings.

Because most non-emergency utility work is performed during daylight hours, color contrast of a utility work zone vehicle with the surrounding background is of particular importance to achieve maximum daytime visibility. Typical surrounding background environments for daytime utility work zones might include foliage, traffic control devices, pavement, sky, and others, corresponding to a variety of colors.

Orange and yellow are the most prevalent colors among maintenance vehicles, with white and fluorescent yellow-green colored vehicles are also being used by some agencies to enhance conspicuity under a variety of conditions. However, utility company vehicles are **not required to use any** specific color scheme, and thus have been found to display a wide range of colors as most color schemes are based upon commercial considerations rather than safety impacts. This is one factor that may create difficulty for motorists to **consistently identify utility work zones**. As utility work is similar in many respects to **highway construction and maintenance**, creating a uniform color guideline or standard for vehicles in utility work would provide the drivers with a better **visual cue for work zone identification**.

Orange-colored vehicles, though not as conspicuous as white or fluorescent yellow-green, are more likely to be recognized as being associated with a work zone. Orange is one of the most highly recognized colors for traffic signs in terms of the meaning of color with three out of four licensed drivers associating orange with construction areas. Thus, using orange as the standard color for work zone vehicles would likely increase drivers' recognition that the vehicle is part of the work zone, thereby increasing the likelihood of an appropriate response upon detection. Additionally, because most utility work zones are relatively small in size and possess relatively few orange-colored traffic control devices, the use of orange for utility work zone vehicles might help increase driver awareness and recognition of the entire work zone area.

5.0 Rationale For Utility Work Zone Guidelines

> *"Road user and worker safety and accessibility in TTC zones should be an integral and high-priority element of every project from planning through design and construction. Similarly, maintenance and utility work should be planned and conducted with the safety and accessibility of all motorists, bicyclists, pedestrians (including those with disabilities), and workers being considered at all times."*
>
> MUTCD Section 6B.01

The utility work zone traffic control guidelines have been developed based on a thorough study of the state-of-the-art literature and surveys of various state and local road agencies, utility workers and safety officers. In addition, the guidelines also address various practical issues often faced by utility workers in the field. Such issues were identified based on numerous covert and overt observations of actual utility work zones. The resultant guidelines are meant to provide information and assistance for the planning and implementation of utility work zone traffic control under various situations.

The state-of-the-art review revealed that utility companies and contractors often generally use their own unique guidelines for temporary traffic control. No uniform set of guidelines or standards have been developed among various utility companies across the nation and, consequently, there is significant variability in the knowledge, skills, and abilities of the utility workforce. This guideline document provides such uniform guidelines, which include temporary traffic control plans for numerous applications, as well as recommended traffic control devices.

The guidelines are applicable for a variety of utility applications, catagorized on the basis of the magnitude of risk associated with each particular application. Guidance is provided to aid the utility workforce in quantifying the level of risk presented by a given application and, subsequently, in identifying appropriate means of mitigating such risk. This guideline serves to supplement, but not override applicable content from the Manual on Uniform Traffic Control Devices (MUTCD).

5.1 Who is it meant for?

This guideline and the associated training program will provide information for the following:

- **Management and safety officials**–management and safety officials of utility companies, contractors, road agencies, permit granting offices, and others. Safety officials can utilize the guidelines and the associated training material to estimate the resources necessary to perform the required utility work zone treatment. They can identify types and specifications of the traffic control devices that need to be purchased and/or modified and determine the training needs for the utility workers.

- **Utility workers, foremen and supervisors**–those from the utility companies, contractors, road agencies and others who are physically planning work or are actually doing the utility work.

5.2 What type of Utility Work is included?

The guidelines apply to various types of utility work, such as electric supply, gas, telephone, cable, sewer cleaning, grass cutting, tree trimming, and landscaping work located in or around public thoroughfares.

6.0 Why Use Different Utility Work Zone Traffic Control Plans?

There are numerous factors, many of which may be site-specific, that impact the elements required for an appropriate utility work zone traffic control plan. Due to the site-to-site variability in traffic and geometric characteristics, as well as differences in the actual work activities being performed, no single utility work zone traffic control plan is able to satisfy all possible conditions that may arise for a specific utility work zone project.

As utility work may include a broad spectrum of activities over a similarly broad range of locations, various traffic control plans must be developed that can address project-specific characteristics affecting both traffic operations and safety. However, it is not **practical to develop traffic control plans for every possible utility application**. Consequently, a compromise is to develop a set of typical utility work zone traffic control plans that serve as a basis for similar types of work based on common work characteristics.

The primary factors guiding traffic control plan selection, as per the MUTCD, are: **(1) type of work, (2) work duration, (3) highway type, and (4) work location**. In addition to these primary factors, there are several other elements which must be considered, including roadway geometrics, traffic and pedestrian volumes, speed limit, and traveler behavioral characteristics. The goal of the utility traffic control plans is to ensure the safety of both workers and road users while minimizing traffic disruption.

This section of the guidelines discusses the elements and factors that must be considered in developing an appropriate utility work zone traffic control plan and presents a set of typical traffic control plans that may be utilized by the utility workforce. In addition to these typical traffic control plans, a set of important questions to be answered are presented to assist utility personnel in the selection of an appropriate plan.

The type of work for which these guidelines are applicable includes all types of utility projects, such as electrical, gas, telephone, cable, water, sewer, traffic signals, and various other applications. Many types of utility projects have similarities which allow several of these applications to be grouped together. In general, utility work is unique from other types of road work requiring temporary traffic control in that it is typically of shorter duration. Prior to introducing a set of typical utility traffic control plans, the importance of the three primary factors from the MUTCD are briefly explained by answering the following questions:

1. Why is work duration important?
2. Why is work location important?
3. Why is type of work important?

6.1 Why is Work Duration Important?

Work duration is defined in terms of the length of time a work operation occupies a spot location. As the work duration period increases, workers and the traveling public are exposed to increasing crash risks. The MUTCD classifies work activities into five distinct categories: (1) Long-Term Stationary, (2) Intermediate-Term Stationary, (3) Short-Term Stationary, (4) Short Duration, and (5) Mobile. At one end of the spectrum, long-term stationary work lasts for over three days. In these cases, due to the high volumes of traffic that must be handled, as well as numerous work-related activities, long-term stationary work requires the most comprehensive traffic control plan in order to ensure both safety and mobility. Conversely, **short duration and mobile work** may occupy a location for only a few minutes. In such cases, it is not uncommon for the traffic control setup period to be longer than the actual period during which the work is being performed. **This means that the hazard potential for workers may actually be increased if an elaborate setup procedure is utilized.** Consequently, careful consideration is required when identifying the needed traffic control plan elements for specific work periods. Unfortunately, at the onset, it is often difficult to determine the exact time period which will be necessary to complete most utility work. The reason for this is that a number of factors come into play, including site traffic volume, experience of the involved workers, and other unforeseen issues.

For short-duration and mobile operations, the MUTCD states "a reduction in the number of devices may be offset by the use of other more dominant devices such as rotating lights or strobe lights on work vehicles." In fact, appropriately **colored or marked vehicles equipped** with such lights may be all that is necessary in locations with low speeds and/or low traffic volumes. In cases where work is of a longer duration or when greater exposure is presented to the workers, more elaborate plans may be necessary. The recommended temporary traffic control plan included in this guideline generally provides for that.

6.2 Why Is Highway Type Important?

The MUTCD classifies highway types into five categories: (1) Two-Lane Highway, (2) Urban

Streets, (3) Intersections and Sidewalks, (4) Multi-lane Undivided Highways, (5) and Freeways. Clearly, the operational characteristics of each of these facilities are substantially different. These operational differences will have an impact on both safety and mobility, requiring careful planning specific to each type of facility.

In general, exposure to safety risks is lowest on low speed and low volume two-lane highways. Due to increased adjacent land use development and higher traffic volumes, urban streets will generally present a greater risk of collisions even though speeds are typically low to moderate. Intersection locations present the largest number of conflict points for both drivers and pedestrians. Multi-lane roadway segments (mid-block) do not present as many conflicts as intersections, but generally speeds are much higher and, therefore, collisions are more severe when they occur. Freeways are subject to the highest traffic volumes, as well as the highest speeds, and introduce the greatest hazards to both workers and motorists. Due to the differences between each of these facilities, various work zone traffic control plans have been developed specific to each type of roadway facility.

6.3 Why is Work Location Important?

The impact of work location is similar to the impact of work duration in regard to exposure to crash risks. The closer the work is being performed to the traveled way, the greater the hazard posed to both the workers and the motorists, and greater the number of traffic control devices needed. The MUTCD identifies five general work locations: (1) Outside the Shoulder, (2) On the Shoulder with No Encroachment, (3) On the Shoulder with Minor Encroachment, (4) Within the Median, and (5) Within the Traveled Way.

Work conducted outside of the shoulder presents the lowest risk to utility workers. The further the work area is from the traveled way, the lower the probability of crash involvement. The closer the work is being conducted to the traveled way, the more temporary traffic control devices will be necessary to ensure safe operations.

Work conducted on the shoulder is clearly of a higher risk than work conducted several feet away from the shoulder due to the greater likelihood of collisions involving errant vehicles. Shoulder work necessitates the use of temporary traffic control devices and the closer the work is conducted to the traveled way, the more thorough the setup that is required. If the work area encroaches onto the traveled way, additional cautionary information must be provided to the motorists. Advance signage, channelization, and tapers are all common elements of such work zone traffic control treatments.

Work that is conducted in the median should be treated in a similar manner to shoulder work. The closer the work area is to the traveled way, the more intricate the temporary traffic control plan must be. The most hazardous case for utility workers occurs when the work is being conducted within the actual traveled way. This may include the closure of one or more lanes and will require, in many cases, the use of barriers in addition to advance warning signage, channelization, tapers, and in some cases, police presence. Specific procedures to be followed in each case will be outlined in the subsequent traffic control plans.

7.0 How is an Appropriate Utility Work Zone Traffic Control Plan Selected?

In order for a proper utility work zone temporary traffic control plan to be selected for a given utility application, the risk level faced by the utility workers and the road users must first be quantified and appropriate elements must be selected in order to mitigate these risks. As a part of this utility work zone guideline, an interactive software program has been developed that assists the user in identifying the most appropriate traffic control plan for the utility work zone in and around public thoroughfares.

The utility work zones that have the highest safety risks are those which occur on freeways or under nighttime conditions along a highly traveled roadway. In these scenarios, high travel speeds and reduced visibility create a high potential for crash involvement. Consequently, in these scenarios, the most conservative traffic control plans should be set up following appropriate retroreflectivity guidelines. Due to this fact, it is recommended that the provisions from the MUTCD be followed explicitly when conducting work **on a freeway or at night time**. The typical traffic control plans presented in this guideline are not applicable for either of these scenarios.

Under other conditions, the risk posed to workers and motorists is lessened to a degree, though a variety of hazards are still present. Due to the wide variability of hazards introduced by numerous factors, several utility work zone plans have been developed for a number of common scenarios. In order for an appropriate traffic control plan to be selected, a series of questions must be addressed relative to the particular application. Based upon the responses to these questions, an appropriate typical plan will be identified by the software program. Each of the questions included in the software application is discussed in the following section.

1. **Is the utility work taking place at nighttime?**
   If the utility work is occurring at nighttime, these typical utility work zone traffic control plans are not applicable and the MUTCD must be followed.

2. **Is the utility work occurring on a freeway?**
   If the utility work is occurring on a freeway, these typical traffic control plans are not applicable and the MUTCD must be followed.

3. Is this a tree cutting or trimming operation?

If the utility work consists of tree cutting or tree trimming, there are specific traffic control plans for when these operations result in either a shoulder closure on a two lane road or a lane closure on a multi-lane road.

4. What is the location of the utility work?

The utility work may be conducted in one of three locations: (1) beyond the shoulder, (2) on the shoulder, or (3) on the roadway. The risk level posed to utility workers and the road users increases from scenarios 1 to 3 as the likelihood of a collision with an errant vehicle increases.

4a) Is a work vehicle parked on the shoulder?

If a work vehicle is parked on the shoulder, an advance warning sign should be provided indicating that utility work is ongoing. Such signage is necessary to caution motorists and alert them to the presence of the utility vehicle, minimizing the likelihood of a collision. If a work vehicle is not parked on the shoulder, there is no immediate obstacle to oncoming traffic. Consequently, fewer temporary traffic control devices will be necessary in such instances.

4b) Is there a minor encroachment on the roadway?

If minor encroachment occurs on the roadway within one travel lane due to the utility work, a taper shall be provided and lanes may remain operational provided that there is at least three meters (ten feet) of the travel lane available. If traffic volumes are low, a 2.7 meter (nine foot) width of lane may be allowed provided that truck volumes are also substantially low. If the minimum lane width requirements cannot be met, the entire travel lane should be closed.

4c) Is the entire road closed?

If the entire road is closed due to an emergency situation such as a fallen tree on a roadway or a fallen wire, appropriate barriers and detour signs should be installed to prevent traffic from entering the work zone. In some cases, local traffic may need to be provided with access. In such instances, appropriate signage and positive guidance treatments should be utilized to safely navigate drivers through the road closure.

I. Is the utility work on or near an intersection?

Work occurring near an intersection requires more extensive use of temporary traffic control devices as traffic may be affected along each of the intersecting roads. Intersection utility work is classified as near side of intersection, far side of intersection, or in the center of the intersection. Work on the near side of the intersection refers to activities occurring on the approach upstream of the intersection and work on the far side of the intersection refers to activities occurring on the approach downstream of the intersection. Different traffic control plans are necessary for each of these applications. In some cases, work spaces may extend into more than one portion of the intersection which requires a combination of elements from the three separate traffic control plans to be used to create a customized traffic control plan.

If there is a closure near an intersection, utility worker safety is maximized by providing sufficient traffic control treatments such that drivers will not inadvertently enter the work zone. Whenever a road closure is necessary, advance warning signs should be provided to alert them of such situations. In the case where traffic is directed to an adjacent travel lane, a combination of signage, barriers, and appropriate delineation should be utilized as specified in the accompanying traffic control plans. Depending upon the location of the closure, varying traffic control devices are required to provide positive guidance to the motorists and pedestrians.

II. Is the work in the middle of the road?

If the work occurs in the interior lanes of a multi-lane facility, utility workers are subject to risk from vehicles traveling in both directions. In such cases, advance warning signs should be provided.

III. Is the adjacent road a two-lanes?

Two-lane roads vary from multi-lane roads especially when an entire lane is closed. For a multi-lane road, traffic can be diverted to another lane without disrupting the vehicles traveling in the opposite direction. For a lane closure on a two-lane road, both directions of traffic are required to share one lane. This results in the need for extensive signage and the use of **flaggers** (traffic regulators).

IV. Is there restricted visibility near the lane closure?

If a lane closure on a two-lane road occurs in an area where visibility is restricted, such as along horizontal or vertical curves, additional advance signage will be required in order to alert motorists of an upcoming work activity. If the work is occurring along a verticel curve, additional spacing should be provided between signs. In addition, appropriate delineation should be provided and work vehicles should be placed upstream of the work zone to maximize safety of the workers.

V. Can the traffic self-regulate without the use of flaggers (traffic regulators)?

If there is a lane closure on a two-lane road with low traffic volume, low speed, and unrestricted visibility, the use of flaggers (traffic regulators) may or may not be needed depending on the ability of traffic to self-regulate. When speeds and volumes are low, motorists can maneuver around lane closures on two-lane roads without guidance from flaggers (traffic regulators) particularly on local roads. When traffic can self-regulate, advance signage is needed to warn motorists of an approaching work zone and channelizing devices are required to guide the motorists around the work zone.

5. Is the adjacent road low traffic volume and low speed?

Lower traffic volumes lead to lower levels of risk exposure for utility workers. The fewer vehicles that pass by a utility work zone, the fewer the opportunities there will be for a collision. Similarly, the lower the travel speed or speed limit on a given road, the less risk posed to the utility worker. At higher speeds, the reaction time of the hghg driver is reduced and the potential of a collision is heightened. Further, collisions at high speed are more likely to result in a serious or fatal injury due to the increased forces generated by such collisions. In cases where both volume and speed are relatively low, the level of risk to the utility work zone crash is minimal.

The user must identify the appropriate category from the choices provided in these questions. Based upon the response to each of these questions, an appropriate traffic control plan can be selected. A typical traffic control plan is presented in Figure 1. Each of the traffic control plan elements presented in this figure are defined in Table 1.

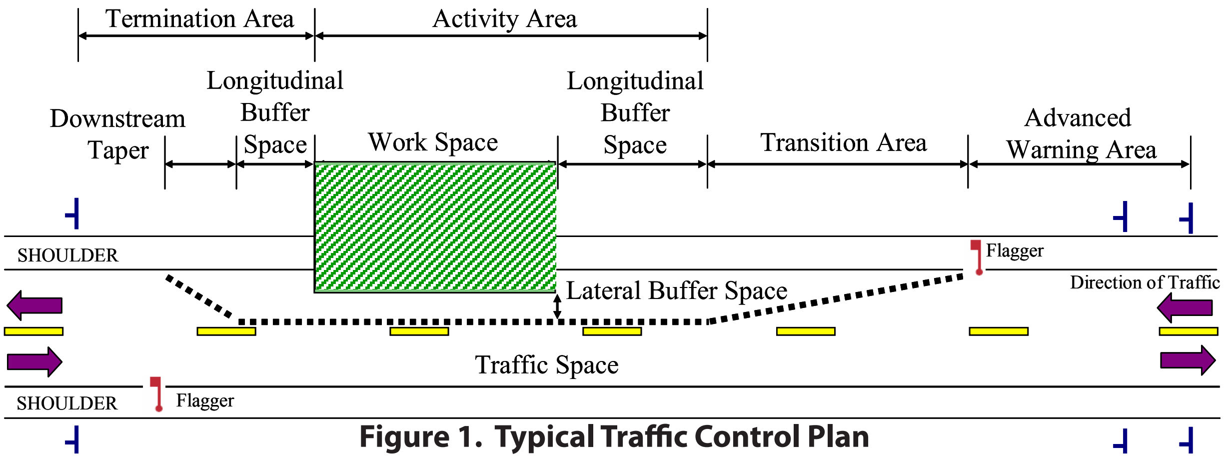


Figure 1. Typical Traffic Control Plan

Table 1. Traffic Control Plan Elements

Traffic Control Plan Element	Traffic Control Plan Element Definition
Activity Area	Section of the highway where the work activity takes place, comprised of the work space, traffic space, and buffer space.
Advanced Warning Area	Area consisting of signage used to provide warning to motorists of what to expect as a part of an upcoming utility activity.
Buffer Space	Optional lateral and/or longitudinal work area that separates traffic from the work space. The buffer space must be free of any work vehicles, workers, equipment, or materials.
Tapers	Gradual transitions, created by a series of channelizing devices and/or pavement markings, which direct traffic from normal paths to zone-specific paths, used in both the transition and termination areas.
Termination Area	Area which may include buffer space and a downstream taper, allowing motorists to return to their normal path and extending to the END ROAD WORK signs, if posted.
Traffic Space	The portion of the highway in which road users are routed through the activity area.
Transition Area	Area utilized to move motorists from their normal path. The transition area must be free of any work vehicles, workers, equipment, or materials
Work Space	Portion of highway closed to road users and occupied by utility workers, equipment and vehicles; usually delineated for road users by channelizing devices or, to exclude vehicles and pedestrians, by temporary barriers.

This guideline includes 25 typical utility work zone traffic control plans, labeled as Figure A through Figure T. Each of these traffic control plans is discussed briefly and presented in the following section. A schematic of the plan selection process is presented graphically in Figure 2. A computer based program has also been developed to aid in the selection process which follows the flow chart in Figure 2 and contains 25 typical utility work zone traffic control plans.

These 25 traffic control plans are generally divided into three categories: (1) work beyond the shoulder, (2) work on the shoulder, and (3) work on the roadway. Each of these categories is explained further in the following section and references are made to the corresponding traffic control plan figures.

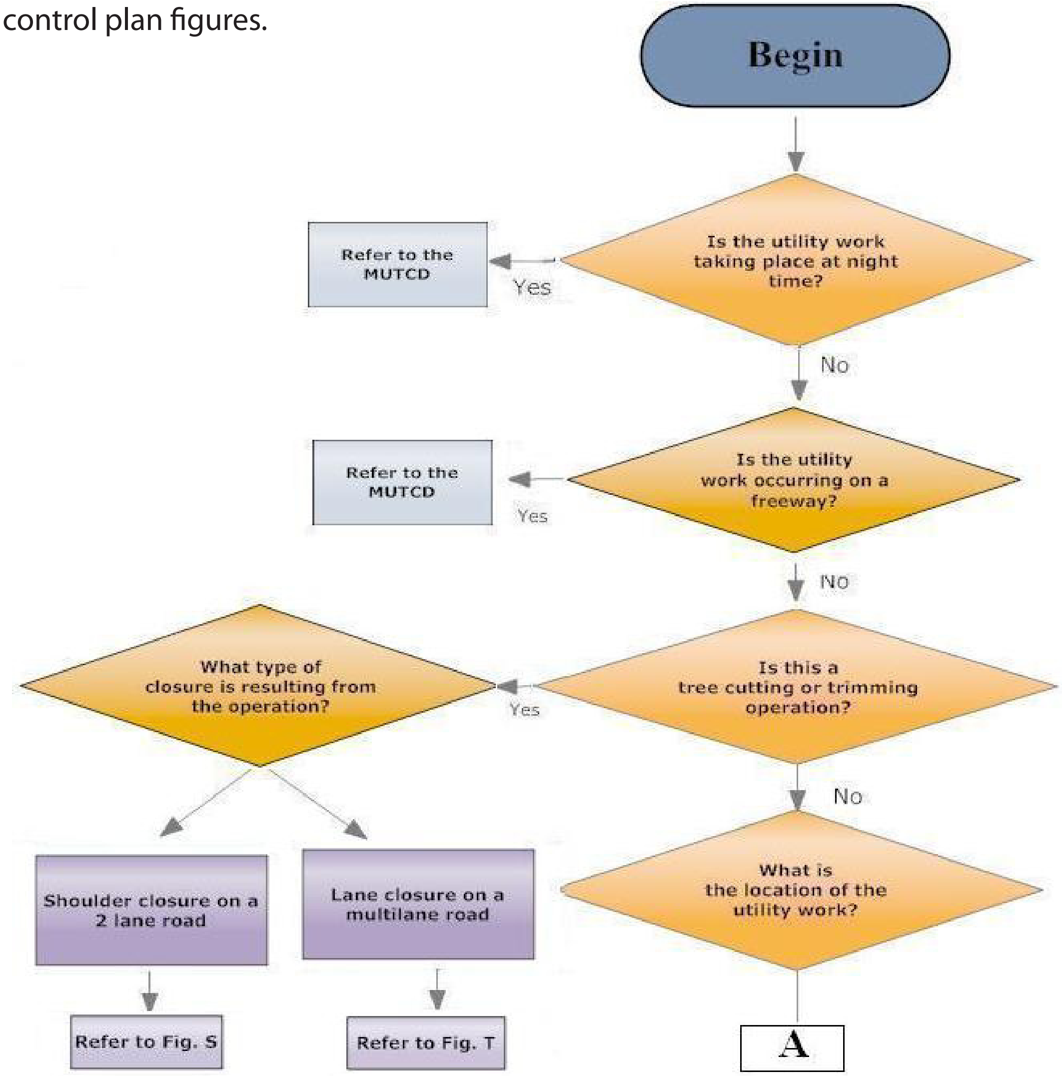


Figure 2. Traffic Control Plan Selection Process

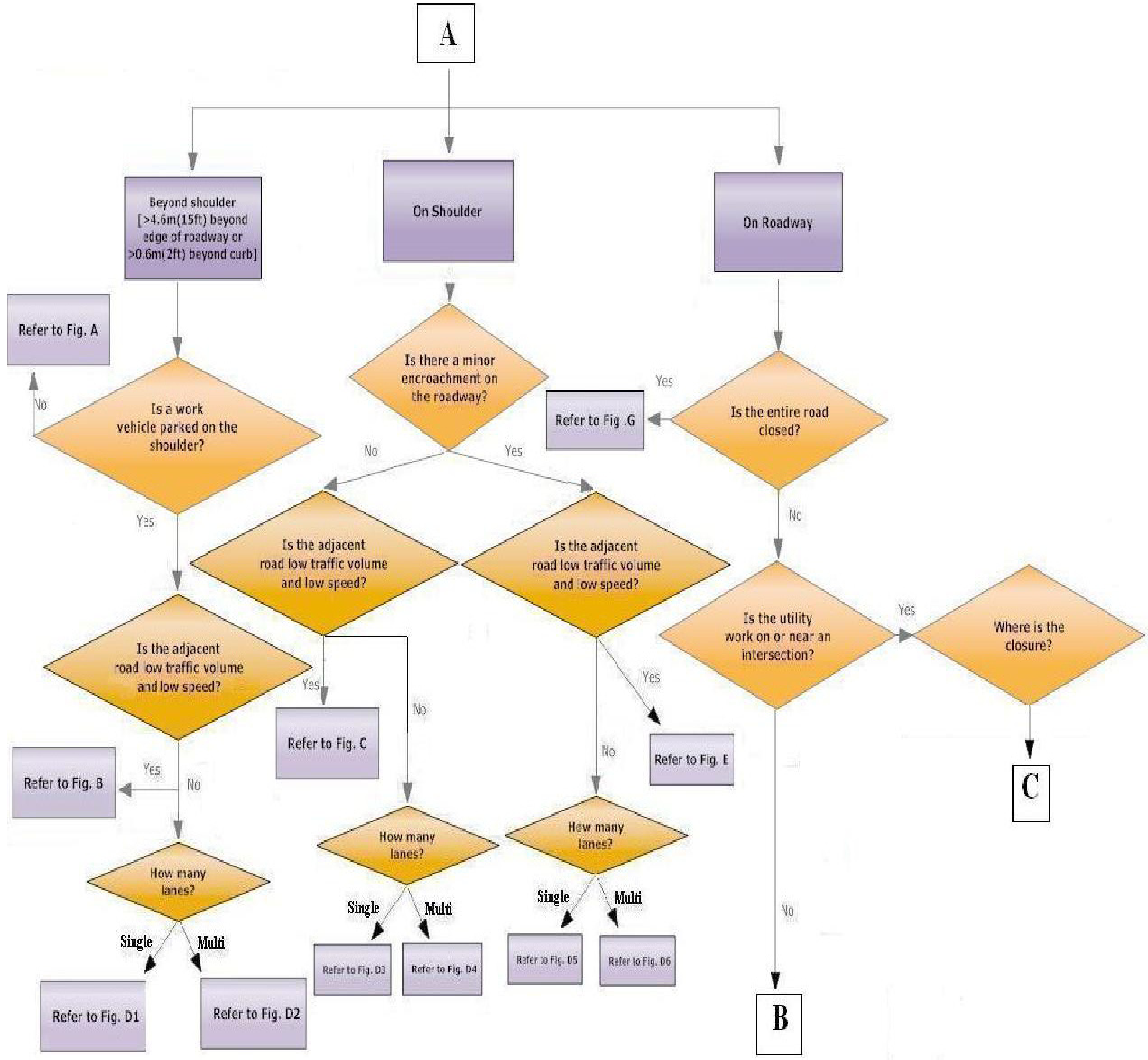


Figure 2. Traffic Control Plan Selection Process (Cont)

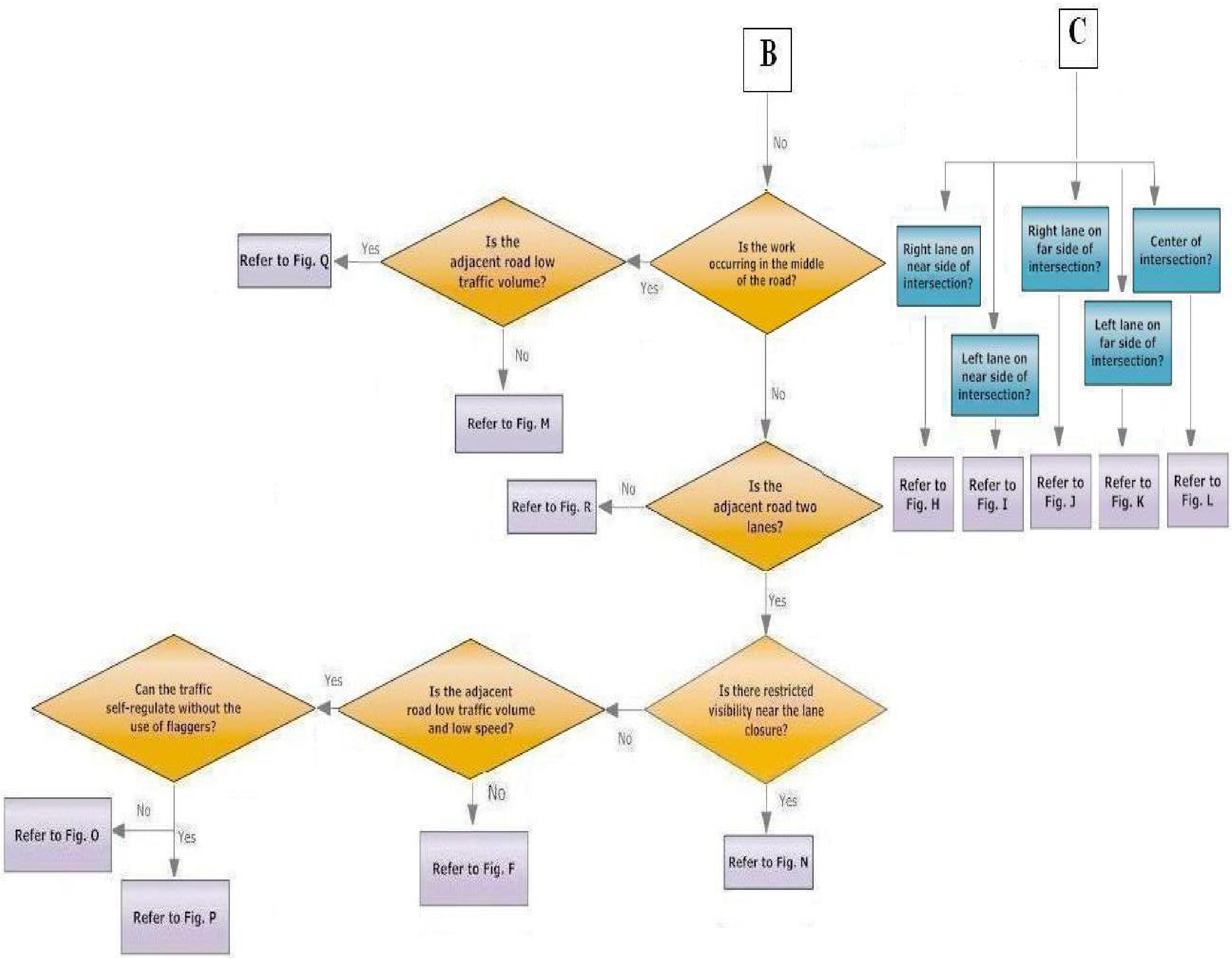


Figure 2. Traffic Control Plan Selection Process (Cont)

7.1 Work Beyond the Shoulder

Work is classified as "beyond the shoulder" if it is being conducted a minimum of 15 ft (4.6 m) past the outer edge of the roadway or 2 ft (0.6 m) beyond a curb where provided. In such cases, Figures A and B present the appropriate setups for utility work conducted while a roadway is in service. In either instance, the work vehicle should be parked such that it creates a buffer between oncoming traffic and the work site. Under all scenarios, the work vehicle should have its warning lights turned on in order to alert motorists of the ongoing activities.

If possible, the vehicle should be parked a minimum of 15 feet from edge of roadway (from figure) or 2 feet beyond the curb as indicated in Figure A. In many instances, this will not be possible and the work vehicle will need to be parked on the shoulder near the work site. Figure D1 and Figure D2 illustrate that a warning sign (e.g., UTILITY WORK AHEAD) should be placed upstream of the vehicle at an appropriate distance as indicated when the adjacent roadway is subject to either high traffic volume or a high (greater than 30 mph) speed limit.

<u>Traffic Control Plan A</u>

Applicable for:

- Utility work 4.6 m (15 ft) BEYOND the edge of the roadway or 0.6 m (2 ft) BEYOND the curb where a curb and gutter are present
- Cases where a work vehicle is NOT parked on the shoulder

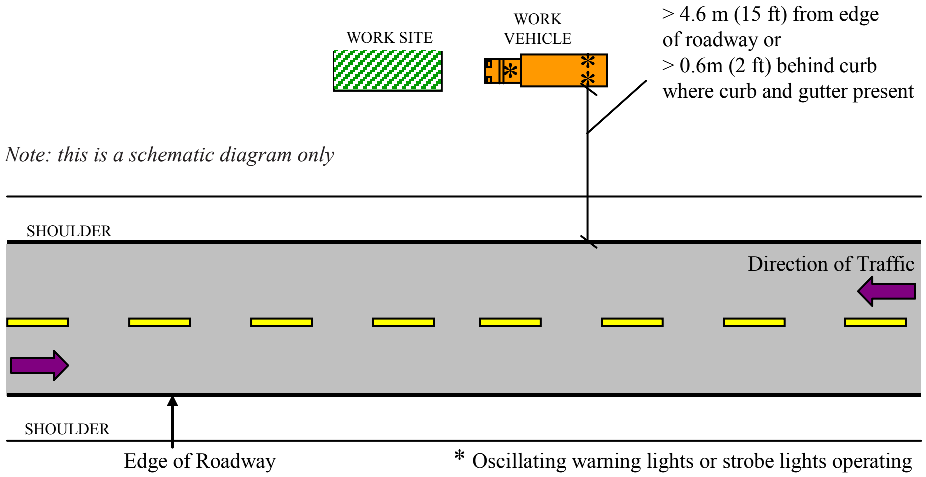


Figure A. Utility Work beyond Shoulder

Traffic Control Plan B

Applicable for:

- Utility work 4.6 m (15 ft) BEYOND the edge of the roadway or 0.6 m (2 ft) BEYOND the curb where a curb and gutter are present
- Cases where a work vehicle is parked on the shoulder
- Cases where the adjacent road is LOW traffic volume and LOW speed.

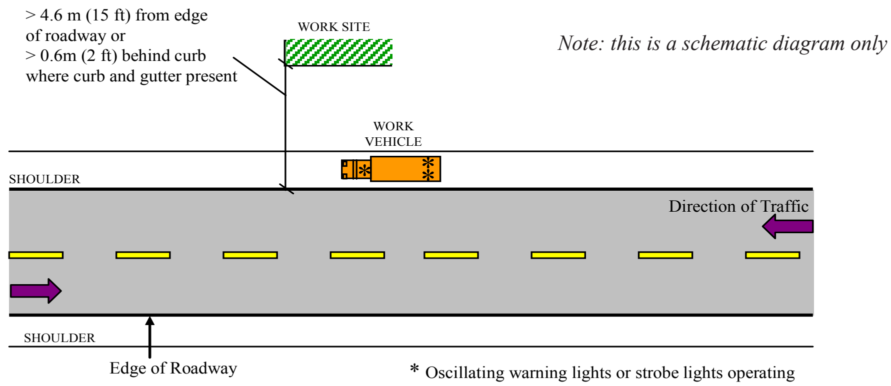
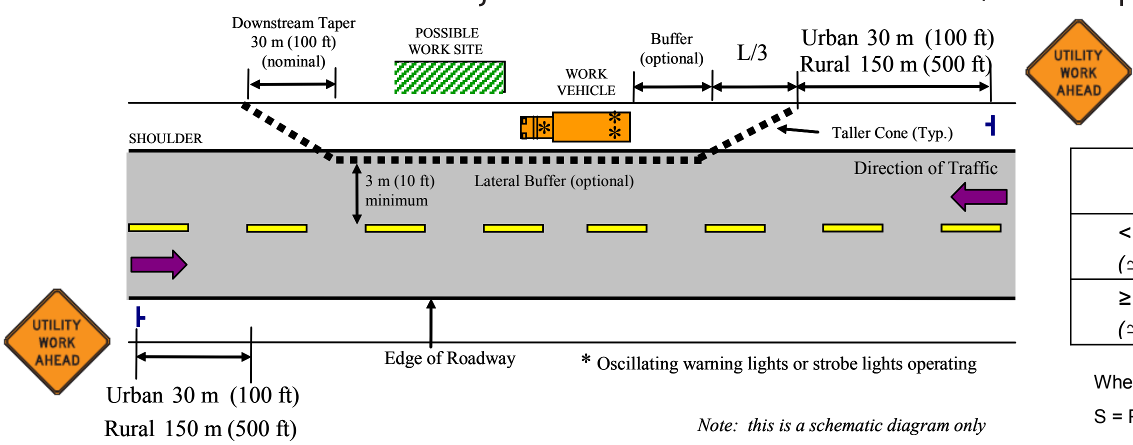


Figure B. Utility Work beyond Shoulder with Work Vehicle(s) Parked on Shoulder

Traffic Control Plan D1

Applicable for:

- Utility work BEYOND the SHOULDER on a TWO-LANE ROAD
- Cases where there is a work vehicle parked on shoulder
- Cases where the adjacent road is HIGH traffic volume and/or HIGH speed



Speed	L (Taper Length)
< 45 mph (≃70 km/h)	W*S² / 60 (W*S² / 155)
≥ 45 mph (≃70 km/h)	W*S (W*S / 1.6)

Where W = Total width of closure,

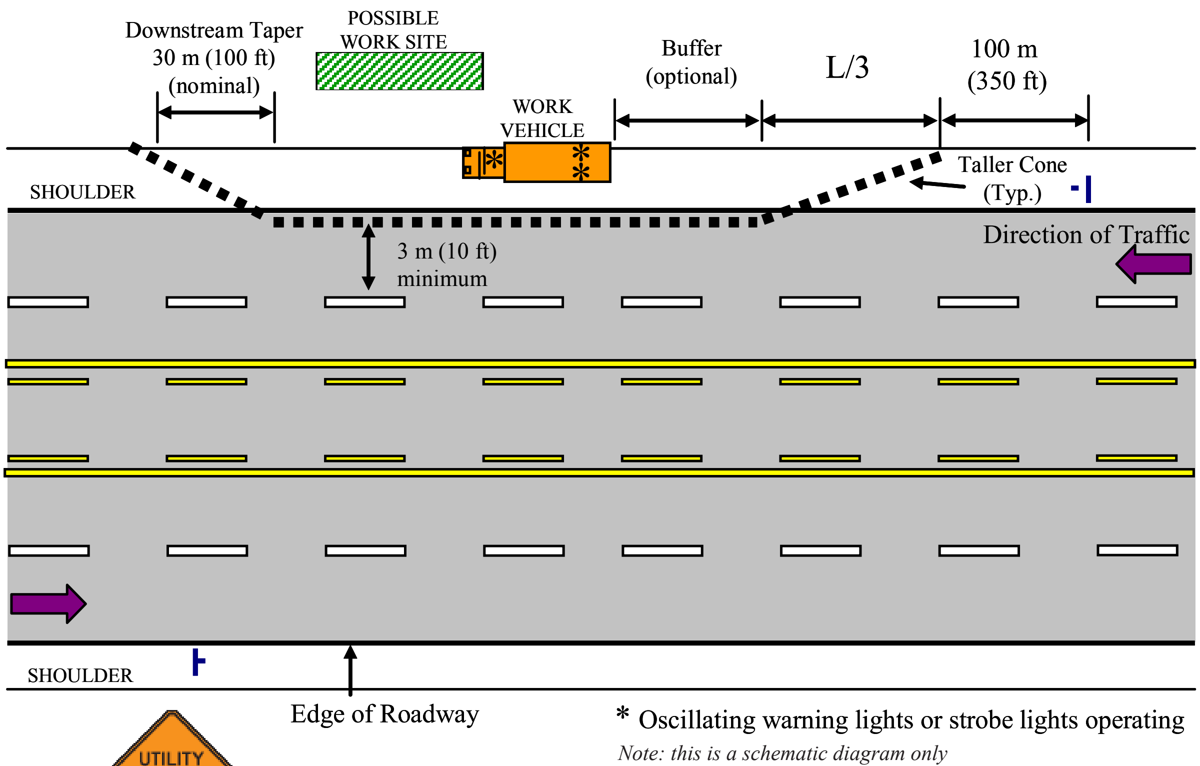
S = Proposed\posted roadway speed limit

Figure D1. Utility Work Beyond Shoulder with Work Vehicle Parked on Shoulder (High Traffic Volume and/or High Speed)

Traffic Control Plan D2

Applicable for:

- Utility Work BEYOND the SHOULDER on a MULTILANE road
- Cases where there is a work-vehicle parked on the shoulder
- Cases where the adjacent road is HIGH traffic volume and/or HIGH speed



Speed	L (Taper Length)
< 45 mph (≃70 km/h)	$W*S^2 / 60$ ($W*S^2 / 155$)
≥ 45 mph (≃70 km/h)	W*S (W*S / 1.6)

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

Figure D2. Utility Work Beyond Shoulder with Work Vehicle(s) Parked on Shoulder (High Traffic Volume and/or High Speed)

7.2 Work on the Shoulder

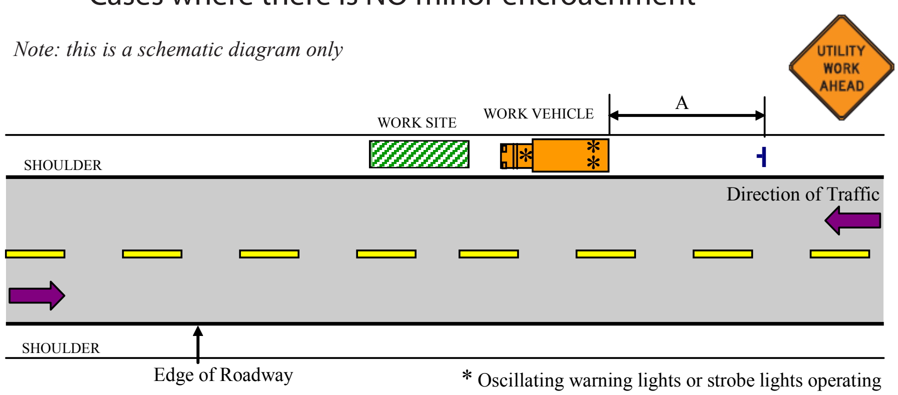
If work is to be conducted on the shoulder, three other factors must be considered: (1) the traffic volume of the adjacent roadway, (2) the speed of the adjacent roadway, and (3) whether minor encroachment of the roadway occurs. If there is no encroachment and the roadway is both low volume and low speed, sufficient protection of the workers can be provided by parking the work vehicle with warning lights turned on upstream of the work site to shield workers from oncoming traffic as shown in Figure C. A UTILITY WORK AHEAD sign should be placed upstream of the work zone on the side of the road where the work is being conducted. If multiple vehicles are needed for the utility work, they may be positioned/placed on the right-of-way or shoulder area, however, they should have rotating or oscillating lights on the first and the last one in the train of vehicles. At locations with either high traffic volume or high travel speed, a taper area should be provided leading up to the vehicle and signage (e.g., UTILITY WORK AHEAD) should be placed in advance of the work zone on each approach as indicated in Figure D3 and figure D4 for two-lane and multi-lane roadways, respectively.

<u>Traffic Control Plan C</u>

Applicable for:

- Utility work ON the SHOULDER on a TWO-LANE road.
- Cases where there is NO minor encroachment

Note: this is a schematic diagram only



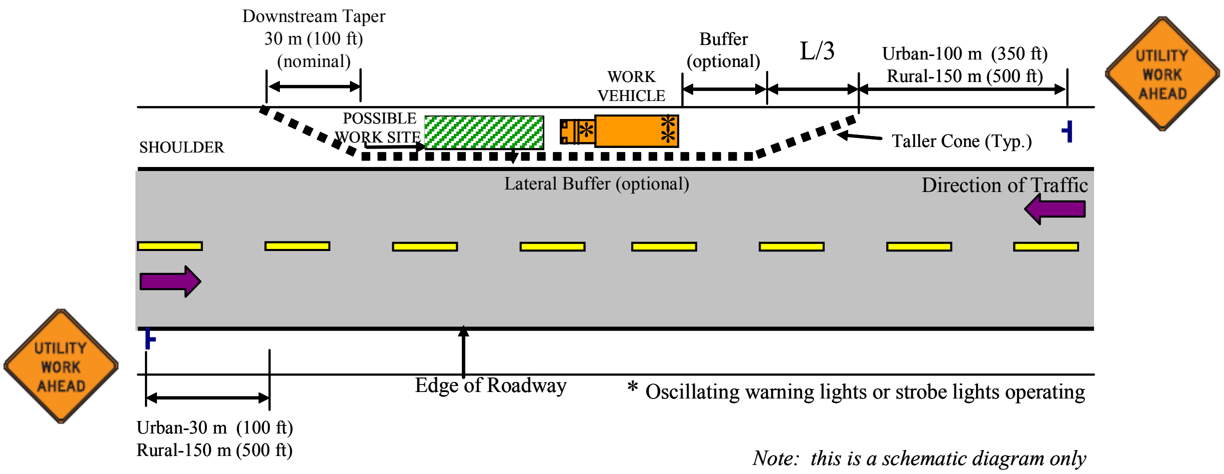
Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Figure C. Utility Work on Shoulder with no Encroachment (Low Traffic Volume and Low

Traffic Control Plan D3

Applicable for:

- Utility work ON the SHOULDER on a TWO-LANE road
- Cases where there is NO minor encroachment
- Cases where the adjacent road is HIGH traffic volume and /or HIGH speed



Speed	L (Taper Length)
< 45 mph *(≃70 km/h)*	W*S² / 60 *(W*S² / 155)*
≥ 45 mph *(≃70 km/h)*	W*S *(W*S / 1.6)*

Where W = Total width of closure,

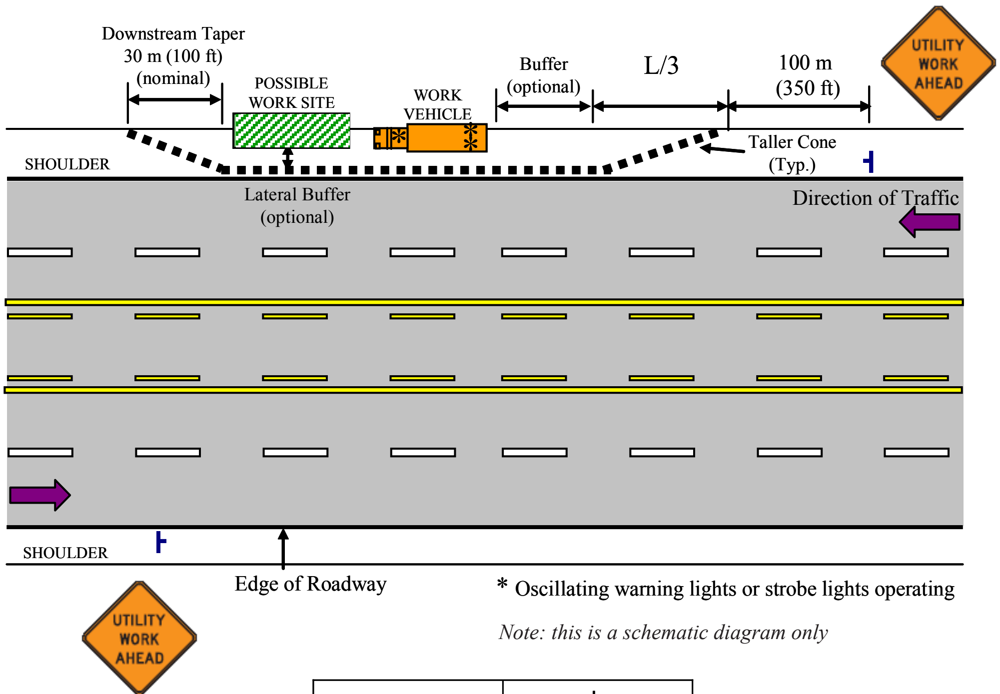
S = Proposed\posted roadway speed limit

Figure D3. Utility Work on Shoulder with no Encroachment (High Traffic Volume and/or High Speed)

Traffic Control Plan D4

Applicable for:

- Utility work ON shoulder on a MULTILANE road
- Cases where there is NO encroachment
- Cases where the adjacent road is HIGH traffic volume and/or HIGH speed



Speed	L (Taper Length)
< 45 mph *(≃70 km/h)*	$W*S^2 / 60$ *($W*S^2 / 155$)*
≥ 45 mph *(≃70 km/h)*	W*S *(W*S / 1.6)*

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

Figure D4. Utility Work On Shoulder with no Encroachment (High Traffic Volume and/or High Speed)

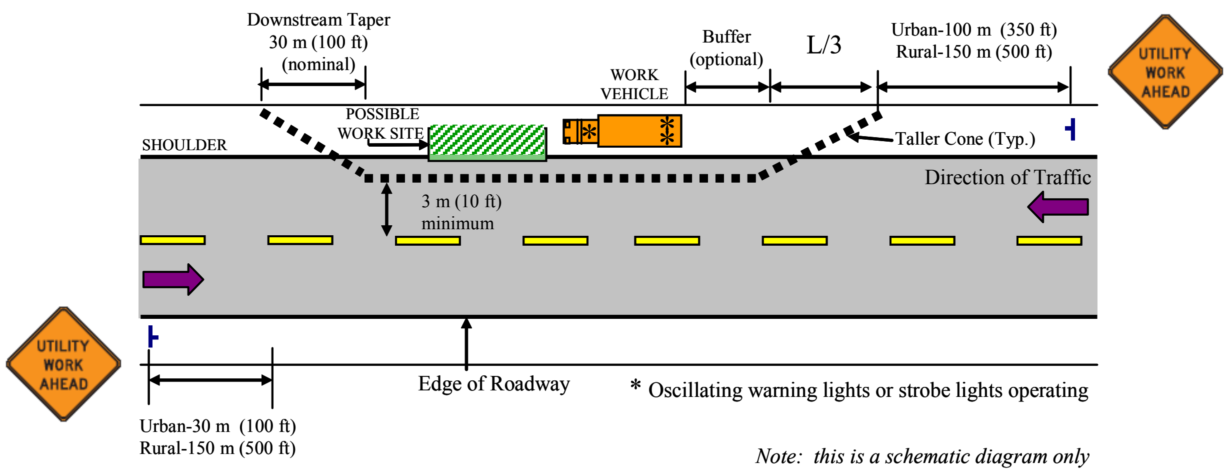
If the work being conducted causes minor encroachment onto the outermost lane, Figures D5, D6, and E are appropriate for high speed/volume two-lane roads, high speed/

volume multilane roads, and low speed/volume two-lane roads respectively. Each of these plans includes a UTILITY WORK AHEAD sign on each upstream approach, in addition to channelizing devices to provide additional worker protection. Figures D5, D6, and E are ony appropriate if at least 10 ft of roadway is available on each lane. If less than 10 ft is available, the entire lane must be closed.

Traffic Control Plan D5

Applicable for:

- Utility work ON the SHOULDER on a TWO-LANE road
- Cases where there IS minor encroachment
- Cases where the adjacent road is HIGH traffic volume and/or HIGH speed



Speed	L (Taper Length)
< 45 mph (≈70 km/h)	W*S² / 60 (W*S² / 155)
≥ 45 mph (≈70 km/h)	W*S (W*S / 1.6)

Where W = Total width of closure,

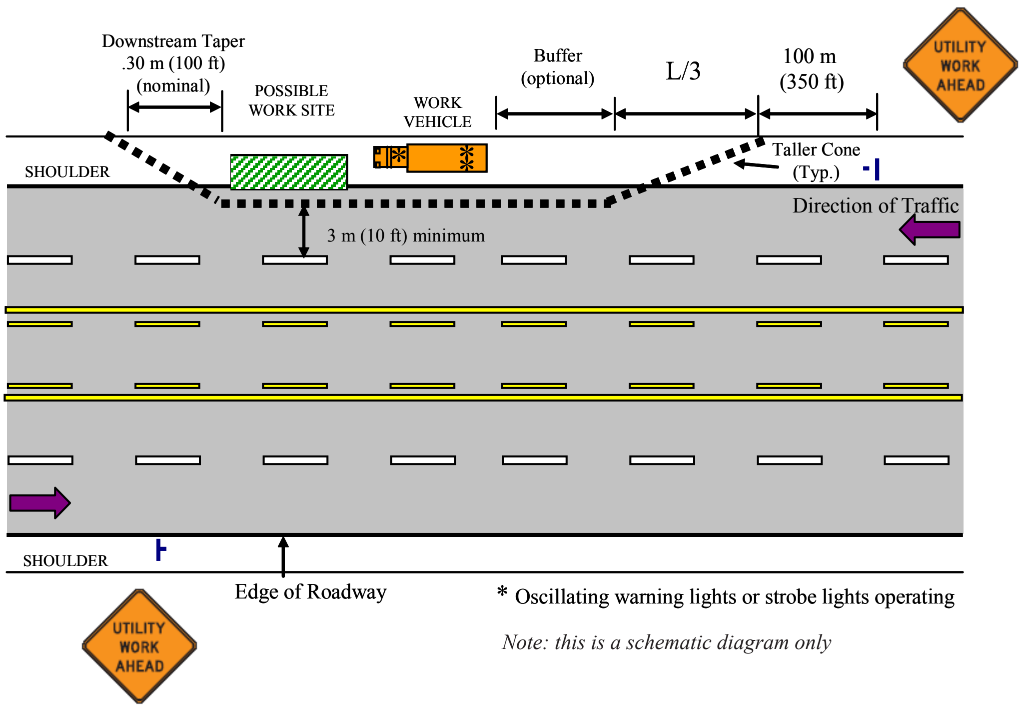
S = Proposed\posted roadway speed limit

Figure D5. Utility Work on Shoulder with Minor Encroachment (High Traffic Volume and/or High Speed)

Traffic Control Plan D6

Applicable for:

- Utility work ON the SHOULDER on a MULTILANE road
- Cases where there IS minor encroachment
- Cases where the adjacent road is HIGH traffic volume and/or HIGH speed



Speed	L (Taper Length)
< 45 mph (≃70 km/h)	W*S² / 60 (W*S² / 155)
≥ 45 mph (≃70 km/h)	W*S (W*S / 1.6)

Where W = Total width of closure,

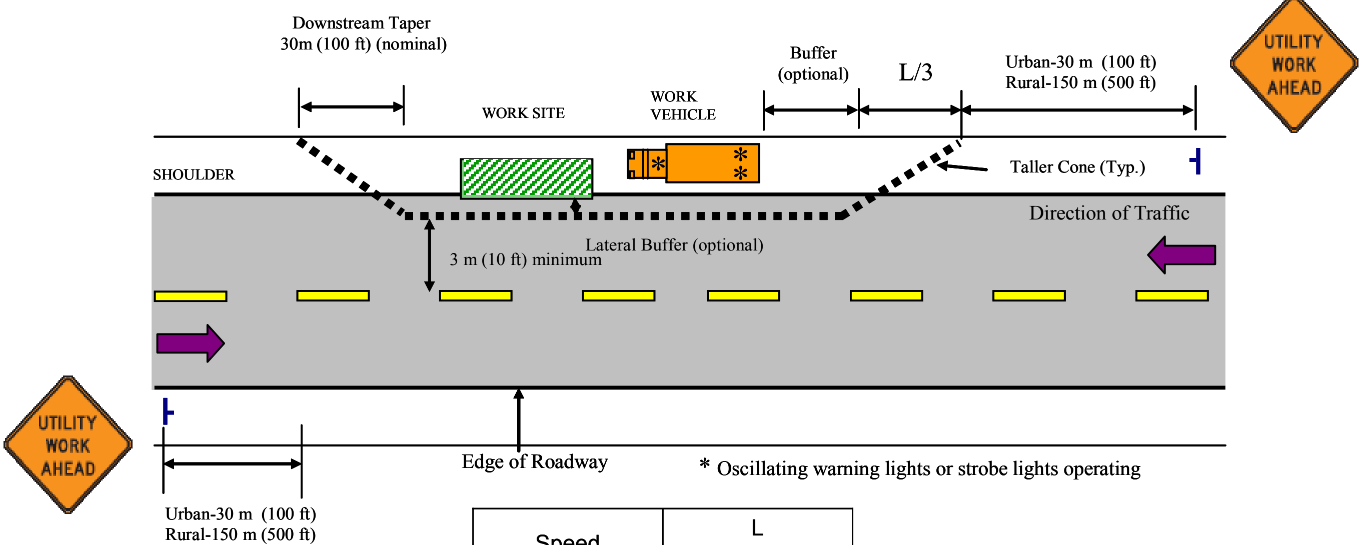
S = Proposed\posted roadway speed limit

Figure D6. Utility Work on Shoulder with Minor Encroachment (High Traffic Volume and/or High Speed)

Traffic Control Plan E

Applicable for:

- Utility work ON the SHOULDER on a TWO-LANE road
- Cases where there IS minor encroachment
- Cases where the adjacent road is LOW traffic volume and LOW speed



Note: this is a schematic diagram only

Speed	L (Taper Length)
< 45 mph *(≃70 km/h)*	$W*S^2 / 60$ *($W*S^2 / 155$)*
≥ 45 mph *(≃70 km/h)*	W*S *(W*S / 1.6)*

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

Figure E. Utility Work on Shoulder with Minor Encroachment (Low Traffic Volume and Low Speed)

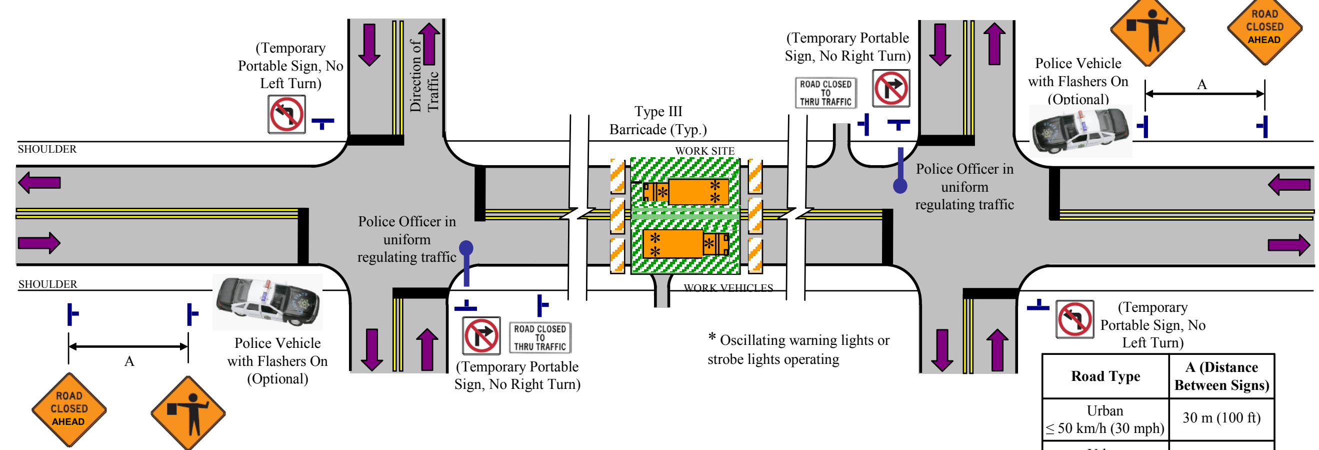
7.3 Work on the Roadway

In some cases, a temporary road closure may be required in order to perform particular types of work including during emergency situations. In cases where such work requires road closures of more than one hour, police vehicles should be stationed on both sides of the work site and uniformed officers should be present to direct traffic under such situations. If intersections are nearby along the road where the work is being performed, the police vehicles should be parked at these intersections where they can direct traffic away from the work area as shown in Figure G. For long duration utility work during the daylight hours, traffic control signs as shown in Figure G should be used on both sides of the road closure.

Traffic Control Plan G

Applicable for:

- Utility work ON the ROADWAY
- Cases where the ENTIRE ROAD is temporarily CLOSED



Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Note: this is a schematic diagram only

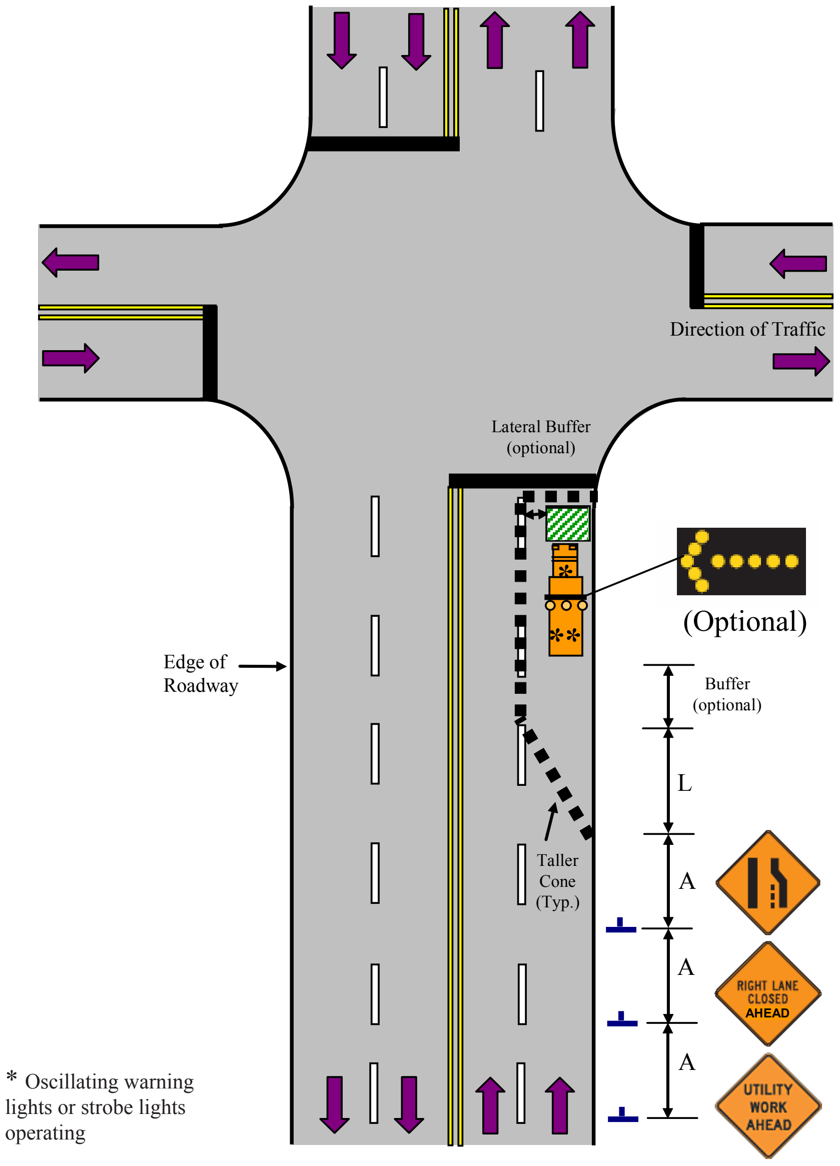
Figure G. Temporary Road Closure

When utility work is conducted at or near an intersection, five specific scenarios are commonly encountered. At work sites where utility work is conducted on the near side of the intersection, the traffic control plans illustrated in Figures H and I should be followed. Figures J and K detail the cases where the closure occurs on the far side of the intersection (downstream approach). In all cases, the work vehicles should be placed upstream of the work site with the warning lights turned on. Delineating devices should be placed along the work site and an advance taper should be created as indicated in the figures. In addition, a series of advance warning signs should be provided along each of the affected approaches (UTILITY WORK AHEAD, followed by RIGHT/LEFT LANE CLOSED AHEAD, followed by a lane ends symbol sign).

Traffic Control Plan H

Applicable for:

- Utility work ON the ROADWAY
- Cases where the work is NEAR an INTERSECTION
- Cases where there is a LANE CLOSURE
- When the lane closure is in the RIGHT LANE on the NEAR SIDE of the intersection



Note: this is a schematic diagram only

Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Speed	L (Taper Length)
< 45 mph (≃70 km/h)	$W*S^2 / 60$ ($W*S^2 / 155$)
≥ 45 mph (≃70 km/h)	W*S (W*S / 1.6)

Where W = Total width of closure,

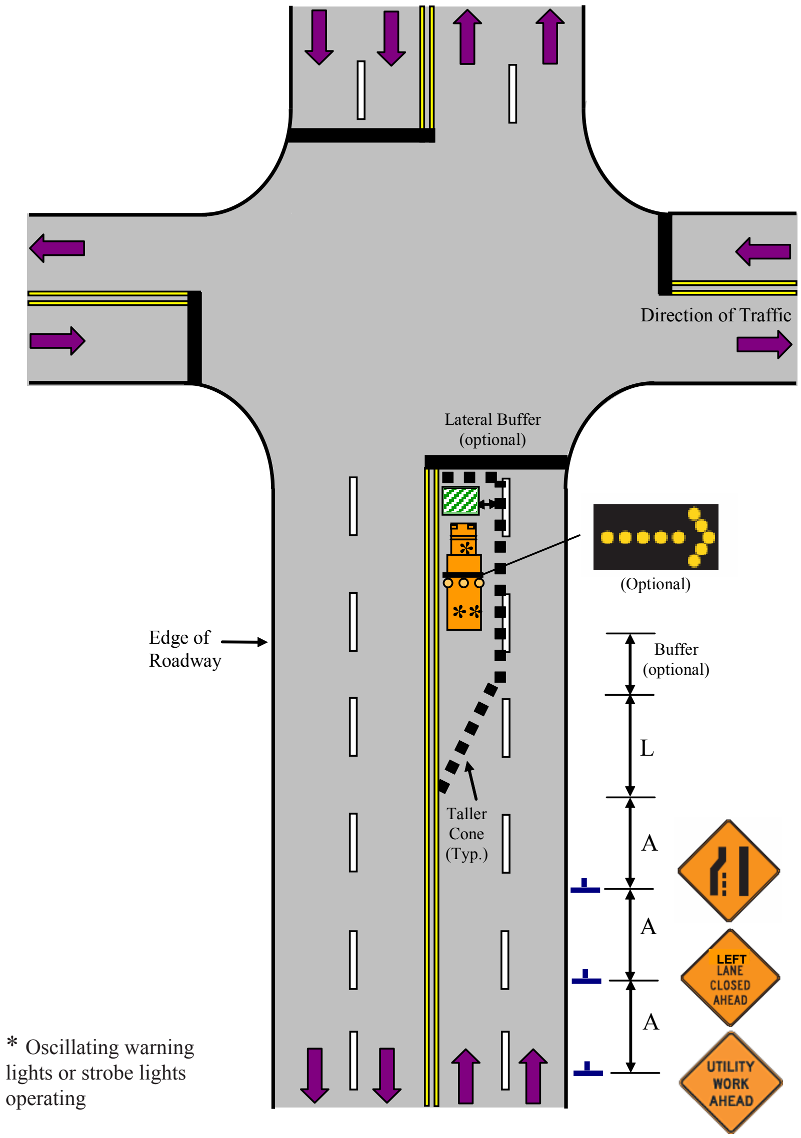
S = Proposed\posted roadway speed limit

Figure H. Right Lane Closure on Near Side of Intersection

Traffic Control Plan I

Applicable for:

- Utility work ON the ROADWAY
- Cases where the work is NEAR an INTERSECTION
- Cases where there is a LANE CLOSURE
- When the lane closure is in the LEFT LANE on the NEAR SIDE of the intersection



Note: this is a schematic diagram only

Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Speed	L (Taper Length)
< 45 mph *(≃70 km/h)*	$W*S^2 / 60$ *($W*S^2 / 155$)*
≥ 45 mph *(≃70 km/h)*	$W*S$ *($W*S / 1.6$)*

Where W = Total width of closure,

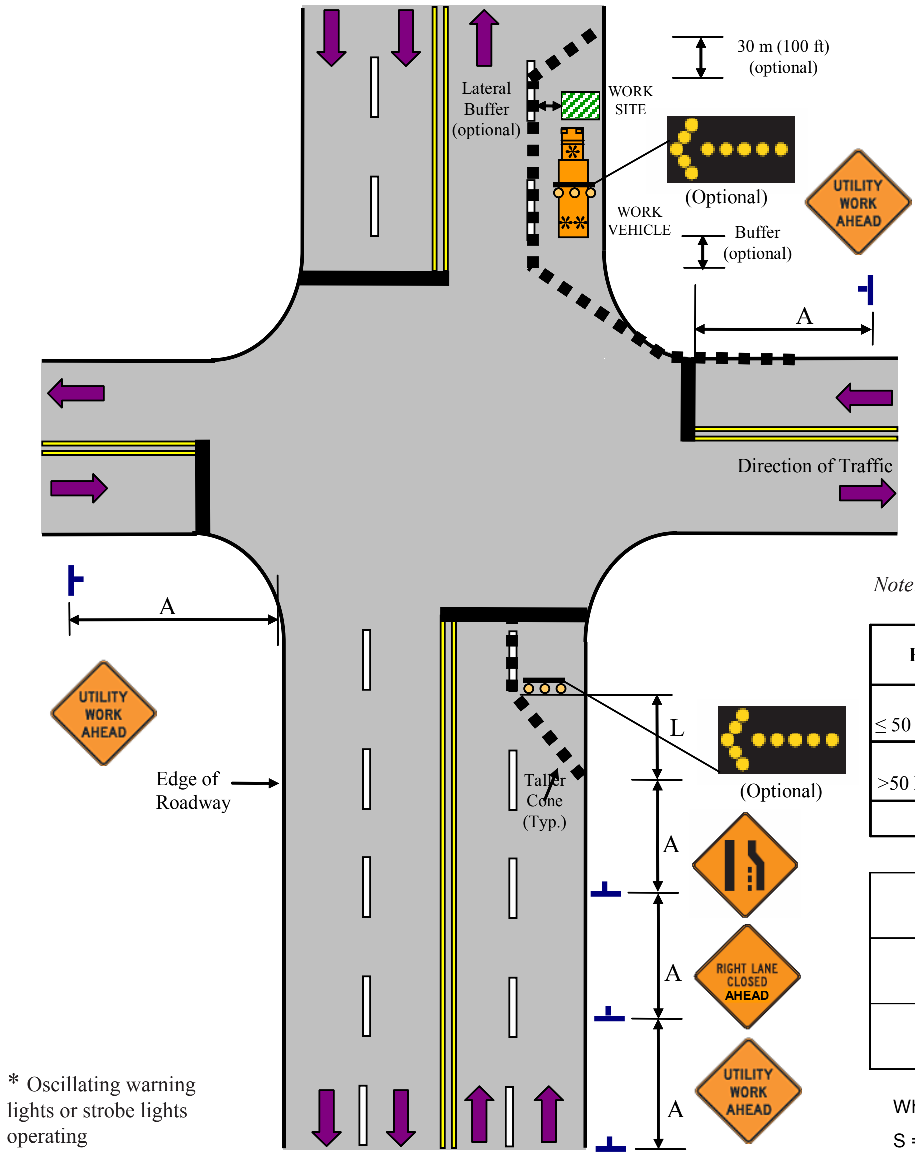
S = Proposed\posted roadway speed limit

Figure I. Left Lane Closure on Near Side of Intersection

Traffic Control Plan J

Applicable for:

- Utility work ON the ROADWAY
- Cases where the work is NEAR an INTERSECTION
- Cases where there is a LANE CLOSURE
- When the lane closure is in the RIGHT LANE on the FAR SIDE of the intersection



Note: this is a schematic diagram only

Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Speed	L (Taper Length)
< 45 mph (≃70 km/h)	$W*S^2 / 60$ ($W*S^2 / 155$)
≥ 45 mph (≃70 km/h)	W*S (W*S / 1.6)

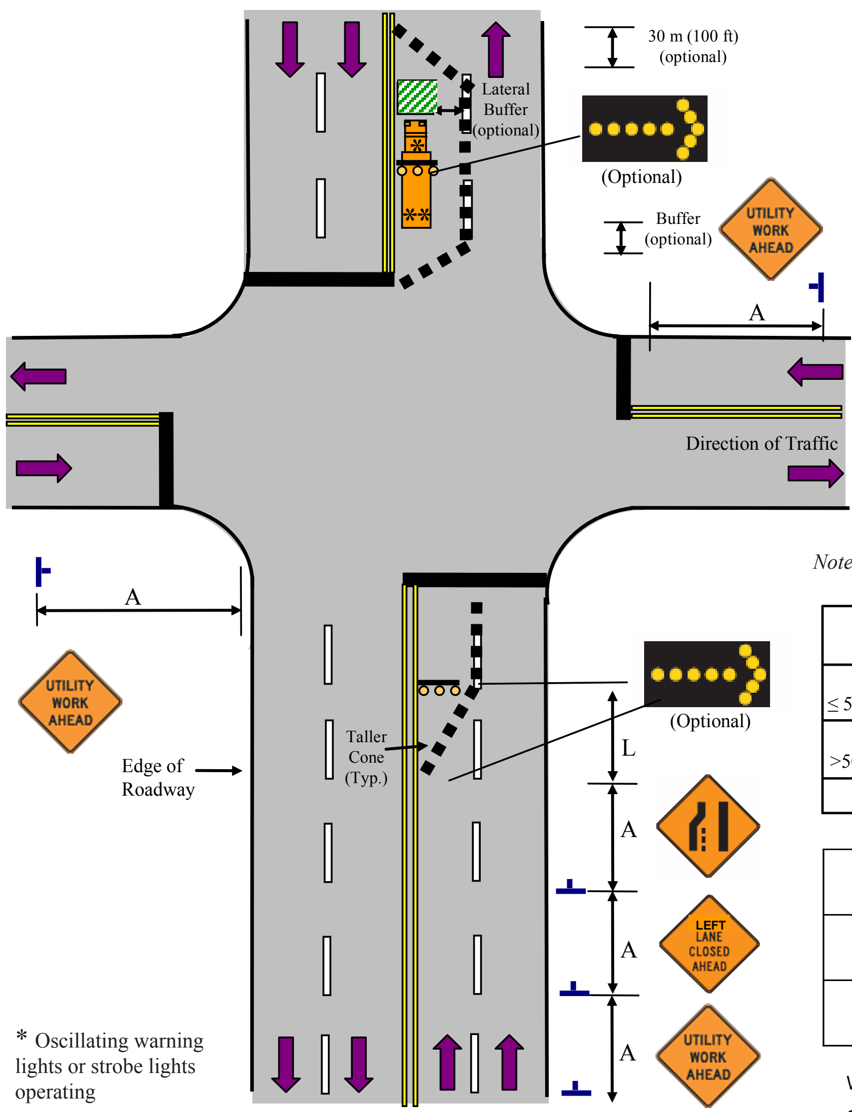
Where W = Total width of closure,
S = Proposed\posted roadway speed limit

Figure J. Right Lane Closure on Far Side of Intersection

Traffic Control Plan K

Applicable for:

- Utility work ON the ROADWAY
- Cases where the work is NEAR an INTERSECTION
- Cases where there is a LANE CLOSURE
- When the lane closure is in the LEFT LANE on the FAR SIDE of the intersection



Note: this is a schematic diagram only

Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Speed	L (Taper Length)
< 45 mph *(≃70 km/h)*	$W*S^2 / 60$ *($W*S^2 / 155$)*
≥ 45 mph *(≃70 km/h)*	W*S *(W*S / 1.6)*

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

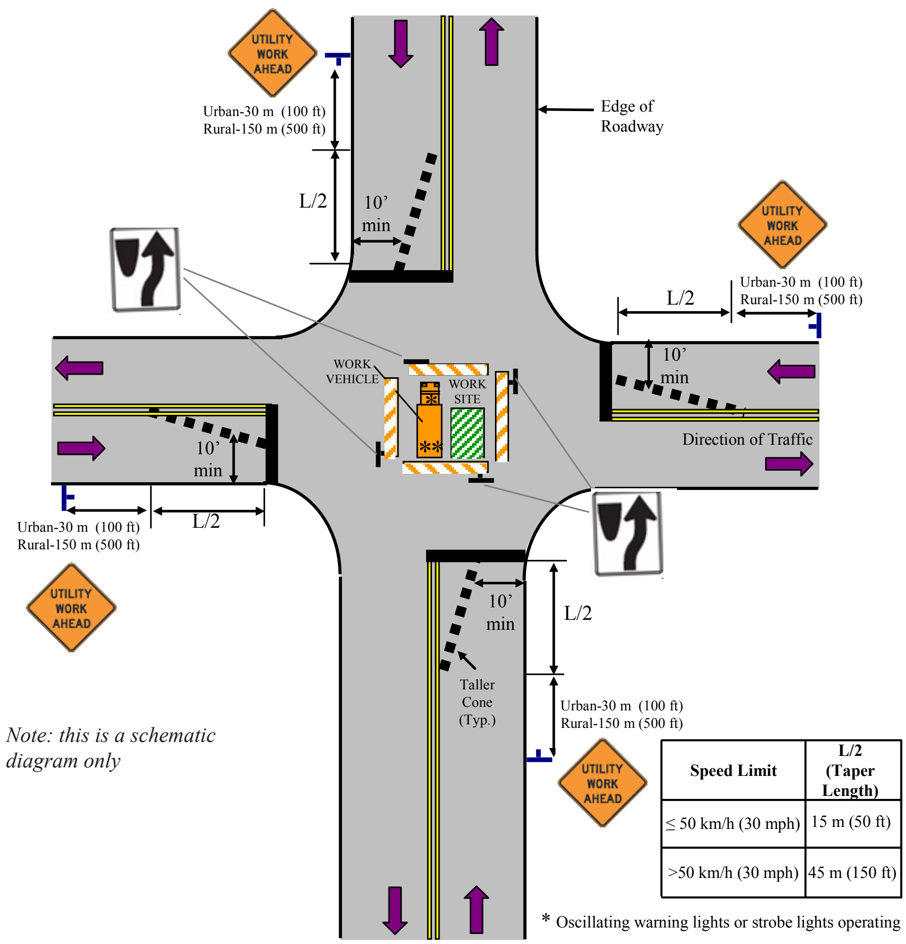
Figure K. Left Lane Closure on Far Side of Intersection

If the center of the intersection must be closed, the setup outlined in Figure L should be followed whereby the work vehicle and work site are surrounded by barriers in each direction along with a MOVEMENT REGULATION sign. In the area leading up to the intersection along each approach, a taper should be provided to divert traffic away from the center of the intersection while maintaining a minimum lane width of 10 feet. In addition, signage should be provided in advance of the taper.

Traffic Control Plan L

Applicable for:

- Utility work ON the ROADWAY
- Cases where the work is AT an INTERSECTION
- Cases where there is a LANE CLOSURE
- Where the lane closure is in the CENTER of the intersection



Speed Limit	L/2 (Taper Length)
≤ 50 km/h (30 mph)	15 m (50 ft)
>50 km/h (30 mph)	45 m (150 ft)

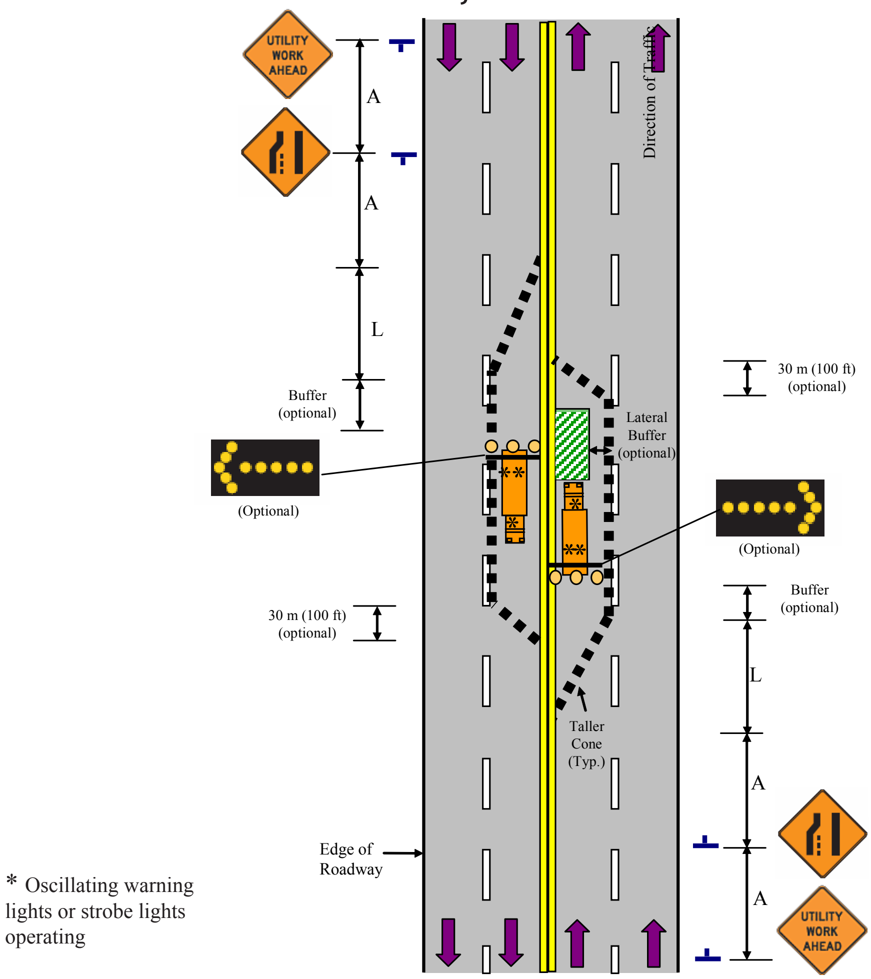
Figure L. Closure in Center of Intersection

If the center lane must be closed in either direction of a multi-lane road, the traffic control plan outlined in Figure M is appropriate. The work vehicle with warning lights turned on should be parked adjacent to the work site and barriers should be placed upstream of both the work vehicle and the work site. An optional arrow board is also recommended. Prior to the barrier, a taper should be provided and delineating devices should run the length of the work site, extending past the downstream edge of the work zone in either direction.

<u>Traffic Control Plan M</u>

Applicable for:

- Utility work ON the ROADWAY
- Cases where the work is in the MIDDLE OF THE ROAD
- Cases where the adjacent road is HIGH traffic volume



Note: this is a schematic diagram only

Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Speed	L (Taper Length)
< 45 mph (≃70 km/h)	$W*S^2 / 60$ ($W*S^2 / 155$)
≥ 45 mph (≃70 km/h)	W*S (W*S / 1.6)

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

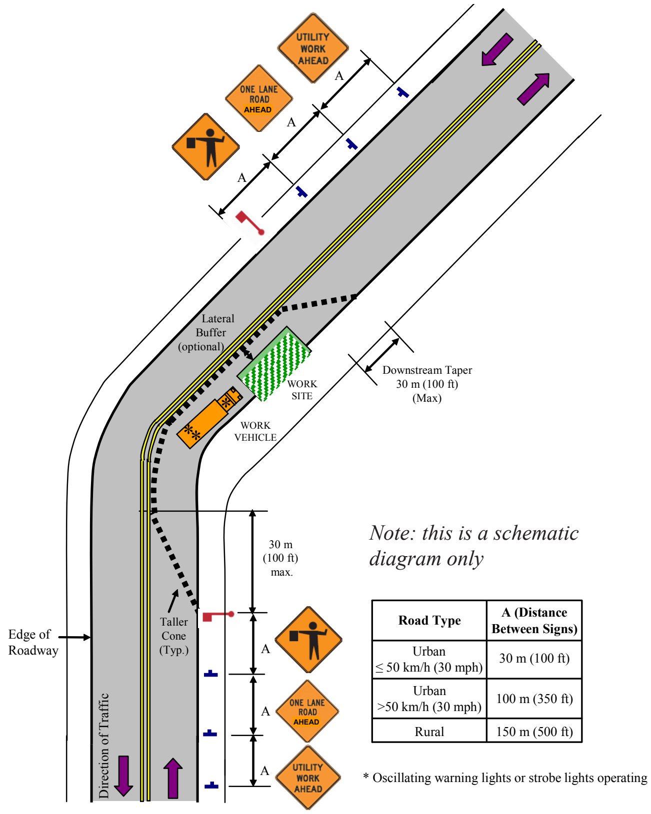
Figure M. Center Lane Closure on Multi-lane Road

In cases where lane closures are necessary on two-lane roads, the work vehicle should be parked upstream of the work site and delineating devices should run along the worksite and form a taper both upstream and downstream of the work area. If flaggers (traffic regulators) are utilized, they should be placed at the start of the taper in each direction and a series of advanced warning signs should be utilized as shown in Figure N when there is restricted visibility. When there is unrestricted visibility, only one flagger (traffic regulator) may be used as shown in Figure O. If the traffic can be self-regulating, flaggers (traffic regulators) are not needed as shown in Figure P.

Traffic Control Plan N

Applicable for:

- Utility work ON the ROADWAY
- The roadway is TWO LANES
- Cases where there ia a LANE CLOSURE
- Cases where there is RESTRICTED VISIBILITY near the closure
- Cases where FLAGGERS (TRAFFIC REGULATORS) are USED



Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Figure N. Lane Closure on Two-Lane Road (Restricted Visibility)

Traffic Control Plan O

Applicable for:

- Utility work ON the ROADWAY on a two lane road
- Cases where there is a LANE CLOSURE
- Cases where the adjacent road is LOW speed and LOW traffic volume
- Cases where a FLAGGER (TRAFFIC REGULATOR) is USED

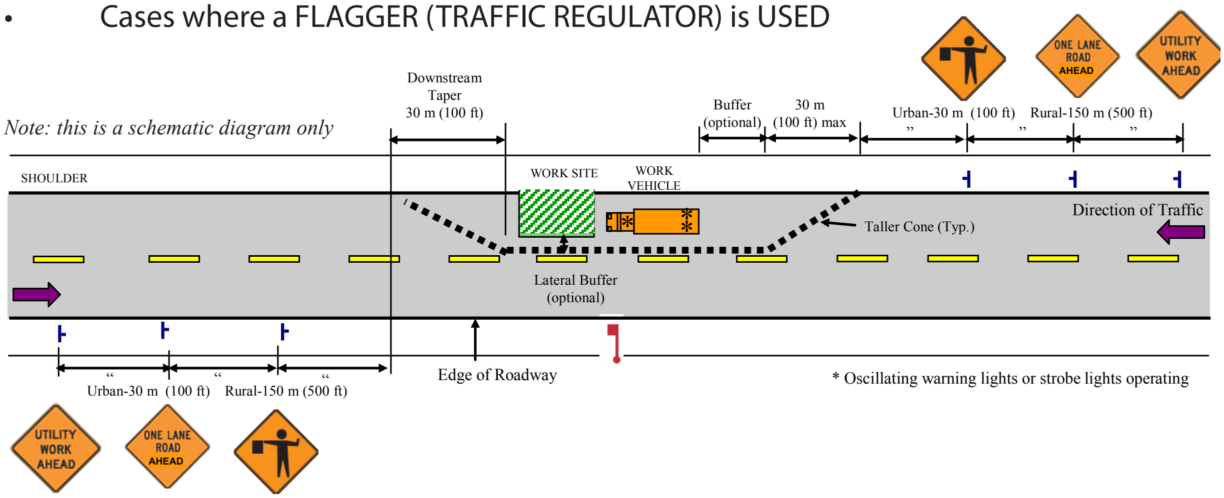


Figure O. Lane Closure on Two-Lane Road with Unrestricted Visibility
(Low Traffic Volume and/or Low Speed Where Traffic Cannot Self-Regulate without the Use of Flaggers)

Traffic Control Plan P

Applicable for:

- Utility work ON the ROADWAY on a two lane road
- Cases where there is a LANE CLOSURE
- Cases where the adjacent road is LOW speed and LOW traffic volume
- Cases where a FLAGGER (TRAFFIC REGULATOR) is NOT USED

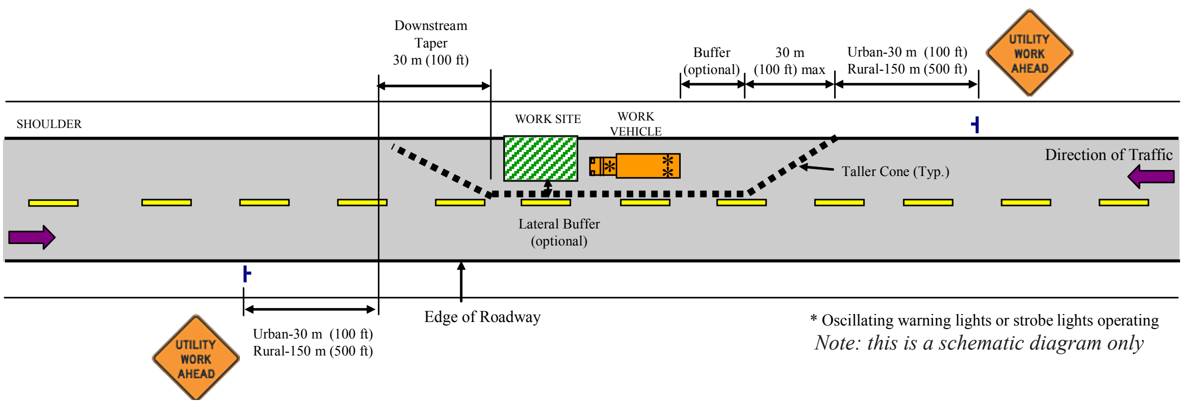


Figure P. Lane Closure on Two-Lane Road with Unrestricted Visibility
(Low Traffic Volume and/or Low Speed Where Traffic Can Self-Regulate without the Use of Flaggers)

In cases where shoulder work will require lane closures, both an upstream and downstream taper should be provided as shown in Figure F. In addition, flaggers (traffic regulators) should be present at the start of the taper and a series of three warning signs (UTILITY WORK AHEAD, followed by ONE LANE ROAD AHEAD, followed by a flagger symbol sign) should be provided with adequate spacing.

<u>Traffic Control Plan F</u>

Applicable for:

- Utility work ON the ROADWAY on a TWO-LANE road
- Cases where there is a LANE CLOSURE
- Cases where the adjacent road is HIGH traffic volume and/or HIGH speed

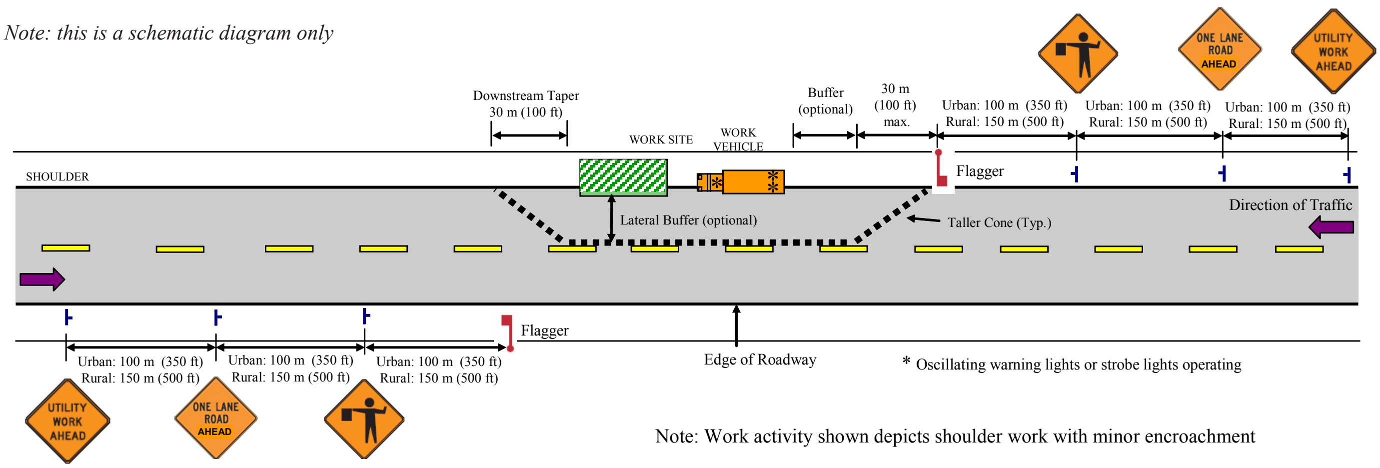


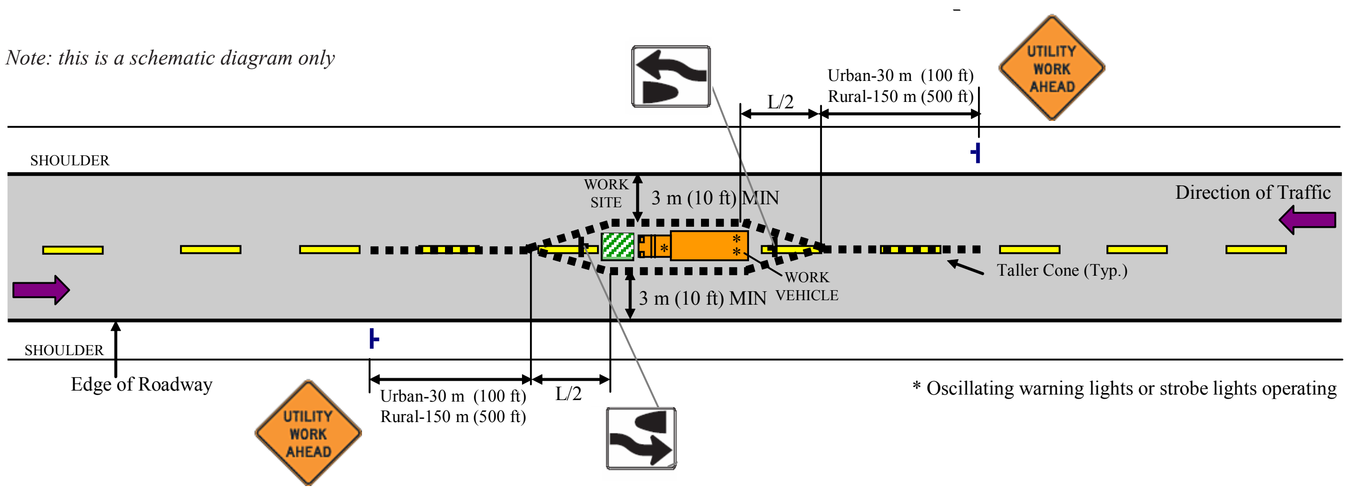
Figure F. Utility Work on Shoulder with Minor Encroachment (High Traffic Volume and/or High Speed)

If utility work is required in the middle of the road, the work setup detailed in Figure Q may be utilized provided that traffic volumes are low. Delineating devices should be placed around the vehicle such that the travel way is reduced to a minimum of 10 feet in each direction. A work vehicle should be parked on either side of the work site and appropriate signage should be provided on the opposite side of the site. In addition, tapers and advanced signage should be utilized as indicated.

Traffic Control Plan Q

Applicable for:

- Utility work ON the ROADWAY
- Cases where the work is in the MIDDLE OF THE ROAD
- Cases where the adjacent road is LOW traffic volume



Speed	L (Taper Length)
< 45 mph *(≃70 km/h)*	W*S² / 60 *(W*S² / 155)*
≥ 45 mph *(≃70 km/h)*	W*S *(W*S / 1.6)*

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

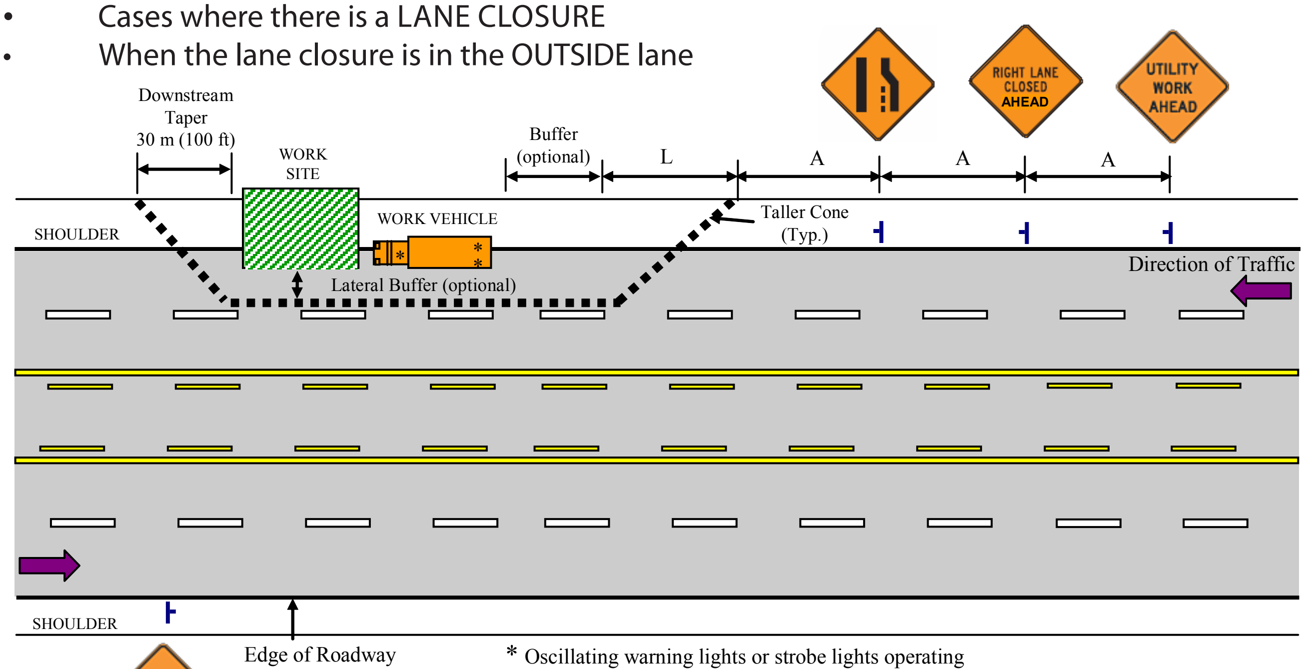
Figure Q. Utility Work in Center of Road (Low Traffic Volumes)

In the instance of the outside lane closed on a multi-lane road, the signage as shown in Figure R should be used. The work vehicle with warning lights turned on should be parked upstream of the work site and an upstream and downstream taper should be used.

<u>Traffic Control Plan R</u>

Applicable for:

- Utility work ON the ROADWAY
- The roadway is MULTI-LANE
- Cases where there is a LANE CLOSURE
- When the lane closure is in the OUTSIDE lane



Road Type	A (Distance Between Signs)
Urban ≤ 50 km/h (30 mph)	30 m (100 ft)
Urban >50 km/h (30 mph)	100 m (350 ft)
Rural	150 m (500 ft)

Speed	L (Taper Length)
< 45 mph (≈70 km/h)	W*S² / 60 (W*S² / 155)
≥ 45 mph (≈70 km/h)	W*S (W*S / 1.6)

Note: this is a schematic diagram only

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

Figure R. Outside Lane Closure on Multi-lane Road

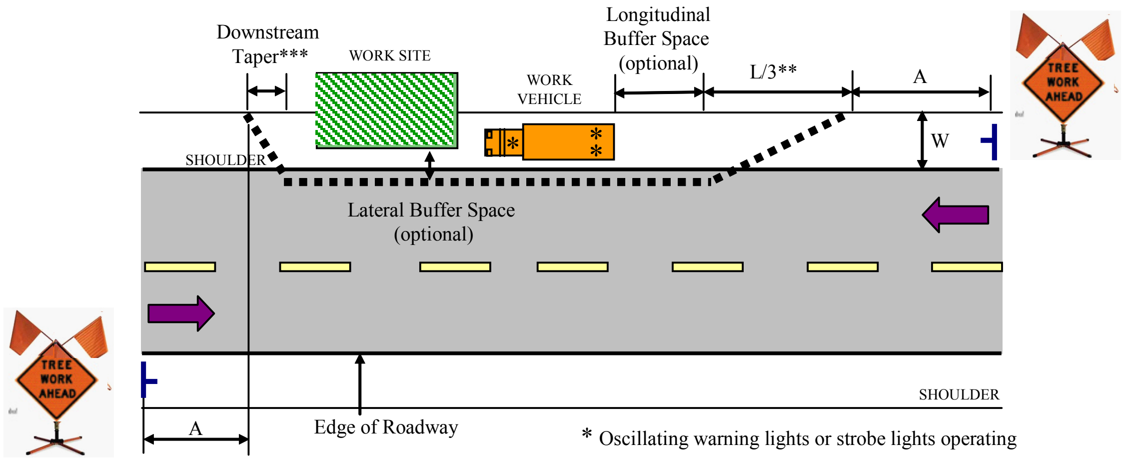
For tree cutting and/or trimming work, separate traffic control plans should be used. If the work results in a shoulder closure on a two-lane road, the traffic control plan should follow Figure S. Figure T should be used when there is a lane closure on a multi-lane road.

Traffic Control Plan S

Applicable for:

- Tree cutting/trimming work
- The roadway is TWO LANES
- When there is a SHOULDER CLOSURE

Note: this is a schematic diagram only



DISTANCE BETWEEN SIGNS

ROAD TYPE	DISTANCE 'A' BETWEEN SIGNS IN FEET
Urban (Low Speed)	100
Urban (High Speed)	350
Rural	500

Speed	L (Taper Length)
< 45 mph *(≃70 km/h)*	W*S² / 60 *(W*S² / 155)*
≥ 45 mph *(≃70 km/h)*	W*S *(W*S / 1.6)*

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

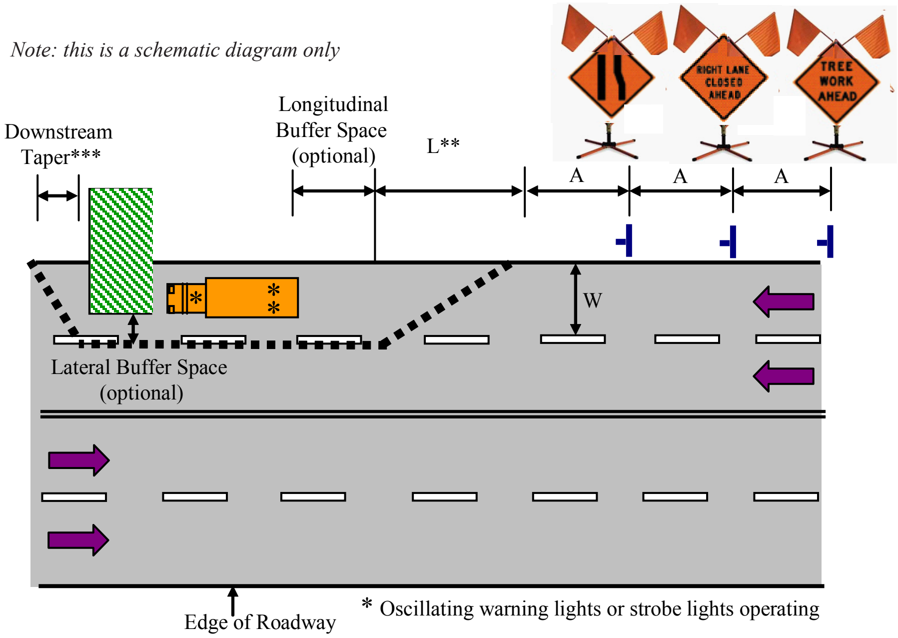
** Taper length is L / 3 when there is a shoulder taper.
Taper length is L / 2 when there is a shifting taper.
Taper length is L when there is a merging taper.
***Optional downstream taper length is 100 feet per lane

Figure S. Tree Cutting/Trimming Shoulder Closure on a Two-Lane Road

Traffic Control Plan T

Applicable for:

- Tree cutting/trimming work
- The roadway is MULTI-LANE
- Cases where there is a LANE CLOSURE
- When the lane closure is in the OUTSIDE lane



DISTANCE BETWEEN SIGNS

ROAD TYPE	DISTANCE 'A' BETWEEN SIGNS IN FEET
Urban (Low Speed)	100
Urban (High Speed)	350
Rural	500

Speed	L (Taper Length)
< 45 mph *(≃70 km/h)*	$W*S^2 / 60$ *($W*S^2 / 155$)*
≥ 45 mph *(≃70 km/h)*	W*S *(W*S / 1.6)*

Where W = Total width of closure,

S = Proposed\posted roadway speed limit

** Taper length is L / 3 when there is a shoulder taper.
Taper length is L / 2 when there is a shifting taper.
Taper length is L when there is a merging taper.
***Optional downstream taper length is 100 feet per lane

Figure T. Tree Cutting/Trimming Lane Closure on a Multi-lane Road

8.0 Considering Pedestrian Safety and Mobility

Consideration of pedestrian safety and mobility should be included in all utility work zone traffic control plans. This issue is often overlooked in the utility work zone traffic control setup. The need for pedestrian accommodations can be identified by an observation of the work zone to determine the existing patterns and needs of pedestrians in that area. The needs of the pedestrians may vary from location to location due to characteristics such as the age of the pedestrians or potential disabilities of the pedestrians.

If a pedestrian facility is being disrupted due to utility work, this issue must be addressed especially in urban areas where the pedestrian volumes may be significant. According to the MUCTD, the following items should be considered when dealing with pedestrians in work zones:

A. Pedestrians should not be led into conflicts with work site vehicles, equipment, and operations.

B. Pedestrians should not be led into conflicts with vehicles moving through or around the work site.

C. Pedestrians should be provided with a reasonably safe, convenient, and accessible path that replicates as nearly as practical the most desirable characteristics of the existing sidewalk(s) or footpath(s). *(1)*"

> *"When existing pedestrian facilities are disrupted, closed, or relocated in a TTC zone, the temporary facilities shall be detectable and include accessibility features consistent with the features present in the existing pedestrian facility."*
>
> MUTCD Section 6D.02

Traffic control plans have been developed to address situations where a sidewalk is blocked resulting in a change of path for the pedestrians at or near the utility work zone. Traffic control plan U should be used when the sidewalk is closed resulting in the need for a pedestrian detour. Traffic control plan V should be used when a diversion for the pedestrians is needed as a result of the sidewalk being closed. Both plans make use of Type III Barricades to block pedestrians from entering into the utility work zone.

> *"It must be recognized that pedestrians are reluctant to retrace their steps to a prior intersection for a crossing or to add distance or out-of-the-way travel to a destination"*
>
> MUTCD Section 6D.01

Pedestrian Control Plan U

Applicable for:
- Pedestrian safety and mobility considerations
- Cases when the sidewalk is CLOSED
- When the sidewalk closure results in a pedestrian sidewalk DETOUR

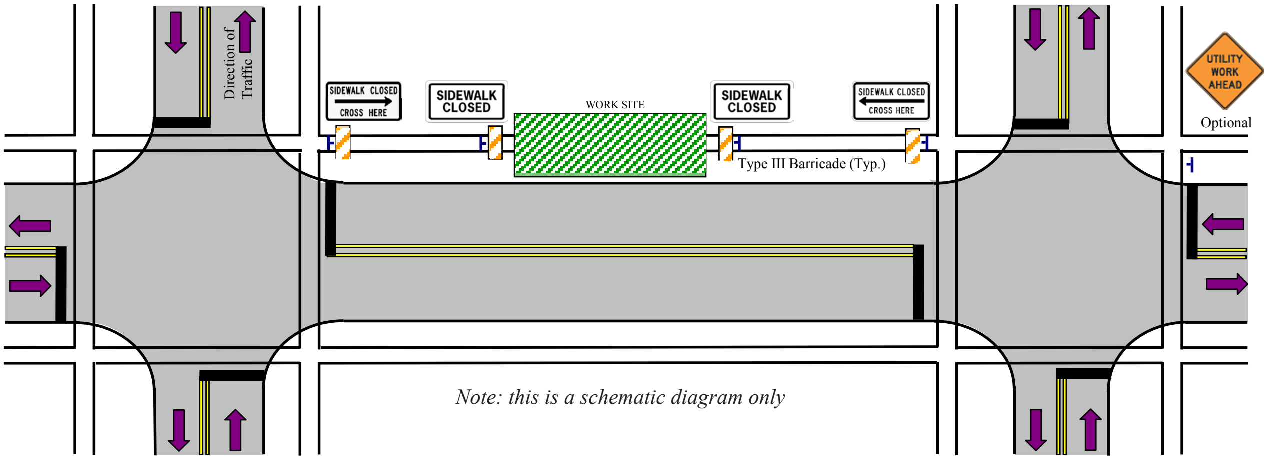


Figure U. Sidewalk Detour for Pedestrians

Pedestrian Control Plan V

Applicable for:
- Pedestrian safety and mobility considerations
- Cases when the sidewalk is CLOSED
- When the sidewalk closure results in a pedestrian sidewalk DIVERSION

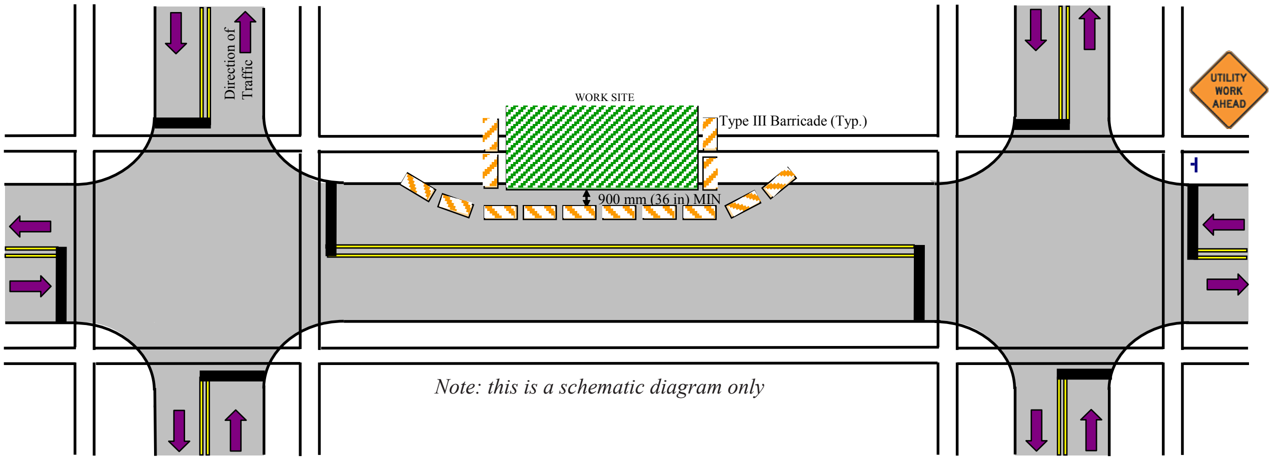


Figure V. Sidewalk Diversion for Pedestrians

9.0 Traffic Control Devices and Worker Safety Equipment

> *"To be effective, a traffic control device should meet five basic requirements:*
>
> *A. Fulfill a need;*
> *B. Command attention;*
> *C. Convey a clear, simple meaning;*
> *D. Command respect from road users;*
> *E. Give adequate time for proper response."*
>
> MUTCD Section 1A.02

The following sections provide recommendations for traffic control devices and work equipment to further enhance the safety of utility workers, motorists and pedestrians. These recommendations include the use of traffic control signs prior to the work zone, arrow panels at the start of the work zone, and appropriate channelizing devices throughout the work zone. In addition, further visual cues can be provided through warning lights and reflective markings directly on the work vehicles or from high-visibility apparel on the utility workers. The Federal Highway Administration 23 CFR Part 630 Subpart J: Temporary Traffic Control Devices should be refered to periodically for updates affecting work zone safety and mobility.

9.1 Traffic Control Signs

Temporary traffic control signage is very important in warning motorists of approaching vehicles. Utility work zones typically occupy relatively small areas and are generally short in duration, though for many applications the actual duration cannot be accurately determined beforehand. The driving maneuvers required at utility work zones are typically not complex and require minimal reaction time in order for drivers to take necessary action. The temporary traffic control is generally set up and removed within the same day at these locations. If required to use post-mounted signs, the necessary installation and removal time can increase substantially; thereby, increasing the total work duration and increasing the workers' exposure to risk. To alleviate this risk, it is recommended that portable temporary traffic control signs be used when conducting utility work.

Portable temporary traffic control signs are lower to the ground as compared to normal permanent traffic control signs. Past research has shown that experienced drivers tend to fixate their eyes lower down and have less vertical variance in eye fixation locations than the inexperienced drivers *(8)*. Consequently, placing signage lower to the ground may produce greater impact on the driving population. Recommendations for portable temporary traffic control signs are as follows and are shown in Figure 3:

- Advance work zone warning signage must be provided with sign message, layout, and configuration per the standards provided in Part 6 of the MUTCD (Temporary Traffic Control).
- Sheeting materials for all utility work zone signage, including advance warning signs, should be fluorescent orange in color with mircoprismatic retro-reflective characteristics as these materials have superior daytime conspicuity properties.
- Signs should be 36 inches x 36 inches, construction zone orange, and mounted a minimum of 12 to 18 inches above the pavement surface or ground mounted. Sign supports should be collapsible so they can be mounted seven feet above ground when on-street parking or pedestrian traffic is present.
- Two orange supplemental flags may be mounted on each sign to increase visibility and conspicuity. When used, the flags should not cover the content on the sign.

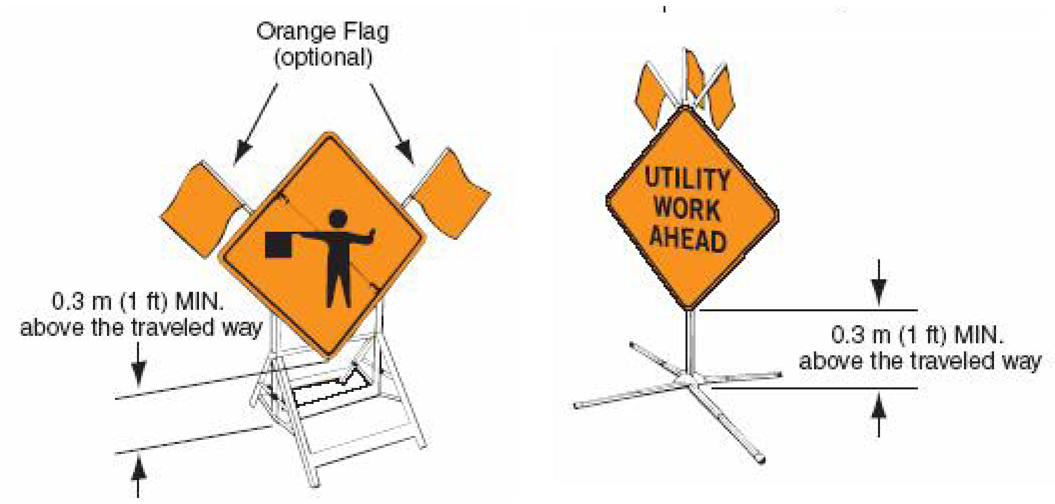


Figure 3. Portable Temporary Traffic Control Signs *(1)*

9.2 Arrow Panels

Flashing arrow panels may be used either exclusively or in conjunction with other delineating devices to guide drivers safely through work zones. The arrow signal is used to attract the motorists' attention and alert them of a change in the roadway environment ahead. They are commonly used as advanced warning devices during mobile and stationary operations to:

- Guide motorists to change lanes when work activities are taking place on the road.
- Caution motorists of work activities taking place on or adjacent to a shoulder, where no lane change is required.
- To increase visibility and the likelihood of drivers responding in a safe and timely manner in utility projects located on roads with horizontal or vertical curves.

The recommendations for arrow panel displays on work vehicles are based on several observational studies documented in the state-of-the-art review and are expected to impact long-term crash and injury reductions of utility workers and motorists. Arrow panels shall meet the minimum size, legibility distance, number of elements, and other specifications shown on Figure 6F-6 of the MUTCD for Type C arrow panels. Arrow displays should operate in flashing or sequential mode. The following specific display types are acceptable: flashing or sequential directional arrows, right sequential chevrons, double flashing arrows, and four-corner caution.

Arrows should be recognizable to drivers from a minimum threshold distance as indicated in the MUTCD. The appropriate decision sight distance requirements are 1,500 feet for roads with posted speeds > 45 mph and 980 feet for roads with posted speeds $\leq$ 45 mph. To accommodate these sight distance requirements, the arrow boards must be designed to an appropriate size and located at a height sufficiently above the ground. Recommendations for these characteristics are as follows:

- The support panel should be 48-inches high x 96-inches wide, contain a minimum of 15 lamps, and have a front panel with a background that is flat, non-reflective black.
- Arrow panels should be mounted at a minimum of 7 feet from the roadway to the bottom of the panel, except on vehicle-mounted panels, which should be as high as practical. The panels should be equipped with a system to raise them into position

when in operation and lower them into travel position when not needed and should be provided with remote controls where possible. Schematics of the recommended truck- and vehicle-mounted arrow panels are also provided in Figure 4.

In addition to the size and location, additional recommendations are provided specific to the characteristics of the light and their operation. The arrow panels mounted on utility work vehicles/trucks should conform to the following technical requirements:

- *Flash Rate:* 25 to 40 flashes per minute
- *Angularity requirements:* For moving operations, work in urban areas (which encompass most utility work), use 'general-purpose (wide) beam' panels as opposed to 'narrow beam' panels
- *Lamp Requirements:* Lamps be certified for use in arrow panels by the state; lamp size of PAR 46 or PAR 36.

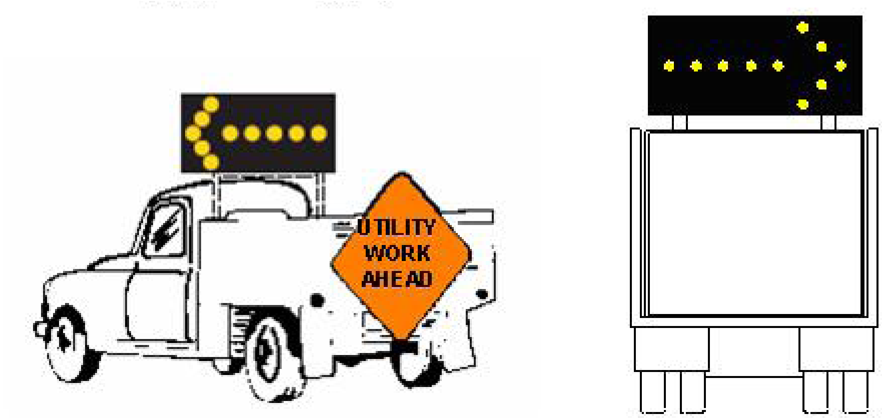


Figure 4. Recommended Use of Arrow Panels on Utility Work Vehicles and Trucks

9.3 Channelizing Devices

Channelizing devices are used to provide guidance to motorists traveling through a work zone. Since utility work zones are typically set up over relatively short distances and are completed within a few hours, it is essential that any channelizing devices used can be quickly and easily installed and removed. To facilitate such timely installation and removal, it is recommended that traffic cones be utilized as channelizing devices in utility work zones. The cones should be orange, contain retro-reflective bands to enhance conspicuity, and be made of a material that will not damage a vehicle if impacted. 36-inch high cones or tubular markers are more desirable than 18- or 28-inch cones in utility work zone applications as they provide increased visibility to motorists and pedestrians since they are taller in height. The spacing of the channelizing devices (e.g. cones) in the taper section, should not be greater than 1.0 times the speed limit expressed in mph or 0.2 times the speed limit using km/hr. Channelizing devices used in the tangent section of the work zone should not exceed the spacing 2.0 times the speed limit in mph or 0.1 times the speed limit in km/hr. In addition, these devices can be transported easily on utility work trucks and facilitate quick installation and removal on-site. The dimensions of the taller cones should meet the standards for tubular markers as provided in the MUTCD and shown in Figure 5. Examples of the taller cones are provided in Figure 6.

> *"The function of channelizing devices is to warn road users of conditions created by work activities in or near the roadway and to guide road users. Channelizing devices include cones, tubular markers, vertical panels, drums, barricades, and temporary raised islands"*
>
> MUTCD Section 6F.58

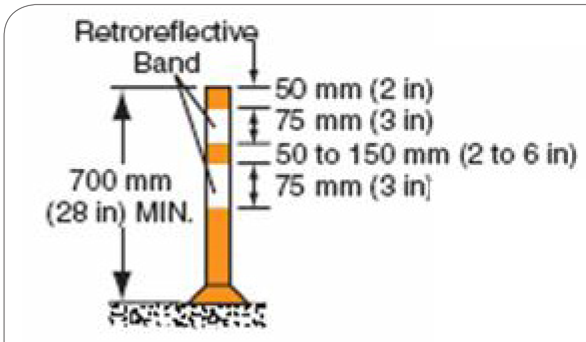


Figure 5. Standards for Tubular Markers as Provided in MUTCD Figure 6F-7 *(1)*

Figure 6. Examples of Taller Cones *(9)*

9.4 Warning Lights on Work Vehicles

Warning lights are intended to attract the attention of nearby road users (motorists and pedestrians) in order to alert them to a potentially hazardous situation and provide advance information to allow sufficient time for taking appropriate action. Many different warning lights are being used on work vehicles in the US as there is currently no uniform standard among the states. Some degree of warning light standardization is necessary to promote driver understanding and recognition of lights on work vehicles.

Past research on human visual perception and the ability to detect flashing warning lights revealed that the conspicuity of a light is primarily dependent upon the intensity of its flash. Other characteristics, such as the type of light (high intensity rotating, flashing, oscillating, or strobe), influences human detection capabilities. The color of the warning light also plays an important role in the memory coding and pattern recognition process.
The characteristics of the recommended warning light system for utility vehicles involved in moving or stationary operations are listed below:

- Warning lights should be visible to drivers from all angles (360 degrees)
- Large vehicles, including those transporting heavy equipment, should be equipped with a minimum of three warning lights. It is recommended that two rotating beacons plus one incandescent flashing light be operated with a flash rate between 60 and 100 cycles per minute. Four-way flashers, mounted on the rear bumper of the work vehicle, should be used in addition to the three-light warning system.
    - A minimum of two warning lights is recommended on large trucks and equipment
    - A minimum of one warning light mounted on the middle of the roof is recommended for passenger cars and light trucks used in work sites
- Warning lights should be amber in color.

9.5 Retro-reflective Markings on Utility Work Vehicles

The conspicuity of utility work vehicles can be increased by the use of retro-reflective markings and appropriate vehicle colors. Recommendations for increasing the visibility of utility work vehicles are as follows:

- Retro-reflective vehicle markings should supplement warning light systems and ideally should be visible on all sides of the vehicle to make its perimeter visible in darkness.
- Retro-reflective material should be affixed to the back of utility work vehicles to increase conspicuity. This material should be at least four inches in width (eight inches is desirable) and of a high visibility color pattern. Fluorescent orange, white, and black diagonal stripes have been found to provide the highest conspicuity for both daytime and nighttime use (see Figure 7).
- The color orange is recommended as the standard color for work zone vehicles as the use of orange will likely increase drivers' recognition that the vehicle is part of the work zone, thereby increasing the likelihood of an appropriate response upon detection. Additionally, because most utility work zones are relatively small in size and possess relatively few orange traffic control devices, the use of orange for utility work zone vehicles may help increase drivers' recognition of the entire work zone area.

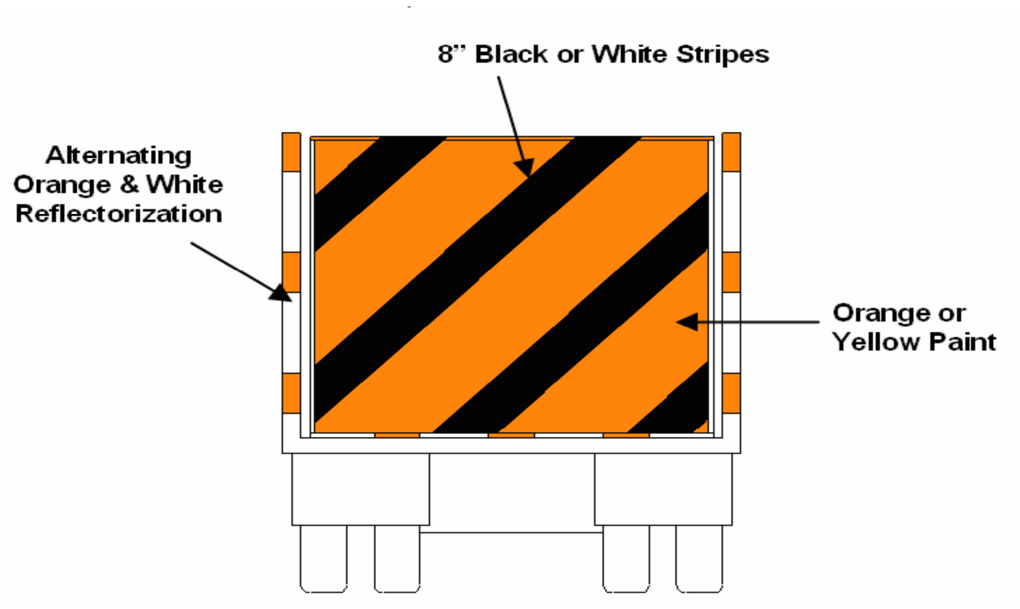


Figure 7. Example of Retro-reflective Material Used on Back of Utility Work Vehicle

9.6 Worker Safety and Visibility

Safety of the utility workers is one of the the most important factors that has been considered in the development of these guidelines. In order to minimize utility worker injuries as a result of being struck either by passing motorists or other work vehicles and equipment, all workers must wear high-visibility safety apparel at all times. As of November 25, 2008, Class 1 high visibility garments can no longer be used—Class 2 and 3 only after that date. This clothing must be orange, yellow, yellow-green, or fluorescent versions of these colors, and must include retro-reflective materials. As a minimum, vests that cover the entire upper torso are desirable.

Workers should also wear orange colored hard hats, safety glasses, and proper work boots depending on the characteristics of the utility work.

"Worker Safety Apparel—all workers exposed to the risks of moving roadway traffic or construction equipment should wear high-visibility safety apparel meeting the requirements of ISEA "American National Standard for High-Visibility Safety Apparel" (see Section 1A.11), or equivalent revisions, and labeled as ANSI 107-2004 standard performance for Class 2 or 3 risk exposure."

MUTCD Section 6D.03

10.0 Practicing Safety Culture

> *"An organization's values and behaviors, modeled by its leaders and internalized by its members, that serve to make safety the overriding priority."*
>
> Institute of Nuclear Power Operation, 2004

The safety and mobility guidelines, as presented in this report, were developed in order to improve the safety of both workers and motorists in utility work zones. In order to achieve safety in utility work zones, it is imperative that a safety culture be developed within utility companies, contractors, and other agencies involved in utility work on or around public thoroughfares. These organizations are responsible for ensuring the safety of their workers, motorists, and pedestrians. Consequently, safety should be continually emphasized and employees should be motivated to focus on safety as a part of their everyday work routine.

This can be accomplished by establishing a commitment to safety at all levels of an agency, from workers to management and policy makers. The utility workers need to take responsibility for their own safety, as well as the safety of motorists, pedestrians and others. The leaders in the utility companies and other agencies, including state, county and city road agencies, must set a positive example for utility workers through mandatory safety training, and by explicitly considering safety in their decision making process. The combination of these efforts and activities will help to establish a successful safety culture.

> *"The safety culture of an organization is the product of individual and group values, attitudes, perceptions, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management."*
>
> Health and Safety Commission, Third Report: Organizing for Safety. ACSNI Study Group on Human Factors. HMSO, London, 1993.

The publication of these guidelines alone cannot substantially improve utility work zone safety. In order for the guidelines to be effective, a safety culture must be developed within each agency. A safety culture helps to create an environment within which individual safety attitudes develop and safety behaviors are promoted. Workers must be motivated to follow the utility work zone traffic control guidelines and other safety requirements set forth by the agency. This motivation can be achieved by providing training on a continuing basis, incentives for the workers to comply, and enforcement of what should be done. The importance of having a safety culture must be stressed and enforced by leaders in order to improve the safety of utility workers, motorists and pedestrians.

10.1 Importance of Safety Training

Safety training is critical to provide utility workers with the necessary abilities to detect job-related hazards and the skills to avoid, abate or minimize the risk associated with such hazards. Workers are typically exposed to safety training programs at various junctures in their careers which may include initial training, on-the-job training, periodic training and specialty training. The purpose of these safety training programs is to ensure that workers gain and retain the knowledge necessary to ensure safety for themselves, other workers, motorists and pedestrians. Safety training should be continuously conducted in order to review and remind utility workers of the importance of considering safety in their everyday jobs.

During the introductory training session, participants should be overloaded with information as part of a comprehensive program. Important material should be presented numerous times as knowledge retention increases with the frequency of presentation. For safety training to be effective, it must be continually reinforced as a part of the safety culture. Workers should initially be provided with on-the-job or classroom training to familiarize them with safe behaviors. Once a training program has been completed, workers will be expected to apply what they have learned in the field. It is imperative that the supervisors review the work and provide both positive and negative feedback, if necessary.

> *"The greater the degree to which the learner has mastered the knowledge or skill, the slower will be the rate of decay. This degree of learning or mastery is usually increased by having the learner gain more practice with the material (called overlearning)."*
>
> Farr, M.J., The Long-Term Retention of Knowledge and Skills, A Cognitive and Instructional Perspective, Recent Research in Psychology, Springer-Verlag, New York, 1987.

10.2 Knowledge Retention

As with any type of educational or training program, participants will not be able to retain

> *"Without appropriate incentives, few workers are willing to acquire intellectual skills. There is no particular way to encourage them to do so other than by orthodox measures, that is, fair assessment and fair compensation for skill development."*
>
> Aoki, M. and R. Dore, eds. The Japanese Firm: The Sources of Competitive Strength, Oxford University Press, 1994, 424 p.

all they have learned without continual reinforcement. Educational retention rates begin to decrease shortly after completing a training program if the acquired knowledge and skills are not utilized. To combat such memory loss, continuous learning should be provided through regular training. In addition, safety issues should be stressed during everyday tasks. Learning of important safety topics can be enhanced if applied in the context of everyday work. Workers must understand how to apply the learned topics in the proper context. To do so, training should present participants with the opportunity to demonstrate their abilities to perform tasks properly under various real-world scenarios. Training should be provided in a familiar environment or in a context which is closely related to the environment in which the training material will be applied. The more closely the learning environment resembles the actual work environment, the more easily the information can be retrieved by the trained workers.

> *"Largely, the evidence is consistent with the rule of thumb that after a retention interval of one year, approximately one-third of the knowledge gain is lost, accumulating to slightly over one-half after a few years."*
>
> Custers, E.J.F.M., Long-term retention of basic science knowledge: a review study, Advances in Health Science Education, Springer Science, New York, 2008.

The retention interval, or time between the initial learning and the retrieval period when the learning is applied, determines the degree of knowledge retention. The shorter the retention interval or the more frequently the learning material is applied, the greater the knowledge retention. To ensure that safety-related knowledge, skills, and abilities are maintained, it is important that organizations continually monitor safety performance. All work-related crashes and incidents should be monitored and workers should be provided with incentives for exhibiting safe behaviors.

Various factors influence the long-term knowledge retention capabilities of individuals. These factors should be considered in the design and implementation of utility work zone training programs. One of the most important determinants of knowledge and skill retention is the degree of original learning. One way to reduce memory loss is to strengthen or increase the degree of original learning, which can be achieved by providing extra practice or trials, or by incorporating 'over learning' techniques into the original learning process.

"The effect of the environment or context of recall on performance depends on the environment of learning. Recall is better if the environment of original learning is reinstated."

Godden, D.R. and A.D. Baddeley (1975). Context-dependent Memory in Two Natural Environments: On Land and Underwater. British Journal of Psychology, 66, p. 325-331.

The types of tasks included in the learning process and the complexity of each task determine the ease with which such knowledge can be acquired and the degree to which it can be retained. For example, hands-on motor skills are better retained than procedural tasks. Furthermore, the more complex a task, more difficult the accompanying knowledge and skills are to acquire and retain. Instruction should enable participants not only to recognize the topics learned, but also to apply them in the proper context. Instruction should be designed to give participants the ability to perform the correct task in a practical situation. When the conditions of learning are varied, it becomes more difficult for the learner to acquire the knowledge or skill, but eventually results in better learning and retention. For example, utility workers can be asked to apply course material appropriately under a number of unique scenarios. Under such varied learning conditions, the information and tasks are better ingrained in memory because learners have multiple retrieval cues.

The situation under which retention is measured also influences the degree of retention. If the environment in which knowledge or skills are to be recalled resembles the environment in which they were originally learned, better retention will be achieved (3). These guidelines, and the accompanying training program, were designed in a manner that addresses these issues and provides a framework that is conducive to implementing and maintaining a utility work zone safety culture.

10.3 Maintaining a Safety Culture

Continuous training is important for utility workers to be able to retain important safety

> *"When it is known in advance that there will be an appreciable period of little or no use of a learned knowledge or skill, it seems most desirable that enough practice or rehearsal be provided, with the proper frequency and spacing, so as to prevent an unacceptable amount of decay from occurring. If this is not possible, then actual refresher training needs to be carried out before performance deteriorates below an acceptable level."*
>
> Farr, M.J., The Long-Term Retention of Knowledge and Skills, A Cognitive and Instructional Perspective, Recent Research in Psychology, Springer-Verlag, New York, 1987.

skills. The ability of a person to retain knowledge or skills is dependent on their own unique characteristics. The characteristics of an individual that impact long-term retention include ability, prior knowledge and motivation. Follow-up training provides a review for the workers in order to remind them of the importance of safety on the job sites and actions that alleviate the potential for crashes. It can act as a reminder of the existing dangers and force the workers to constantly consider their safety, the safety of others in the work zones and the safety of passing motorists. Many workers do not realize the importance of such repetitive training, thus the supervisors and managers must use creative ways of getting the message across. Due to the nature of utility work, there is often high staff turnover. This makes regular continual training even more important.

Regular training is a key component for safe utility work, but it is not enough in and of itself. A comprehensive utility work zone safety culture should be established that stresses the importance of safety at all levels of an organization with an ultimate goal of preventing the occurrence of crashes and providing safety to both workers and motorists. Further, a safety culture should provide targeted training for the workforce so that utility workers are able to identify potential hazards and take appropriate actions to mitigate these hazards. Workers should understand why their training is necessary and must be cognizant of the hazards that are present as a part of their daily work. Workers should also be encouraged to develop new ideas to improve work zone safety. The importance of safety to the individual workers, management, and the traveling public should be stressed at all times. Only with the commitment of all involved parties is it possible to realize the ultimate goal of eliminating work zone related traffic crashes.

11.0 Resource Materials

Additional resource materials for utility work zone traffic control guidelines and training can be found at the following websites:

- American Road and Transportation Builders Association: http://www.artba.org/
- American Traffic Safety Services Association: http://www.atssa.com/
- Federal Highway Administration: http://www.fhwa.dot.gov/
- Institute of Transportation Engineers: http://www.ite.org/
- Manual on Uniform Traffic Control Devices: http://mutcd.fhwa.dot.gov/
- National Highway Institute: http://www.nhi.fhwa.dot.gov/home.aspx
- National Work Zone Safety Information Clearinghouse: http://www.workzonesafety.org/
- Occupational Safety and Health Administration: http://www.osha.gov/
- Texas Transportation Institute: http://tti.tamu.edu
- Transportation Research Board: http://www.trb.org/

Flagger safety is a concern in utility work zones. Workers performing flagging duties must be aware of the potential risks and be knowledgeable of proper flagging procedure in order to minimize these risks. As such, extensive training material and programs are available exclusively for flaggers (traffic regulators). Refer to the following website for listings of training programs and materials: http://www.workzonesafety.org/training/

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