Overview of the Work Zone Design Process

Disclaimers:

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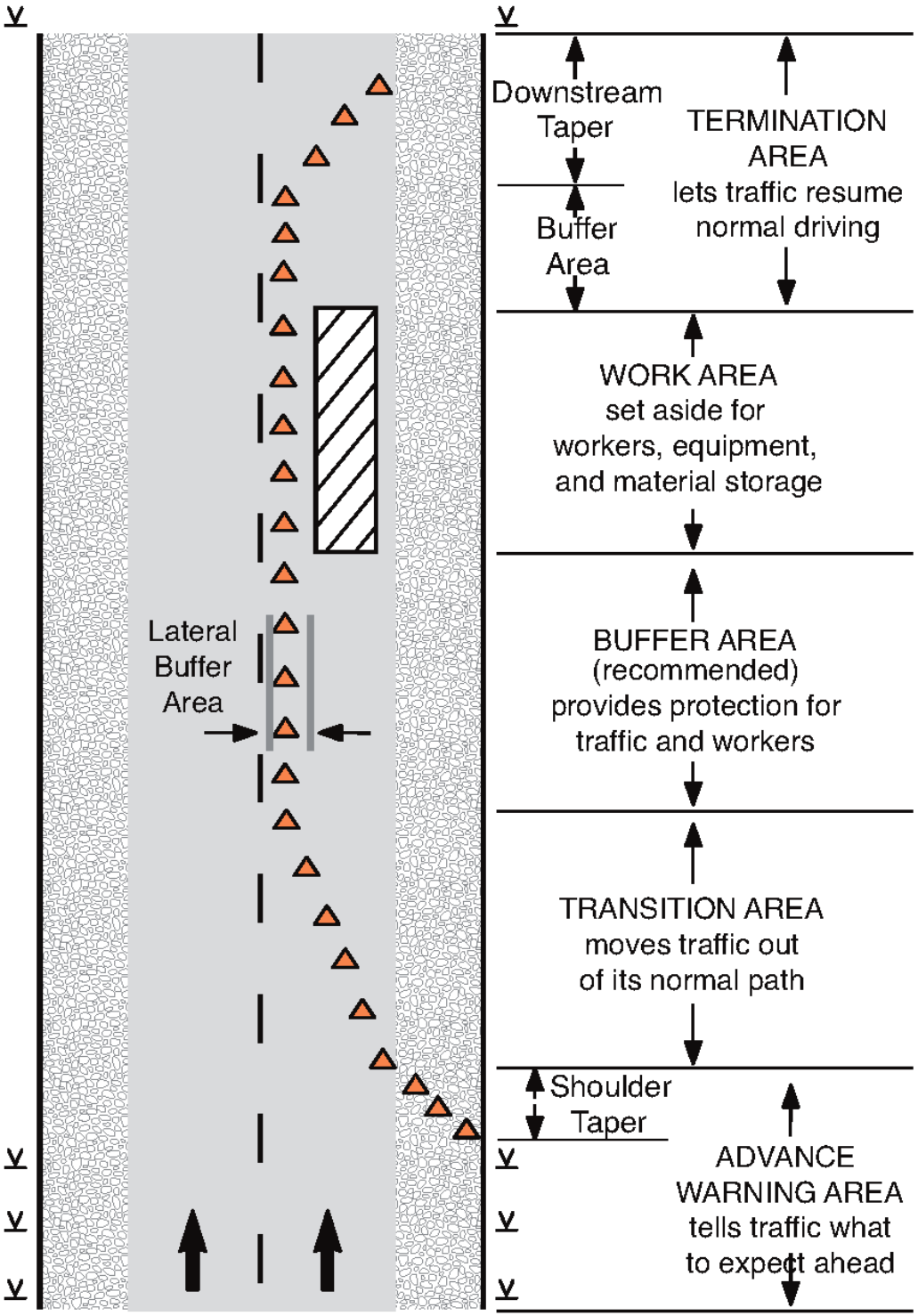
Learning Objectives

- Review work zone terminology and design elements
- Discuss TMP's
- Review design resources
- Discuss fundamental principles
- Consider design issues
- Examine project constructability and staging

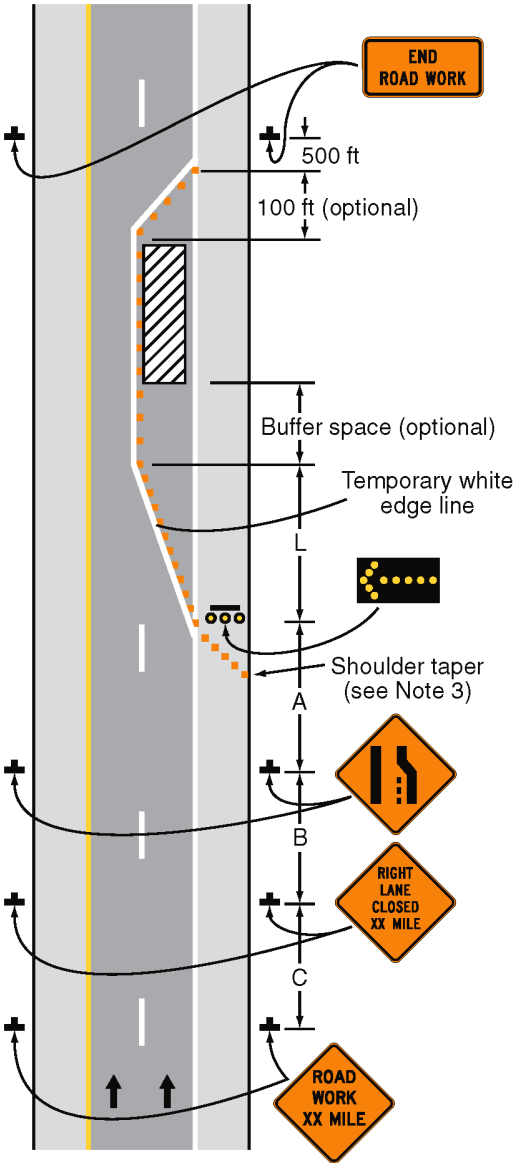
Work Zone Terminology

Work Zone Elements



Example Lane Closure

- Single lane closure
  - 2 lane divided highway



Example Lane Closure

- Advance signing

Speed Limit (mph)	Sign Spacing (ft) A	B	C	Merging Taper (ft) for 12' lane	Buffer (ft)
30	200	200	200	180	200
35	350	350	350	245	250
40	350	350	350	320	305
45	500	500	500	540	360
50	1000	1500	2640	600	425
55	1000	1500	2640	660	495
60	1000	1500	2640	720	570
65	1000	1500	2640	780	645

Example Lane Closure

Speed Limit (MPH)	**Sign Spacing** (ft) A	B	C	**Merging Taper** (ft) for 12' lane	**Buffer** (ft)
55	1000	1500	2640	**660**	495

L = W X S

W = 12 ft

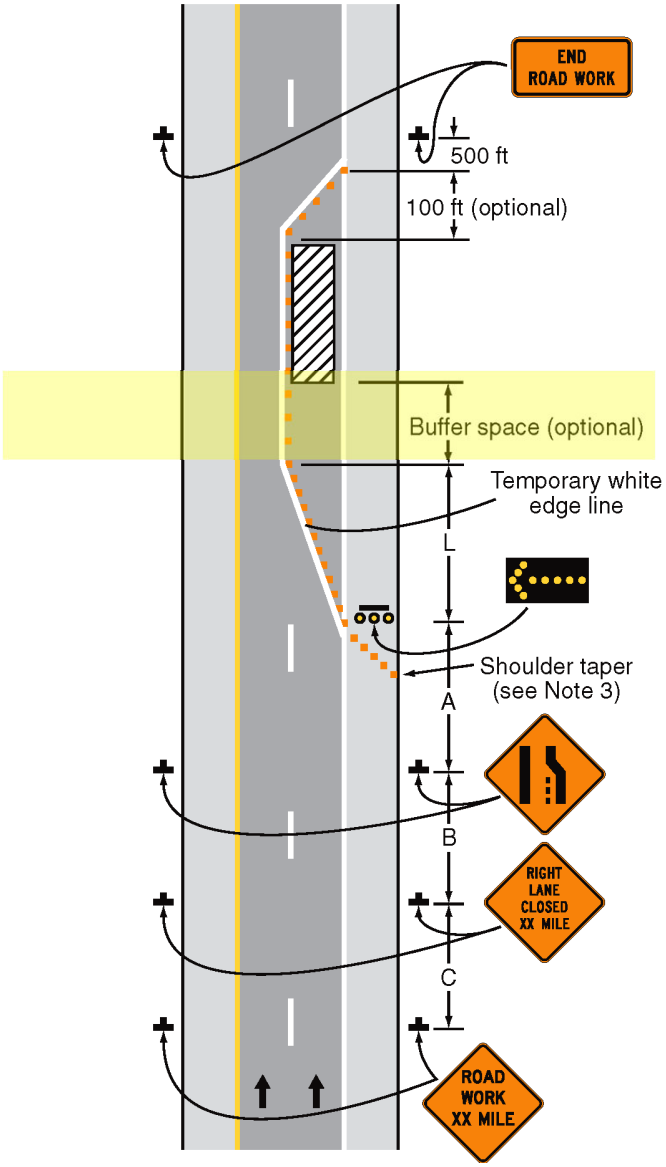
S = 55 mph

L = 12 x 55

L = 660 ft

Example Lane Closure

- Buffer space



Example Lane Closure

Speed Limit (MPH)	**Sign Spacing** (ft) **A**	**B**	**C**	**Merging Taper** (ft) for 12' lane	**Buffer** (ft)
55	1000	1500	2640	660	**495**

Buffer Lengths

A buffer area is recommended to separate traffic from the work area or oncoming vehicles and provide recovery space for an errant vehicle. The buffer area should not include any work activity nor storage of equipment, vehicles or material.

Suggested Buffer Lengths

Speed (mph)	**Length** (ft)	**Speed** (mph)	**Length** (ft)
20	115	45	360
25	155	50	425
30	200	55	495
35	250	60	570
40	305	65	645

A lateral buffer area may also be used. Its width should be based on conditions at the work site.

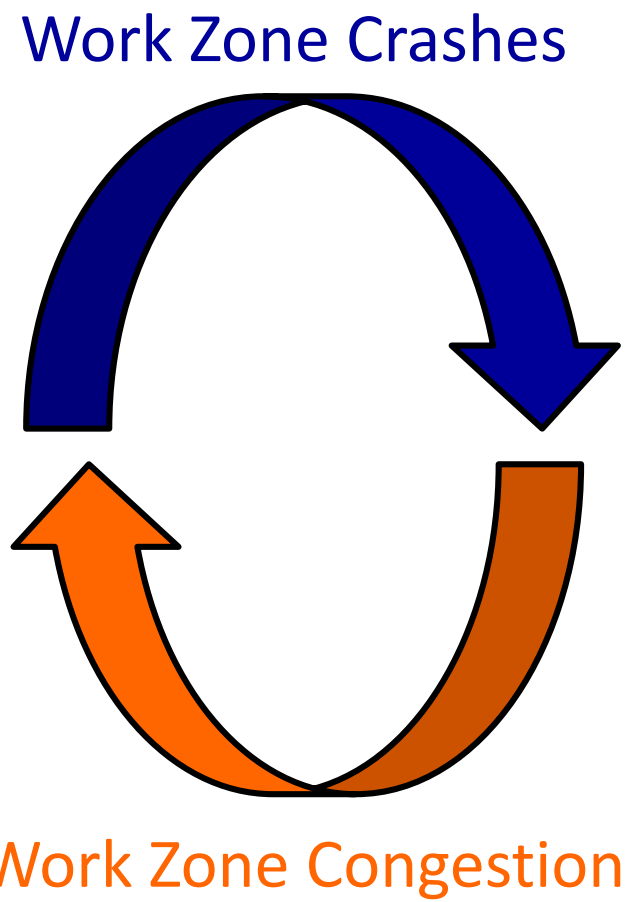
Challenges for Designers

- What can you do if the site does not have enough space for the recommended buffer and taper lengths?
- How do horizontal and vertical curves affect the layout?

Transportation Management Plans

Background

- 2004: Federal Work Zone Safety & Mobility Rule established to help manage traffic and safety issues on federally-funded highway projects.
- 2007: Deadline for state Departments of Transportation (DOTs) to establish a work zone planning process – producing a Transportation Management Plan (TMP).
- 2016: TMP process generally considered “best practice” for all significant projects, regardless of funding.



Goals of WZ Safety & Mobility Rule

Project-Level

- Consider safety and mobility issues for all users as early as possible.
- Assure consistent, systematic consideration of construction traffic and safety impacts.
- Manage and mitigate impacts.

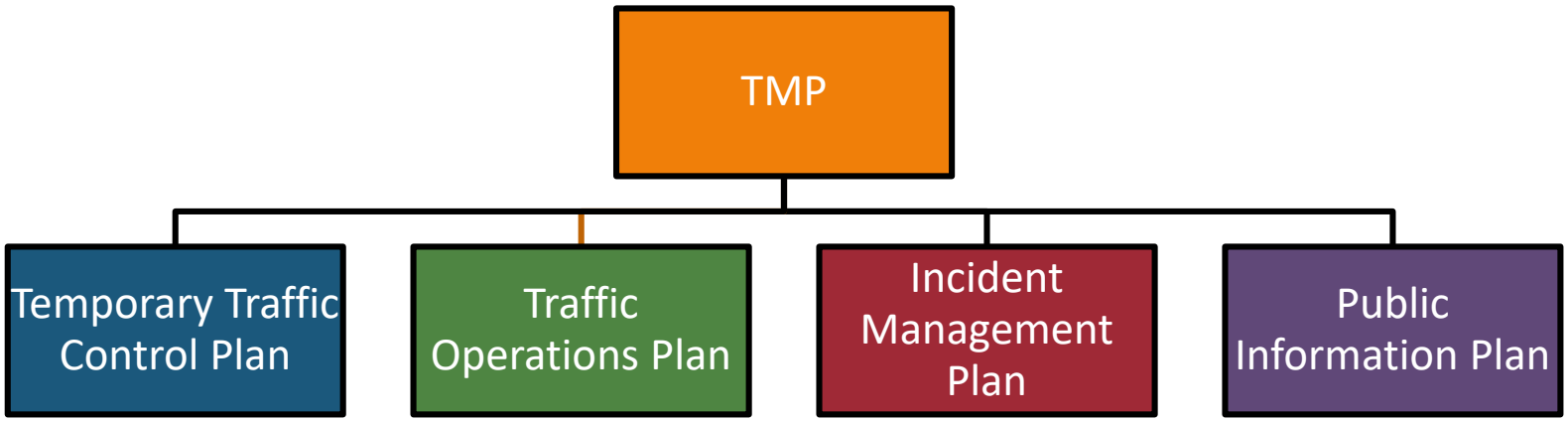
Agency-Wide Programmatic

- Monitor and assess impacts of individual work zones and the construction program as a whole.
- Establish a data-driven process for long-term improvements to work zone policies and procedures.

TMP Content Varies with Project Complexity

Typical Elements

- Temporary Traffic Control (Maintenance of Traffic) Plan
- Traffic Operations Plan
- Traffic Incident Management Plan
- Public Information & Outreach Plan



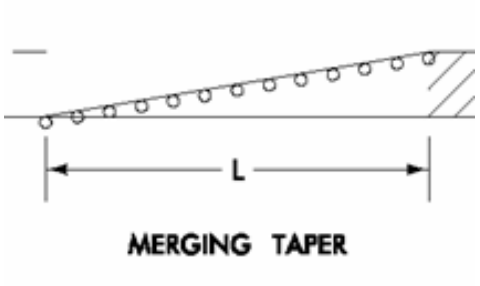
Why Do TMPs?

- TMP helps agency, contractor and first responders prepare for traffic issues unique to each site/project.
- TMP process has been successful in:
  - Improving travel conditions
  - Creating a better safety environment
  - Reducing complaints from the public.

Source: FHWA Center for Accelerating Innovation

Maintenance of Traffic (MOT) or Temporary Traffic Control (TTC) Plans

- A plan for safe and expeditious traffic movement and workforce safety
- How/when traffic is maintained during construction
- Sometimes not given proper time or attention
- Switches/stage changes often the most complicated and dangerous times



Designer Responsibility to Translate the TMP into the PS&E

- Plan Sheet Drawings
- Specifications
  - Standard Construction Specifications
  - Special Provisions
- Estimated Quantities and Method of Payment

Temporary Traffic Control Plan Components

- Traffic Staging/Phases
- Diversion/detour alignments
- Tapers and lane drops
- Pedestrian accommodations
- Temporary Traffic control (signals, sign type, sign location)
- Need for flaggers, etc.
- Illumination and warning lights
- Temporary Portable Concrete Barrier locations
- Pavement marking, drums, cones, and other channelization devices
- Policies for removal of signs, etc.
- Arrangements for worker parking
- Notes such as handling of signs that are not in use
- Permanent signs removed and temporary storage

Some Factors to Consider

- Traffic speeds.
- Estimated traffic volumes, vehicle types, and direction of travel.
- Required number of travel lanes.
- Temporary traffic control layouts including signing, marking, channelization devices, traffic signals, traffic delineators, barriers, and detours.
- Restrictions on work periods such as rush hours, holidays, special events, nights, weekends.
- Characteristics of adjacent highway segments.
- Requirements for partial completion and opening sections to traffic.
- Available maneuvering space for traffic.
- Requirements for installing, maintaining, moving, or removing traffic control devices.
- Turns or cross movements required by traffic.

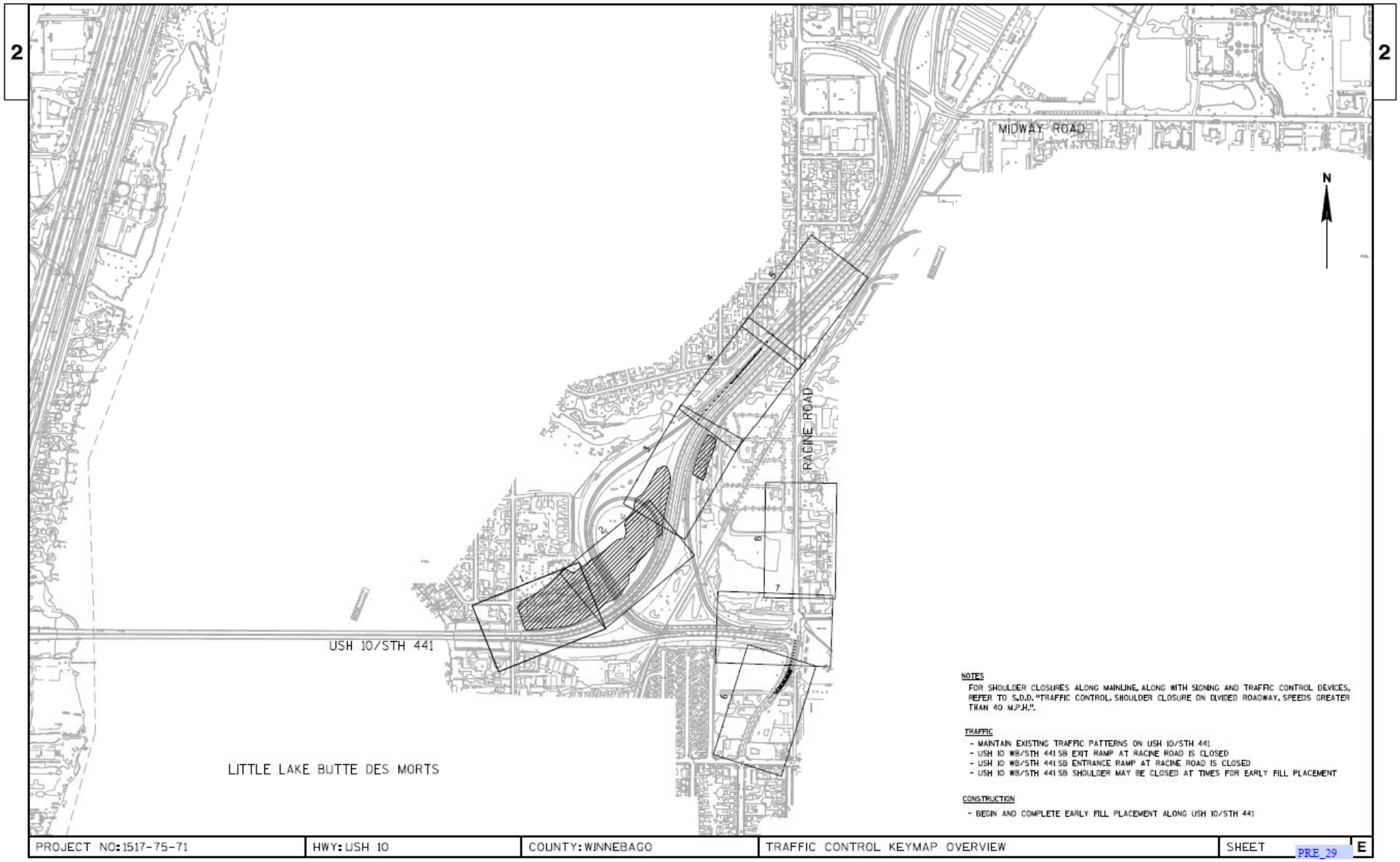
Conditions Requiring Special Attention

- High volume or high-speed traffic.
- Rush hour or seasonal traffic patterns.
- Heavy use by pedestrians.
- Changing work conditions or other conditions that would be confusing to the traveling public.
- Hazards due to nighttime operations.
- Complex detours or traffic patterns.
- Closely spaced intersections, interchanges, or other decision points.

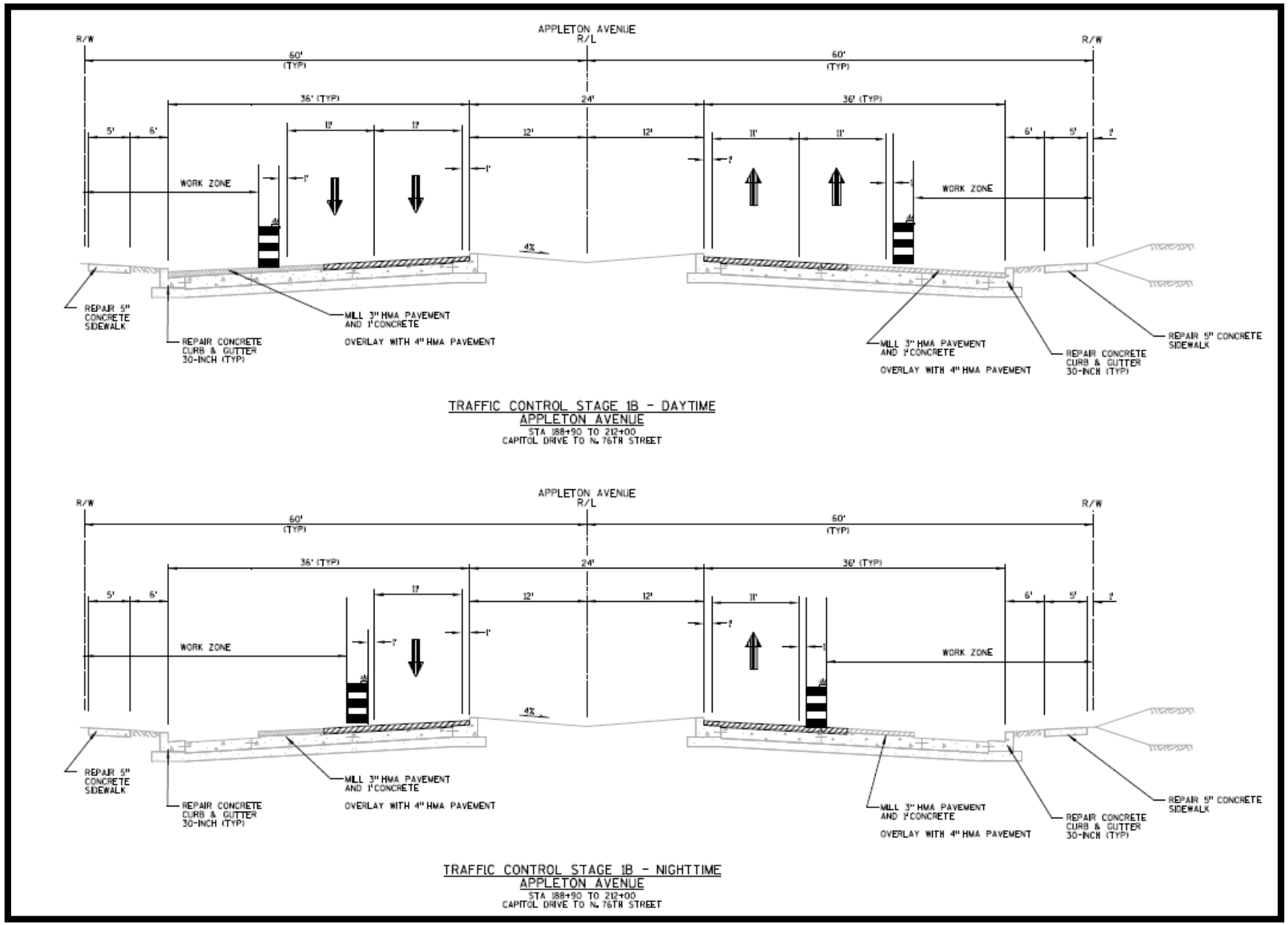
Non-Contractual Considerations

- Contractor role in public outreach, if any
- Special agreements reached with other agencies relating to traffic control or traffic management (including pedestrians and transit)
- Crash reporting requirements
- Any special guidance on traffic management for the project engineer

TTC Plan Components - Overview Sheet



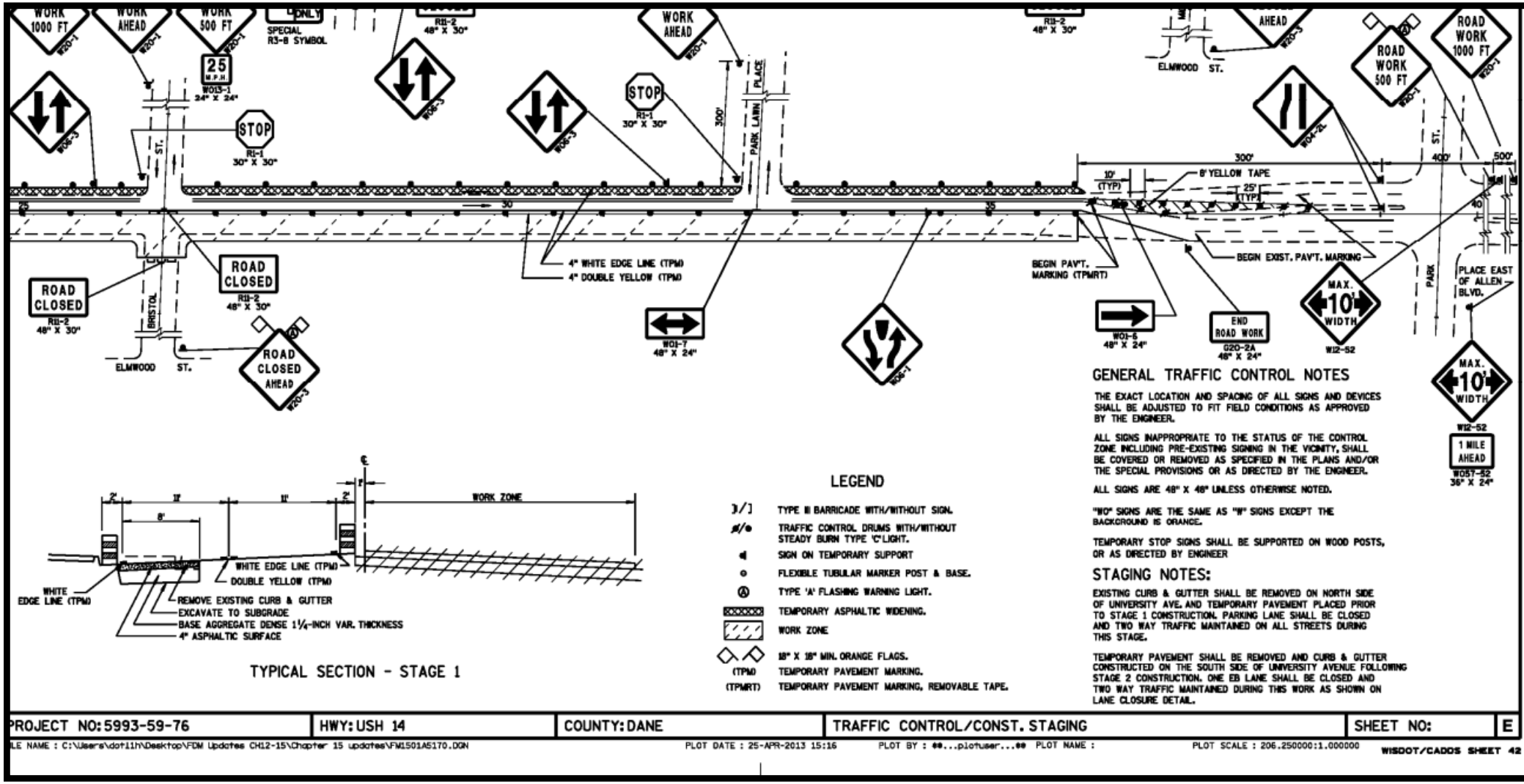
Work Zone Typical Sections



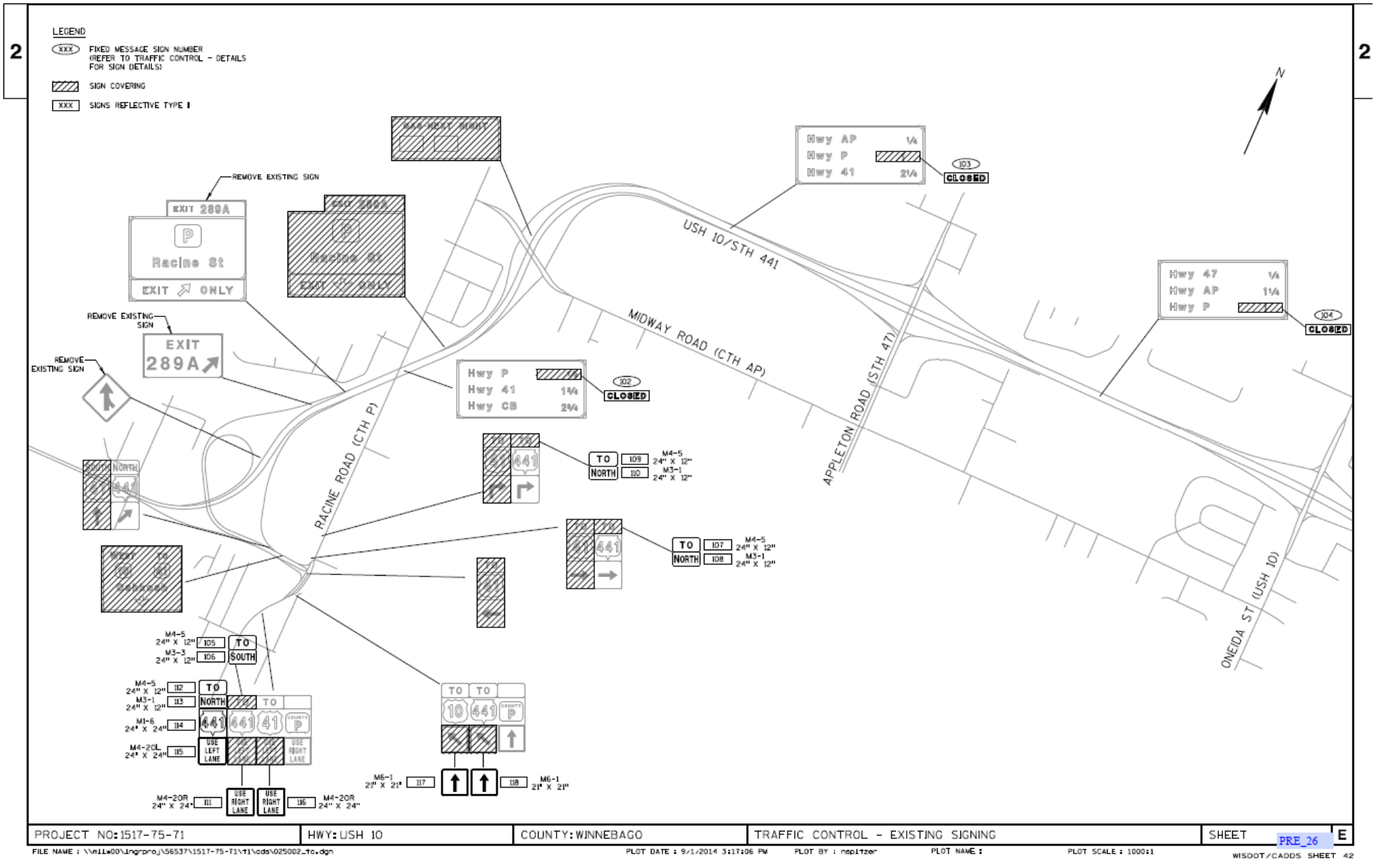
TRAFFIC CONTROL STAGE 1B - DAYTIME
APPLETON AVENUE
STA 188+90 TO 212+00
CAPITOL DRIVE TO N. 76TH STREET

TRAFFIC CONTROL STAGE 1B - NIGHTTIME
APPLETON AVENUE
STA 188+90 TO 212+00
CAPITOL DRIVE TO N. 76TH STREET

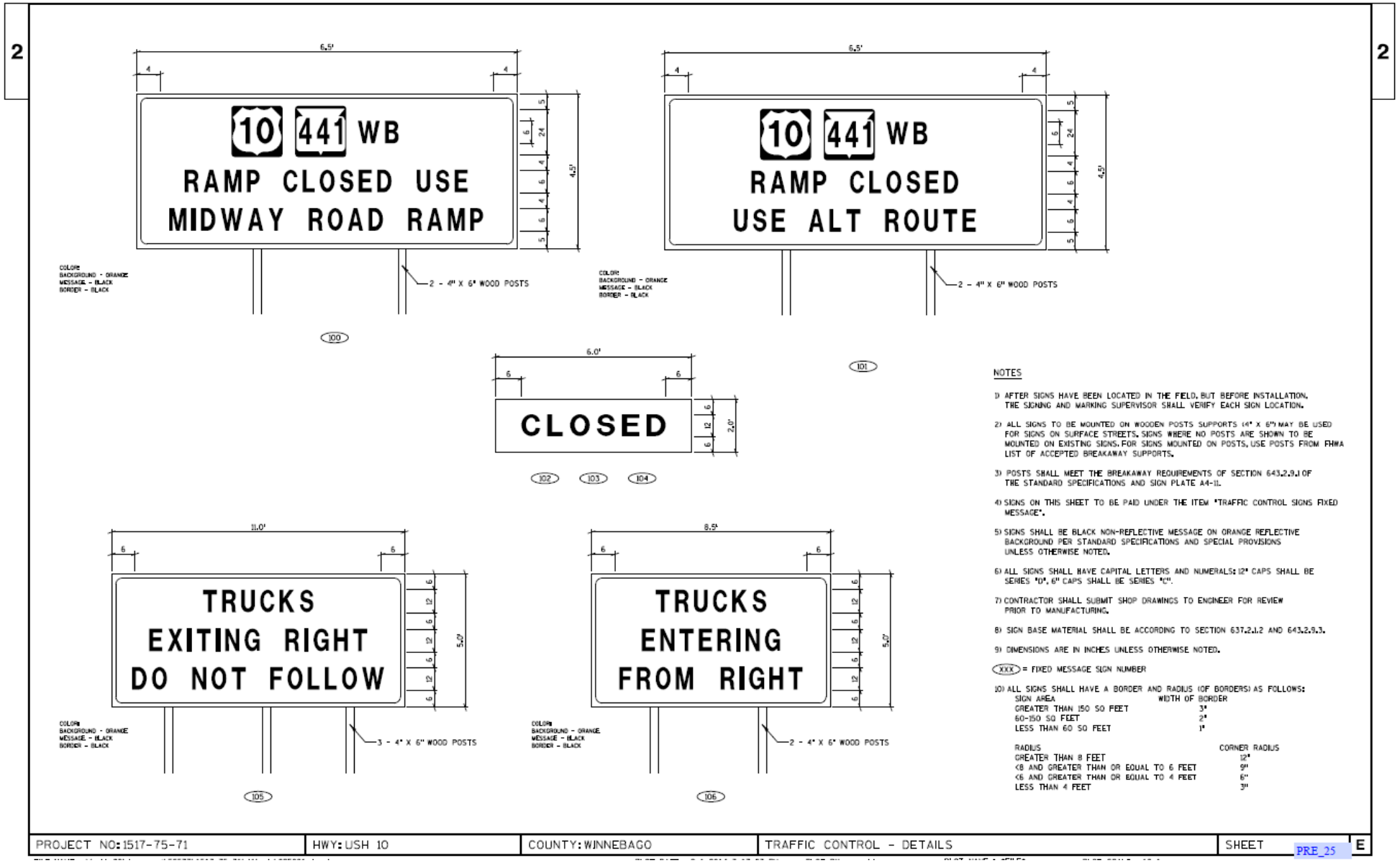
Detail Sheets – Temporary Traffic Control Signing & Marking



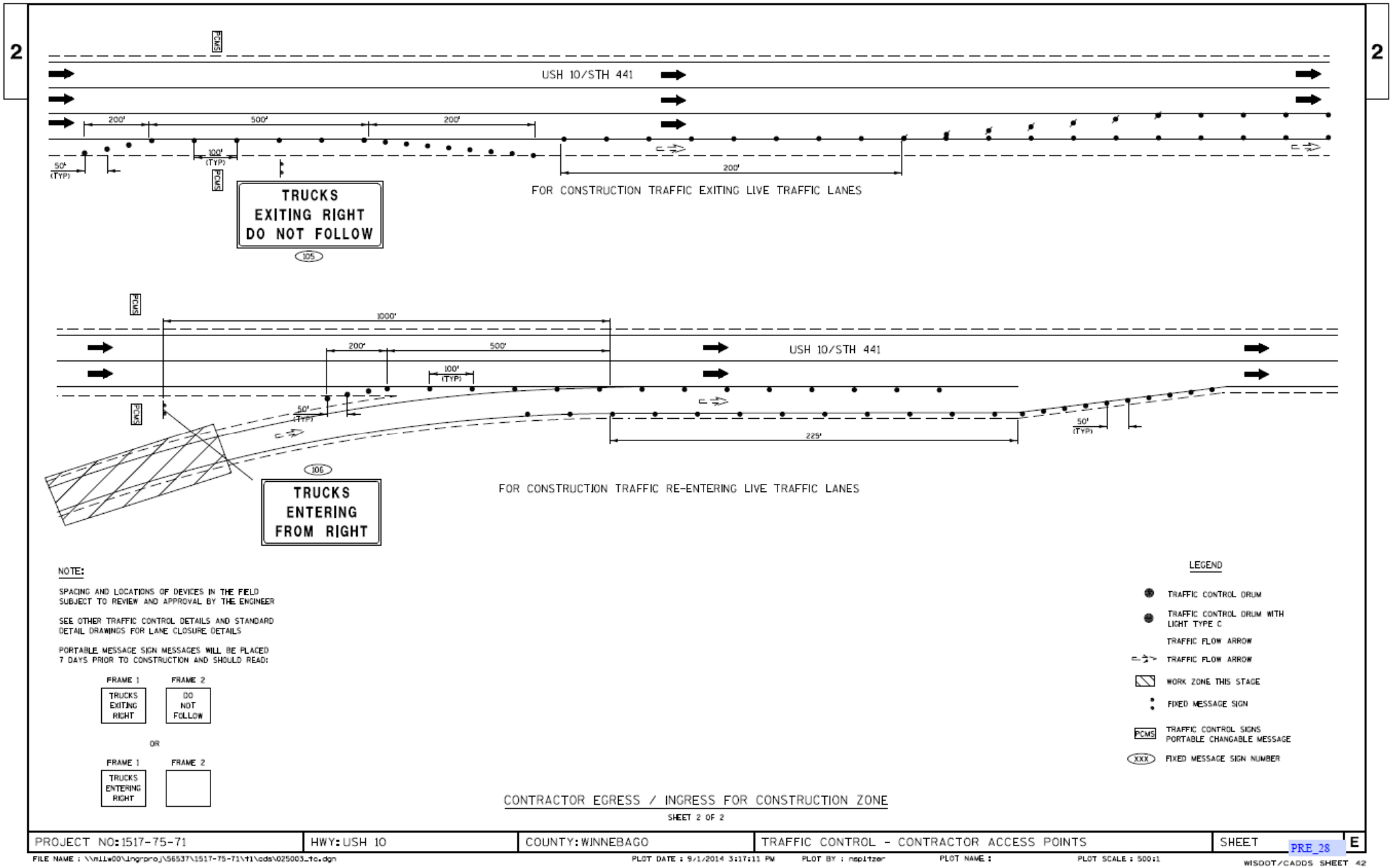
Existing Directional Signs & Work Zone Guide Signs



Fixed Message Sign Details



Construction Ingress and Egress



Design Resources

Designer Resources

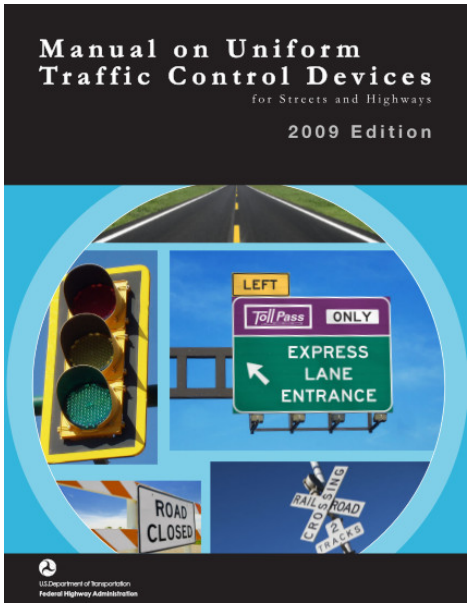
National

- Manual on Uniform Traffic Control Devices (MUTCD)
- AASHTO Roadside Design Guide
- NCHRP 581 (Design of Construction WZ's on High Speed Highways)
- FHWA Work Zone Safety Grant materials available from National Work Zone Safety Information Clearinghouse at www.workzonesafety.org search: University of Wisconsin–Madison to find TOPS Lab Work Zone Designer Documents

State-Specific

- State Design Manual/State WZ Traffic Control Manual
- Standard Detail Drawings
- Standard Specifications
- Materials Manuals
- Construction Manuals

MUTCD



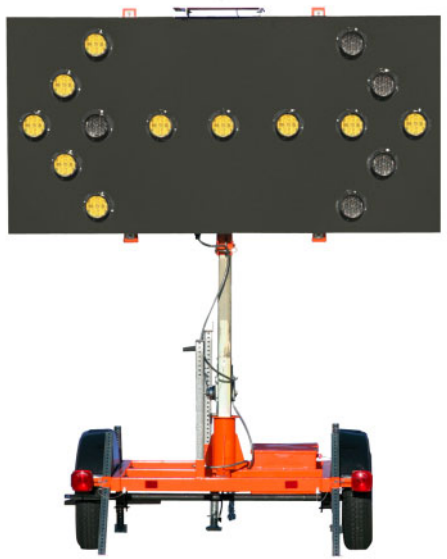
- Contains standards and guidance for design, installation, and maintenance of traffic control devices in work zones.
- Lists approved Temporary Traffic Control (TTC) devices (cones, drums, barricades, signs, etc.)
- Includes 46+ Typical Application Drawings illustrating various work zone traffic control layouts (mainly for smaller projects).
- Emphasizes the importance of accommodating **all** road users (including pedestrians, bikes, transit, motor vehicles, motorcycles, heavy trucks).

Temporary Traffic Control Devices and Techniques

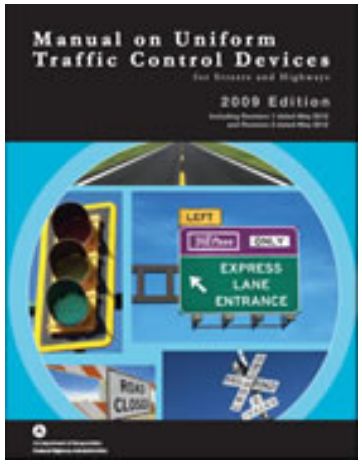
- Signs
- Portable Changeable Message Signs (PCMS)
- Barricades
- Cones
- Drums
- Vertical Panels
- Tubular Markers
- Pavement Marking
- Signals
- Flaggers
- Automated Flagger Assist Devices (AFADs)
- Positive Protection Devices (Barriers)
- Crash Attenuators
- Lighting







MUTCD


Manual on Uniform
Traffic Control Devices
2009 Edition
LEFT
ONLY
EXPRESS
LANE
ENTRANCE
ROAD
CLOSED

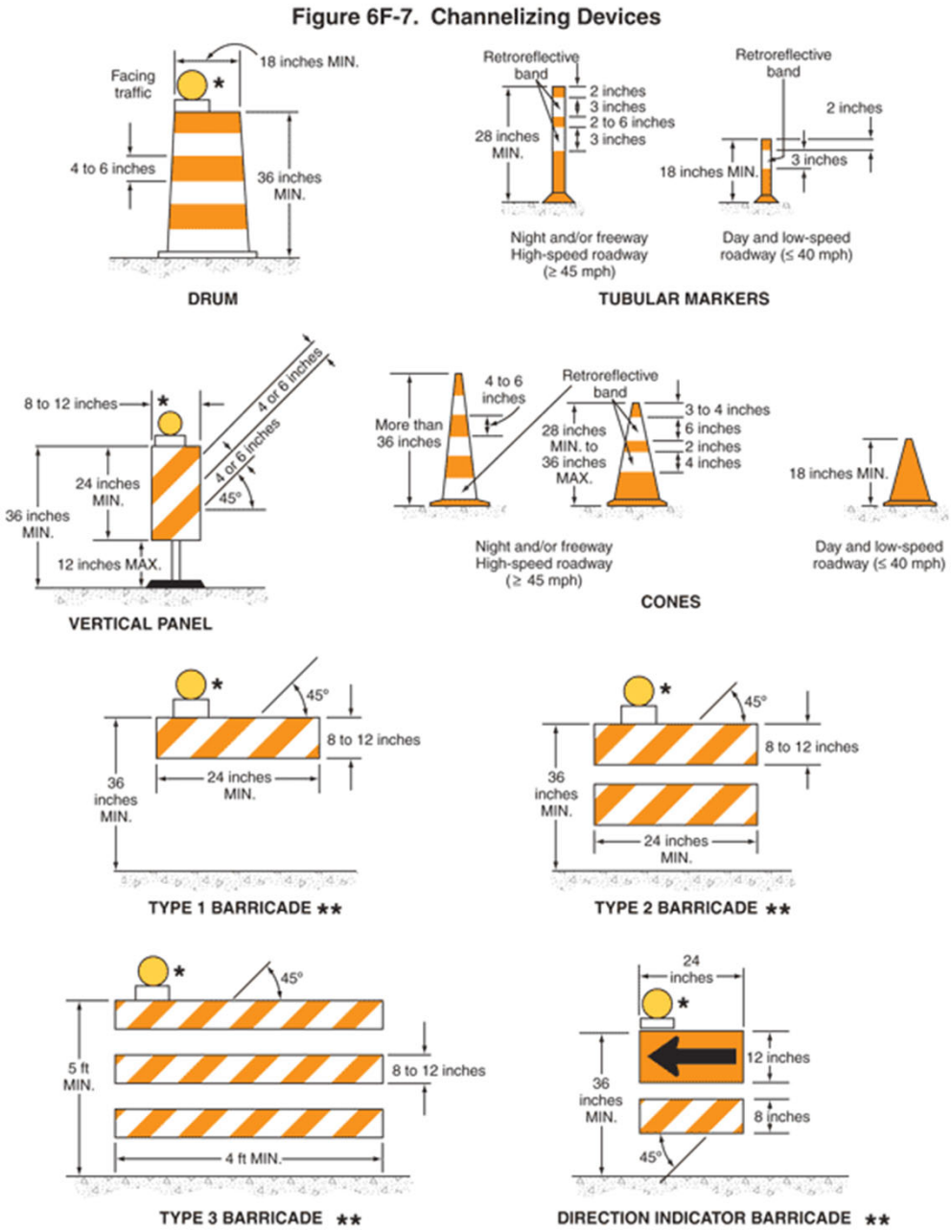
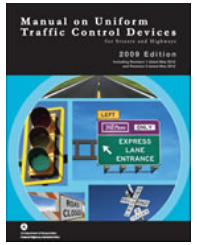


Figure 6F-7. Channelizing Devices
Facing traffic
18 inches MIN.
4 to 6 inches
36 inches MIN.
DRUM
Retroreflective band
2 inches
3 inches
2 to 6 inches
3 inches
28 inches MIN.
Night and/or freeway High-speed roadway (≥ 45 mph)
Retroreflective band
2 inches
3 inches
18 inches MIN.
Day and low-speed roadway (≤ 40 mph)
TUBULAR MARKERS
8 to 12 inches
4 or 6 inches
4 or 6 inches
45°
24 inches MIN.
36 inches MIN.
12 inches MAX.
VERTICAL PANEL
4 to 6 inches
More than 36 inches
Retroreflective band
3 to 4 inches
6 inches
2 inches
4 inches
28 inches MIN. to 36 inches MAX.
Night and/or freeway High-speed roadway (≥ 45 mph)
18 inches MIN.
Day and low-speed roadway (≤ 40 mph)
CONES
45°
8 to 12 inches
36 inches MIN.
24 inches MIN.
TYPE 1 BARRICADE **
45°
8 to 12 inches
36 inches MIN.
24 inches MIN.
TYPE 2 BARRICADE **
45°
5 ft MIN.
8 to 12 inches
4 ft MIN.
TYPE 3 BARRICADE **
24 inches
12 inches
36 inches MIN.
8 inches
45°
DIRECTION INDICATOR BARRICADE **
* Warning lights (optional)
** Rail stripe widths shall be 6 inches, except that 4-inch wide stripes may be used if rail lengths are less than 36 inches. The sides of barricades facing traffic shall have retroreflective rail faces.



MUTCD Sign "Menu"

Figure 6F-4. Warning Signs and Plaques in Temporary Traffic Control Zones (Sheet 1 of 3)

Figure 6F-5. Exit Open and Closed and Detour Signs

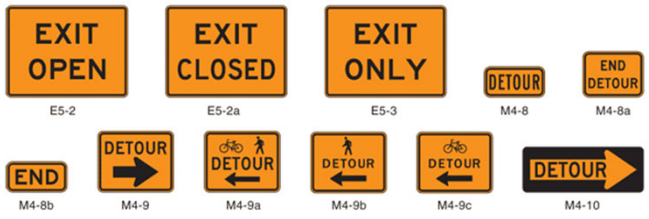


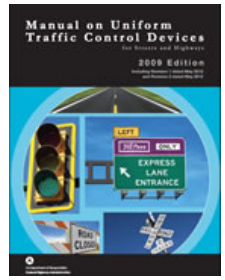
Figure 6F-4. Warning Signs and Plaques in Temporary Traffic Control Zones (Sheet 2 of 3)

Figure 6F-4. Warning Signs and Plaques in Temporary Traffic Control Zones (Sheet 3 of 3)

* An optional STREET WORK word message sign is shown in the "Standard Highway Signs and Markings" book.
** An optional STREET CLOSED word message sign is shown in the "Standard Highway Signs and Markings" book.
*** An optional FLAGGER (W20-7a) word message sign is shown in the "Standard Highway Signs and Markings" book.
**** An optional FRESH TAR word message sign is show in the "Standard Highway Signs and Markings" book.

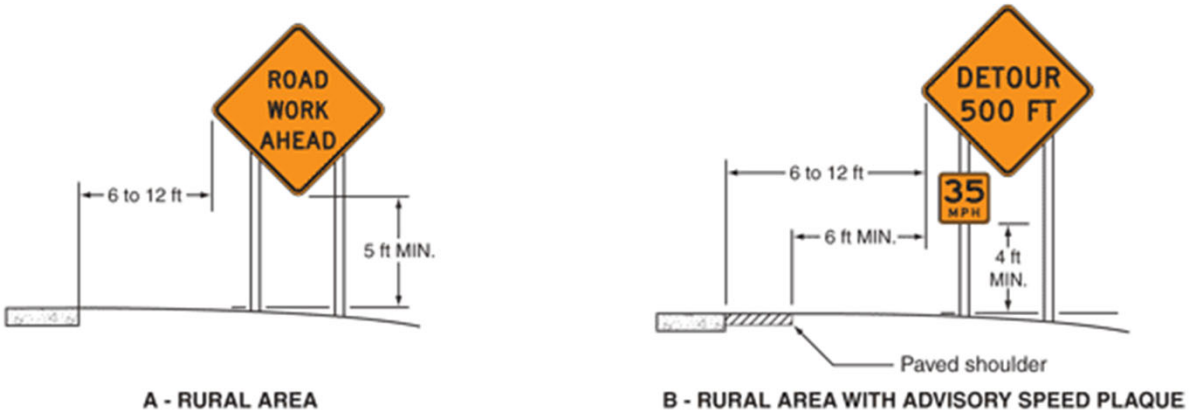
Unique or Special Situation Signs

What are your options if the sign you need/want is not on the MUTCD “menu”?



Mounting Height

Figure 6F-1. Height and Lateral Location of Signs—Typical Installations



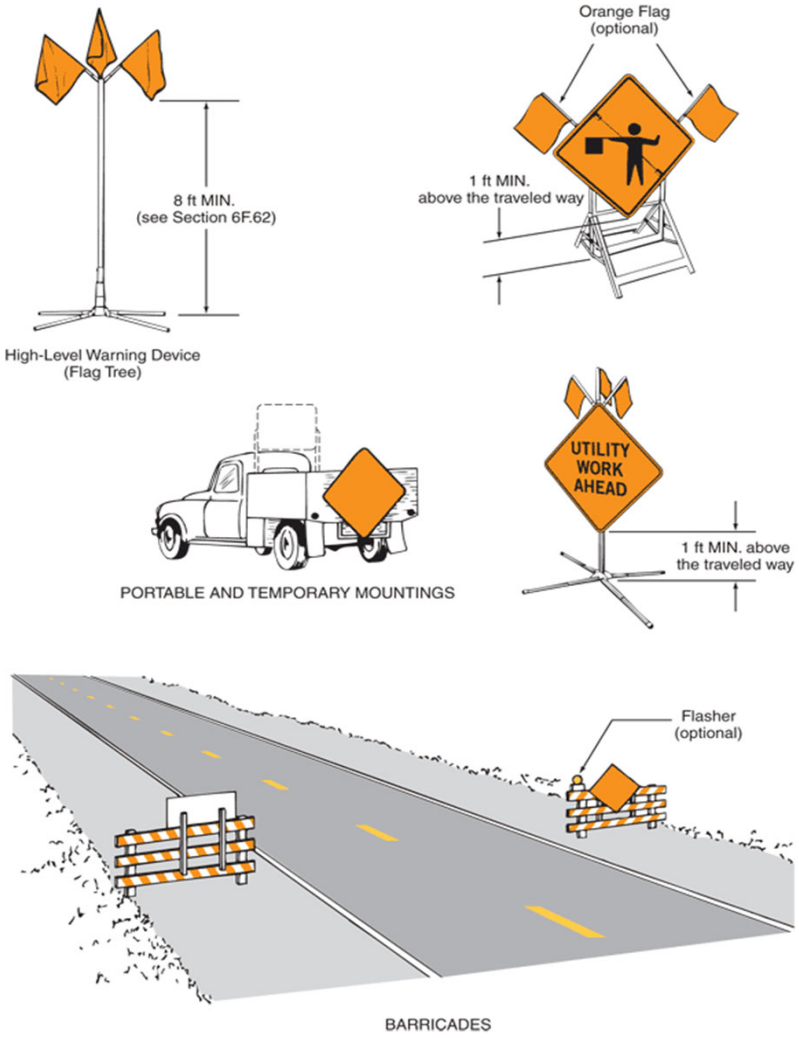
A - RURAL AREA

B - RURAL AREA WITH ADVISORY SPEED PLAQUE

C - BUSINESS, COMMERCIAL, OR RESIDENTIAL AREA

D - BUSINESS, COMMERCIAL, OR RESIDENTIAL AREA (WITHOUT CURB)

Figure 6F-2. Methods of Mounting Signs Other Than on Posts



Specifying Crashworthy Devices

In the old days, Type III barricades were "sturdy." This is the result.

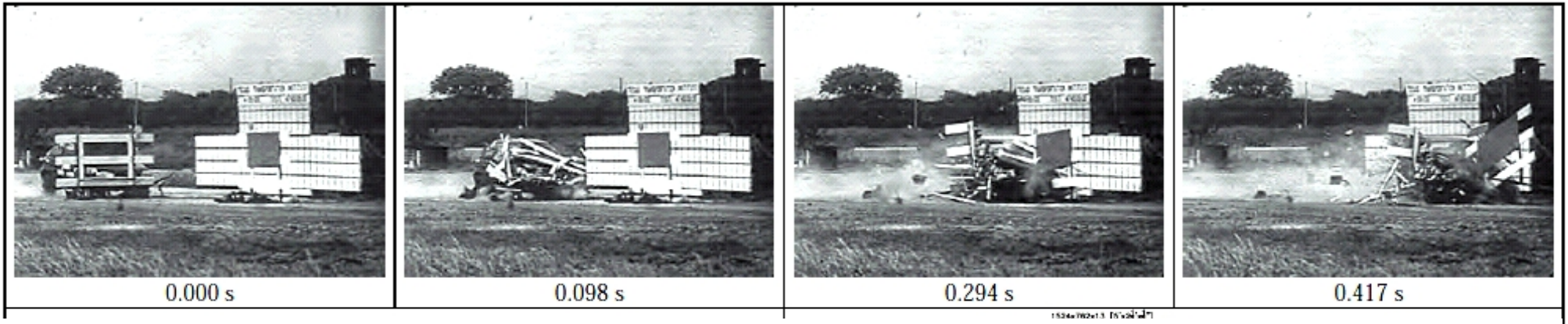


Figure 6.20. Vehicle after Test 3.

Crashworthy Devices

NCHRP Reports 350 (Safety Performance Evaluation of Highway Features)
NCHRP 553 (Crashworthy Work-Zone Traffic Control Devices)
AASHTO Manual for Assessing Safety Hardware (MASH)

Cones, Barrels & Delineators

- Lightweight devices (<100 lb)
- Good crash history
- Vendors self-certify
- *If used, lights must be firmly attached to drums.*

Barricades & Sign Supports

- Subtle design features affect crashworthiness
- Freeways: Level 3 crash test required – 62 mph
- Several generic designs tested to NCHRP 350 criteria
- MASH tests required in future

Approved Portable Mounting Systems

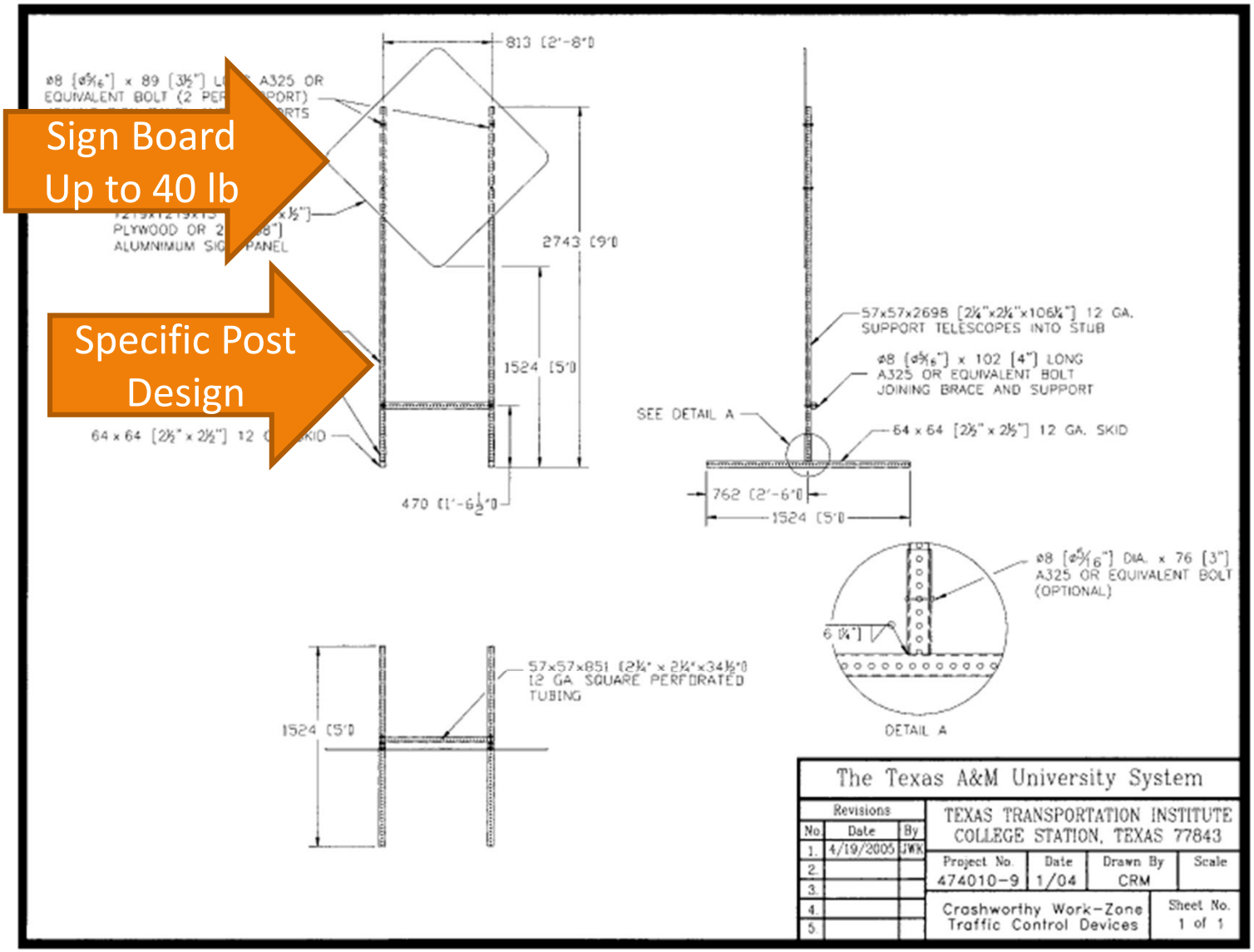
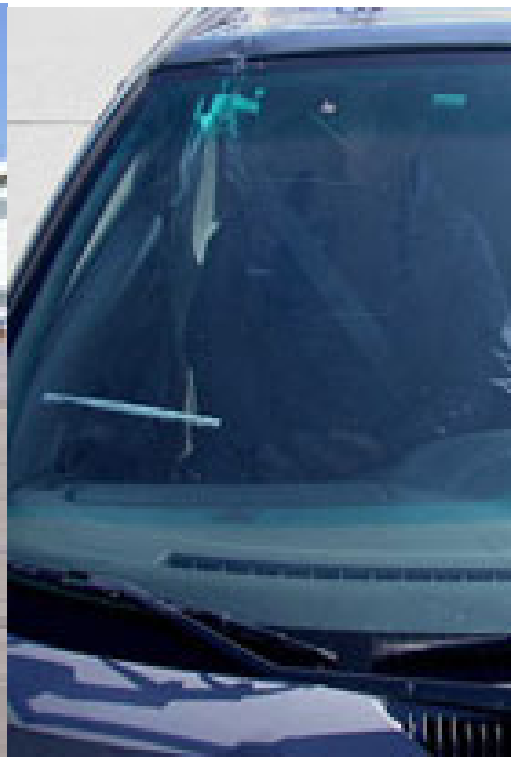


Figure 9.8. Details of the strong dual-upright sign support system with sign panel mounted at a height of 1.5 m (5 ft).

Crash Testing Necessary to Validate Crashworthy Performance

90° Test Of Michigan Standard Sign



Redesigned with Stiffer Uprights

Crashworthy Temporary Sign Supports

https://www.youtube.com/watch?v=CBb44Kkan8g

Untested Devices

Source: Wisconsin DOT

Where To Find Crashworthy Systems:

FHWA Policy and Guidance Center
Countermeasures that reduce crash severity

https://safety.fhwa.dot.gov/roadway_dept/countermeasures/reduce_crash_severity/

Other Devices

Barriers, Longitudinal Barricades & Crash Cushions

- Extensive crash testing required
- *Proper installation is essential*

Trailer-Mounted Equipment

- Crash testing currently not required
- Delineate
- Shield where possible
- Remove when not needed

Source: John Shaw

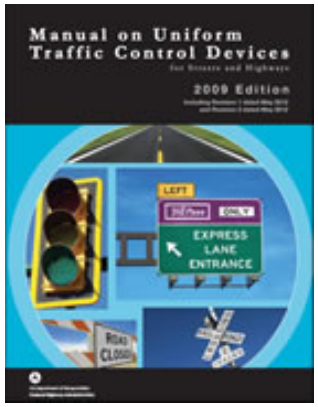
Agency Standard Detail Drawings (SDDs)

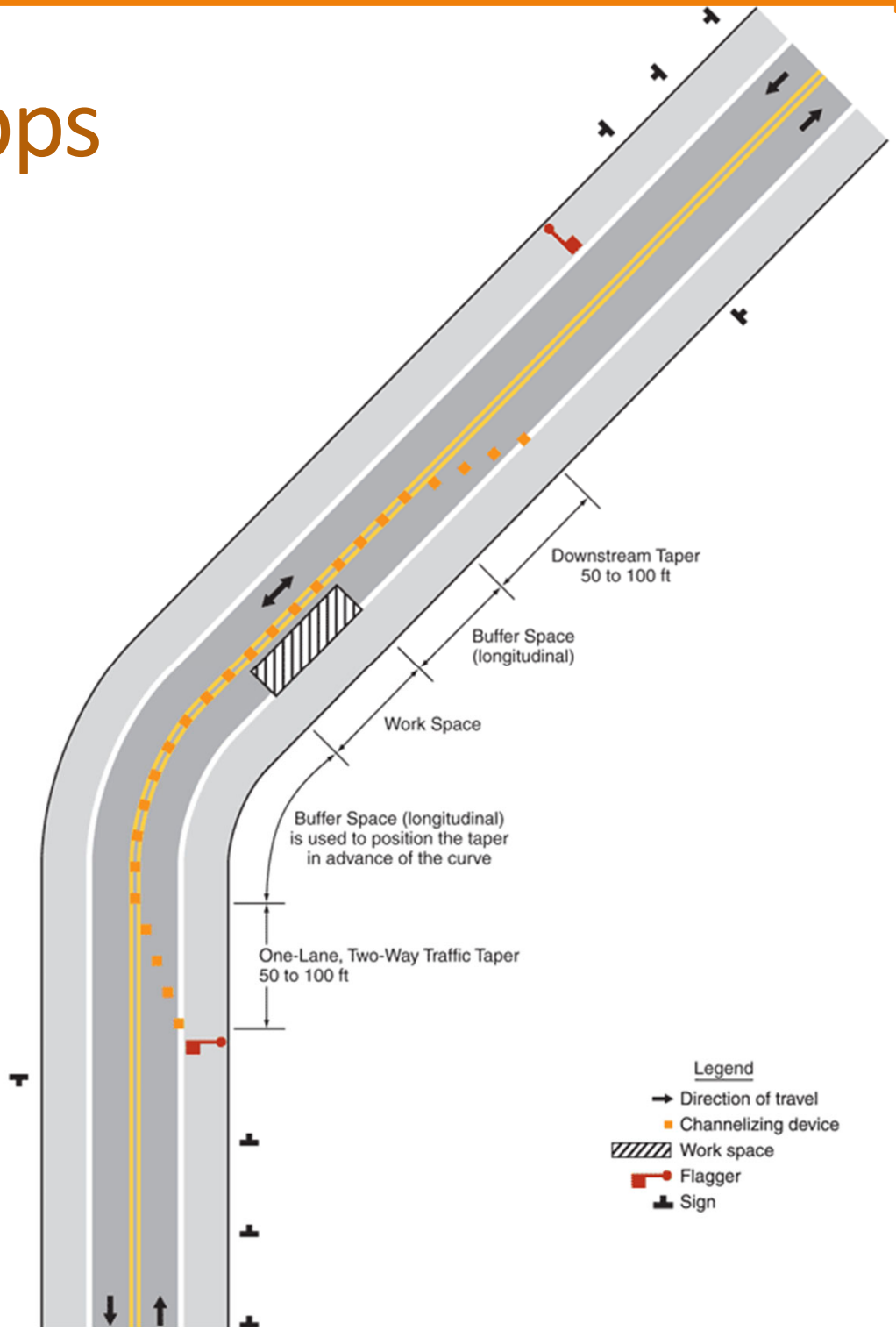
- Mainline closures & detour signing
- Advance warning signs
- Signing for moving operations
- Signing for lane closures with barriers
- Ramp construction staging
- Single lane crossover with barrier
- Two lane closure
- Exit and entrance ramp closure
- Intersection within single lane closure
- Shoulder closure
- Temporary bypass, etc.

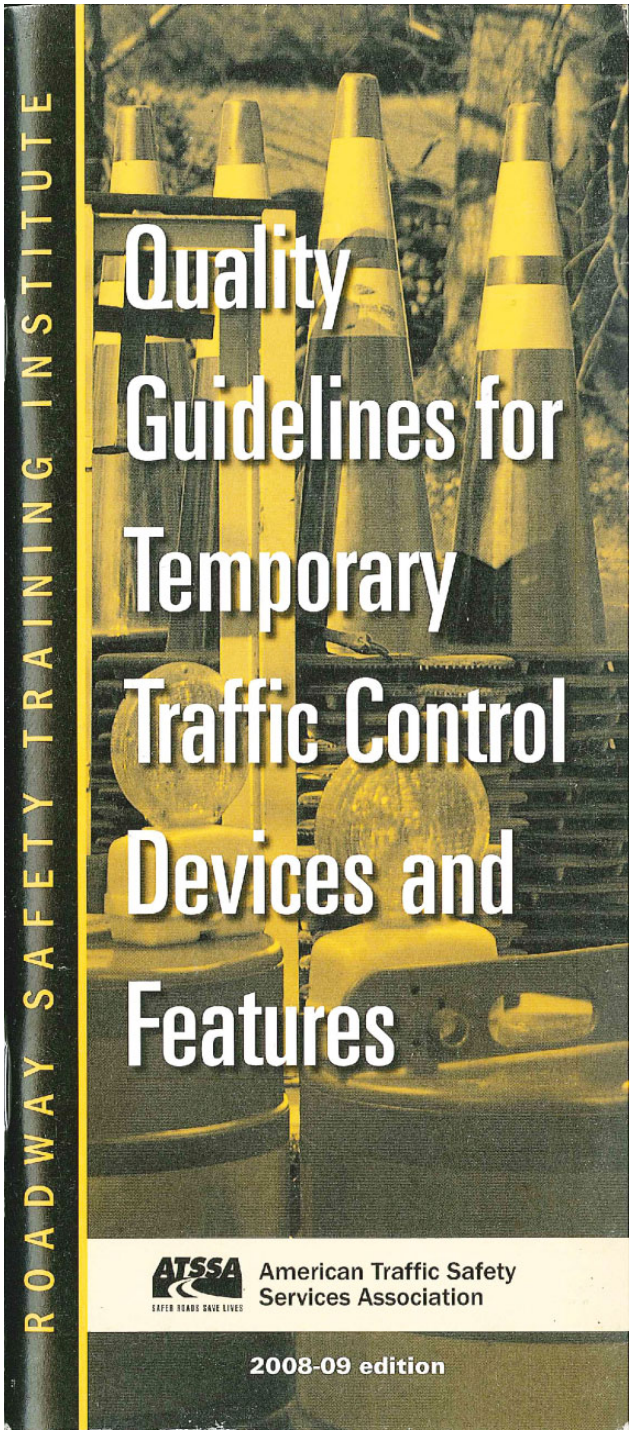
Common Traffic Management Techniques

- One-Lane, Two-Way Traffic Control
- Lane constriction
- Intermittent closure
- Lane closure
- Two-way operation on one-side of a divided highway
- Using shoulder, or portion of shoulder, as a driving lane(s)
- Construct temporary bypass lane(s)
- Diverting a portion of the traffic
- Full road closure with all traffic diverted

Typical Apps







ATSSA TTC Quality Guide

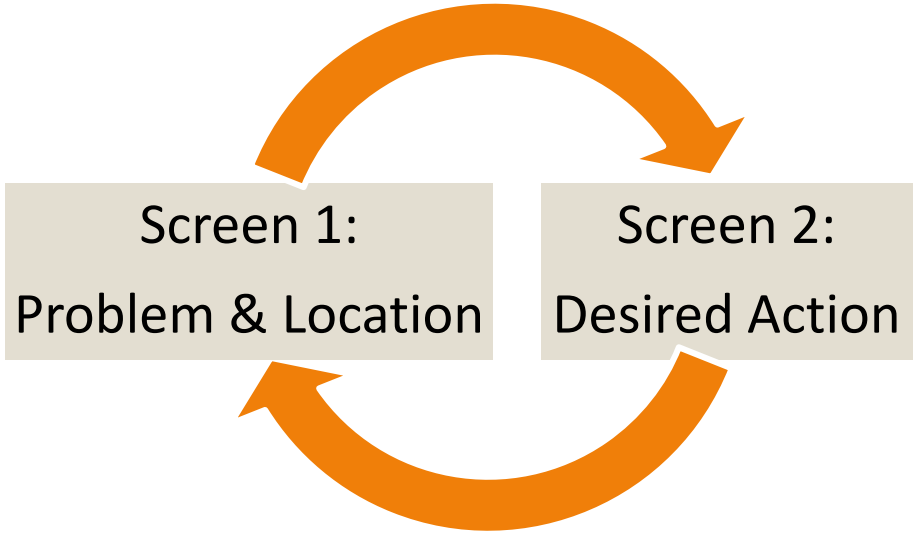
Acceptable

Marginal

Unacceptable

PCMS Principles

- Two phases maximum
- Understandable in either order
- Readable at highway speed
- MUTCD-compliant messages and abbreviations



NCHRP 581:

Design of Construction Work Zones on High-Speed Highways

Chapter 1: Introduction

Chapter 2: Design Controls and Principles

Chapter 3: Conceptual Design and Planning of Work Zones

Chapter 4: Roadway Design

Chapter 5: Roadside Design and Barrier Placement

Chapter 6: Ancillary Design Information

NCHRP 581:

Content Examples

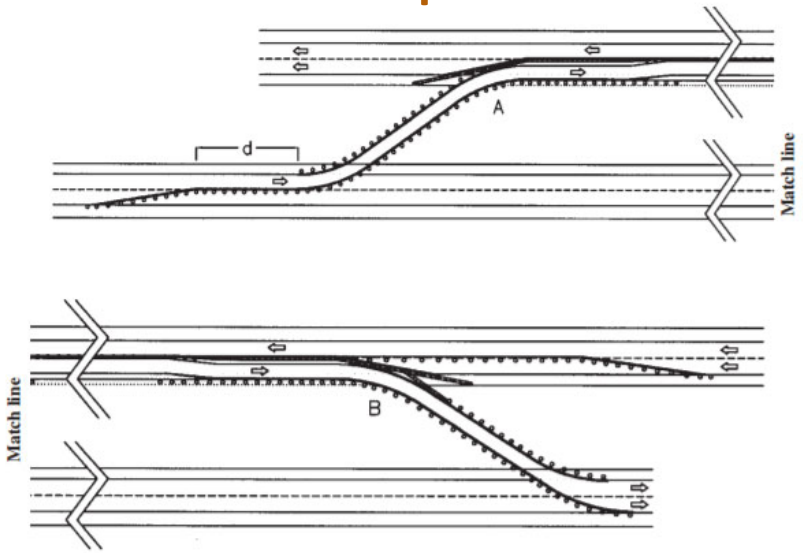


Exhibit 4-7. Example plan view of median crossover.

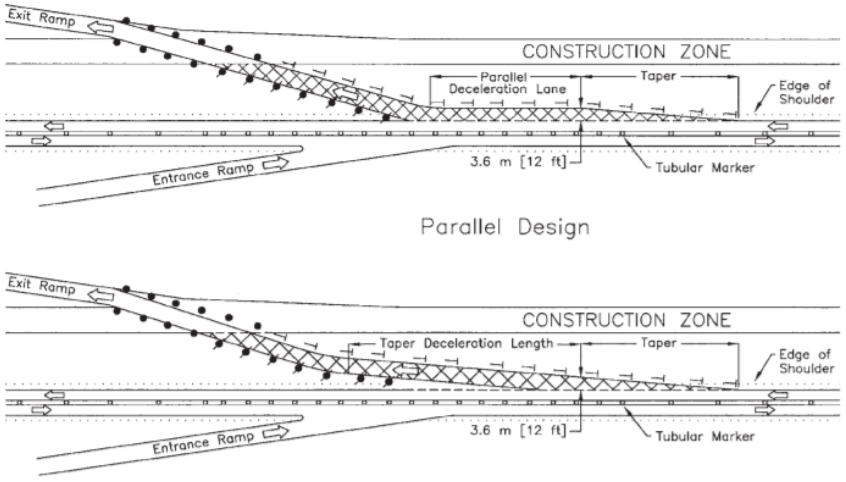


Exhibit 4-15. Temporary interchange exit ramp for a median crossover.

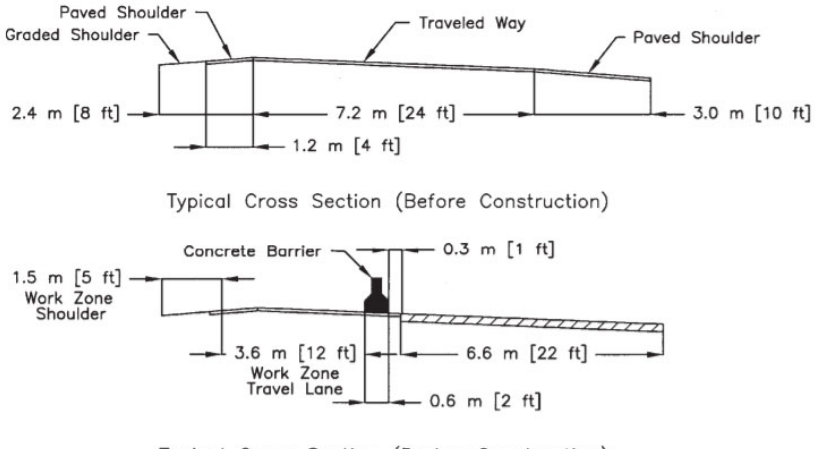


Exhibit 5-3. Cross sections for outside lane and shoulder closure for part-width construction on a four-lane divided highway.

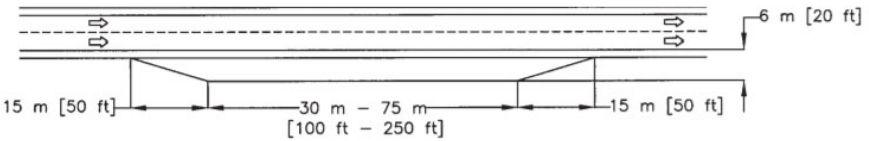
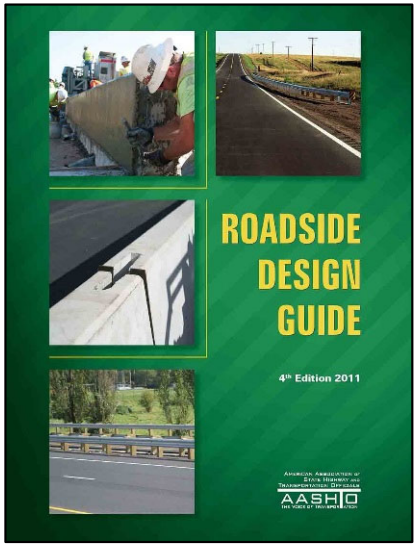
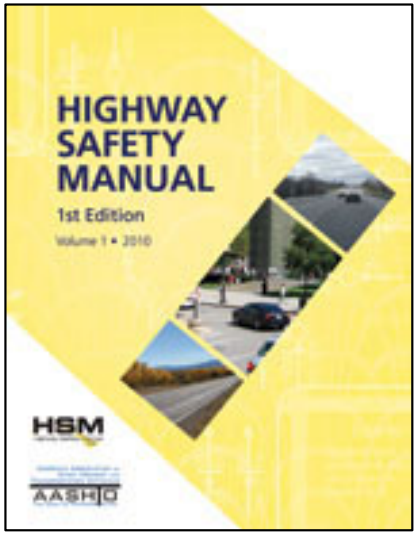


Exhibit 6-3. Example emergency turnout.

AASHTO Resources

- **AASHTO A Policy on Geometric Design of Highways and Streets (Green Book):** Limited guidance on work zones.
- **AASHTO Roadside Design Guide:** Chapter 9 discusses traffic barriers, traffic control devices and other features in work zones.
- **AASHTO Highway Safety Manual:** Includes methods for estimating increase in crashes due to construction.





Fundamental Principles

1: Know Your Site

Street View and Photolog are useful, but there is still no substitute for spending time at the site:

- 3D geometrics – physical dimensions
- How motorized and non-motorized traffic/users make use of the facility
- Differences between night and day
- Quality of detour/alternate routes – safety, pavement condition, lane widths, grades, degree of curvature, truck route? Require mitigation improvements?
- Interaction with other roadways and infrastructure

"Only through endless walking can the designer absorb into his being the true scale of…spaces." --Edmund Bacon *Design of Cities,* 1974

2: Accommodate All Users at All Times

Plan and design for the safe accommodation of all road users during every stage of construction:

- Pedestrians and bicyclists
- Transit vehicles and riders
- Motor vehicles including motorcycles
- Heavy trucks (including those carrying hazardous materials and oversize/overweight loads that require state issued permits)
- Construction-related traffic
- Incident management vehicles

Challenges:

- Adequate accommodation for infrequent types of road users
- Stage changes and other transitional periods
- Extended lulls in construction activity
- Adverse weather and lighting conditions
- Access to properties adjacent to the roadway

3: Make the Work Zone "Self-Explaining"

- Keep geometrics and roadside design as similar to permanent layouts as site conditions allow
- Provide visual cues that show drivers what speed and maneuvers are appropriate
- Make transitions gradually and delineate them clearly
- Provide clear route guidance
- Avoid over-reliance on signage
- Avoid frequent or abrupt changes in geometrics and number of lanes
- Avoid abrupt increases and decreases in running speeds
- Avoid violating driver expectations

Also see: MUTCD Section 5G.01

4: Manage Queueing and Delay

Know your traffic:

- Get data about how traffic volume varies by season, day of week, and time of day.
- Identify periods with unusually high/low volumes of pedestrians, buses, heavy trucks, etc.
- Evaluate site-specific traffic effects of holidays and events

Obtain a traffic analysis and use its results to manage traffic impacts:

- Adjust lane closure days/hours to minimize queuing and delay
- Provide queue warning to prevent back-of-queue crashes
- Manage queues by encouraging diversion of excess flow to alternate routes

5: Make Sensible Investments in Alternate Routes

- Provide clear alternate route signing and marking
- Resolve localized bottlenecks such as insufficient left turn capacity
- Improve signal timing and progression
  - Fix malfunctioning loop detectors, etc.
  - Install GPS-based controller clocks to maintain tight coordination
- Address issues that disproportionately affect throughput:
  - Illegal parking
  - Loading zones
  - Poorly-positioned bus stops

6: Expect the Unexpected

Design-in a contingency plan for:

- Traffic incidents in the work zone
- Occupational injuries on the work site
- Lost/misdirected motorists
- Lost/misdirected materials delivery vehicles
- Construction delays

7: Coordinate with Other Agencies & Organizations

Reduce unexpected and unusual situations by coordinating plan preparation with:

- Other highway agencies
- Transit
- Law enforcement & other emergency responders
- Schools
- Utilities
- Railroads

8: Include Appropriate Contractual Provisions

- Training requirements for workers and their supervisors
- Routine inspection of traffic control elements
- Inspection and maintenance of roadside safety

9: Promote worker and road user safety

- Be alert for site defects and point them out to someone who can resolve them.
- Stay up-to-date on best practices for work zone safety.
- Mentor junior staff about common pitfalls and their solutions.
- Encourage sharing of technical information about work zone design, including both positive and negative examples.
- Encourage constructive dialogue on procedures, policies, standards, and legislation that can improve work zone safety.
- Use project-related public outreach to reinforce work zone safety messages.
- Set a positive example by complying with traffic laws and using safe practices when driving through work zones.

Class Exercise

- A suburban arterial normally operates at 45 to 50 mph.
- During construction the safe running speed will be about 35 mph.
- What could you do to give the roadway the “feel” of a 35 mph facility?

Class Exercise

Situation

- A suburban arterial normally operates at 45 to 50 mph.
- During construction the safe running speed will be about 35 mph.
- What could you do to give the roadway the “feel” of a 35 mph facility?

Potential Tactics

- Install advisory 35 mph speed signs.
- Space the channelizing devices closely.
- Use temporary pavement marking or a double row of channelizing devices to narrow the lanes and provide a wider lateral buffer for worker protection.
- Install temporary fencing along the outside curbline to make the road space look narrower to drivers and keep pedestrians out of the work zone.
- Create temporary pedestrian refuges to allow two-stage crossings and emphasize ped/bike safety.
- Require construction vehicles, contractor vehicles, and agency vehicles to observe a 35 mph maximum speed.
- Time the traffic signals for 35 mph progression and provide signage indicating that this is the case.

Traffic Management Exposure Control Measures

Exposure control can be accomplished by diverting some or all traffic away from the work site, reducing the duration to complete the project, or altering the time when work is conducted.

- Off Peak or Night Work Zone Operations
- Contracting Strategies to Expedite Completion
- Innovative Construction Techniques to Expedite Completion

Off Peak or Night Work Zone Operations

Source: Pavementinteractive.org

Construction Techniques to Expedite Completion

Slide-In Bridge Construction

Source: FHWA

Construction Techniques to Expedite Completion

Precast Concrete Panel Pavement Systems

Source: FHWA

Frequent Design Problems

Sign Clutter

Photo: Transport Research Laboratory

British Example

- Overuse of traffic signs can dilute important messages and cause information overload.
- Even without construction, many locations are cluttered with traffic signs and advertising.
- Adding work zone signs can worsen clutter, especially if all permanent signs remain in place.

- *Is there enough time to read and mentally process all signs at normal driving speed?*
- *Are some signs hidden by others?*

Sign Clutter Reduction

High Priority

Low Priority

- Determine and prioritize all permanent and temporary messages
  1. Regulations and essential safety messages
  2. Major routing decisions
  3. Informational / “nice to have”
- Evaluate sign spacing and legibility
- Purge illegal advertising signs
- Remove or cover unnecessary signs
- Position pedestrian, bike, and transit signs where they are less likely to distract motorists
- Where possible, simplify wording and graphic design of signs

Pavement Edge Drops

Source: Wisconsin DOT

- Edge drop hazards → rollover crash risk
- Verify grade differences during plans development
- Mitigation methods:
  - Temporary barriers
  - Temporary backfill
  - Adjust/revise grades
  - Change construction sequence
  - Limit traffic to low speed

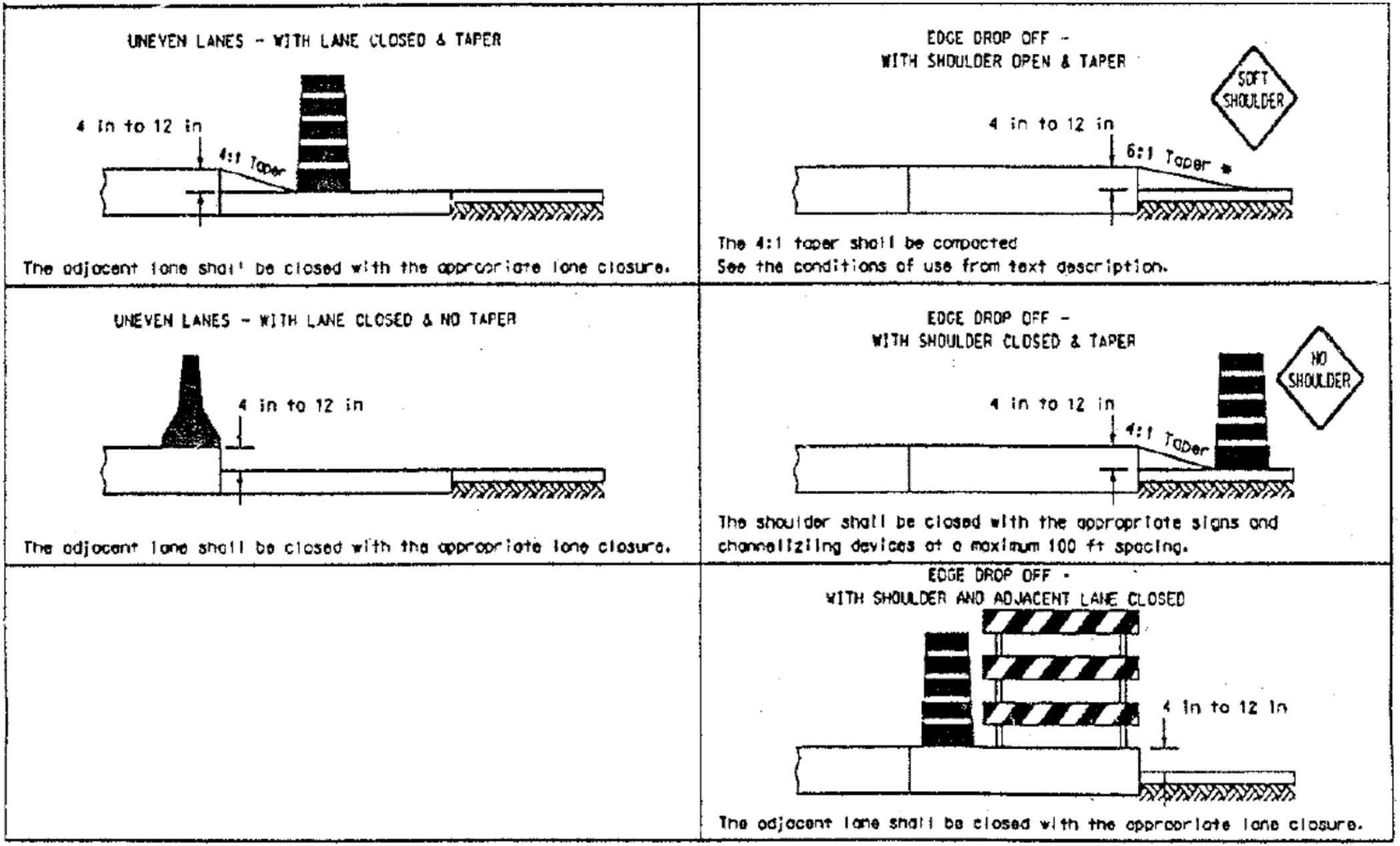


Figure 25. North Dakota's Longitudinal Edge Drop-Off Guidelines

Constructability

What is Constructability?

Constructability is a pre-construction process exploring:

- Extent to which a design facilitates **ease of construction**, subject to the overall requirements for the completed project.
- A system for **integration of construction knowledge and experience** in planning, engineering, procurement, and field operations in the building process.
- **A process for balancing various project and environmental constraints** to maximize achievement of project goals.

Source: Institute of Professional Engineers of New Zealand, Practice Note #13 (2008)

Constructability includes:

- Review of completeness and adequacy of project documentation.
- Analysis of buildability, scheduling, logical sequencing, and complexity of project elements.

Construction of the Eiffel Tower, May 1888

Consequences of Poor Constructability

Constructability issues can result in:

- Traffic delays
- Construction delays
- Change orders / cost overruns
- Disputes
- Public/political dissatisfaction with project delivery
- Claims that the PS&E package was inadequate

Source: Institute of Professional Engineers of New Zealand, Practice Note #13 (2008)

Common Constructability Issues

- Conflicting work operations requiring the same physical space.
- Work operations and traffic management requiring the same space.
- Inability to get materials in/out of a work area efficiently.
- Inability to use areas (for construction or for traffic) because work elsewhere is not completed.
- *They are often made worse when there are two or more contracts, contractors, or agencies doing work in the same area.*

Constructability Tools

- Clear project objectives
- Independent plan reviews
- 3D renderings of each project stage

Construction of the Eiffel Tower, December 1888

Class Discussion

- What are some constructability issues you have encountered in your previous projects?
- What were the mobility and safety impacts?
- How did you communicate the problem to others in your organization?
- How did you resolve the problem?
- What steps are being taken to avoid similar problems in the future?

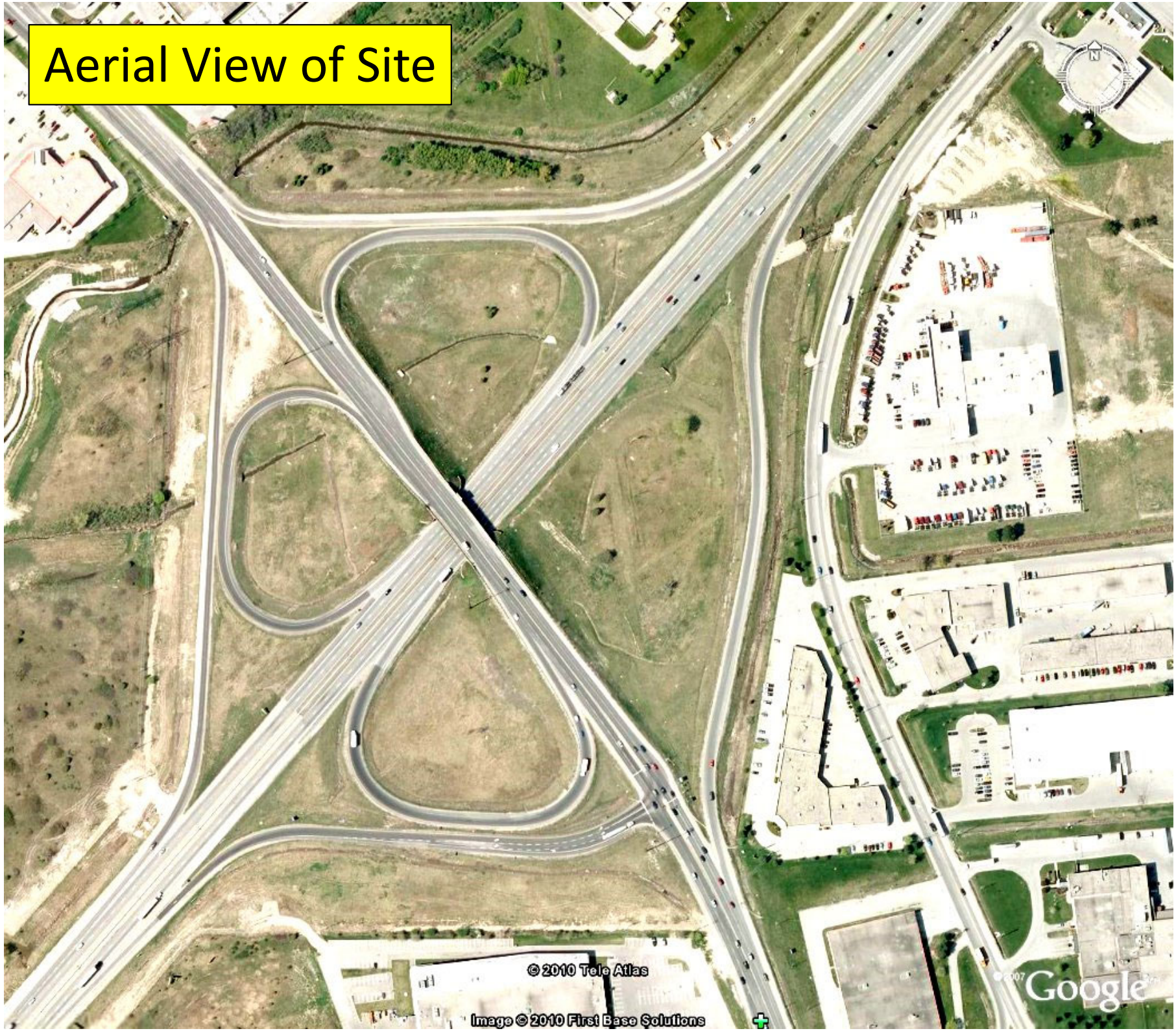
Staging Alternatives

A Small Group Exercise

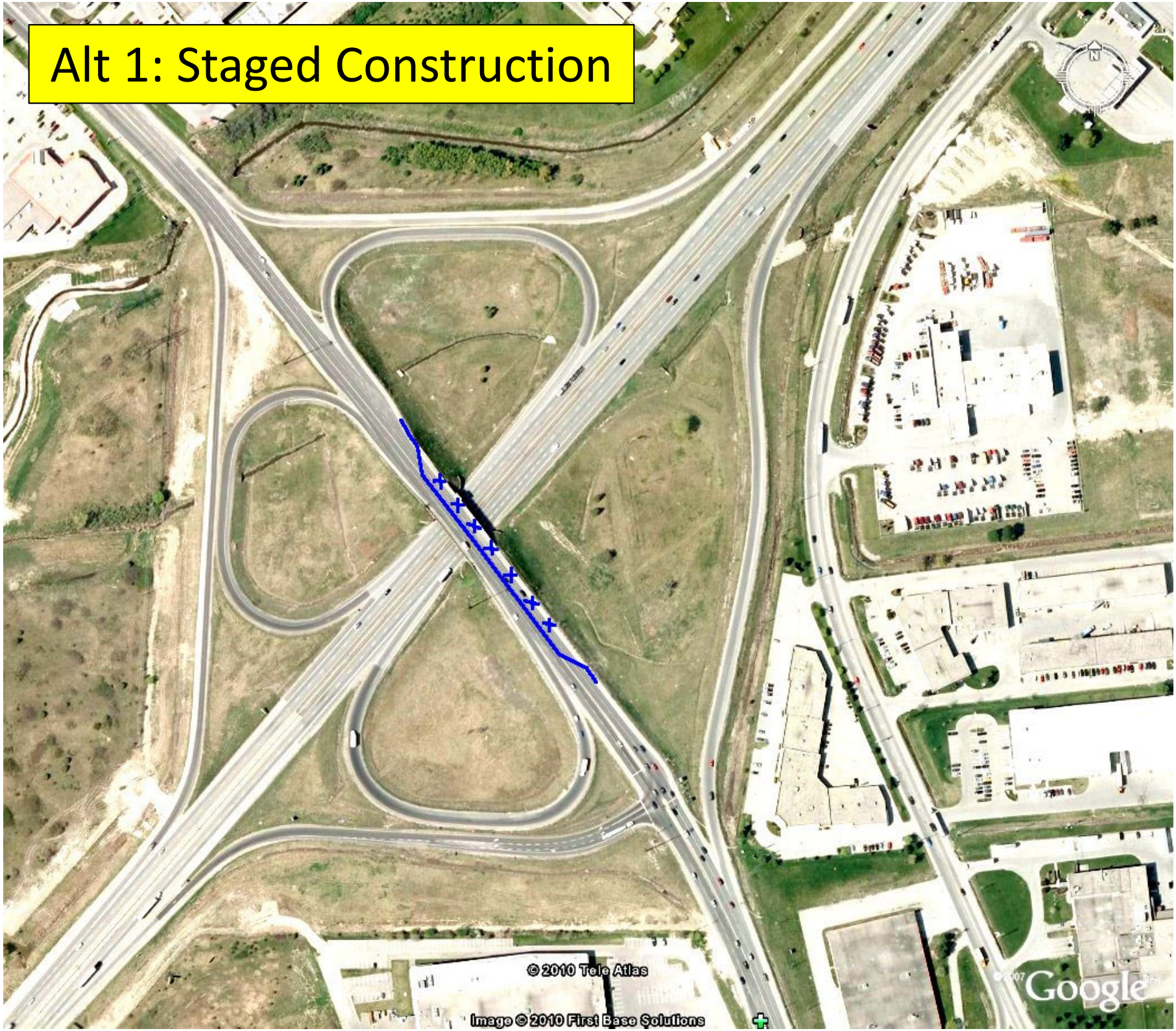
Re-Decking Wellington Rd Bridge

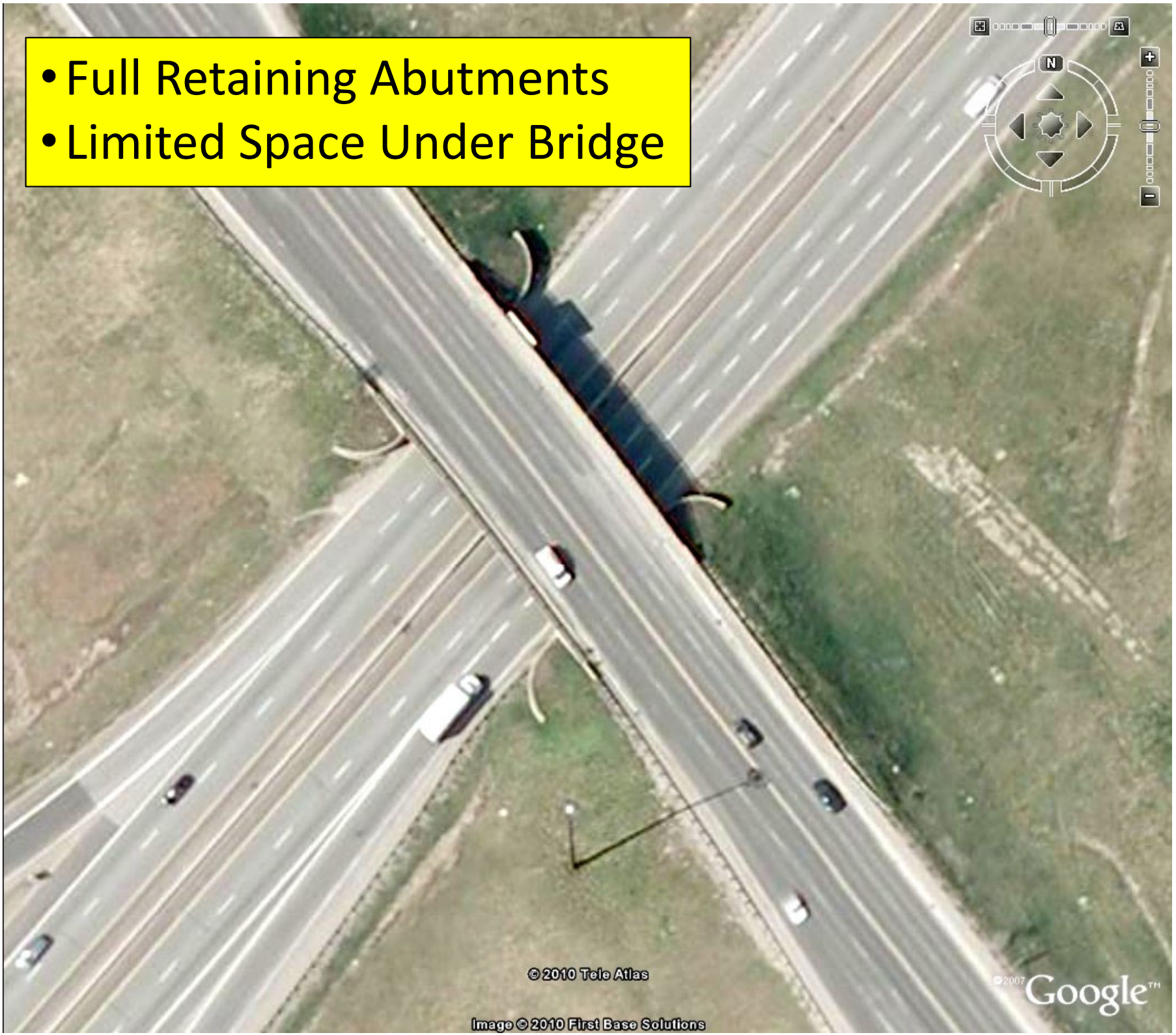
Re-Decking Wellington Rd Bridge

Aerial View of Site



Alt 1: Staged Construction




• Full Retaining Abutments
• Limited Space Under Bridge
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Staging Considerations:
• Demolition Debris
• Work Duration
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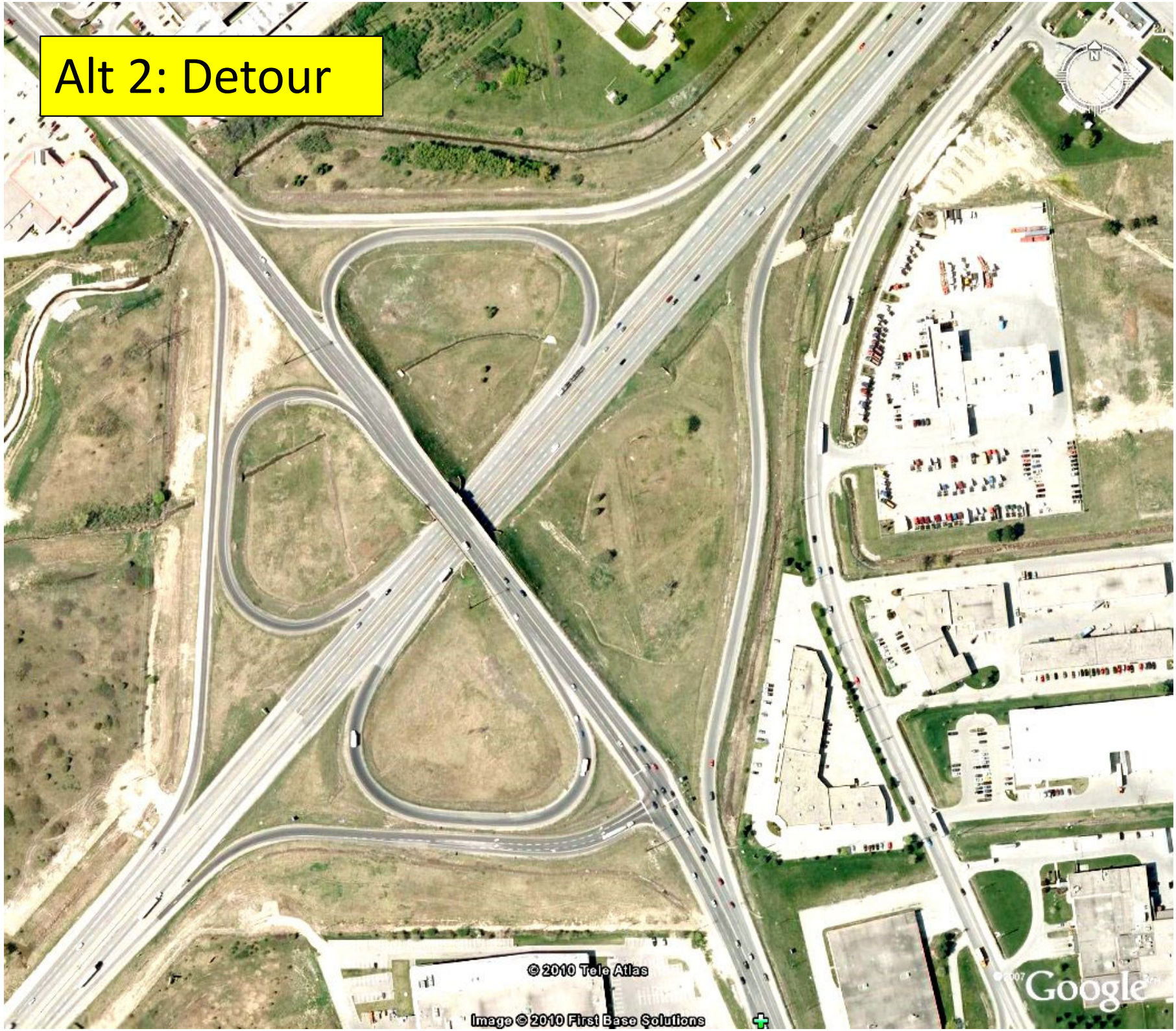
Alt 2: Detour
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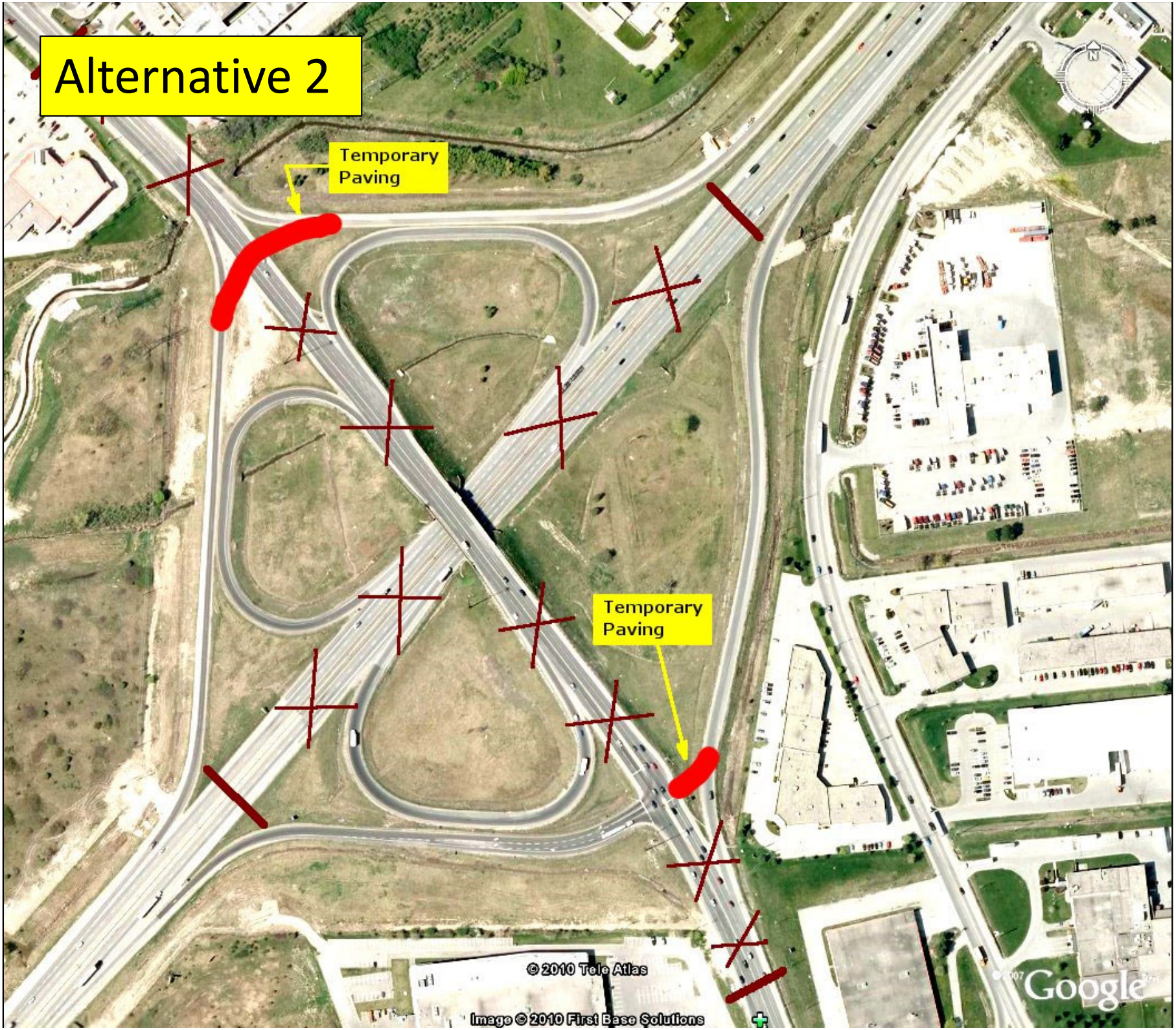
Alternative 2
Temporary Paving
Temporary Paving
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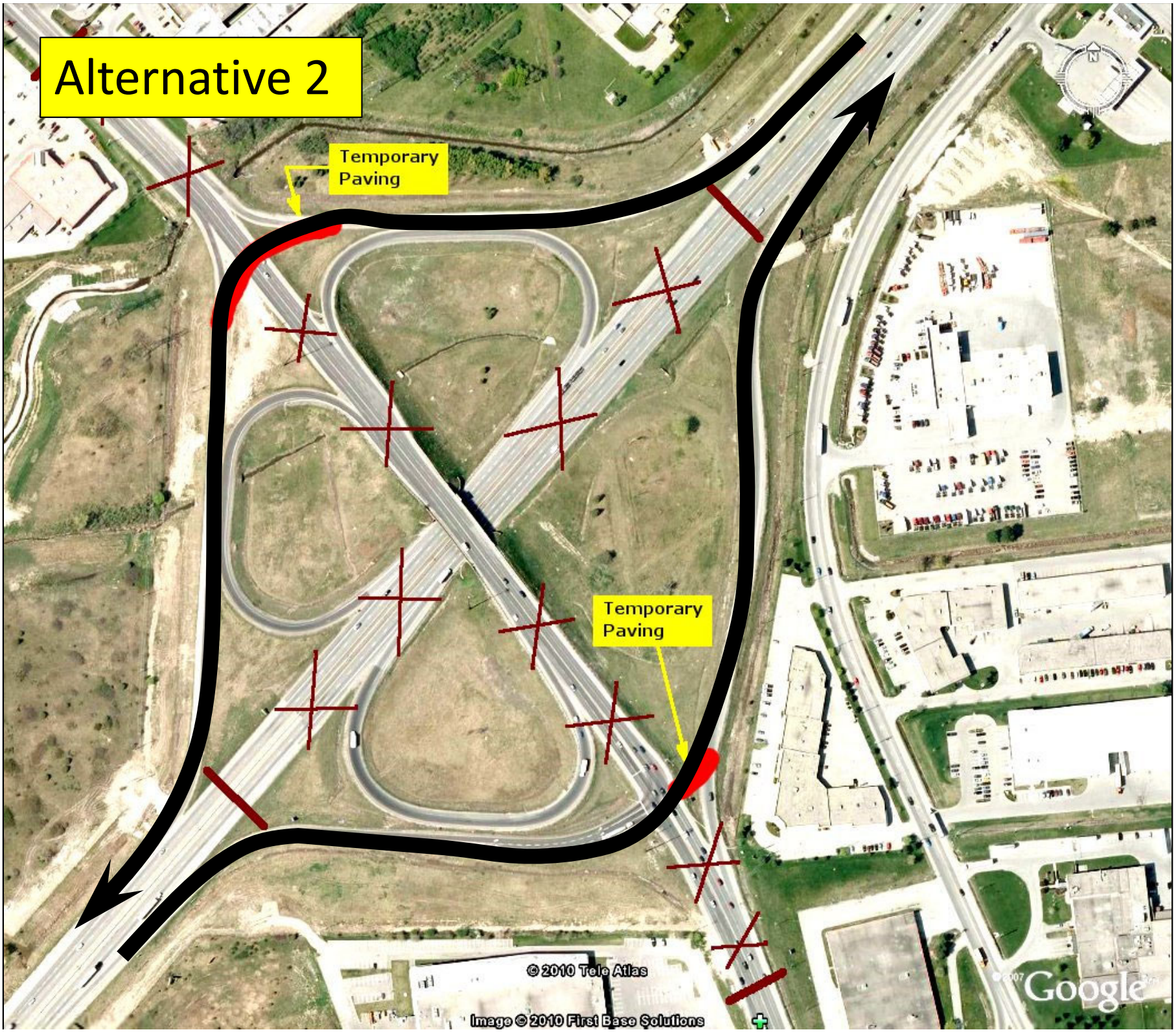
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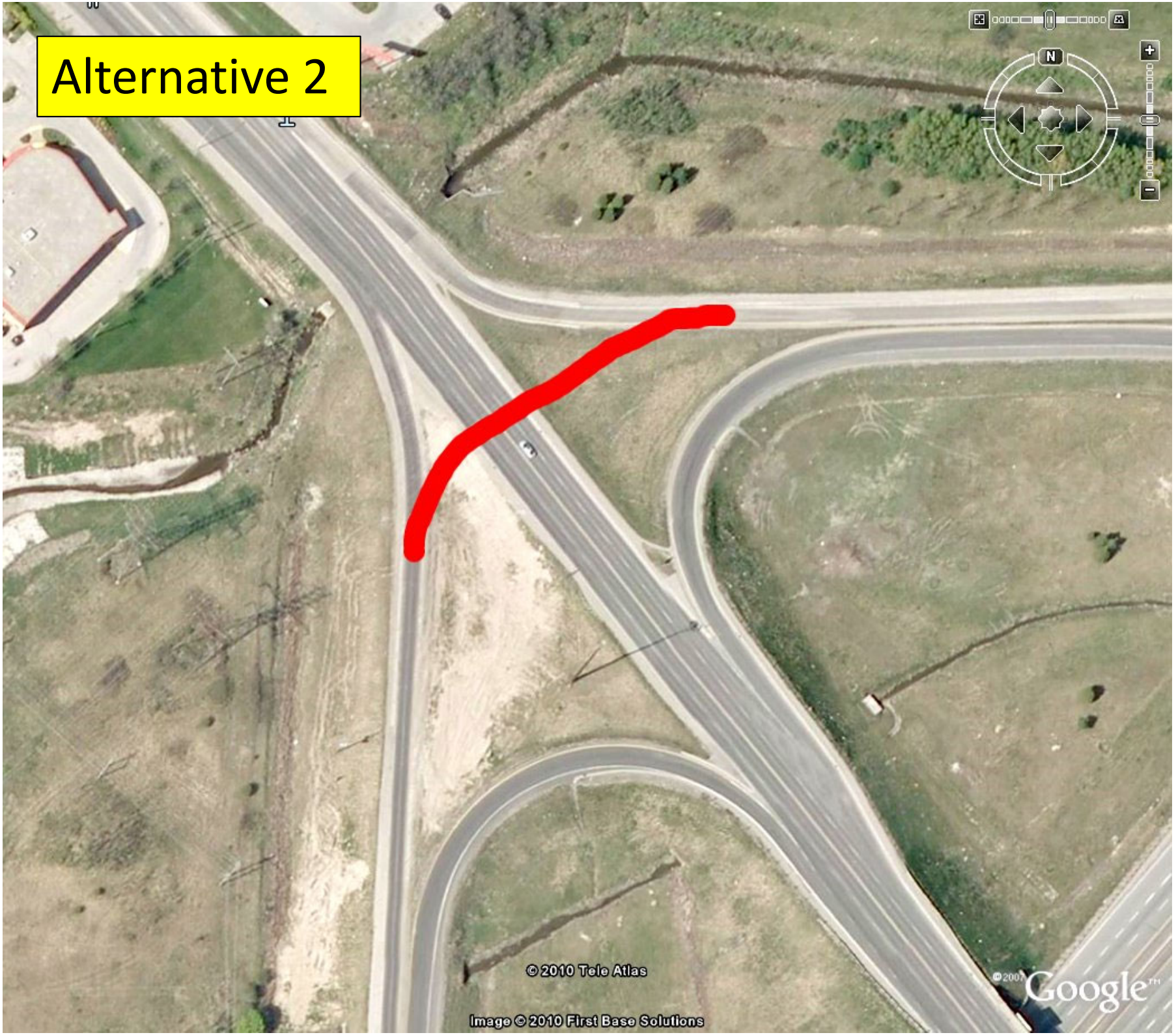
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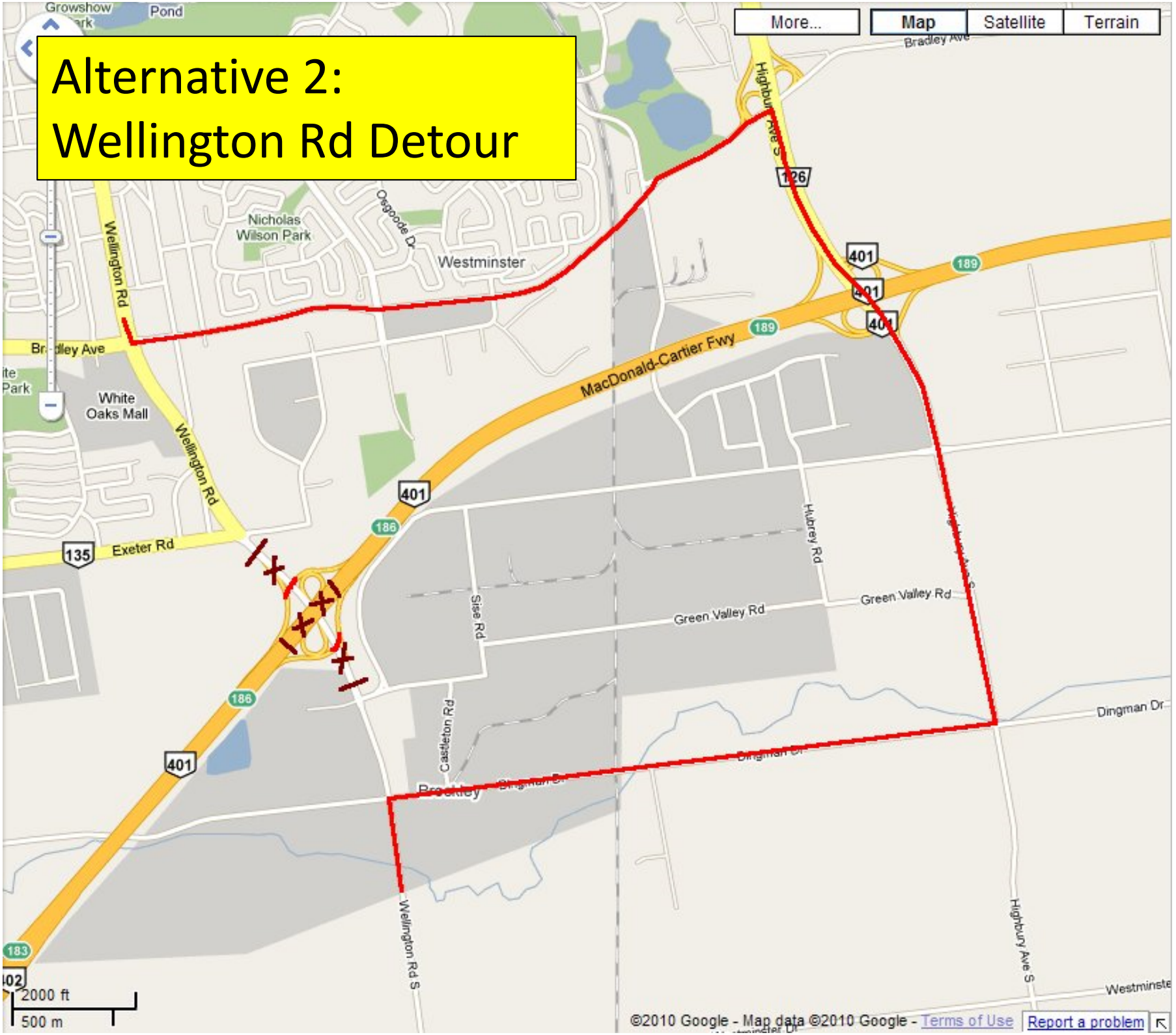
Alternative 2:
Wellington Rd Detour
More...
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Highbury Ave S
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Nicholas Wilson Park
Osgoode Dr
Westminster
Wellington Rd
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MacDonald-Cartier Fwy
White Oaks Mall
Exeter Rd
135
186
Hubrey Rd
Green Valley Rd
Sisse Rd
Castleton Rd
Dingman Dr
Wellington Rd S
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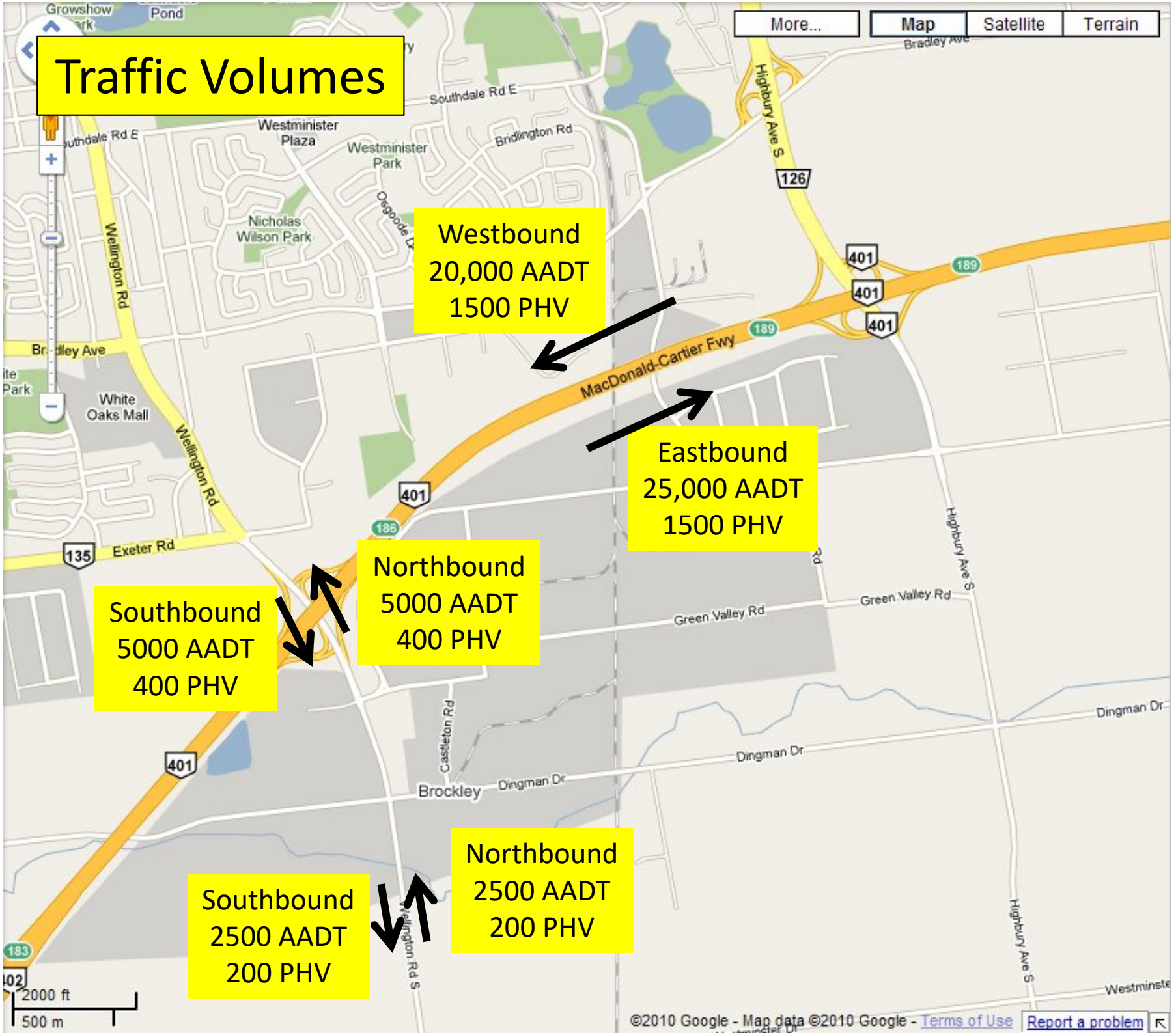
Traffic Volumes
Westbound
20,000 AADT
1500 PHV
Eastbound
25,000 AADT
1500 PHV
Northbound
5000 AADT
400 PHV
Southbound
5000 AADT
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Northbound
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Southbound
2500 AADT
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More...
Map
Satellite
Terrain
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Westminister Plaza
Westminister Park
Bridlington Rd
Highbury Ave S
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Nicholas Wilson Park
Wellington Rd
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Green Valley Rd
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Brockley
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