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Purpose

The purpose of the Wisconsin DOT Traffic Engineering & Operations Guide is to familiarize engineers with ITS elements and the process and information necessary to design Intelligent Transportation System (ITS) elements for WisDOT. ITS elements have many similarities to traffic signal and roadway lighting elements, but also have many unique characteristics and considerations. The intended audience for the guide is WisDOT regional traffic staff, regional design staff, and consultants. The guide is written at a level that assumes working knowledge of signal design, roadway signing design, and electrical design as it applies to roadway design elements.

This guide is intended to be a living document; hence, it will be revised periodically to reflect new requirements and advancements in technology. It will also be changed to make it more useful to its readers. The guide is maintained by the Division of Transportation System Development - Bureau of Highway Operations (DTSD-BHO) Traffic Engineering Section. The procedure to revise the manual is explained below.

1. Notify Bureau of Highway Operations - Design manual users should contact the BHO with any problems or errors they perceive with the manual and provide a proposed solution. The key is to be specific in identifying what the problem is, where it exists in the manual and how you think it can be fixed.
2. Research Issue - The BHO will research the issue. This may involve coordinating with other agencies to ensure the proposed solution does not conflict with other requirements in the manual or in outside reference manuals. A log will be kept of proposed changes, originators, and outcomes.
3. Draft changes to the Manual - The BHO will draft changes to the chapter and coordinate with other chapter originators to ensure the change is incorporated into other chapters as necessary.
4. Edit and Publish Changes - The BHO will edit the proposed changes and publish them on-line at the Internet site where the manual is held and maintained.

References

Various documents are required to perform ITS design as outlined in this guide, and are referenced as follows:

- Wisconsin Dept. of Transportation Facilities Development Manual (FDM)
- Wisconsin Dept. of Transportation Standard Specifications for Highway and Structure Construction, Latest Edition (Standard Specifications)
- Federal Highway Administration Manual on Uniform Traffic Control Devices (MUTCD)
- Manual on Uniform Traffic Control Devices, Wisconsin Supplement
- American Association of State Highway Transportation Officials (AASHTO) Roadside Design Guide
- AASHTO A Policy on Geometric Design of Highways and Streets, Latest Edition
- National Electric Code (NEC)
- International Municipal Signal Association (IMSA)
- National Fire Protection Association
- Illumination Engineering Society of North America (IESNA)

Layout

The organization of the design manual is broken into individual chapters relating to ITS devices commonly used in Wisconsin. Within the chapters, similar sections are repeated throughout the guide to address:

- Technology & Standards
- System Setup
- Schematic Plans & Functional Requirements
- State Supplied Materials
- Construction & Installation
- Testing & Acceptance
- As Builts & Documentation

- Maintenance & Reevaluation

Contacts

The Bureau of Highway Operations is the contact for the Traffic Engineering & Operations Guide. The Statewide Traffic Operations Center (STOC) main phone number is (414) 227-2166. The designer is required to contact WisDOT BHO for any ITS inquiries after determining the need for such ITS devices.

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Acronyms

A list of acronyms commonly used within this manual are provided for your clarification:

BHO – Bureau of Highway Operations

CAD – Computer Aided Design

CCTV – Closed Circuit Television

DMS – Dynamic Message Sign (also known as Variable Message Sign)

FDM – Facilities Development Manual

ITS – Intelligent Transportation System

NEC – National Electrical Code

PCMS – Portable Changeable Message Signs

SDD – Standard Detail Drawing

SDS – System Detector Station

STOC – Statewide Traffic Operations Center

STSP – Standard Specification

TGM – Traffic Guidelines Manual

TOIP – Traffic Operations Infrastructure Plan

TSDM – Traffic Signal Design Manual

The WisDOT Traffic Operations Infrastructure Plan (TOIP) complete document can be found at The University of Wisconsin Traffic Operations & Safety Laboratory website: http://www.topslab.wisc.edu/workgroups/toip.html. For more information on the TOIP contact the BHO Traffic Engineering Operations Section.

The Wisconsin Traffic Operations Infrastructure Plan, a long-range planning effort undertaken by the Bureau of Highway Operations, outlines Wisconsin's statewide traffic operations infrastructure needs and opportunities, culminating in a series of sketch technology recommendations and associated costs. To identify which proposed operational infrastructure deployments best serve the mobility and connectivity needs of Wisconsin, each of the 37 Connections 2030 Multimodal Corridors was evaluated. Based on the Deployment Density Class output, the corridors were then prioritized by need. The resulting top five corridors are defined as Priority Corridors. The next eight are defined as Emerging Priority Corridors. Collectively, they connect almost every major metro area in Wisconsin and encompass the most critical freight and tourism routes in the State. These Corridors are intended to be the focus of traffic operations infrastructure investment. Recommendations are broken out into the three subsections as indicated below.

Summary cost estimates

Planning level cost estimates were developed for all thirteen Priority and Emerging Priority Corridors. The estimates were developed by SRF, SEH and Jacobs in three functional areas: Traffic Management and Surveillance, Traveler Information, and Signal Systems. This section provides summary cost estimates for recommended operations infrastructure investment. Costs are presented in three distinct ways as requested by WisDOT:

- Total Costs
- Total Costs of Priority and Emerging Priority Corridors
- Total Cost by Technology layer

Detailed breakouts of each functional area's costs, along with assumptions and detailed maps, are presented in a series of three appendices provided to WisDOT.

Priority and emerging priority corridor summaries

This section presents traffic operations infrastructure deployment recommendations for Wisconsin's thirteen Priority and Emerging Priority Corridors. Corridor maps with roadway segment technology recommendations are displayed, along with accompanying text and key summary statistics. Only Priority and Emerging Priority Corridors are presented in this document. The final report features recommendations for all 37 statewide multimodal corridors.

Metro-node summaries and recommendations

This section presents traffic operations infrastructure recommendations by MPO regions around the state. These maps contain the same deployment recommendations as the corridors maps. They have, however, been summarized at the MPO level for most metro regions in Wisconsin.

Purpose

Intelligent Transportation Systems (ITS) refers to a broad range of technologies, including information processing, communications, traffic control, and electronics, which can be used to improve the safety, efficiency, dependability, and cost effectiveness of the transportation system. More specifically, ITS technologies can:

- Collect and transmit real-time information on traffic conditions and bus transit schedules for travelers before and during their trips, making trips more predictable and thereby saving traveler's time and money;
- Improve the efficiency of the roadway network with technologies such as traffic signals that respond to flows and peak demands;
- Improve the productivity and cost effectiveness of public transit through automated vehicle locator systems that increase on-time performance and in-vehicle monitoring systems that ensure timely vehicle maintenance;
- Mitigate congestion by reducing the number of traffic incidents, clearing them more quickly when they occur, and rerouting traffic around them where appropriate;
- Support better emergency response times and services;
- Improve safety through monitors that detect early bridge and roadway icing and alert drivers;
- Improve the productivity of commercial fleets by using automated tracking, dispatch and weigh-in-motion systems that speed vehicles through much of the paperwork typically associated with interstate commerce; and
- Assist drivers in reaching desired destinations with navigation systems enhanced with path finding or route guidance.

Given all the different existing and emerging technologies, it is important that standards be developed nationally and regionally to ensure that projects are integrated and will work together with ITS systems from other agencies and jurisdictions. Federal law requires that all Federally funded ITS projects be in conformance with an adopted national ITS architecture and appropriate technical standards in order to provide consistency with ITS strategies and projects. However, it is recognized that not all elements of the national architecture may be applicable for every state or region. Thus, conformance with the national architecture is interpreted to mean use of it to develop a regional architecture, which is required for larger metropolitan areas such as Milwaukee or Madison. An ITS architecture is a structured approach or framework for defining, planning, and integrating ITS. It defines needed systems and functions and how to integrate different types of existing and future technology projects so they work seamlessly and cost effectively. The architecture identifies agreements and standards and the interconnections and information exchanges among the different systems of each agency and jurisdiction. A common vocabulary defined by the ITS architecture allows better communication between colleagues.

Integration Benefits Save Time and Resources

The National Intelligent Transportation Systems (ITS) Architecture is a framework for developing and deploying ITS. It consists of resources (knowledge) and tools that help facilitate the deployment of effective and interoperable ITS. The National ITS Architecture helps regions gain the full benefits of intelligent transportation systems by aiding the purchase of compatible equipment and services.

The National ITS Architecture guides multilevel efforts in implementing systems that are compatible nationwide to:

- Minimize the risk and cost of deployment
- Improve inter-jurisdictional, interagency, and public-private communications
- Increase efficiency and effectiveness
- Improve product quality
- Streamline operations

The National ITS Architecture accommodates multiple designs using diverse technologies of ITS system components, while assisting agencies to achieve the benefits of interoperability of easier administration, enhanced use, and easier management. Its purpose is to make sure that systems are compatible from one location to another and with each other in a particular location, for example, that the information being gathered for real-time ramp metering could also be used for traveler information. Thus systems can be integrated both functionally and geographically. Individual implementers can use this architecture to guide the design of their own systems, thus eliminating duplication of effort, which will reduce costs and errors. With the National ITS Architecture, implementers are able to avoid the costs and delays associated with false starts.

Regional ITS Architectures

Organizations included in the Architecture are public and private organizations that perform transportation and public safety functions. These include state, county, and municipal traffic agencies, emergency service providers (law enforcement agencies, emergency medical responders, fire departments, and tow service providers), media, and information service providers (ISPs). The geographical extent of Wisconsin's Regional Architectures is bound by the regions established by the Wisconsin Department of Transportation. Information flow connections crossing the line bounding these counties are considered to end in generic "terminators" in order to make the Architecture geographically extensible.

The Regional ITS Architectures throughout Wisconsin were developed to address interagency coordination among transportation and public safety organizations in the region that provide transportation services. Information exchanged among transportation and public safety organizations must be timely, accurate, useful, and consistent to enable these organizations to fulfill their functions. As demand for related services increases and organizational responsibilities increase, existing systems owned and operated by these organizations will require enhancements. Transportation and communications technology is growing exponentially, providing multiple solutions to real or perceived system deficiencies. In order to address these increased demands in a logical, efficient, and readily understandable manner, a common method of describing these systems and proposed enhancements is needed, readily available to all participating organizations. Any architecture shows the relationships established by interconnections among system elements. In an ITS regional architecture, these elements include transportation user services performed, actual subsystems owned or operated by each participating organization, and the information flows among them.

Two important uses of the Architecture are to provide a comprehensive description of the existing transportation infrastructure in the region and to provide a baseline for future infrastructure and system development. The Architecture shows what regional transportation-related organizations are doing today, and the subsystems, information flows, and processes that make these activities possible. It does so in the language and grammar defined by the FHWA National Architecture and satisfies the interim federal regional architecture requirement. It should also be one of several regional architectures developed and eventually integrated into the Wisconsin ITS Architecture, in order to provide a consistent platform for ITS project evaluation across the state. Planned subsystems and information flows are also included and flagged in the architecture, to show the direction of transportation communications infrastructure evolution. Future transportation projects can be readily entered into the architecture, allowing the proposed informational connectivity to be compared with existing and planned conditions. This is expected to be the more important of the two uses, as regional ITS architectural compliance is and will remain a requirement for federal ITS project funding.

The National ITS Architecture is a common framework for planning, defining and integrating intelligent transportation systems and their technologies. It defines: Tasks and functions, such as gathering traffic information or requesting a route; the physical devices that carry them out, such as loop detectors or telecommunications links; and the paths and connections by which data flows among the various physical devices to accomplish the task or fulfill the function.

Development of regional ITS Architectures throughout Wisconsin were completed in 2002 and includes the following federally required components:

- Description of the region;
- List of participating agencies and other stakeholders and their ITS inventories;
- An operational concept that assists in defining roles and responsibilities of the participating agencies and other stakeholders;
- List of interagency agreements necessary to operate and implement the systems identified in the inventory;
- Functional requirements for systems;
- Interface requirements between systems and information flows between subsystems and terminators;
- ITS standards that support regional and national interoperability; and
- Sequence of ITS projects required for implementation.

Development of the regional architecture started with a stakeholder outreach effort focused on determining existing and planned ITS deployments. User needs were assessed and user services that could fill stakeholder needs were determined. All ITS deployments must fit within the current or future regional ITS architectures.

1.4.1 Project Development Process

The project development process for ITS projects consists of all steps found in FDM Chapter 3. Chapter 3 outlines five different "steps" as follows:

- Concept definition
- Investigation
- Determination
- Final design, and
- Reconstruct administration.

For information on the department's project development process, refer to FDM Chapter 3, Facilities Development Process: http://roadwaystandards.dot.wi.gov/standards/fdm/03-00toc.pdf

With the FDM providing thorough guidance on these five steps, this manual does not reiterate this information. However, ITS projects typically require additional steps in the development process as follows:

- Pre-letting administration
- System integration
- Management and operations
- Evaluation and testing

While steps 6 through 9 are not typically required for most highway improvement projects, they are essential in ITS projects.

1.4.1.1 Pre-Letting Administration

A large portion of ITS equipment is highly technical in nature, requiring pre-letting activities such as:

a) conducting pre-letting meetings explaining contract structure or special requirements unique to the contract being administered

b) conducting pre-qualification of prime contractors for various items and vendors as noted in this manual and as identified under final design in the project development process (such as fiber optic technicians, electronic sign manufactures, other equipment manufacturers)

Pre-qualification requirements are attached to the project proposal, and information must be received and reviewed prior to bid. Under the pre-qualification process, only those bids from contractors who both submit pre-qualification material and meet the stated requirements (as determined by the Department) will be accepted.

1.4.1.2 System Integration

System integration of elements contained within ITS projects must be identified and updated during the investigation, determination, and final design steps in the project development process, but must also be developed and identified prior to completion of construction. System integration elements include, but are not limited to:

a) Identification of central system database additions, such as ramp processors, detectors, and updates to central map

b) Communication channel and drop assignments

c) Field termination diagrams illustrating loop detector inputs for field processor assemblies

d) Development of database configuration files for field processor interface during construction

e) Field testing of ITS elements (processor assemblies, DMS, CCTV, etc.)

It is envisioned that these system integration elements be performed by, or under direct supervision of the Statewide Traffic Operation Center Systems Engineer.

1.4.1.3 Management & Operations

Management and operations of ITS equipment is a consideration also that should be identified and updated during the investigation, determination, and final design steps in the project development process. However, similarly to system integration, final development of management and operations tasks must be concluded prior to completion of construction.

Tasks involved in the development of management and operations include:

a) Consideration of staffing involved to manage the equipment at the operations center(s)

b) Written commitments with respect to operations and maintenance of “shared” equipment (e.g., communication conduit, local agency video, fiber optic cable, etc.)

c) Preventative maintenance schedules and responsibilities

d) Emergency maintenance of equipment

e) Standard maintenance of equipment

1.4.1.4 Evaluation and Testing

Intelligent Transportation Systems make extensive use of electronic and computerized equipment. The marketplace of electronics and computers is constantly evolving, and evaluation and testing of equipment must routinely take place to ensure that a system does not become outdated, and that the information being obtained and distributed through the system be as efficient and reliable as possible. Evaluation and testing is necessary for all types of equipment across the ITS spectrum. Any equipment being considered for evaluation and testing must be coordinated through the appropriate WisDOT Program/Project Manager.

Other helpful links and information regarding construction bid letting, engineering and related services, procedures and standards, and programs, refer to http://www.dot.wisconsin.gov/business/engrserv/index.htm.

A systems engineering analysis is required for all Intelligent Transportation Systems (ITS) projects using Federal funds according to the Final Rule on Architecture and Standards Conformity. The ITS Architecture Implementation Program identifies minimum systems engineering practices that must be included in the project implementation phase.

The primary benefit of doing systems engineering is that it will reduce the risk of schedule and cost overruns and will provide a system of higher integrity. Other benefits include:

- Better system documentation
- Higher level of stakeholder participation
- System functionality that meets stakeholders' expectation
- Potential for shorter project cycles
- Systems that can evolve with a minimum of redesign and cost
- Higher level of system reuse
- More predictable outcomes from projects.

US DOT recognized the potential benefit of the systems engineering approach for ITS projects and included requirements for a systems engineering analysis in the FHWA Rule that was enacted on January 8, 2001. The Rule requires a systems engineering analysis to be performed for ITS projects that use funds from the Highway Trust Fund. The Rule specifies seven requirements that the systems engineering analysis must include at a minimum including:

- Identifying which part of the regional architecture is being implemented
- Participating agencies and their responsibilities
- Defining of systems requirements
- Analyzing of alternative system configurations and tech options to meet the requirements
- Exploring procurement options
- Identifying of project-applicable standards and testing procedures
- Determining procedures and resources needed for operations and management of the system.

The Rule allows each project sponsor to use a systems engineering approach that is tailored to fit the needs of each ITS project. The systems engineering approach is actually broader than the seven specific requirements identified in the Rule. In order to implement a good systems engineering process, one must meet or exceed the specific systems engineering analysis requirements identified in the Rule. The FHWA Division determines how the systems engineering analysis requirements in the Rule should be applied to ITS projects in each region and how compliance should be demonstrated by each project sponsor. Federal oversight is provided based on oversight requirements defined in the stewardship agreements with each state. Several states have established checklists that prompt project sponsors to consider the systems engineering analysis requirements as part of the project development process.

Contact the FHWA Division Office for more information. The web address for FHWA's Wisconsin Division is http://www.fhwa.dot.gov/widiv.

The Rule in its entirety can be found at http://www.access.gpo.gov/nara/cfr/waisidx_03/23cfr940_03.html.

The Vee Development Model is the recommended development model for ITS projects. Illustrated in Figure 1.5-1 is the Vee Development model in the context of the life cycle framework. This model has gained wide acceptance in the systems engineering community. The reason for this acceptance is that the model illustrates some key systems principles about the relationship of the early phases of the development to the end results of the project. Detailed information regarding the Vee Development model and its use in ITS projects is explained on the FHWA website at http://www.fhwa.dot.gov/cadiv/segb/views/process/index.htm.

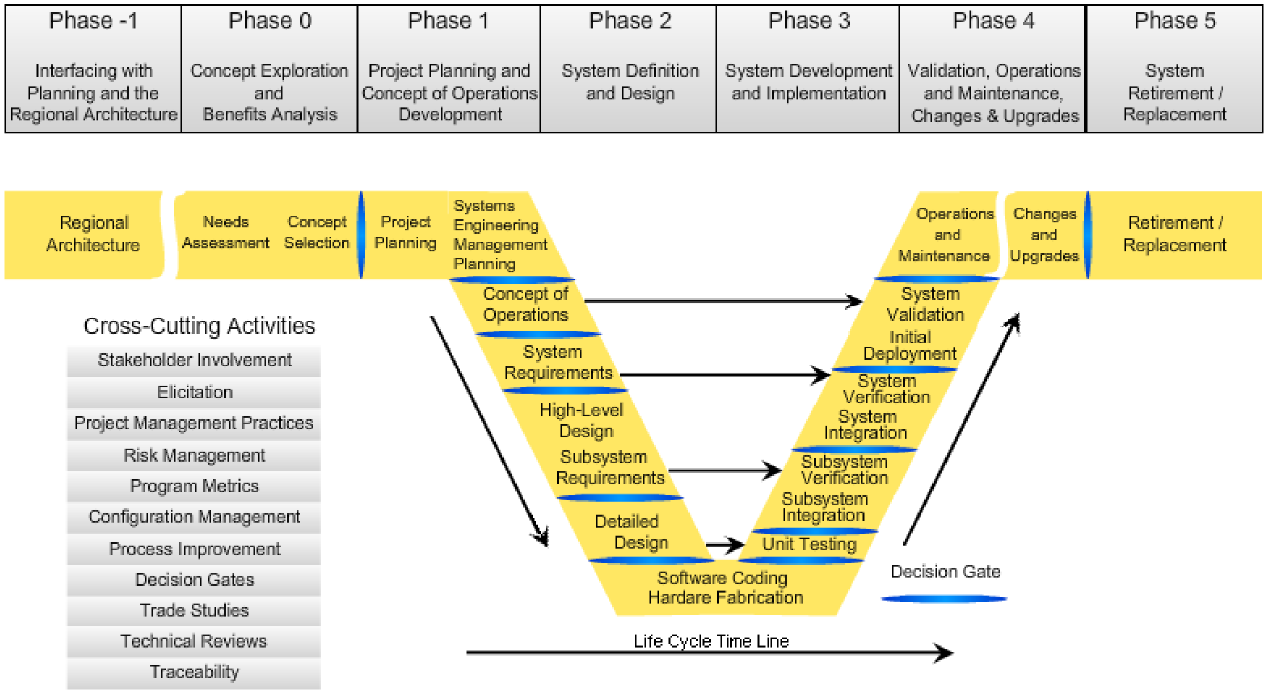


FIGURE 1.5-1 – Vee Development Model / Systems Engineering Process Overview

5.1.1 Introduction

The guidance in Chapter 5 is intended for the placement of ***new*** ramp meters as part of new ramp construction projects only. The STOC must be contacted if retrofitting a ramp meter to existing ramp geometry or in any other circumstances where the addition of a ramp meter is being considered.

Ramp metering is the primary operations tool for addressing recurring freeway congestion. Ramp meters allow the freeway to carry maximum volume at a uniform speed. Ramp meters are traffic signals placed at the freeway on-ramps. They control the rate at which vehicles enter the mainline to minimize the impacts of merging traffic on mainline performance. By controlling traffic at the ramps such that mainline performance is maximized, more vehicles can enter from the ramps than if the mainline flow was permitted to breakdown.

When platoons of vehicles attempt to force their way into freeway traffic, turbulence and shockwaves are created, causing the mainline flow to breakdown. Reducing the turbulence in merge zones can lead to a reduction in the sideswipe and rear-end type accidents that are associated with stop-and-go, erratic traffic flow.

Ramp meters may be controlled locally based on time-of-day and day-of-week, or via traffic responsive metering where metering is enacted based on volume, occupancy, or speed being obtained by the local freeway detection. Ramp meter plans are stored in the controller in the same manner as surface street intersection traffic signals.

Ramp meters may also be controlled from a central system based on ramp and mainline traffic conditions in much the same way as surface street traffic signals use adaptive (or traffic responsive) control. Ramp meters can be turned on and off from the operations center, or can be controlled by central software in corridor or system-wide traffic control strategies utilizing ramp metering algorithms to disperse traffic volumes throughout the system.

5.1.2 Needs Assessment

To get a high level viewpoint as to where ramp meters should be installed, refer to the TOIP. In the ramp meter design process, the designer must follow several steps to ensure successful implementation and proper operational capabilities. Many of these steps, such as highway lighting and communication requirements, must be addressed early in the design process and not after design for the proposed location has been completed. These steps are shown in Table 5.1 Ramp Meter Design Process Checklist and detailed further in subsequent sections.

5.1.2.1 Data Collection

Prior to assessing the needs of a potential ramp meter location, various data needs to be collected to properly evaluate the proposed ramp meter location, such as:

- AM and PM peak period/hour volumes, speeds, and accident rates
- Future peak period/hour volumes (e.g., design year projected volumes)
- Site-specific issues or concerns based on an initial site visit (right-of-way, utilities, landscape, existing signing inventory)
- Ramp vertical grades
- Existing ramp width, flange to flange
- Existing ramp length to painted gore
- Current construction funding for the project

Without this data collection, a proper ramp meter type and design cannot be guaranteed. The last item, current construction funding for the project, is a major concern with respect to whether the ramp is altered geometrically, and to what extent the ramp is altered (e.g., minor alterations, major reconstruction).

5.1.2.2 Criteria

Initial screening criteria to determine if a ramp meter is needed are provided below. If it is determined that the criteria are met, a more detailed traffic analysis should be completed, such as using microsimulation. Ramp meters should be evaluated on a corridor wide basis.

1. Mainline volumes of at least 1,200 vehicles per hour per lane
2. Ramp volumes of at least 240 vehicles per hour for a one lane ramp, and 400 vehicles per hour for a two lane ramp
3. Mainline speeds of less than 30 mph in the peak hour
4. Accident rate in the vicinity of the ramp in excess of 80 per hundred million vehicle miles
5. Two of the above four traffic criteria should be met for at least 50% of the corridor evaluated

5.1.2.3 Types

Based on the initial data collection and criteria application, the designer can determine the type of ramp meter proposed. For the basis of this determination, an average vehicle length of 25 feet should be used, which factors not only average lengths of vehicles but also spacing between vehicles. Ramps with a known high truck volume may require a longer average vehicle length assumption.

The ramp must provide storage for a **minimum of 10%** of the *current* peak hour volume to ensure that the ramp meter queue does not back into the surface street. This factor is key in determining whether the ramp will contain 1, 2, or 3 SOV lanes. For ramp meters designed in conjunction with ramp reconstruction, the ramp should accommodate a **minimum of 10%** of the *design* year (e.g., year 2020) projected peak hour volume. For ramp meters retrofitted to existing conditions, a storage minimum of 5% of the current peak hour volume may be used **only with approval from the State Traffic Operations Center**.

Ramp meters are broken into six different types, dependent upon the number of lanes required for a location and the usage of high-occupant vehicle (HOV) lanes for priority treatment. Note that service ramps will be designed to accommodate HOV bypass lanes at ramp meters **only** if there is a written request from transit and a demonstration of operational need by transit at particular locations. Also, a written commitment is necessary from the enforcement jurisdiction to enforce the HOV lanes for the life of the facility.

- **SOV** - single-lane ramp meter, termed Single Occupant Vehicle
- **SOV/HOV** - dual-lane ramp meter including High-Occupant Vehicle priority treatment
- **2 SOV** - dual-lane ramp meter with no high-occupant vehicle priority treatment
- **2 SOV/HOV & 3 SOV** - three-lane ramp meter with and without high-occupant priority treatment. Three lane ramps should be considered only under the most favorable conditions, such that the ramp will be on tangent or a large radius curve approaching the ramp meter stop bar. A three-lane loop ramp is not recommended due to safety considerations.
- **Metered Four-Lane Ramps** – four-lane ramp meter or two separate ramp meters that are next to each other with and without high-occupant priority treatment
- **System to System Ramp Meters** - a special classification of ramp meter requiring additional considerations due to the unique nature of freeway system interchanges. These ramp meters should only be installed if absolutely necessary. Use of this ramp meter must be approved by the State Traffic Operations Center who will assist in determining the feasibility of a system to system ramp meter.
- **Temporary Ramp Meters** – used for ramps under construction, or ramps that only need ramp metering for a short period of time. Since communications and power may not exist near a ramp because of construction or other factors, many temporary ramp meters are self-contained units that are programmable on site, and can be powered with solar power. If the ramp will be under construction for a longer period of time, and power is available, wooden poles and signals on span wire can be used until a permanent installation can be placed. If the ramp will never have a permanent ramp meter, and only needs one for a limited time, portable self-contained ramp meters should be considered for cost effectiveness. Temporary ramp meters use the same upper heads as traffic signals, but also include a three section lower unit. These ramp meters are pretimed with a yellow phase. There is no stop bar detection.

Table 5.1 Ramp Meter Design Process Checklist

1. **Collect initial data** required for the proposed ramp meter design location (see 5.1.2.1)	
2. Review **criteria** to determine if a ramp meter is needed (see 5.1.2.2)	
3. Determine the **ramp meter type** required for the design location (see 5.1.2.3 & 5.3.1)	
4. **Evaluate geometric requirements** and potential modifications for the location (see 5.3.1)	
5. Determine the **location of the ramp meter stop bar** and signals, with potential iteration of steps 4 and 5 (see 5.3.2)	
6. Determine the **location of the ramp meter controller cabinet** (see 5.3.3)	
7. Begin the process to **establish electrical service** for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location (see 5.5.4)	
8. Prepare the **underground infrastructure**, including detectors, conduit, and pull boxes (see 5.3.5 & 5.3.6)	
9. Perform **cable routing** to provide hardwire interconnection between the controller cabinet and ramp meter devices such as signals, detectors, electrical service, etc. (see 5.3.7)	
10. Prepare **signing and pavement markings** as required for the ramp meter design (see 5.3.4, 5.3.8, & 5.3.9)	
11. Based on the data collected under step 1, incorporate or modify **highway lighting** if not already present. This step typically is coordinated through the Region's Highway Lighting Engineer (see 5.3.10)	
12. Determine the **communications medium** used for the proposed location (see 5.5.3)	
13. **Revisit steps 6 through 12** until final design is complete	
14. Determine the **construction details, special provisions, and standard specification bid items** needed for the proposed design, along with those that **need to be modified** and **created** to provide a complete construction plan (see 5.5.5 and Appendix 70)	

5.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format. For example, for the 20th ramp meter that is installed in the State in Milwaukee County (40), the number for the device should be RM-40-0020 (i.e., RM-County number-next sequential four digit number). The device number and related information will be stored in the ITS inventory management system.

If the device requires a TELCO (landline phone line), a street address must be established during this process.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at: http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

5.2.2 Communications Assignments

Refer to Chapter 50, ITS Communication Systems for information regarding the appropriate communication network to use for ramp meters. Contact the STOC to discuss communication requirements.

5.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

5.3.1 Geometric Considerations

Geometric requirements for metered ramps depend upon several factors, including:

- *Peak hour volume* which affects the **storage length** and **width** of the ramp
- *Design speed* of the mainline for the ramp under consideration, which affects the **acceleration distance** after the stop bar (acceleration distances per *AASHTO A Policy on Geometric Design of Highways and Streets, latest edition*)
- *Right-of-way availability,* which will factor into the **length** and **width** of the ramp
- *Construction funding*, which may influence the extent to which the ramp can be modified, affecting **ramp width, length, and acceleration lanes.**

These considerations will indicate whether a ramp meter is retrofitted to existing conditions, rehabilitated while maintaining the current alignment, or completely reconstructed. Table 5.3-1 provides recommended and minimum widths for ramp meters based on configuration type. Refer to 11-30-1 for basic entrance ramp design.

	Ramp With Shoulders			**With Curb and Gutter**
Ramp Meter Configuration	Traveled Way	Shoulder		Traveled Way
		Inside	Outside	
SOV	12 ft	4 ft	8 ft	15 ft
2 SOV	24 ft	4 ft	8 ft	24 ft
SOV / HOV	24 ft	4 ft	8 ft	24 ft
HOV LANE	12 ft	n/a	n/a	15 ft
2 SOV / HOV	36 ft	2 ft	2 ft	36 ft
3 SOV	36 ft	2 ft	2 ft	36 ft

Table 5.3-1: Ramp Meter Width Requirements

Single-Lane (SOV) Ramps

Requirements for entrance ramps with one metered lane are shown in Fig. 5.3-1 & 5.3-2. For longer ramps, it may be desirable to add an *intermediate queue detector* to limit the delay per vehicle proceeding through the ramp meter. The stop bar signals should be placed to allow adequate visibility when traveling down the ramp. Refer to 11-10-5 for sight distance requirements.

Metered Two-Lane (SOV/HOV, 2 SOV) Ramps

Requirements for entrance ramps with two metered lanes are shown in Fig. 5.3-3 & 5.3-4.

SOV/HOV

2 SOV

Metered Three-Lane (2 SOV/HOV, 3 SOV) Ramps

A three-lane ramp may be designed when two single occupant vehicle (SOV) and an HOV lane or three SOV lanes are required. Requirements for entrance ramps with three metered lanes are shown in Fig. 5.3-5. A three-lane loop ramp <u>is not</u> recommended due to safety considerations.

Metered Four-Lane Ramps

In certain situations, two ramps come together for a four-lane ramp meter or for two separate ramp meters that are next to each other. This occurs in very rare instances. Contact the State Traffic Operations Center for assistance in this type of ramp meter design.

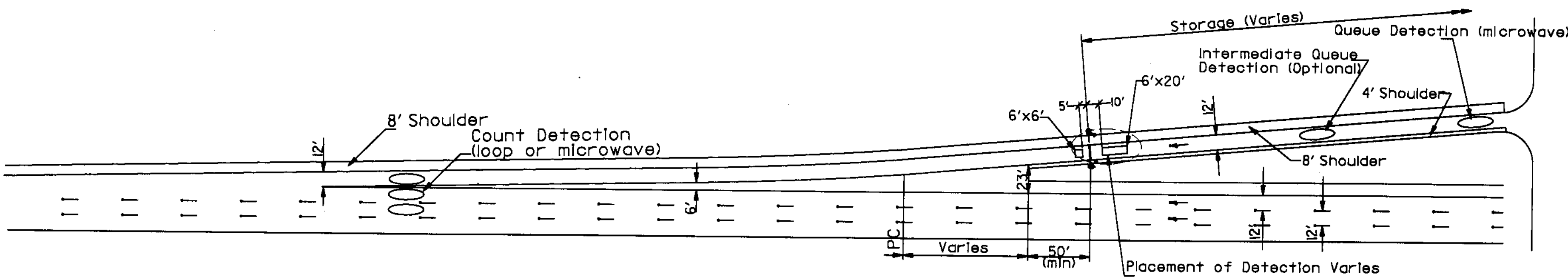
System to System Ramps

Due to higher rates of speed, system to system ramps require additional safety and advance warning considerations than found under single or dual lane metering. Close coordination with the State Traffic Operations Center is critical to decide if a system to system ramp meter is really needed, and if so, what geometric constraints exist.

Figure 5.3-1: Ramp Meter Design Guidelines, 1-Lane Diamond Leg Ramp

GENERAL NOTES

1. See FTMS Detail Design Drawing "stopbars.dgn" for complete stop bar layout.
2. Minimum acceleration distance required shall conform to "A Policy on Geometric Design of Highways and Streets", latest edition (AASHTO).
3. Total storage to be determined by demand analysis using current ramp volumes, 15-minute periods minimum.
4. Loops are necessary for demand and passage detection.
5. All other detection can use loops or microwave detection. Detection zones are shown



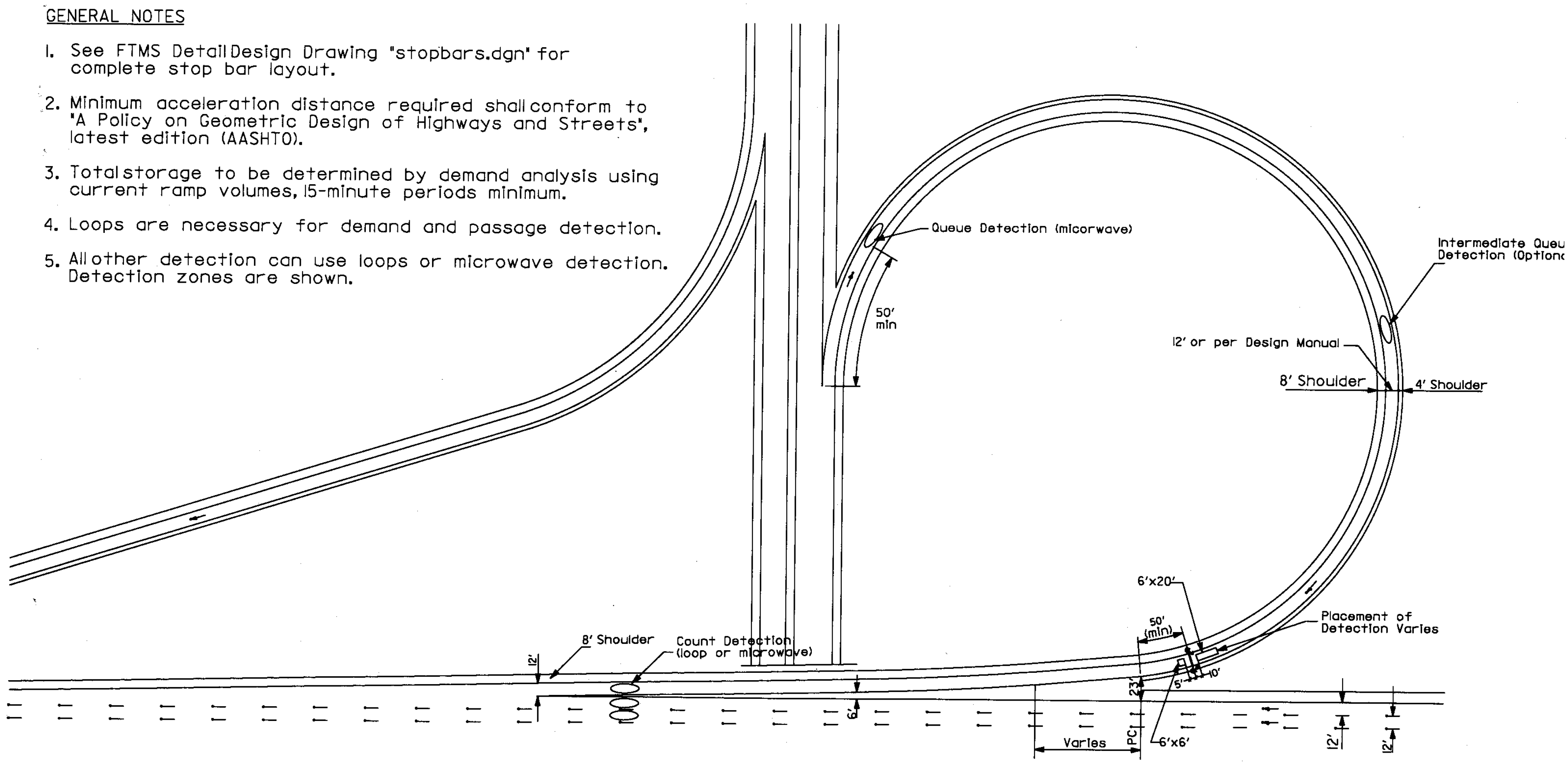
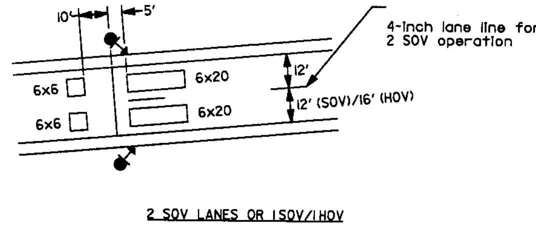


Figure 5.3-2: Ramp Meter Design Guidelines, 1-Lane Loop Ramp

GENERAL NOTES

1. See FTMS Detail Design Drawing "stopbars.dgn" for complete stop bar layout.
2. Minimum acceleration distance required shall conform to "A Policy on Geometric Design of Highways and Streets", latest edition (AASHTO).
3. Total storage to be determined by demand analysis using current ramp volumes, 15-minute periods minimum.
4. HOV lane preferred placement on left-side.
5. Loops are necessary for deamnd and passage detection.
6. All other detection can use loops or microwave detection. Detection zones are shown.



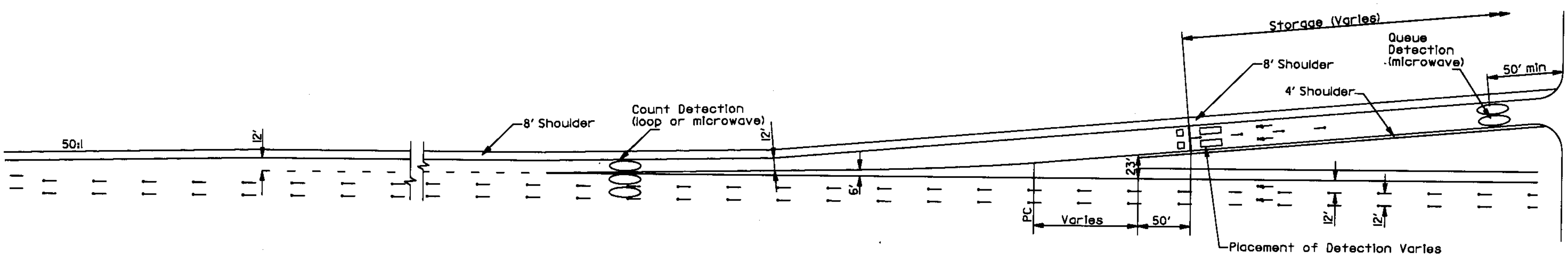


Figure 5.3-3: Ramp Meter Design Guidelines, 2-Lane Diamond Leg Ramp

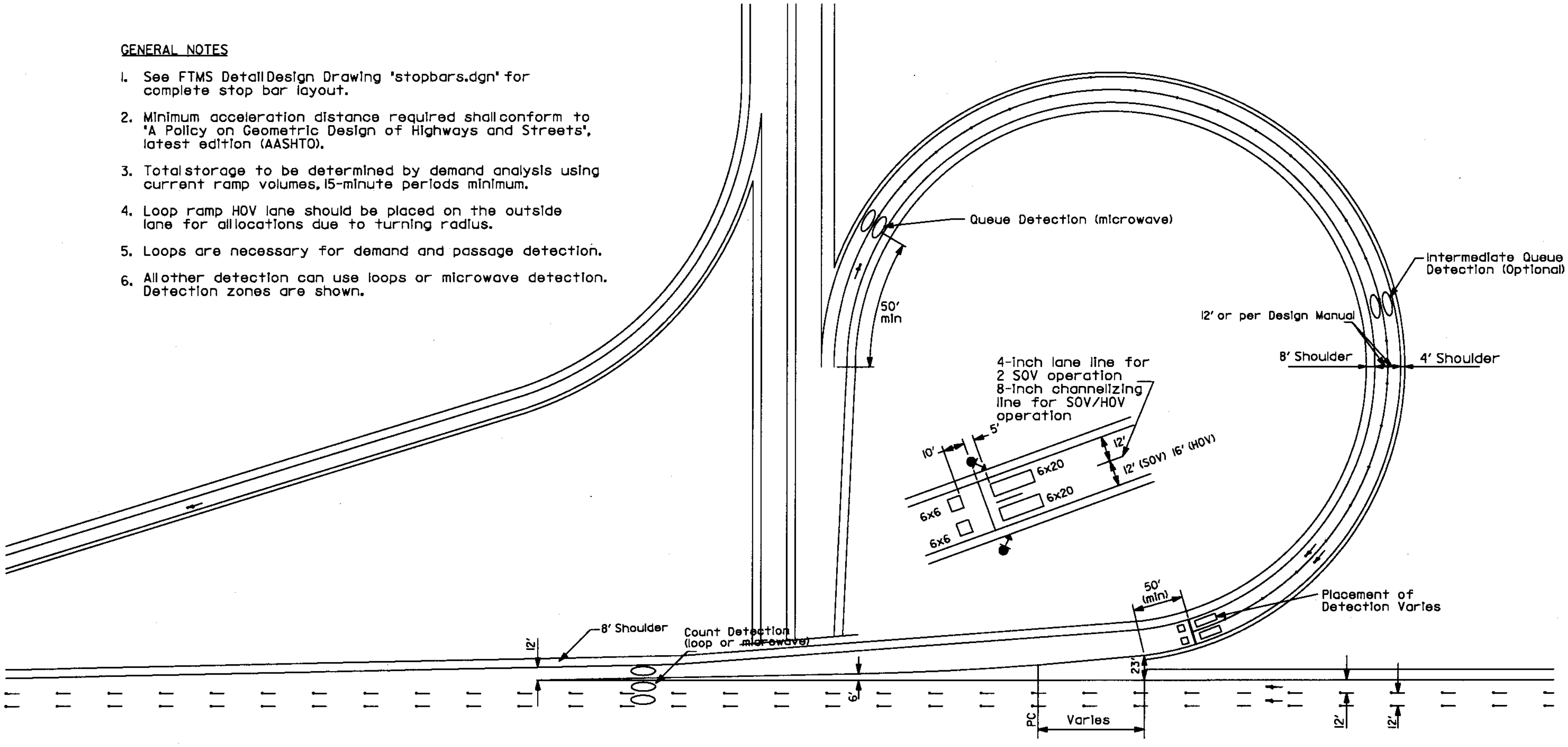


Figure 5.3-4: Ramp Meter Design Guidelines, 2-Lane Loop Ramp

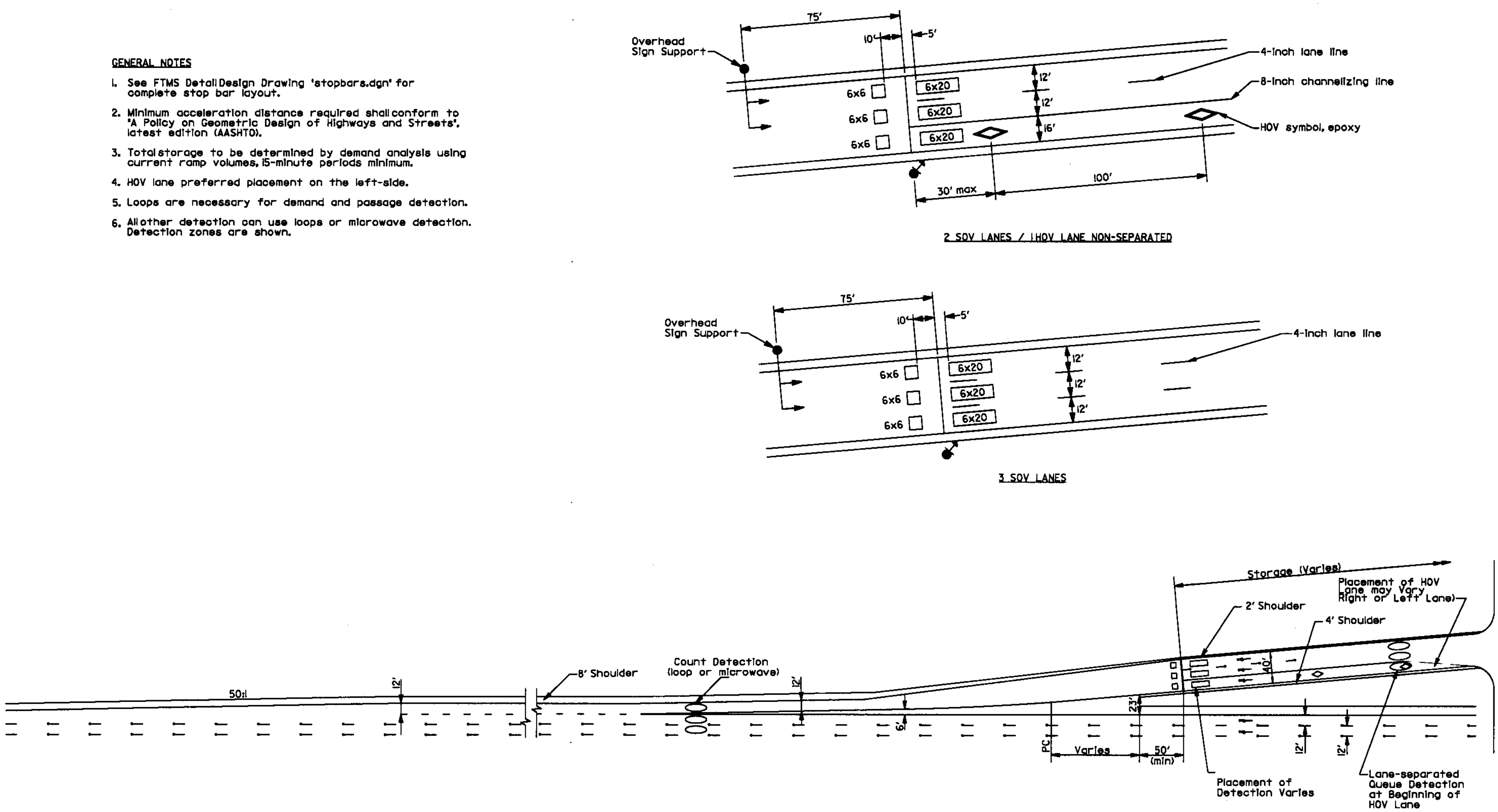


Figure 5.3-5: Ramp Meter Design Guidelines, 3-Lane Diamond Leg Ramp (Non-Separated HOV)

5.3.2 Ramp Meter Stop Bar/Signal Placement

Ramp meter stop bar placement revolves around the following fundamental issues:

- Ramp acceleration required
- Ramp storage required
- Stop bar signal sight distances

Once the acceleration and storage distance requirements have been established (from the *initial data collection* and *determination of ramp meter type*), the placement of the stop bar can be determined. If the ramp is being widened or lengthened, the stop bar placement must also be determined side-by-side with the geometric design of the ramp. For sight distance, the most desirable location for a stop bar is at the end of a tangent section of the ramp. For loop ramps, the stop bar placement typically should be near the freeway gore, provided adequate acceleration distance is present parallel to the mainline.

Under any circumstance, the placement of the stop bar for ramp meters must be reviewed by the State Traffic Operations Center prior to proceeding with final design and layout of the ramp.

When the use of a overhead sign support (mast-arm) becomes necessary, such as a non-separated 2 SOV / HOV ramp meter, placement of the overhead signals should be over the two single occupant vehicle lanes, with the side-mounted Type 2 signal assembly placed at the HOV lane. Only under the most restrictive geometric constraints should the overhead signals be placed over one SOV lane and the HOV lane.

5.3.3 Controller Cabinet Placement

Once the ramp meter type, geometric layout, and stop bar placement of the ramp has been determined, the placement of the controller cabinet can be established. This placement involves many factors, including:

- Visibility of the stop bar signals from the controller cabinet
- Distance between the controller cabinet and the loop detectors
- Distance between the controller cabinet and the signals on the ramp
- Grades
- Drainage
- Maintenance Accessibility (parking availability for maintenance vehicles)

For maintenance considerations, it is very important that the **stop bar signals be visible from the controller cabinet**. The distance between the cabinet and stop bar is dependent on the loop detector inductance ratio.

The slope of the terrain for cabinet placement must be no steeper than 4:1. Placement of the cabinet on 3:1 slopes or steeper requires grading provisions to provide a level area around the cabinet.

5.3.4 Advance Warning Sign Placement

Placement of a traditional advanced warning sign (e.g., "Ramp Metered When Flashing") depends upon the functional intent of the warning signs.

- ***Post-Entrance Notification*** - The functional intent of the sign in this scenario is to warn road users that a freeway entrance ramp is metered and that road users will encounter a ramp control signal. A RAMP METERED WHEN FLASHING sign **shall** be installed on the ramp that metering is being implemented. The placement of advance warning signs under this scenario should provide adequate site distance upon entering the ramp, yet allowing sufficient distance between the sign and estimated back of queue.
- ***Pre-Entrance Notification*** - The functional intent of the sign in this scenario is to warn road users upon entering the ramp that metering is currently being implemented. A RAMP METERED WHEN FLASHING sign may be installed in advance of the ramp entrance on the arterial approaching the metered ramp. Criteria for installation of this sign may include long queue lengths or heavy turn movements on to the ramp. If used, the placement of advance warning signs under this scenario should provide adequate sight distance along the cross street, allowing the motorist ample time to decide whether to enter the freeway system at that location, or bypass the ramp meter and travel along alternate routes.

A minimum distance of 100-ft must be maintained between the advance warning sign and any existing signs.

For system connector ramps, or high-speed urban interchange ramps, overhead advance warning signs must be designed to provide additional warning of ramp meters. Overhead advance warning signs are “blank-out” signs that read RAMP METERED, and contain 2 yellow signal beacons above which flash alternately. Upon metering start-up, the RAMP METERED is displayed and the yellow beacons flash. In non-metering conditions, the display is blank. These advance-warning signs are typically installed above a freeway guide-sign, and mounted to a full-span or cantilever sign structure. Design issues with overhead advance warning signs include:

- **Placement** - The back of the design year queue must be calculated for the ramp meter. The overhead warning sign is placed to ensure that motorists have **adequate sight distance for the sign** based on roadway alignment, and **adequate perception and reaction time** based from the point of viewing the sign to the end of the ramp meter queue, in coordination with the vehicle’s approach speed.
- **New Type I Guide Signs** - If a new freeway guide-sign and advance warning sign is installed, sign spacing becomes a concern, and must be coordinated with the Region traffic/signing engineer. Typically, 800-ft minimum spacing is required between WisDOT Type I signs.
- **Installation on Existing Sign Structures** - If the advance warning signs are to be placed on an existing structure, a thorough structural review **must** be conducted to determine the load capabilities of the existing structure, and whether that structure is capable of supporting the overhead advance warning sign.

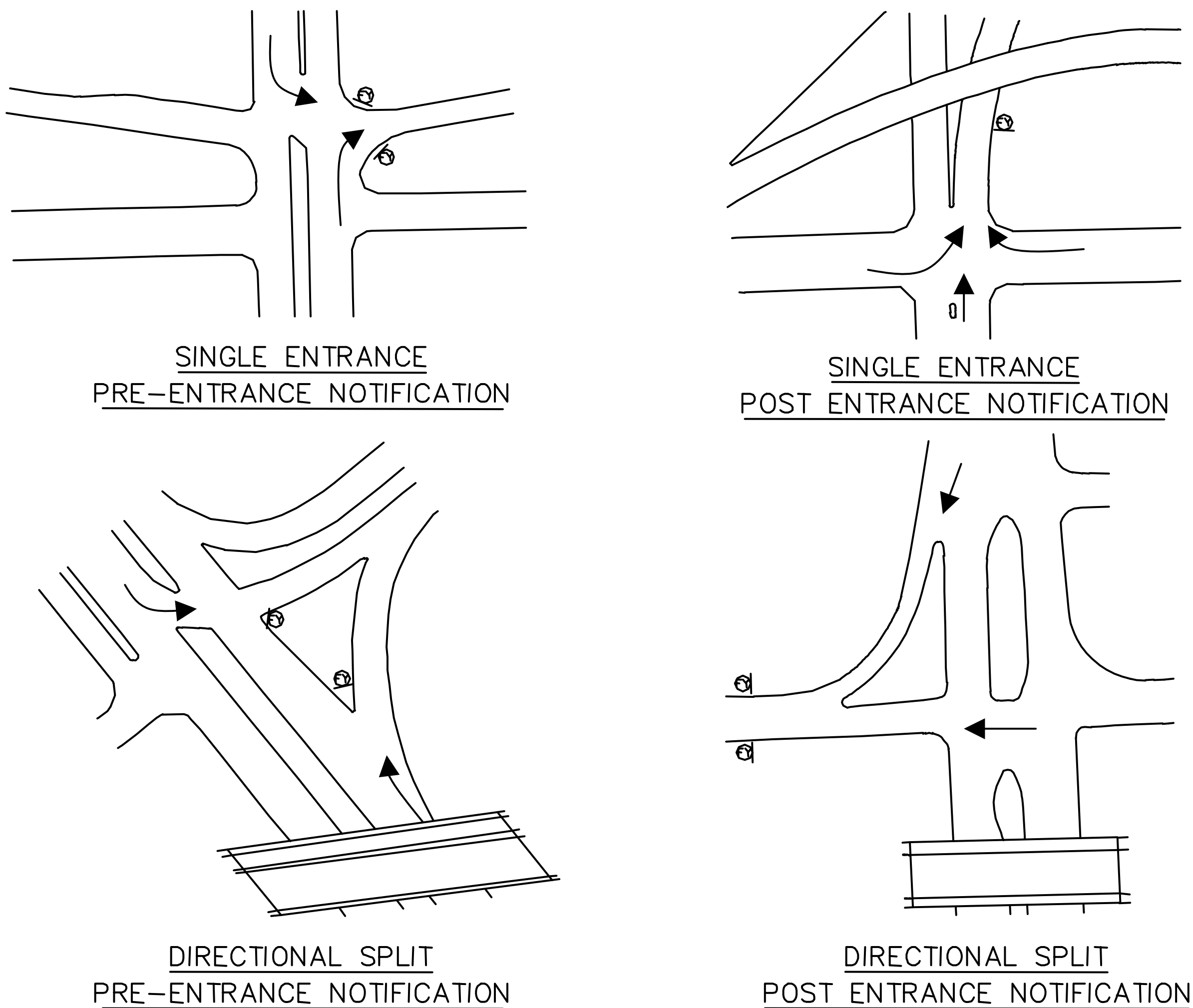


Figure 5.3-7: Typical Advanced Flasher Assembly Placement

5.3.5 Loop Detector Placement

When determining loop detector placement, be sure to maintain an inductance ratio of at least 1.25. Ramp meters involve the following types of loop detectors:

- **Demand Loops** - A 6 x 20-ft loop is placed just upstream of the stop bar in each metered lane. The distance between the leading edge of the loop and the stop bar pavement marking line is 25 feet, leaving a five-foot space between the lagging edge of the demand loop to the stop bar.
- **Passage Loops** - In each metered lane, a 6 x 6-ft loop is placed just downstream of the stop bar. The distance between the leading edge of the loop and the stop bar pavement marking line is 10 feet.
- **Queue Loops** – Each queue loop should be 6 feet long (along the ramp) and sized to fit the width of each lane or ramp. Each queue detector placement is unique in its placement upstream of the stop bar. This involves a trade-off between maximizing ramp storage without having vehicles detected, while at the same time anticipating additional vehicles entering from the side street (i.e., platoons of vehicles entering as a result of a traffic signal). The designer must consult the State Traffic Operations Center to obtain guidance in placement of queue detectors.
- **Entrance Ramp Reporting Loops** - A reporting loop detector (for traffic counts) should be placed on multi-lane entrance ramps downstream of the stop bar where the ramp narrows to a single lane prior to entering the freeway. Reporting loops also must be placed on any non-metered entrance ramps within the interchange of the ramp meter. Entrance ramp loops should be sized to fit the ramp such that vehicles cannot avoid passing over the loop.
- **Exit Ramp Reporting Loops** - Reporting loops also must be placed on any exit ramps within the interchange of the ramp meter. Exit ramp reporting loops should be sized to fit the ramp such that vehicles cannot avoid passing over the loop.
- **Turning Count Reporting Loops** - Reporting loops at the entrance of a ramp meter counting entering traffic by direction is preferred, but optional. These loops are typically installed on a ramp that has a traffic island at the entrance separating the directional movements.
- **Mainline Loops** - Loops should be placed upstream of the entrance ramp gore. These loops are used when the ramp meter is operated locally in response to traffic conditions along the mainline. Placement of mainline loops should also be coordinated with the spacing considerations as documented in Chapter 10, System Detector Stations.
- **Non-Intrusive Detectors**
  - **Microwave Detection** – Can be used instead of any of the above mentioned loops, except for demand and passage detection, since it doesn't do well at point detection. Microwave detection can be placed on a detector camera pole or lighting pole. It has the ability to detect volume and speed in up to three to four lanes.
  - **Video Detection** – Used for mainline as well as ramp meter detection. It may be used for demand and passage detection, though it is not the preferred option.

Loop detectors are typically illustrated at precise locations in the plan. A loop detector chart provides additional information in the plan, such as the loop description (type), location (station), size (in feet), and the number of turns of wire contained within the loop. Mainline loops do not require a station, since most ITS plan sets do not require the contractor to establish stationing along the mainline. In this instance, since each lane contains primary and secondary loops (for speed data), the location is the lane number. The farthest left-hand (inside) lane on a freeway direction is always Lane 1, with lane number progressions increasing from left to right.

Table 5.3-2 illustrates a typical loop detector chart and information provided on the design location sheets.

LOOP DETECTOR DETAILS - RM-118

	DESCRIPTION	LOCATION	SIZE	NO. OF TURNS
1	QUEUE A	48B+60	6' X 6'	3
2	DEMAND A	58B+30	6' X 20'	3
3	DEMAND B	58B+30	6' X 20'	4
4	DEMAND C	58B+30	6' X 20'	3
5	PASSAGE A	58B+65	6' X 6'	3
6	PASSAGE B	58B+65	6' X 6'	4
7	PASSAGE C	58B+65	6' X 6'	3
8	NORTHBOUND PRIMARY	LANE 1	6' X 6'	3
8	NORTHBOUND PRIMARY	LANE 2	6' X 6'	5
8	NORTHBOUND PRIMARY	LANE 3	6' X 6'	4
9	NORTHBOUND SECONDARY	LANE 1	6' X 6'	3
9	NORTHBOUND SECONDARY	LANE 2	6' X 6'	5
9	NORTHBOUND SECONDARY	LANE 3	6' X 6'	4
10	REPORTING - EB MAIN STREET ENTRANCE	45B+80	6' X 12'	3
11	REPORTING - WB MAIN STREET ENTRANCE	SEE PLAN	6' X 20'	3
12	REPORTING - HOV LANE	52B+70	6' X 6'	3
13	REPORTING - NB ENTRANCE RAMP	61B+75	6' X 15'	5
14	REPORTING - NB EXIT RAMP	SEE PLAN	6' X 10'	3

NOTES:
1. DEMAND / PASSAGE LOOPS STATIONED ASSUMING STOPBAR STATION 58B+55
2. ALL LOOPS ARE STATIONED TO THE LEADING EDGE

Table 5.3-2: Loop Detector Detail Chart

5.3.6 Underground Infrastructure

When the controller cabinet, electrical service, loops, stop bar, and advance flasher assemblies have been placed, the underground conduit infrastructure can be designed. HDPE ducts are the recommended conduit installation for ramp meter raceways and all ITS deployments for WisDOT. Issues to keep in mind when designing the ramp meter conduit infrastructure include:

- **Conduit Size** - 3-Inch conduit is typically used for ramp meter raceways. Conduit entering electrical service pedestals must be sized per pedestal requirements.
- **Conduit Fill** - The size and number of conduits along a run is dependent on percentage of fill as established by the National Electric Code (NEC). Although it may not violate the NEC fill code, no more than 13 loop detector lead-in cables should be designed for installation in a single 4-inch conduit. Installation of more than 13 lead-in cables becomes difficult due to the quantity and weight of the cables.
- **Pull Box Spacing** - Pull boxes should be spaced no greater than 250 - 350 feet within a ramp meter.
- **Terrain** - Conduit infrastructure should be designed on relatively flat (4:1 slope or flatter) terrain. For steeper sloped terrain (3:1 or greater) , conduit may be run perpendicular to (i.e., up or down) the slope to locations where the terrain is more suitable for conduit installation.

5.3.7 Cable Routing

General

Cable routing for ramp meters involves the connection of all equipment to the controller cabinet, including loop detectors, signal assemblies, advance flashers, and the electrical service electrical service. Other devices such as cameras (see Chapter 15) and blank-out signs (see Chapter 20) may be added to a ramp meter site and require cable routing as described in their respective chapters. When routing cables for a ramp meter, issues to consider include:

- **Grouping of cables** - It is desirable to "group" cables within individual conduits throughout the system based on destination. For example, given a three-lane ramp meter with mainline detection and exit ramp loop(s), cables can be grouped such that the stop bar cables (conductor and loop lead-in cables) occupy the same conduit. The mainline and exit ramp lead-in cables can be grouped in a separate conduit, while the equipment cables near the entrance ramp (5-conductor for advance flashers and queue/reporting loop lead-in cables) grouped in yet another conduit. By grouping cables, the ramp meter cabling system is easier to maintain.
- **Separation of Power and Communication** - The power distribution traffic signal cables, or any cabling for AC power, running between the controller cabinet, signal heads, and advance flasher assemblies, must be in separate conduits from copper communications cable, yet may be installed through the same pull boxes. The communications cable performance will be degraded by close proximity to AC power conductors. It is strongly recommended that the traffic signal cables be installed in separate conduits from fiber optic communications cables as well, but if necessary, they may be run in the same duct, since the AC power conductors do not affect the performance of the fiber optic communication cable.

- **Power Service Cabling** – The power distribution wires used between the power source (examples include a meter breaker pedestal at the utility connection or an adjacent lighting distribution cabinet with a circuit dedicated for ITS use) and the cabinet or step-down transformer must be installed in an entirely separate conduit and pull box system. The conduit may be installed in the same trench as other ducts, but must be connected to a different set of pull boxes. The pull boxes for the power distribution system must all be grounded independently. The conduit for this installation should be 2-inch HDPE duct(s).

Stop Bar Signal Cables
The number of conductors required for the stop bar signals is dependent on the number of lanes being metered, and the number of signals wired independently. For a five-section ramp meter signal assembly (R-Y-G upper signals, R-G lower signals), a minimum of three conductors is required to power the assembly. The upper and lower red indications are wired in series, as well as the upper and lower green indications. In addition to the conductors assigned to the individual signal heads, the White conductor in the traffic signal cable must be used as the neutral return conductor.

Ramp Meter Type	Wiring Configuration	# of Conductors Required	Indications Wired
1 Lane Metering	Jumpered	Three Total Conductor 3 to first signal 3 Jumpered to second signal	 Red1, Yellow1, Green1 Red2, Yellow2, Green2
2 Lane Metering	Independent	Six Total Conductor 3 to first signal 3 to second signal	 Red1, Yellow1, Green1 Red2, Yellow2, Green2
3 Lane Metering	Independent	Nine Total Conductor 3 to side-mount signal 6 to overhead signal	 Red1, Yellow1, Green1 Red2, Yellow2, Green2 Red3, Yellow3, Green3
4 Lane Metering	Independent	Twelve Total Conductor 3 to first signal 3 to second signal 3 to third signal 3 to fourth signal	 Red1, Yellow1, Green1 Red2, Yellow2, Green2 Red3, Yellow3, Green3 Red4, Yellow4, Green4

Table 5.3-3: Ramp Meter Signal Conductors

If a ramp meter has two advance flasher assemblies, and a single 5-conductor is wired between the controller cabinet and the first advance flasher assembly, and another 5-conductor cable is wired between that advance flasher and the second flasher, the 2 advance flasher assemblies are considered to be ***jumpered***. If, however, 2 separate 5-conductor cables are run from the controller cabinet, one to each advance flasher assembly, the flasher assemblies are considered to be wired ***independently***. The same can be said for ramp meter stop bar signals. Typically, only single lane ramp meter stop bar signals are *jumpered*.

Common practice is to use 7-conductor, 12-conductor, and 19-conductor traffic signal cables for ramp meter stop bar signalization.

The cabling is installed in the following sequence:

1 Lane Metering:
- Cabinet to first signal base – 1/7C Cable
- First signal base to second signal base – 1/7C cable (Jumpered)

2 Lane Metering:
- Cabinet to first signal base – 1/12C Cable
- First signal base to second signal base – 1/7C cable (Independent)

3 Lane Metering:
- Cabinet to first signal base – 1/19C cable
- First signal base to second base – 1/12C cable (Independent)
- Second signal base to third signal base – 1/7C cable (Independent)

4 Lane Metering:
With the large number of potential variations on 4-lane metering layout, it is not practical to define all possibilities here. The conductor assignment should be done in a manner consistent with the 3 lane metering conductor assignment with the use of the Black, White/Black, and Blue conductors for Red, Yellow, and Green signals respectively for Heads 7 and 8 on the 4th signal base.

As WisDOT uses low current draw LED traffic signal heads for ramp meters, it is unlikely that 14 AWG traffic signal cable will not be sufficient; however, it is up to the designer to verify that the voltage drop to the signal heads is less than 3%.

Advance Flasher Assembly Signal Cables
The conductor size required between the controller cabinet and advance flasher assembly signals is dependent upon the number of signals being wired onto the same conductor, and the distance to the cabinet. 5-conductor traffic signal cables are used for advance flasher assemblies.

As WisDOT uses low current draw LED traffic signal heads for ramp meters, it is unlikely that 14 AWG traffic signal cable will not be sufficient; however, it is up to the designer to verify that the voltage drop to the signal heads is less than 3%.

In addition to the conductor cable routing, a wire chart must be developed for individual ramp meters. Traffic signal cables used in Wisconsin conform to the requirements as established by the International Municipal Signal Association (IMSA). More specifically, as documented in section 655 of Wisconsin's Standard Specifications, signal cables are required to conform to IMSA specification 20-1. IMSA 20-1 provides a 600 volt cable, solid copper conductors with polyethylene insulation, spirally wrapped with mylar tape and a polyethylene jacket. The individual conductors within the cable conform to a standard color code.

For each ramp meter, the cable routing must be illustrated under the "from", "and", "to" columns. The head number identifies the upper or lower heads on signal displays, or the left or right signal displays on a mast arm. For consistency in maintenance, the conductors used for individual **stop bar indications** are as follows:

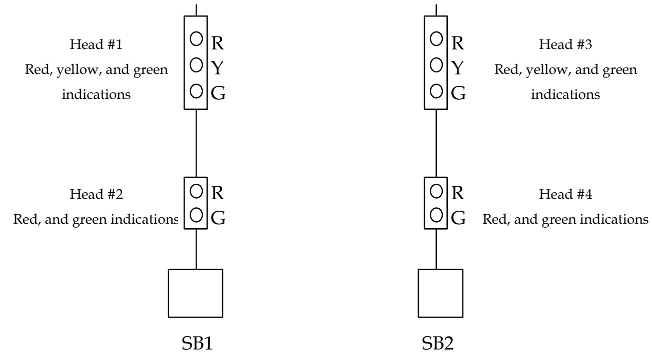
- **Red Indications** - Red insulation color. Utilize conductor numbers 3, 8, and 13 except for 4 lane configurations, which will make use of the Black conductor for the fourth red signal.
  Yellow Indications - Orange insulation color, except when wiring the first signal in a three-lane ramp meter. Blue insulation color is used in this instance to make consistent use of the white striped conductors at the first signal. Utilize conductor numbers 5, 10, and 15 except for 4 lane configurations, which will make use of the White/Black conductor for the fourth yellow signal.
  Green Indications - Green insulation color. Utilize conductor numbers 4, 9, and 14 except for 4 lane configurations, which will make use of the Blue conductor for the fourth green signal.

Advance Flasher Assembly Cables
For advance flasher assembly cables, a single conductor is required to power the amber signal indications. A 5-conductor cable is typically used, and the orange conductor is used at all times. If a set of 2 advance flasher assemblies are wired independently, or are jumpered together, the orange conductor is still maintained throughout the cable(s), since the conductor is landed on the same output in the controller cabinet.

A 5-conductor cable is also used for overhead advance warning signs used in system connector ramp meter design. Since most of these signs are placed farther in advance of the ramp meter than with advance flasher assemblies, the cable gauge becomes crucial. If the distance between the controller cabinet and sign exceeds 1000-ft, additional electrical equipment (such as a relay assembly) may be required. Design of this equipment should be coordinated with and reviewed by the State Electrical Engineer.

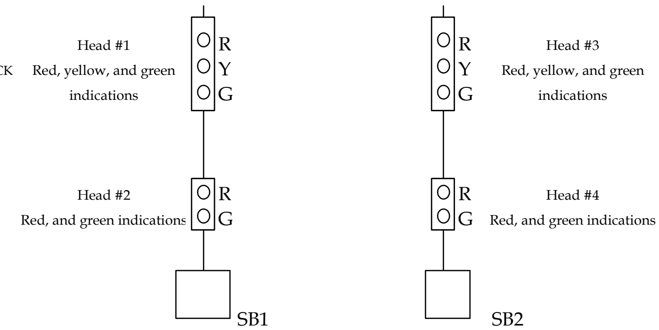
Loop Detectors
Each loop detector reporting to the ramp meter controller cabinet requires a lead-in cable between the loop and the cabinet. **A maximum of 48 detectors can be housed in a standard 2070 field cabinet**.

FROM	TO	COND. SIZE	HEAD #	COLOR CODE
CB1	SB1	7C	1	RED, ORANGE, GREEN
			2	RED, GREEN
SB1	SB2	7C	3	RED, ORANGE, GREEN
			4	RED, GREEN
CB1	FY1	5C	5	ORANGE
FY1	FY2	5C	6	ORANGE



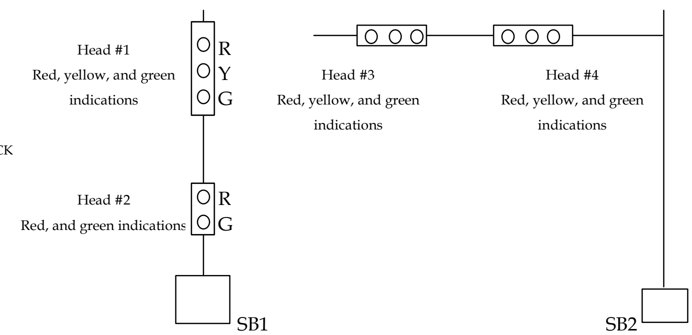
SINGLE LANE METERING

CB1	SB1	12C	1	RED-BLACK, ORANGE-BLACK, GREEN-BLACK
			2	RED-BLACK, GREEN-BLACK
SB1	SB2	7C	3	RED, ORANGE, GREEN
			4	RED, GREEN
CB1	FY1	5C	5	ORANGE
FY1	FY2	5C	6	ORANGE



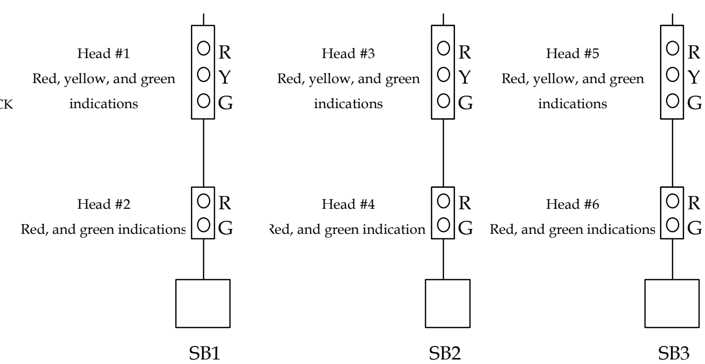
DUAL-LANE METERING

CB1	SB1	19C	1	RED-WHITE, BLUE-WHITE, GREEN-WHITE
			2	RED-WHITE, GREEN-WHITE
SB1	SB2	12C	3	RED-BLACK, ORANGE-BLACK, GREEN-BLACK
			4	RED, ORANGE, GREEN
CB1	FY1	5C	5	ORANGE
FY1	FY2	5C	6	ORANGE



3-LANE METERING, NON-SEPARATED HOV

CB1	SB1	19C	1	RED-WHITE, BLUE-WHITE, GREEN-WHITE
			2	RED-WHITE, GREEN-WHITE
SB1	SB2	12C	3	RED-BLACK, ORANGE-BLACK, GREEN-BLACK
			4	RED-BLACK, GREEN-BLACK
SB2	SB3	7C	5	RED, ORANGE, GREEN
			6	RED, GREEN
CB25	FY21	5C	7	ORANGE
FY21	FY20	5C	8	ORANGE



3-LANE METERING, SEPARATED HOV

Figure 5.3-8: Traffic Signal Wiring Diagram Example

Electrical service

The power distribution wires running between the electrical service and the controller cabinet consists of stranded copper single conductors, cross-linked polyethylene (XLP), USE rated. Section 655 of the standard specifications provides guidance on additional requirements. The bid items for Electrical Wire Traffic Signals (gauge #) AWG or Electrical Wire Lighting (gauge #) AWG will meet the requirements. The gauge of conductors must be calculated per the requirements of the National Electrical Code.

Consistent with the design practice recommended in the National Electric Code, the power distribution system should be designed for a maximum of a 3% voltage drop between the electrical service location, which may be a utility connection point or a dedicated circuit in an adjacent installation such as a lighting distribution cabinet, and the Ramp Meter or other field cabinet. When calculating the voltage drop, it is important that the ultimate potential power draw is considered. The sum of the size of the circuit breakers within the cabinet should be used as the potential draw. This will mean a 50-Amp power draw should be used as most ITS cabinets come with 2-25-Amp circuit breakers.

Depending on the availability and location of electrical service locations, these requirements may dictate the use of step-down voltage transformers adjacent to field cabinets. Refer to the SDD and specification for use of step-down voltage transformers.

Electrical Wire Routing

The conduit system for ramp meters should be bonded together, because power cables are running within the system. Bonding all metallic components of the system together assures that there will be no difference in voltage potential across two points in that system. In addition, grounded conductor should be run with current-carrying cables (such as traffic signal conductors, power distribution wires, etc.), which returns the circuit's current at zero voltage. The bonding/grounding wires in system typically use Electrical Wire Traffic Signals 10 AWG and should be placed according to State Standard Specifications for electrical wiring. The gauge of grounded conductors must be calculated per the requirements of the National Electric Code. A conservative method is to use the same size as associated power conductors. There is a distinct method required for the bonding system.

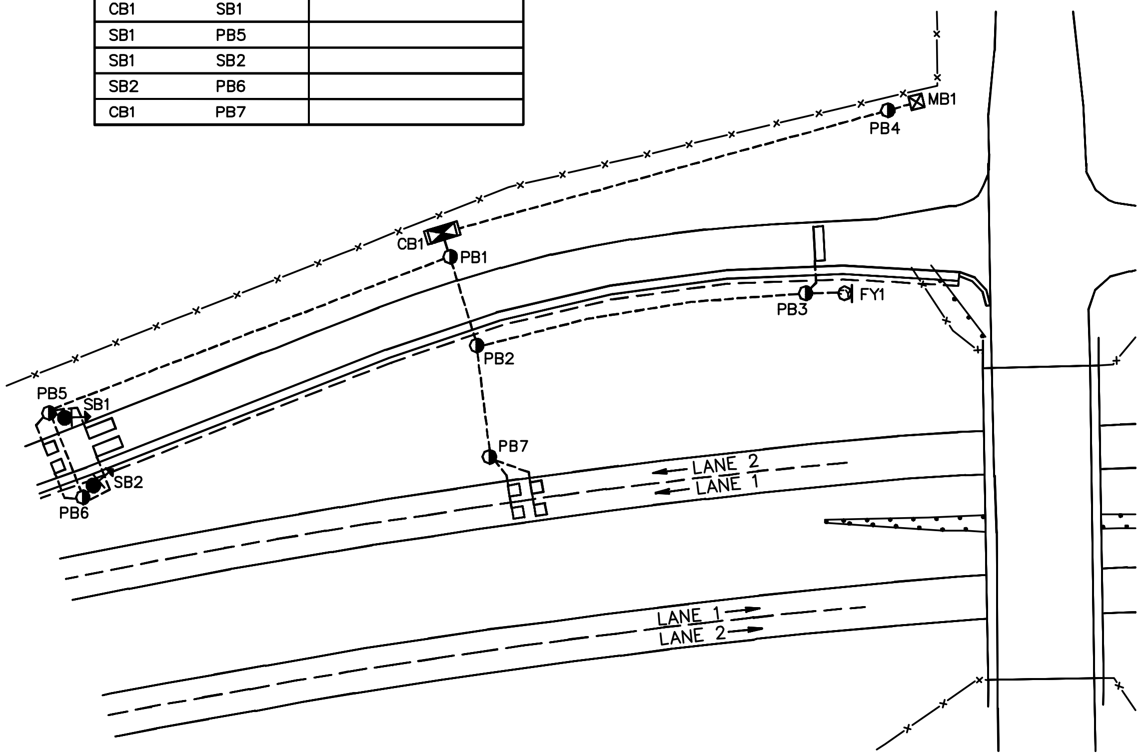
There is a distinct method required for the bonding/grounding system. For the bonding system, the wire should be run from free standing item to free standing item (i.e., poles, cabinets, electrical services, where the wire is attached to the item's grounding electrode), and then from the freestanding item to its nearest pull box. The conduit between the cabinet and nearest pull box also needs a run of wire. At pull boxes, the bonding wire is fastened to the pull box via a grounding lug, thereby grounding each pull box. Once all freestanding items have been bonded together, a bonding wire should be installed to the last pull box in the system. Bond pull box per SDD 9B4-9.

Bond and ground all conduit systems, since equipment is frequently added to various locations in the future. For assistance in bonding and grounding of underground systems, consult the State Electrical Engineer.

The grounded conductor only should be run with current-carrying (ungrounded) cables. Therefore, the grounded conductor will follow the exact same routing as described under "Stop Bar Cables" and "Advance Flasher Assembly Cables" described previously. The grounded conductor may be sized by individual circuit, or as a combination thereof. The gauge of grounded conductor required is also dependent on load as documented in the NEC. A conservative method is to use the same size as associated power conductors.

ROUTING TABLE

ELECTRICAL WIRE, TRAFFIC SIGNALS, NO. 10			
BONDING/GROUNDING		NEUTRAL	
FROM	TO	FROM	TO
CB1	PB1	CB1	FY1
CB1	PB4	CB1	SB1
CB1	FY1	SB1	SB2
FY1	PB3		
CB1	SB1		
SB1	PB5		
SB1	SB2		
SB2	PB6		
CB1	PB7		



*No. 10 gauge wire used as a working example. Size based on voltage drop.

Figure 5.3-9: Electrical Wire Routing Example

5.3.8 Ramp Meter Signing

Signing required for ramp meters is again dependent on the type of ramp meter being designed. Examples of different types of ramp meter signs are shown in Figure 5.3-10. Usage of these signs is explained as follows:

- **R10-6 (L or R)** - These signs are placed <u>at</u> the stop bar. In one, two, and three lane (median separated) metering, where side-mounted signals are used, these signs are fastened to the signal assembly. Under three-lane (no median separation) metering, a mast-arm is used for 2 lanes of signals, and the R10-6 sign on the mast-arm side is placed on a wood post.
- **R3-11 (MOD 4 & 5)-** The R3-11 HOV signs are placed on the ramp, typically near the "entrance" of the HOV lane. If the HOV lane exceeds 400 feet in length, a second R3-11 sign may be placed along the ramp as reinforcement of the lane restriction.
- **R3-10 (MOD and MOD 2) –** The R3-10 HOV signs are optional for ramp meter design. They are typically placed along the cross street, visible in advance of entering the lane. These signs warn the motorist that the ramp ahead has a restrictive lane. The SE Region has determined that R3-10 signs are not required for ramp meter operation. However, the designer should consult the appropriate Region signing representative to determine whether these signs are appropriate for ramp meters containing HOV priority lanes.
- **R10-10 (L, C, or R) (MOD)** - These signs are also used in conjunction with two or three lane metering, where signal assignment by lane is needed for proper ramp meter operation. In many instances, the operation of a ramp meter "staggers" metering, with the left lane green while the right and/or center lane signals remain red, and vice versa.
- **SP-11** - This sign is placed on the advance warning sign assemblies, and is accompanied by two yellow flashing beacons.
- **W4-2 (L or R)** - These signs are used in conjunction with two or three lane metering, where the ramp tapers down to one lane after the stop bar. The direction of the lane drop (i.e., the use of W4-2L or W4-2R) must match the direction of the taper on the ramp. These signs are typically placed between 75 and 100 feet downstream of the stop bar, depending on existing signing, overhead sign supports, beginning of taper, etc.

- **W9-1 (L or R) -** In the case of double tapers (e.g., tapers from 3 lanes to 1 from both sides of the ramp), a W4-2 sign is used on one side of the ramp, with a "RIGHT (LEFT) LANE ENDS" sign, W9-1, placed on the opposite side. This configuration is used in place of both W4-2L and W4-2R, which would give the indication that 4 lanes are narrowing to two lanes. The W9-1 sign should be placed on the side of the ramp with the HOV lane.

These signs are only signs typically associated with ramp metering, and do not include signing such as R1-2 (yield), R5-57 (pedestrians prohibited), or other signing that may be required for a particular ramp. All signing must also adhere to the Manual on Uniform Traffic Control Devices (MUTCD). Central office sign plates must be used, and all signing must be reviewed by and coordinated with the District Signing Engineer. Bid items for signing can be found in the Standard Specifications.

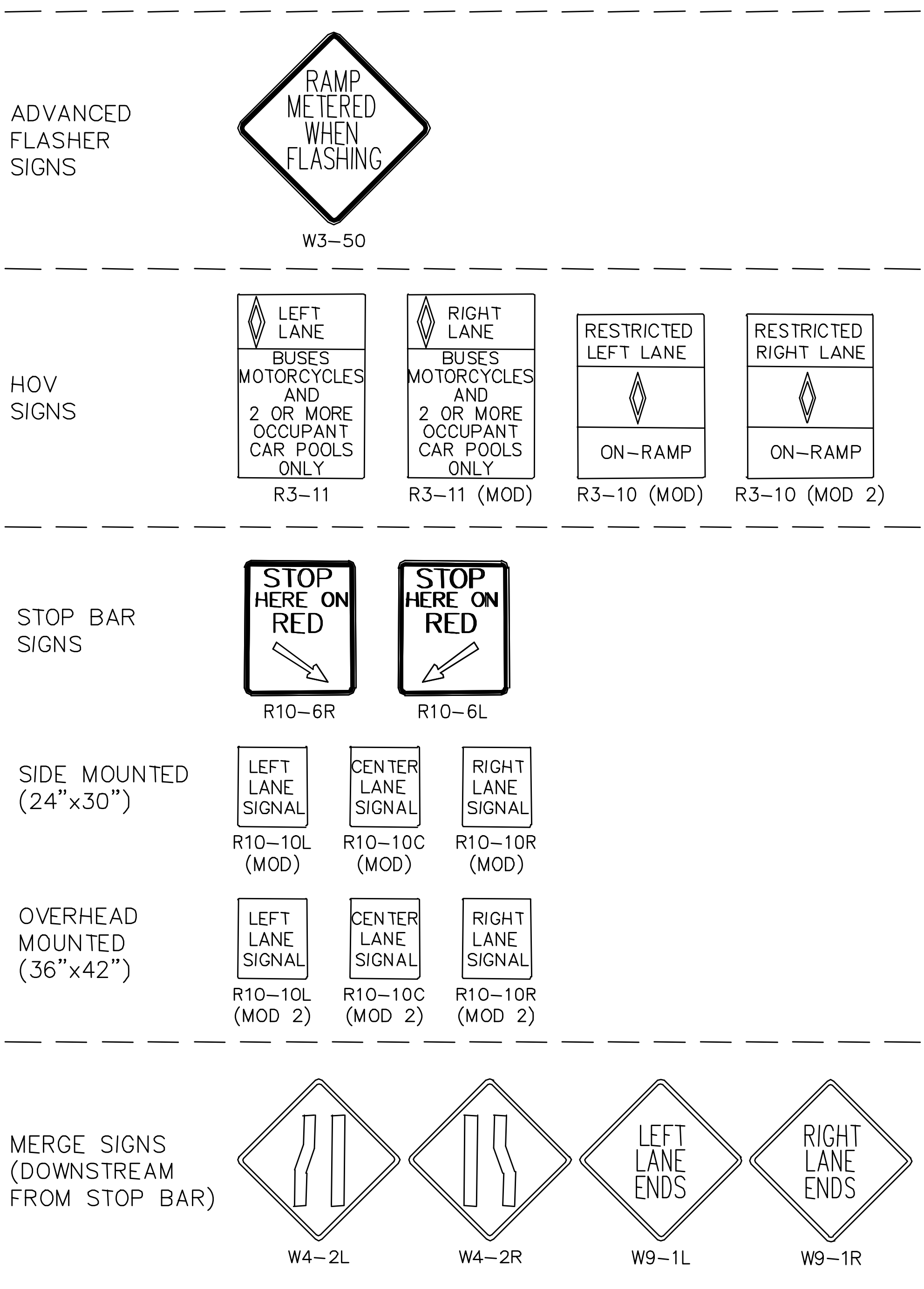


Figure 5.3-10: Ramp Meter Signing

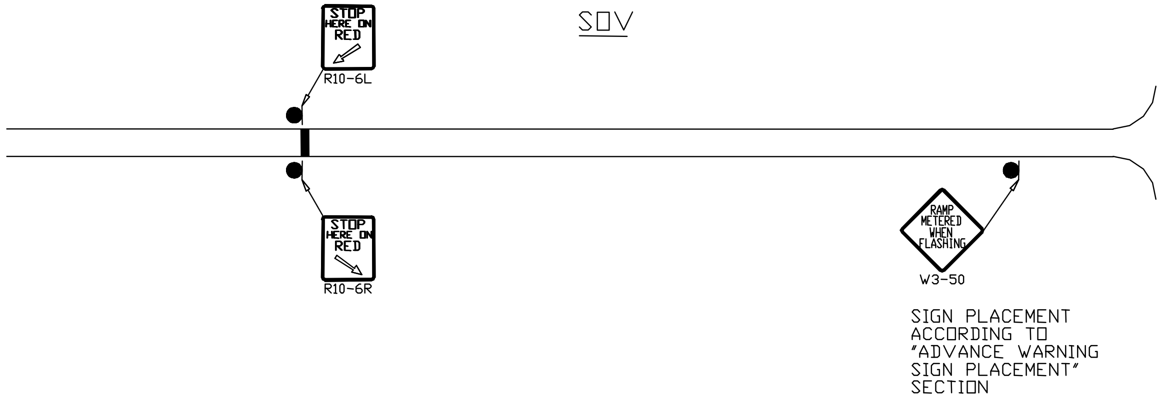


Figure 5.3-11: 1-Lane Ramp Meter Signing Placement

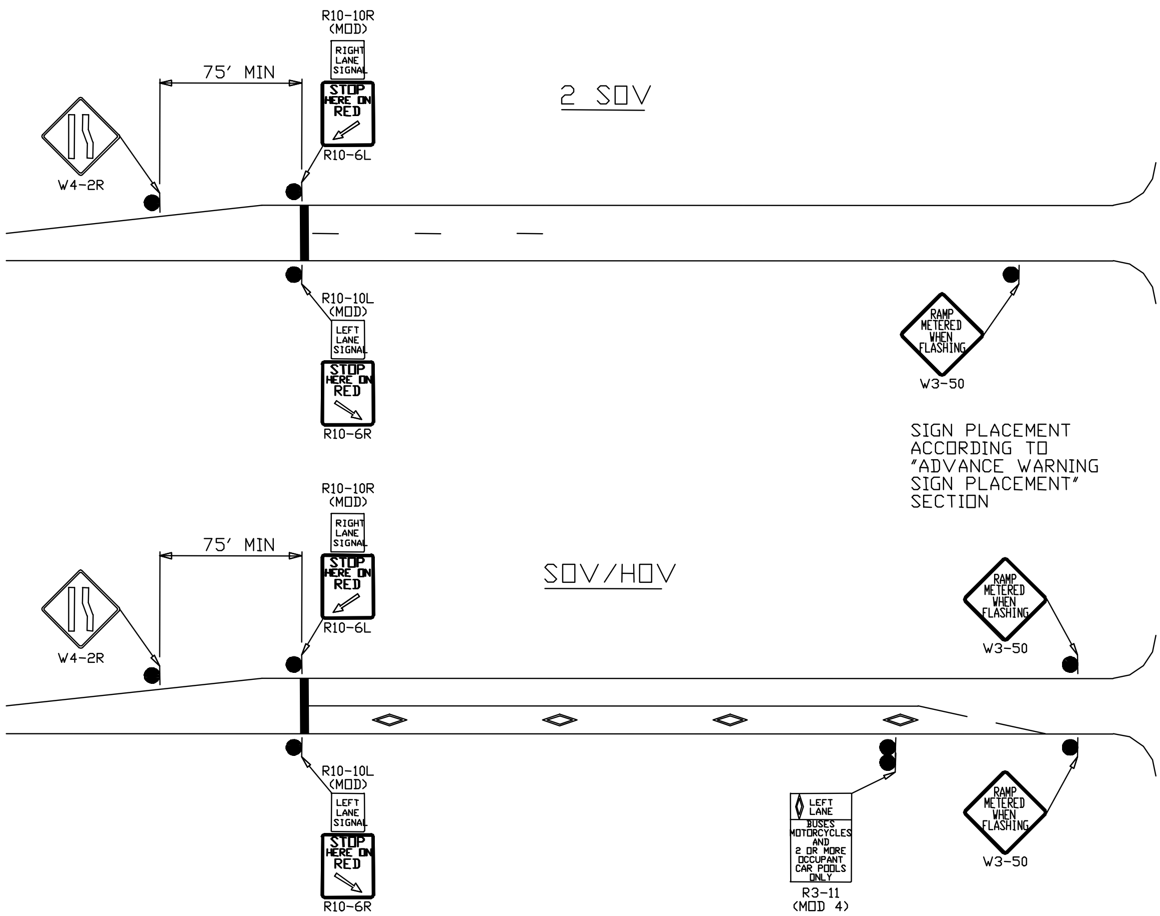


Figure 5.3-12: 2-Lane Ramp Meter Signing Placement

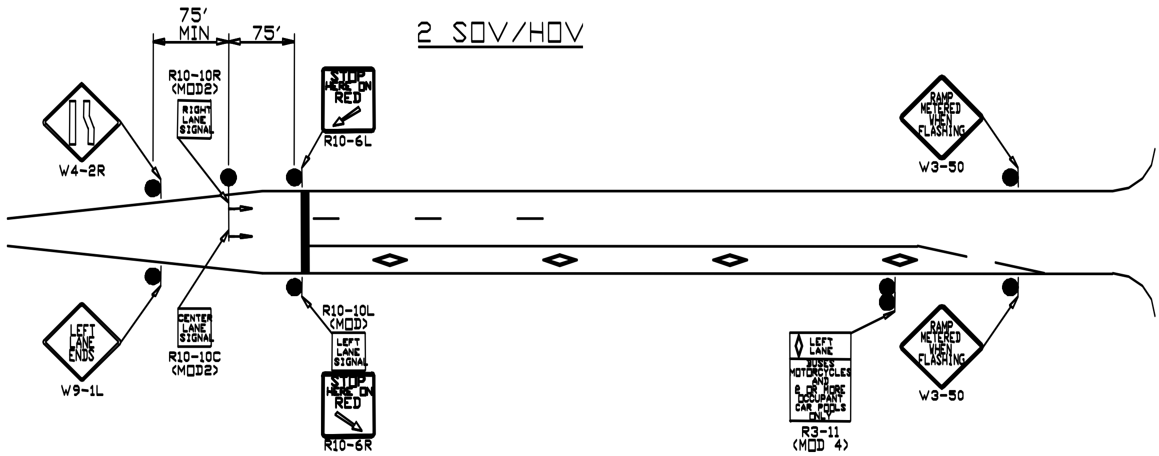


Figure 5.3-13: 3-Lane Ramp Meter Signing Placement

5.3.9 Ramp Meter Pavement Marking

Pavement marking for ramp meters is dependent upon the type of ramp meter. All ramp meters must contain 4-inch epoxy edge-lines (yellow and white).

- **Epoxy, 4-inch Lane-Line** - A white, epoxy, 4-inch lane-line is used in a 12 ½ -ft marking, 37 ½ -ft spaced pattern to separate multiple SOV lanes on a ramp meter. Typically, only three to four "skips" are required just upstream of the stop bar, rather than dividing the SOV lanes along the entire ramp. By doing this, motorists establish a dual-lane queue at the stop bar, and other motorists will move into these two queues upstream. During free-flow conditions, however, multiple lanes are not established on the ramp. Where significant ramp curvature exists, this lane line may need to be extended further upstream along the ramp for safety considerations.
- **Epoxy, 18-inch Stopbar** - At all ramp meter locations, a white, epoxy, 18-inch stop bar pavement marking is required across the ramp at the location of the ramp meter signals.
- **Epoxy, 8-inch Channelizing Line** - For ramp meters containing an HOV lane without physical (i.e., median) separation between the SOV lane, a white, epoxy, 8-inch channelizing line is required from a point just downstream of the ramp entrance to the stop bar. The location of the beginning of this channelizing line must allow ample sight distance to the HOV lane to allow motorists to make the appropriate lane change.
- **Wet Reflective Tape** – For entrance and exit ramps, place 8" wet reflective tape in the gore area. Refer to SDD 15C 8-f.
- **Epoxy, 8-inch Channelizing DOT Pattern** - At the "entrance" of the HOV lane, a white, epoxy, 8-inch "skip" line is used in a 5-ft marking, 5-ft spaced pattern. This marking is established from the beginning of the channelizing line, and angled upstream and across the ramp to the edge of pavement. When a high-occupant vehicle enters the HOV lane, it crosses the skip line. HOV skip lines typically run between 75-ft and 100-ft in length, dependent upon width of the HOV lane and ramp alignment.
- **Epoxy, HOV Symbols** - For the length of the HOV lane, white, epoxy, "diamond" symbols are spaced 100-ft apart. A symbol must be within 30-ft of the stop bar. The 100-ft spacing may be shortened between symbol nearest to the stop bar and the symbol immediately upstream to maintain this requirement. HOV symbols serve as a Regional reinforcement of usage of the lane.

The HOV symbol can be found in SDD 15C 7-a. The 8-inch channelizing lines require construction details.

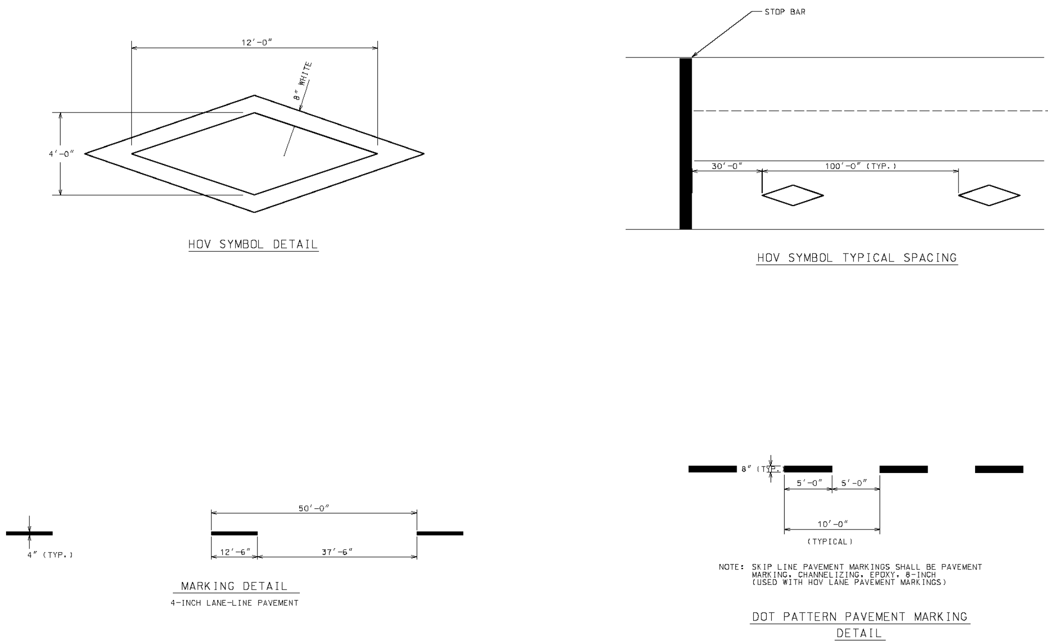
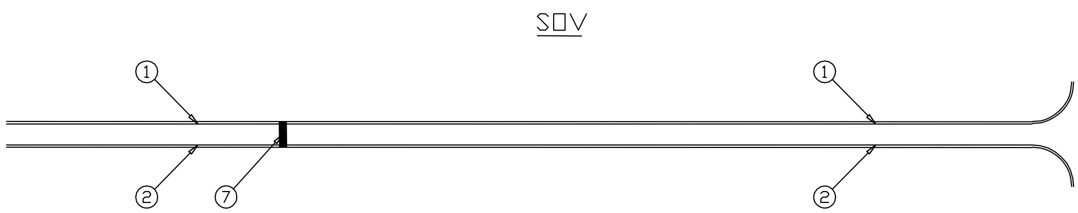
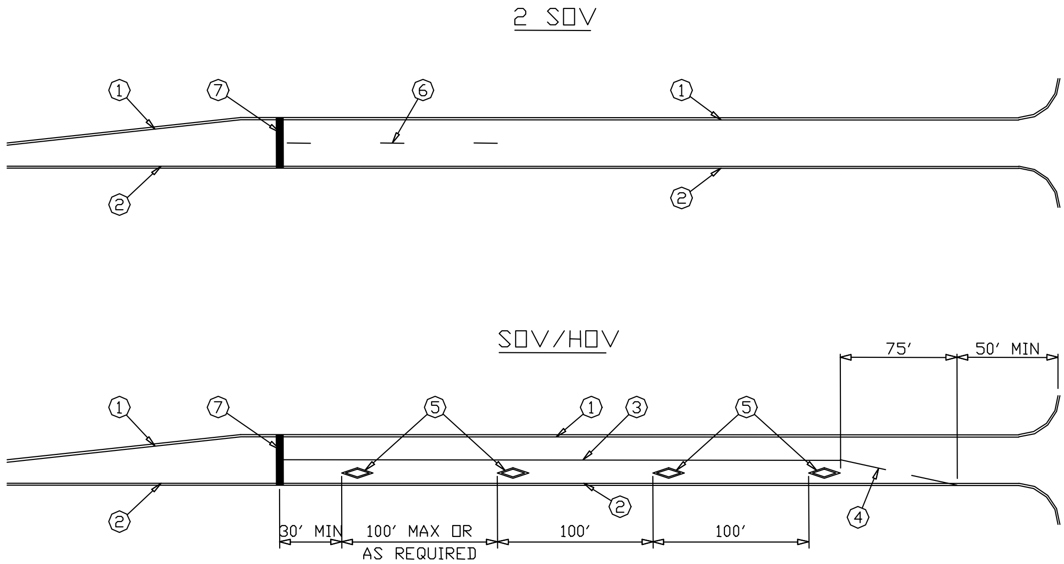


Figure 5.3-14: Ramp Meter Pavement Marking Details



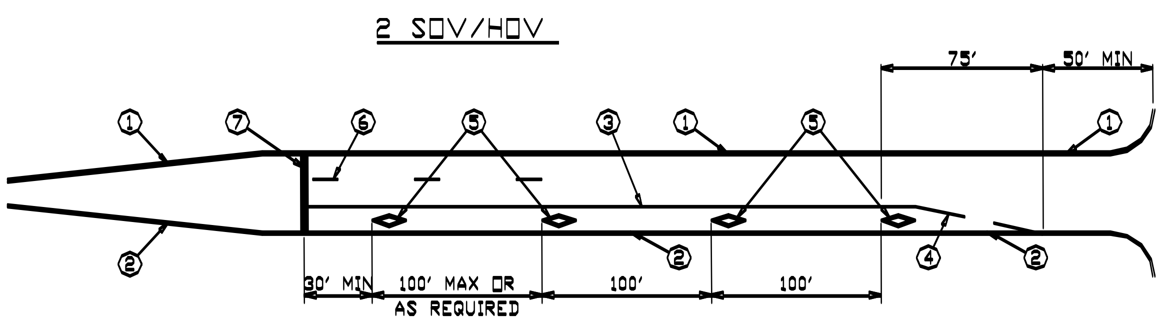
LEGEND
(1) PAVEMENT MARKING, EPOXY, 4-INCH WHITE
(2) PAVEMENT MARKING, EPOXY, 4-INCH YELLOW
(3) PAVEMENT MARKING, CHANNELIZING, EPOXY, 8-INCH
(4) PAVEMENT MARKING, CHANNELIZING, EPOXY, 8-INCH HOV SKIP LINE (5 FT-5 FT PATTERN)
(5) PAVEMENT MARKING, EPOXY, HOV SYMBOL
(6) PAVEMENT MARKING, EPOXY, 4-INCH LANE LINE (12.5 FT-37.5 FT PATTERN)
(7) PAVEMENT MARKING, STOPBAR, EPOXY, 18-INCH

Figure 5.3-15: 1-Lane Pavement Marking Requirements



LEGEND
(1) PAVEMENT MARKING, EPOXY, 4-INCH WHITE
(2) PAVEMENT MARKING, EPOXY, 4-INCH YELLOW
(3) PAVEMENT MARKING, CHANNELIZING, EPOXY, 8-INCH
(4) PAVEMENT MARKING, CHANNELIZING, EPOXY, 8-INCH HOV SKIP LINE (5 FT-5 FT PATTERN)
(5) PAVEMENT MARKING, EPOXY, HOV SYMBOL
(6) PAVEMENT MARKING, EPOXY, 4-INCH LANE LINE (12.5 FT-37.5 FT PATTERN)
(7) PAVEMENT MARKING, STOPBAR, EPOXY, 18-INCH

Figure 5.3-16: 2-Lane Pavement Marking Requirements



LEGEND
(1) PAVEMENT MARKING, EPOXY, 4-INCH WHITE
(2) PAVEMENT MARKING, EPOXY, 4-INCH YELLOW
(3) PAVEMENT MARKING, CHANNELIZING, EPOXY, 8-INCH
(4) PAVEMENT MARKING, CHANNELIZING, EPOXY, 8-INCH HOV SKIP LINE (5 FT-5 FT PATTERN)
(5) PAVEMENT MARKING, EPOXY, HOV SYMBOL
(6) PAVEMENT MARKING, EPOXY, 4-INCH LANE LINE (12.5 FT-37.5 FT PATTERN)
(7) PAVEMENT MARKING, STOPBAR, EPOXY, 18-INCH

Figure 5.3-17: 3-Lane Pavement Marking Requirements

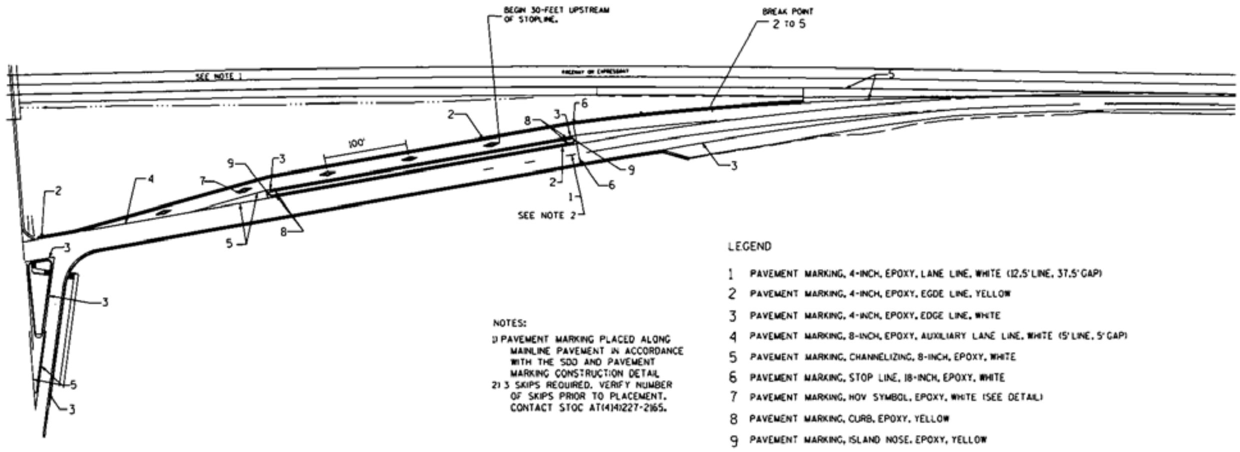


Figure 5.3-18: Typical Ramp Meter and HOV Lane Marking

5.3.10 Ramp Lighting

Ramp lighting is required for every ramp meter. The stop bar area must be lighted, and static signing and pavement markings must be visible under all lighting conditions. WisDOT roadway lighting guidelines can be found in Section 11-50-15 of the *Facilities Design Manual*. Ramp lighting must also be coordinated through the Region's Highway Lighting Engineer. To avoid delays in design, notify the Highway Lighting Engineer early in the design process to complete the lighting design and establish review submission due dates.

5.4 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

5.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

5.5.2 Ramp Meter Controller Equipment

For ramp metering installation, a Ramp Meter Processor Assembly is used, consisting of the following devices:

- Type 334 Cabinet
  - Model 200 switch packs
  - Model 208 monitor unit
  - Model 222 dual vehicle detector modules (for loop detector inputs) and rack
  - Model 242 DC dual isolation modules (for microwave detector or video image detector inputs or loops shared from a different cabinet)
  - HOV Programmable Logic Controller (for ramp meters with HOV lane only)
- Type 2070 controller unit
  - CPU
  - Input/output interface
  - Unit chassis
  - Unit power supply with external power connection
  - Unit standby power supply
  - Front panel assembly
  - Internal system interface
  - Connectors
  - Communications system interface
  - Model 412C program module
  - Model 400 modem module

5.5.3 Communication Requirements

Ramp meter controllers (i.e. Model 2070 processor assemblies), contain 1200 to 14,400 baud (bits per second) modems internal to the processor unit. The communication medium selected for ramp meter design can include spread spectrum radio, Ethernet over fiber (with an Ethernet to serial converter), dedicated twisted pair copper, or leased telephone circuit. Contact the State Traffic Operations Center to discuss communication requirements.

5.5.4 Electrical Service Requirements

Consistent with the design practice recommended in the National Electric Code, the electrical service and power distribution system should be designed for a maximum of a 3% voltage drop between the electrical service location, which may be a utility connection point or a dedicated circuit in an adjacent installation such as a lighting distribution cabinet, and the Ramp Meter or other field cabinet. When calculating the voltage drop, it is important that the ultimate potential power draw is considered. Good design practice dictates that the sum of the size of the circuit breakers within the cabinet be used as the potential draw. In most cases for ITS design this will mean a 50-Amp power draw should be used as most ITS cabinets come with 2-25-Amp circuit breakers.

A 100 Amp, 2-Circuit, 120/240 volt, single phase, three wire underground electrical service is the most commonly used and preferred electrical service for Ramp Meter cabinets, or any ITS field cabinet; however, other systems must be considered in instances where the electrical service location is of such a distance from the field cabinet that maintaining the above described 3% maximum voltage drop is not possible.

Power distribution conductors must be sized appropriately to design for the above-mentioned 3% maximum voltage loss with a maximum conductor size of 1/0 AWG.

Due to WisDOT safety regulations, voltage in excess of 120V must not be brought into ITS field cabinets. Rather, step-down transformers must be installed adjacent to the field cabinets with only the 120V conductors installed into the cabinet. For further clarification, it is not acceptable to “split” the 240V service into two 120V circuits in the field cabinet.

The electrical service will be furnished and installed by the local power company up to a demarcation point, typically an electrical service (meter) pedestal. The electrical service must conform to the requirements of the local power company. **The location of the electrical service pedestal must receive approval from the utility company.** The electrical service will include two 50-amp circuit breakers rated at 22,000 AIC. The requirements for power cable between the electrical service and controller cabinet can be found in 5.3.7 *Cable Routing*.

At locations which require a remotely located electrical service or which require an adjacent step-down transformer, a 100 Amp outside rated breaker box with space for 6 circuits, but no main breaker, will be attached to the side of the cabinet so that the cabinet may be shut down without entry into the higher voltage step-down transformer. Also, a 50 Amp single circuit breaker rated at 22,000 AIC will be installed within the breaker box to serve as a local electrical service disconnect point. Remote service should be labeled in the field as ITS with State Traffic Operations Center’s phone number.

5.5.5 Ramp Metering Construction Standards
Construction details, Standard Special Provisions, and Special Provisions can be found in Appendix 70.

5.6.1 Testing

5.6.1.1 Controllers and Detectors
Reference Standard Specifications 675.3.(14) through 675.3.(20) for testing procedures. In 675.3.(15), traffic flow information includes volume and speed data.

5.6.1.2 Field System Integrator
Refer to Standard Specification 670.3.2.1 for field system integrator duties.

- **Contractor-furnished equipment and materials**, refer to Standard Specification 670.3.3.1.
- **Department-furnished equipment** and materials, refer to Standard Specification 670.3.3.2

5.6.2 Acceptance
Notify the State Traffic Operations Center after testing is complete. The State Traffic Operations Center Maintenance Representative will do the final concurrence of acceptance before the State Traffic Operations Center accepts ownership and maintenance of the ramp meter.

5.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

5.7.2 Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as "GPS data points". The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
  - Latitude (Y-coordinate) in decimal degrees
  - Longitude (X-coordinate) in decimal degrees
  - Altitude (Z-coordinate) in feet
  - Date (day, month, year) of point collection
  - Time (24 hour format) of point collection
  - Initials of field personnel collecting data points
  - Abbreviation for Element Type (see table of elements below)
  - Location description (for example, street and cross street)
  - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 95% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

Relevant Elements

Abbreviation	Description
CAM	CCTV poles (capture point at pole location)
CAB	Field equipment cabinets (unless attached to pole that is already being located)
PB	Pull boxes (when used with a fiber optic infrastructure installation, or when connected to in-pavement loops)
MH	Manholes (when part of fiber infrastructure)
JB	Junction boxes (such as on a bridge)
CV	Communication vaults (when part of fiber infrastructure)
MBP	Meter breaker pedestals
HUT	Equipment shelters (i.e. fiber optic communication huts)
ANT	Antenna poles (capture point at pole location)
OHS	Dynamic message signs (capture at base of sign support with connections to power and/or communications)
YF	Yellow Flashers (ramp metered when flashing signs)
HAR	Highway advisory radio transmitters (at antenna location)
SGN	Highway advisory radio signs (at sign location)
RMS	Ramp meters (capture point at pole location)
RWIS	RWIS sites (including tower, pull boxes and meter breaker pedestal)
GTE	Ramp closure gates
PG	Point Generic (fiber access/splice locations and other infrastructure not described above)
MD	Microwave detectors/detector poles (capture point at pole location)

5.7.3 Documentation

The following fields are used in the ITS inventory system. This data should be provided to the BHO-STOC as soon as it is available. The data must be provided before the equipment is accepted.

CartêGraph ITS Inventory Database Fields

General:

- ID
- TOC Location Description
- Installation Address
- Installation Phone Number – (Circuit ID for anything that has a leased telephone service)
- Service Provider Meter Number
- Service Provider Utility Account
- TOC Monitor ID – (Links with STOC's Monitor database)
- Region
- TOC Type
- Maintaining Authority
- Maintaining Authority Contact
- Service Provider

Details:

Events – Lists work orders and other events

Detectors:

- ID
- Detector Number
- Description
- Loop Location

Aux Equip:

- ID
- Serial Number
- Description
- Manufacturer
- Model

Cabinets:

- ID
- Serial Number
- Description

Supports

- Bolt circle
- Height
- Lowering system

5.7.4 Deployment Inventory

A listing of all the devices installed and the associated serial numbers, as-built CAD files, and testing and calibration results should be provided to BHO-STOC. **An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60 ITS Software.**

5.8.1 Maintenance

5.8.1.1 New Ramp Meters

Once the State Traffic Operations Center Maintenance Contractor accepts the ramp meter equipment per 5.6.2, the State Traffic Operations Center will accept the ramp meter onto the Statewide Maintenance Contract.

5.8.1.2 Existing Ramp Meters

If a contractor is working on an existing ramp meter, the contractor is responsible for locates and any maintenance until seven days after the as-builts have been delivered to the State Traffic Operations Center. At that time, the State Traffic Operations Center will accept the ramp meter onto the Statewide Maintenance Contract.

5.8.2 Reevaluation

In addition to periodic ramp meter timing updates, ramp meters should be evaluated for their effectiveness. Existing ramp meter installations should be reviewed to determine if there are locations where ramp meters no longer are as beneficial as they used to be. It may be beneficial to remove ramp meters that are no longer necessary.

10.1.1 Introduction

System detector stations collect real time data on freeway traffic flow. The data is used for traffic management functions such as detecting incidents, traffic flow information, and archiving for planning and historical analysis. System detector stations typically provide real-time information into a system; they do not collect data for use in a closed system (e.g. signalized intersection)

Each system detector station is typically configured to measure and collect three standard traffic flow parameters on a lane-by-lane basis:

- Volume
- Occupancy (similar to traffic "density")
- Speed

10.1.2 Needs Assessment

If there is a need to monitor traffic flow on the system, SDS should be used. Prior to determining the type and location of a system detector station, various data needs to be collected, such as:

- Mainline peak hour volume-to-capacity ratio for proposed location(s)
- Corridor spacing requirements (½ -mile spacing is typically used in congested urban areas, where the mainline peak hour volume-to-capacity ratio is 0.70 or greater; 1-mile spacing is typically used in moderately congested areas, where the mainline peak hour volume-to-capacity ration is 0.50 or greater, and 2-3 mile spacing is used in rural areas where the peak hour volume-to-capacity ratio is less than 0.50. Spot location detection may be used in rural interchanges where mainline and ramp data is collected for historical purposes for planning uses.
- Site-specific issues or concerns based on an initial site visit (right-of-way, utilities, landscape, and pavement condition)
- New roadway construction project or existing pavement

The location of the detector station based on spacing requirements is affected by the placement of mainline detectors along a corridor. Mainline detection for ramp meters must be considered when determining locations for system detector stations. If urban interchanges are spaced approximately 1 mile apart, then one bi-directional detector station would be placed approximately halfway between the interchanges. While the directional ramp meter mainline loops may be a few hundred feet apart (near the ramp meters), the goal of detector station spacing is to get an overall average close to the spacing requirements, not precise distances upstream and downstream to the nearest detectors.

10.1.2.1 Types

Within Wisconsin, two different types of detector stations have been implemented on large scales to measure various traffic parameters:

- Loop Detector Stations - Loop detectors configured in a "trap" configuration, spaced at a consistent distance apart (typically 16-ft) leading edge to leading edge, are used for permanent detection statewide.
- Microwave Detector Stations - Microwave detectors are above-ground units mounted either over a traffic lane (e.g., on a bridge overpass), or along the side of the freeway mounted on a pole, in a "side-fire" configuration approximately 15 feet high. For microwave detectors mounted over a traffic lane, speed can be measured, whereas via side-fire configuration, the speed parameter is calculated. The side-fire configurations, however, have proven to be more accurate than the overhead position. Microwave detectors are typically used for temporary installations to provide traffic data during construction projects, or in a permanent configuration where the freeway pavement is relatively new. Additional types of detector stations may be implemented based on new technology, case-specific needs, or evaluation

purposes.

10.1.2.2 Other Types

At times, other types of detection may be advantageous to deploy in place or in addition to the traditional system detector stations. These other types may act as stand alone devices or may not integrate directly with the system; however, the data that these systems collect can be beneficial for both operations and planning.

- Probe data, including the use of cellular probes
- Automatic Traffic Recorders – typically only record volume, but may gather additional data such as classification.

For specific procurement product information, see Chapter 70.5 State Supplied List. Contact the BHO-STOC for product information.

Follow the System Detector Station Design Process checklist shown in Table 10.1

Table 10.1 System Detector Station Design Process Checklist

Collect initial data required for the proposed system detector station location	
Determine the **detector station type** required for the design location	
Determine the **location of the controller cabinet** and meter service pedestal	
Prepare the **underground infrastructure**, including detectors, conduit, and pullboxes	
Perform **cable routing** to provide hardwire interconnection between the controller cabinet and detector station devices such as detectors, electrical service, etc.	
Determine the **communications medium** used for the proposed location (See Chapter 50, Communication Systems.)	
Revisit steps 3 through 6 until final design is complete	
Begin the process to **establish electrical service** for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location.	
Determine the **construction details** needed for the proposed design, details which **need to be modified**, and new details which **need to be created** to provide a complete construction plan.	
Determine the **special provisions** needed for the proposed design, special provisions which **need to be modified**, and new special provisions which **need to be created** to provide a complete construction plan.	
Determine the **standard specification bid items** and **procurement items** that will need to be included in the estimate and miscellaneous quantities to provide a complete construction plan.	

10.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format. For example, for the 20th system detector station that is installed in the state will be in Milwaukee County (40), the number for the device should be SDS-40-0020 (i.e. SDS-County number-next sequential four digit number). The device number and related information will be stored in the ITS inventory management system.

If the device requires a TELCO (landline phone line), a street address must be established during this process.

10.2.2 Communications Assignments

Refer to Chapter 50, ITS Communication Systems for information regarding the appropriate communication network to use for closed-circuit television cameras. Contact the STOC to discuss communication requirements.

10.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

10.3.1 Design Process

In the System Detector Station (SDS) design process, the designer must follow several steps to ensure successful implementation and proper operational capabilities. Many of these steps, such as power and communication requirements, must be addressed early in the design process.

1. Collect initial data required for the proposed system detector station location
2. Determine the detector station type required for the design location
3. Determine the location of the controller cabinet and meter service pedestal
4. Prepare the underground infrastructure, including detectors, conduit, and pullboxes
5. Perform cable routing to provide hardwire interconnection between the controller cabinet and detector station devices such as detectors, electrical service, etc.
6. Determine the communications medium used for the proposed location (See Chapter 8, Communication Systems.)
7. Revisit steps 3 through 6 until final design is complete
8. Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location.
9. Determine the construction details needed for the proposed design, details which need to be modified, and new details which need to be created to provide a complete construction plan.
10. Determine the special provisions needed for the proposed design, special provisions which need to be modified, and new special provisions which need to be created to provide a complete construction plan.
11. Determine the standard specification bid items and procurement items that will need to be included in the estimate and miscellaneous quantities to provide a complete construction plan.

10.3.2 Cabinet and Equipment Placement

10.3.2.1 Cabinet Placement

The placement of the controller cabinet involves:

- Visibility of the mainline detectors from the controller cabinet
- Distance between the controller cabinet and the loop detectors
- Off-freeway accessibility for maintenance vehicles, whenever possible
- Safety of the cabinet location (do not place the cabinet on the outside of a curve)
- Grades
- Drainage
- Maintenance Accessibility (parking availability for maintenance vehicles)

For maintenance considerations, it is very important that the mainline detectors be visible from the controller cabinet. Due to the necessary loop to lead-in inductance ratio, the distance between the cabinet and loop detectors is also an important factor. Appendix C provides an overview of loop inductance calculation and maximum lead-in cable distance. The slope of the terrain for cabinet placement must be no steeper than 4:1. Placement of the cabinet on 3:1 slopes or steeper requires grading provisions to provide a level area around the cabinet.

10.3.2.2 Detector Placement

Detector placement (either loops or microwaves) should follow the following guidelines.

- Detection should be placed outside of any “weaving” areas.
- For interchange detection, the detectors must be placed within the exit and entrance ramp gores.
- For non-interchange areas, detectors must be placed away from lane-drops, acceleration/deceleration lane introductions, and other similar features.
- Placement of side-fire microwave detectors (on poles) must be outside of the clear zone if breakaway

pedestal bases are not used, and is good practice even with breakaway bases.

- Placement of side-fire microwave detectors (on poles) should be accessible for maintenance vehicles (e.g., bucket trucks).

10.3.3 Underground Infrastructure

When the controller cabinet, electrical service and detectors have been placed, the underground conduit infrastructure can be designed. Issues to keep in mind when designing the conduit infrastructure include:

- Conduit Size - 3-Inch conduit is typically used for detector station raceways, since a) cost savings between 3-inch and smaller diameter conduits is minimal, and b) 3-inch conduit may provide for greater future expansion depending on the number of cables and % fill of the conduit. Conduit entering electrical service pedestals must be sized per pedestal requirements.
- Conduit Fill - The size and number of conduits along a run is dependent on percentage of fill as established by the National Electric Code (NEC). Although it may not violate the NEC fill code, no more than 13 loop detector lead-in cables should be designed for installation in a single 3-inch conduit. Installation of more than 13 lead-in cables becomes difficult due to the quantity and weight of the cables.
- Pull Box Spacing - Pull boxes should be spaced no greater than 200 feet. If a conduit run contains only one or two lightweight cables (e.g., loop lead-ins), this distance can be stretched to approximately 300 feet.
- Terrain - Conduit infrastructure should be designed on relatively flat (4:1 slope or flatter) terrain. For steeper sloped terrain (3:1 or greater) , conduit may be run perpendicular to (i.e., up or down) the slope to locations where the terrain is more suitable for conduit installation.

10.3.4 Cable Routing

10.3.4.1 General

Cable routing for system detector stations typically involves the connection of all equipment to the controller cabinet, including loop detectors, microwave detectors, and the electrical service electrical service. Other devices, such as cameras (see Chapter 15), may be added to a system detector station site, and require cable routing as described in their respective chapters. The power distribution cable running between the controller cabinet and the electrical service should be in a separate conduit. Power and communication cables should not be mixed together.

10.3.4.2 Loop Detectors

Each loop detector reporting to the ramp meter controller cabinet requires a lead-in cable between the loop and the cabinet. A maximum of 64 loops can be housed in a 2070 controller cabinet. Appendix C provides guidance on loop inductance and maximum lead-in cable length calculations.

10.3.4.3 Microwave Detectors

Microwave detectors utilize 12-pair cable, or “Microwave Detector Cable” as called under the Appendix B, Special Provisions. One microwave detector cable is required for each unit. A 2070 controller cabinet can accept 32 detector inputs, or the number of detection “zones” a microwave detector captures. In a side-fire configuration collecting data for 3 freeway lanes.

10.4 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

10.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at

http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

10.5.2 Communication Requirements

System Detector Stations (SDS) require communications to bring the data collected into the system. The communication medium selected for SDS sites is open to the following communication types as described in Chapter 8, Communication System.

- Leased Communications - Either leased fiber optics or leased high-speed data lines (ISDN, 56k).
- State-Owned Communications - Fiber optic communications.
- Wireless Ethernet Radio - capable of bandwidth between 3MB to 20 MB.

10.5.3 Power Requirements

A 100 Amp, 120/240 volt, single phase, and three wire underground electrical service is required for electrical service installation. Two 2070 controller cabinets can be powered by a single 100-amp service. The electrical service will be furnished and installed by the Wisconsin Electric Power Company up to a demarcation point, which consists of a electrical service. The electrical service must conform to the requirements as found in the Electric Service and Metering Manual as issued by Wisconsin Electric. The location of the electrical service must receive approval from the utility company. The electrical service will include two 50-amp circuit breakers rated at 22,000 AIC. The requirements for power cable between the electrical service and controller cabinet can be found under the Cable Routing section of this chapter.

At locations which require a remotely located electrical service, a 100 Amp outside rated breaker box with space for 6 circuits, but no main breaker, will be attached to the side of the cabinet. Also, a 50 Amp single circuit breaker rated at 22,000 AIC will be installed within the breaker box to serve as a local electrical service disconnect point.

10.5.4 System Detector Stations Construction Standards

Construction details, Standard Detail Drawings, and Special Provisions can be found in Appendix 70.

10.6.1 Testing

10.6.1.1 Controllers and Detectors

Reference Standard Specifications 675.3.(14) through 675.3.(20) for testing procedures. In 675.3(15), traffic flow information includes volume and speed data.

10.6.1.2 Field System Integrator

Refer to Standard Specification 670.3.2.1 for field system integrator duties.

- **Contractor-furnished equipment and materials**, refer to Standard Specification 670.3.3.1.
- **Department-furnished equipment** and materials, refer to Standard Specification 670.3.3.2

10.6.2 Acceptance

Notify the State Traffic Operations Center after testing is complete. The State Traffic Operations Center Maintenance Representative will do the final concurrence of acceptance before the State Traffic Operations Center accepts ownership and maintenance of the System Detector Station.

10.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

10.7.2 Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as "GPS data points". The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
  - Latitude (Y-coordinate) in decimal degrees
  - Longitude (X-coordinate) in decimal degrees
  - Altitude (Z-coordinate) in feet
  - Date (day, month, year) of point collection
  - Time (24 hour format) of point collection
  - Initials of field personnel collecting data points
  - Abbreviation for Element Type (see table of elements below)
  - Location description (for example, street and cross street)
  - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 95% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

Relevant Elements

Abbreviation	Description
CAM	CCTV poles (capture point at pole location)
CAB	Field equipment cabinets (unless attached to pole that is already being located)
PB	Pull boxes (when used with a fiber optic infrastructure installation, or when connected to in-pavement loops)
MH	Manholes (when part of fiber infrastructure)
JB	Junction boxes (such as on a bridge)
CV	Communication vaults (when part of fiber infrastructure)
MBP	Meter breaker pedestals
HUT	Equipment shelters (i.e. fiber optic communication huts)
ANT	Antenna poles (capture point at pole location)
OHS	Dynamic message signs (capture at base of sign support with connections to power and/or communications)
YF	Yellow Flashers (ramp metered when flashing signs)
HAR	Highway advisory radio transmitters (at antenna location)
SGN	Highway advisory radio signs (at sign location)
RMS	Ramp meters (capture point at pole location)
RWIS	RWIS sites (including tower, pull boxes and meter breaker pedestal)
GTE	Ramp closure gates
PG	Point Generic (fiber access/splice locations and other infrastructure not described above)
MD	Microwave detectors/detector poles (capture point at pole location)

10.7.3 Documentation

A listing of all the devices installed and the associated serial numbers, as-built CAD files, and testing and calibration results should be provided to BHO-STOC.

The following fields are used in the ITS inventory system. This data should be provided to the BHO-STOC as soon as it is available. The data must be provided before the equipment is accepted.

CartêGraph ITS Inventory Database Fields General:

- ID
- TOC Location Description
- Installation Address
- Installation Phone Number
- Service Provider
- Service Provider Utility Account
- TOC Monitor ID
- Region
- TOC Type
- Maintaining Authority
- Maintaining Authority Contact
- Service Provider

Details:

- Events – Lists work orders and other events
- Detectors:
    - ID
    - Detector Number
    - Description
    - Loop Location
- Aux Equip:

- ID
- Serial Number
- Description
- Manufacturer
- Model

- Cabinets:
    - ID
    - Serial Number
    - Description

- Supports:
    - Bolt circle
    - Height
    - Lowering system

10.7.4 Deployment Inventory

An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60 ITS Software.

10.8.1 Maintenance

10.8.1.1 New SDS

Once the State Traffic Operations Center Maintenance Contractor accepts the SDS equipment per 10.6.2, the State Traffic Operations Center will accept the SDS onto the Statewide Maintenance Contract.

10.8.1.2 Existing SDS

If a contractor is working on an existing SDS, the contractor is responsible for locates and any maintenance until seven days after the as-builts have been delivered to the State Traffic Operations Center. At that time, the State Traffic Operations Center will accept the SDS onto the Statewide Maintenance Contract.

10.8.2 Reevaluation

In addition to periodic SDS equipment updates, SDS should be evaluated for their effectiveness. Existing SDS installations should be reviewed to determine if there are locations are as beneficial as they used to be. It may be beneficial to remove SDSs that are no longer necessary.

15.1.1 Introduction

The guidance in Chapter 15 is intended for the placement of *new* Closed circuit television (CCTV) cameras as part of new construction projects only. The STOC must be contacted if retrofitting a CCTV camera to existing systems or in any other circumstances where the addition of a camera is being considered.

CCTV cameras are a key part of traffic management systems. The primary benefit of CCTV cameras is the ability to provide visual information required to make informed decisions. CCTV cameras are used for roadway surveillance, verification of incidents detected by other means (e.g., cellular calls, speed detectors, etc.), and for assistance in determining appropriate responses to an unplanned event or incident. Beyond these tasks, cameras can be utilized for:

- Monitoring traffic movements on the mainline and ramps.
- Changeable Message Sign (CMS) verification.
- Verification of stranded motorists and incidents.
- Observing localized weather and other hazardous conditions.

Use of CCTV camera images has expanded outside of Statewide Traffic Operation Center. When local agencies are granted access to the images, CCTV cameras assists in the coordination and efficient use of available resources, such as emergency vehicle deployment. Motorists can access CCTV cameras via the local television stations or the Internet to look at current travel conditions and plan alternate routes to avoid delays caused by incidents, construction, and special events.

15.1.2 Needs Assessment

If there is a need to monitor traffic on the system, CCTV camera should be used. Prior to determining the location of a CCTV camera, various data needs to be collected, such as:

- Corridor spacing requirements (1-mile spacing is typically used in urban areas, where full freeway or arterial coverage is desired. Spot location CCTV camera surveillance may be used in rural interchanges where sight distance is greater and surveillance is needed for incident verification, crash investigation sites, ramp meter operation, or variable message sign verification).
- Site-specific issues or concerns based on an initial site visit (right-of-way, utilities, landscape)

15.1.2.1 Types

Guidelines for choosing the type of CCTV equipment and related hardware are listed below.

- **Dome Cameras:** Should be used for most CCTV camera applications. All moving parts (including pan/tilt/zoom) are internal to the dome, so there is less mechanical failure and maintenance due to weather conditions. Water slides off of the dome exterior so special wiper blades are not needed.
- **Barrel Cameras:** Should be used when extended vertical viewing is necessary (a dome camera can only see to the top of the clear part of the dome) or if there is a special mounting consideration that precludes the use of a dome camera.
- **Infrared Cameras:** Should be used under bridges where there is low light.
- **Inside Dome Cameras:** Should be used inside buildings, such as welcome centers.
- **30 Foot Camera Poles:** Should be used for arterial applications, where a 50-ft or 80-ft camera pole height is not needed to see the roadway corridor. These poles have the option for special powder coat paint (color determined by vendor catalogue at time of procurement) to match existing aesthetic plans.
- **50 Foot Camera Poles:** Should be used for most freeway CCTV camera applications. The height facilitates seeing the roadway for 1/2 mile in any direction, and is typically high enough to be above most tree foliage.
- **80 Foot Camera Poles:** Should be used for locations where terrain and land availability do not allow for the 50-ft camera to view enough of the roadway. These poles are typically deployed in

Interchanges. Also, new technology for cameras is allowing visual distance to be more than ½ mile in a direction (added distance can be from 1-3 miles in a direction) and having a taller pole may reduce the amount of camera pole sites needed for corridor camera coverage.

- **High Mast Light Towers:** Provide for an excellent extended view due to their height but are dependant on the lighting design for location rather than the ideal location from an ITS perspective. CCTV cameras can be installed on new or existing High Mast Light Towers (HMLT) provided that the towers are manufactured with cables and maintenance lowering halos specifically to allow for the installation of a camera on the halo. While the HMLTs manufactured for inclusion of CCTV cameras are made to account for a system in which the video CODEC and communications equipment are installed in an adjacent cabinet, it is possible to install an IP camera, Ethernet radio, and power supply on the halo using the camera power conductors in the tower's cable to power the power supply using 120VAC. Additionally, a 6-foot piece of threaded pipe must be used to extend the drop of the camera to remove it from the glare of the HMLT light fixtures. Close coordination is required with the lighting designer and the party responsible for lighting maintenance.
- **Camera Lowering System:** Should be used for poles taller than 30 feet. This allows for maintenance of the camera without deploying a bucket truck, and one person can perform the maintenance. The Statewide Procurement has 50-ft and 80-ft camera poles equipped with lowering systems. External lowering systems can be applied to camera poles that are currently deployed and do not have an internal camera lowering system (any pole height).
- **Video CODEC:** This equipment is necessary to facilitate the data transfer from the camera to the Operation Center. Video transmission is accomplished through an encoder (deployed at the camera site) and a decoder (deployed at the Operation Center). Communication is facilitated through an ethernet/fiber communication link or a leased line telephone link. Most Video CODEC utilize MPEG2/MPEG4/MJPEG technology for full motion video using 1.5 to 5.0 MB of bandwidth for each camera site.

For specific procurement product information, see Chapter 70.5 State Supplied List. Contact the STOC for product information.

Follow the CCTV Camera Design Process checklist shown in Table 15.1

Table 15.1 CCTV Camera Design Process Checklist

1. Collect initial data	
2. Determine CCTV Camera Type (see 15.1.2)	
3. Assign name to CCTV camera device (see 15.02)	
4. Determine Location of Controller Cabinet (see 15.3.3)	
5. Establish communication Network (see 15.4.1)	
6. Establish Power Service	
7. Prepare underground infrastructure (see 15.3.4)	
8. Perform Cable Routing (see 15.3.5)	
9. Modify/Create construction details and special provisions	
10. Install CCTV camera	
11. Maintenance and reevaluation.	

15.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format. For example, for the 20th camera (CCTV) that is installed in the state will be in Milwaukee County (40), the number for the device should be CCTV-40-0020 (i.e., CCTV-County number-next sequential four digit number). For portable traffic cameras, the naming convention is similar to PCMS, for example, PTCS-02-2004 (i.e., PTCS - Old District Number - Old District Number+next sequential three digit number). For more information on portable traffic cameras, refer to Chapter 40, Smart Work Zones. The device number and related information will be stored in the ITS inventory management system.

If the device requires a TELCO (landline phone line), a street address must be established during this process.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at:

http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

15.2.2 Communications Assignments

Refer to Chapter 50, ITS Communication Systems for information regarding the appropriate communication network to use for closed-circuit television cameras. Contact the STOC to discuss communication requirements.

15.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

15.3.1 Design Process

In the CCTV camera design process, the designer must follow several steps to ensure successful implementation and proper operational capabilities. Many of these steps, such as power and communication requirements, must be addressed early in the design process.

1. Collect initial data required for the proposed CCTV camera location.
2. Determine the CCTV camera type required for the design location.
3. Assign name to CCTV camera device for proper recording.
4. Determine the location of the controller cabinet and meter service pedestal.
5. Prepare the underground infrastructure, including camera pole, conduit, and pullboxes or vaults.
6. Perform cable routing to provide hardwire interconnection between the controller cabinet and CCTV camera station devices.
7. Determine the communications medium used for the proposed location.
8. Revisit steps 3 through 6 until final design is complete.
9. Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location.
10. Determine the construction details needed for the proposed design, details that need to be modified, and new details that need to be created to provide a complete construction plan.
11. Determine the special provisions needed for the proposed design, special provisions that need to be modified, and new special provisions that need to be created to provide a complete construction plan.
12. Determine the standard specification bid items and procurement items that will need to be included in the estimate and miscellaneous quantities to provide a complete construction plan.

15.3.2 Camera Placement

Camera placement is based largely on the spacing requirements as documented under the *Initial Data Collection* section of this chapter. Placing cameras involves field verification of camera sites using a video recorder and bucket truck. When performing this video review, the following issues must be kept in mind when placing a camera:

- **Foliage** - Whenever possible, the video review should be done while trees are in full foliage. If this is not done, the view from installed CCTV camera sites may be minimized since foliage has a detrimental effect on sight distance.
- **Right-of-way**- If the camera is being placed on a local arterial, right-of-way restraints are critical. Arterial right-of-way is much narrower than typically found on the freeway. If the camera is placed outside of WisDOT right-of-way, permits and easements will be required to construct the site.
- **Maintenance** - The camera must be able to be maintained via a bucket truck. If the designer is unable to access the proposed location with a bucket truck during design, future maintenance (and installation) of the site may be cumbersome.
- **Site distance to other ITS equipment** - It is desirable for CCTV cameras to be capable of viewing nearby ramp meters or variable message signs.
- **Cross-street viewing** - Whether the proposed camera is being placed along the freeway or along an arterial, coverage of major cross streets is desirable. Cross street video surveillance is very important if an entrance ramp is being metered, or if the street is typically used as an alternate route.
- **Viewing of other features** - It is desirable for CCTV cameras to be capable of viewing features surrounding the freeway, such as park-and-ride lots and crash investigation sites.
- **Future Construction** – Find out if there is any planned construction (1-10 years) in the area where the camera will be placed. You may need to coordinate with the plan designer or construction manager of

the projects to ensure that the camera, or any of its components, will not need to be relocated or replaced during the construction process.

- **Blind Spots** - When a camera-lowering device is used there will be a blind spot at the pole. It is very important that the pole be orientated so the blind spot is located in the least desirable viewing sector. A pole orientation detail should be included in the plan set, so the contractor places the anchor bolts correctly in the concrete base.
- **Permanent Structures** – It is acceptable to install cameras on existing structures (poles, sign bridges, buildings, etc.) when power is available and stand alone options are not available.

15.3.3 Cabinet and Equipment Placement

Placement of equipment for camera sites involves the controller cabinet, camera pole, and electrical service.

15.3.3.1 Cabinet Placement

The placement of the controller cabinet includes the following:

- Visibility of the camera from the controller cabinet.
- Distance between the controller cabinet and the camera.
- Off-freeway accessibility for maintenance vehicles whenever possible.
- Safety of the cabinet location.
- Grades.

For maintenance considerations, it is very important that the **camera be visible from the controller cabinet**. The slope of the terrain for cabinet placement must be no steeper than 4:1. Placement of the cabinet on 3:1 slopes or steeper require grading provisions to provide a level area around the cabinet.

Pole Mount Cabinets may be used if a controller cabinet size or capability is not needed. These cabinets are mounted directly to the pole. The pole mount cabinet has enough space to house electric service, a video encoder, and other communication equipment. Conduit is run from the bottom of the pole mount cabinet to the nearest pullbox or vault.

15.3.3.2 Camera Pole Placement

The camera pole should be placed within 350-ft of the controller cabinet. Extending beyond this distance requires re-design of the camera power cable size (gauge) and size of the coaxial cable, which transmits the video images.

Placement of the camera pole must be outside of the clear zone (as determined by *AASHTO: A Policy On Geometric Design of Highways and Streets* or the *AASHTO Roadside Design Guide*, latest editions). The poles also must be accessible for maintenance vehicles, including large bucket trucks, unless using a lowering system, in which case maintenance may be performed with smaller vehicles.

15.3.4 Underground Infrastructure

When the controller cabinet, electrical service and camera pole site have been placed, the underground conduit infrastructure can be designed. Issues to keep in mind when designing the conduit infrastructure include:

- <u>Pull Box Spacing</u> - Pull boxes should be spaced within 200 feet.
- <u>Terrain</u> - Conduit infrastructure should be designed on relatively flat (4:1 slope or flatter) terrain. For steeper sloped terrain (3:1 or greater) , conduit may be run perpendicular to (i.e., up or down) the slope to locations where the terrain is more suitable for conduit installation.
- <u>Conduit Size</u> - 4-Inch conduit is typically used for camera cable raceways. Conduit entering electrical service pedestals must be sized per pedestal requirements.
- <u>Conduit Fill</u> - The size and number of conduits along a run is dependent on percentage of fill as established by the National Electric Code (NEC). For new conduit installation, the percent fill must not exceed 31%. For installation of cable in existing conduit, 40% of the available area may be used.
- <u>Conduit in Camera Base</u> - Two 4-inch conduits, and one 2-inch conduit or three 2-inch conduits should be placed in the camera's concrete base. This will allow one conduit for electrical wire, one conduit for communication wire, and one conduit for coaxial cable (which is sensitive to electric-magnetic fields).

15.3.5 Cable Routing

15.3.5.1 General

Cable routing for camera sites typically involves the connection of all equipment, including the camera pole and the electrical service, to the controller cabinet or pole mount cabinet. Other devices such as ramp meters or system detector stations (Chapters 2 and 3) may be added to a camera site, and require cable routing as described in their respective chapters. The power distribution cable running between the controller cabinet or pole mount cabinet and the electrical service should be in a separate conduit. Power and communication cables should not be mixed together.

15.3.5.2 Camera Cables

Camera cables consist of two different types: *conductor cables* for power and control, and *coaxial cable* for transmission of the video image between the camera and the video encoder. The maximum distance between the camera and controller for these cables must be kept within 350 feet. If this 350-ft maximum distance requirement is unobtainable, the size of the camera cables (for power, control, and video) must be redesigned and incorporated appropriately.

15.3.5.3 Electrical service

The power distribution wires running between the electrical service and the controller cabinet consists of stranded copper single conductors, cross-linked polyethylene (XLP), USE rated. Section 655 of the standard specifications provides guidance on additional requirements. The bid items for "Electrical Wire Lighting (gauge #) AWG will meet the requirements. The gauge of conductors must be calculated per the requirements of the National Electric Code.

15.3.5.4 Electrical Wire Routing

The conduit system for camera sites needs to be bonded together, due to the fact that power cables are running within the system. Bonding all metallic components of the system together assures that there will be no difference in voltage potential across two points in that system. In addition, grounded conductor needs to be run with current-carrying cables (such as traffic signal conductors, power distribution wires, etc.), which returns the circuit's current at zero voltage. The bonding/grounding wires in system typically use Electrical Wire Traffic Signals 10 AWG (Item 655.0515) in the State's Standard Specifications. The gauge of grounded conductor must be calculated per the requirements of the National Electric Code. There is a distinct method required for the bonding system. Examples of this method can be found in Chapters 2 and 3.

The pull boxes do not require grounding if the total voltage encountered in the pull box is 50 volts or less. In some Districts, a policy has been made to bond and ground all conduit systems, since equipment is frequently added to various locations in the future. For assistance in bonding and grounding of underground systems, consult the State Electrical Engineer.

15.4.1 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

15.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at

http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

15.5.2 Communication Requirements

Closed-circuit television cameras require communication methods offering larger bandwidth than that required for typical ramp meter or detector station controllers. Communication requirements also are contingent upon whether full-motion video is desired, or if slow-scan images are adequate. The communication medium selected for camera sites is open to the following communication types as described in Chapter 50, Communication System.

- Leased Communications - Either leased analog video (fiber optics) for full-motion video or leased high-speed data lines (ISDN, 56k) for slow-scan images.
- State-Owned Communications - Fiber optic communications for full-motion video.
- Wireless Ethernet Radio- full motion video or slow scan images, capable of bandwidth between 3MB to 20 MB.

15.5.3 Power Requirements

A 100 Amp, 120/240 volt, single phase, three wire underground electrical service is required for electrical service installation. Typically, two controller cabinets can be powered by a single 100-amp service. The electrical service will be furnished and installed by the local power company up to a demarcation point, which consists of an electrical service (meter) pedestal. The electrical service must conform to the requirements of the local power company. The location of the electrical service must receive approval from the utility company. The electrical service will include two 50-amp circuit breakers rated at 22,000 AIC. The requirements for power cable between the electrical service and controller cabinet can be found under the Cable Routing section of this chapter.

At locations which require a remotely located electrical service, a 100 Amp outside rated breaker box with space for 6 circuits, but no main breaker, will be attached to the side of the cabinet. Also, a 50 Amp single circuit breaker rated at 22,000 AIC will be installed within the breaker box to serve as a local electrical service disconnect point.

15.5.4 CCTV Camera Construction Standards

Construction details, Standard Detail Drawings, and Special Provisions can be found in Appendix 70.

15.6.1 Testing

15.6.1.1 CCTV Cameras

Reference Standard Specifications 675.3.(14) through 675.3.(20) for testing procedures. In 675.3(15), traffic flow information includes volume and speed data.

15.6.1.2 Field System Integrator

Refer to Standard Specification 670.3.2.1 for field system integrator duties.

- **Contractor-furnished equipment and materials**, refer to Standard Specification 670.3.3.1.
- **Department-furnished equipment** and materials, refer to Standard Specification 670.3.3.2

15.6.2 Acceptance

Notify the State Traffic Operations Center after testing is complete. The State Traffic Operations Center Maintenance Representative will do the final concurrence of acceptance before the State Traffic Operations Center accepts ownership and maintenance of the camera.

15.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

15.7.2 Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as "GPS data points". The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
  - Latitude (Y-coordinate) in decimal degrees
  - Longitude (X-coordinate) in decimal degrees
  - Altitude (Z-coordinate) in feet
  - Date (day, month, year) of point collection
  - Time (24 hour format) of point collection
  - Initials of field personnel collecting data points
  - Abbreviation for Element Type (see table of elements below)
  - Location description (for example, street and cross street)
  - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 95% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

Relevant Elements

Abbreviation	Description
CAM	CCTV poles (capture point at pole location)
CAB	Field equipment cabinets (unless attached to pole that is already being located)
PB	Pull boxes (when used with a fiber optic infrastructure installation, or when connected to in-pavement loops)
MH	Manholes (when part of fiber infrastructure)
JB	Junction boxes (such as on a bridge)
CV	Communication vaults (when part of fiber infrastructure)
MBP	Meter breaker pedestals
HUT	Equipment shelters (i.e. fiber optic communication huts)
ANT	Antenna poles (capture point at pole location)
OHS	Dynamic message signs (capture at base of sign support with connections to power and/or communications)
YF	Yellow Flashers (ramp metered when flashing signs)
HAR	Highway advisory radio transmitters (at antenna location)
SGN	Highway advisory radio signs (at sign location)
RMS	Ramp meters (capture point at pole location)
RWIS	RWIS sites (including tower, pull boxes and meter breaker pedestal)
GTE	Ramp closure gates
PG	Point Generic (fiber access/splice locations and other infrastructure not described above)
MD	Microwave detectors/detector poles (capture point at pole location)

15.7.3 Documentation

A listing of all the devices installed and the associated serial numbers, as-built CAD files, and testing and calibration results should be provided to BHO-STOC.

The following fields are used in the ITS inventory system. This data should be provided to the BHO-STOC as soon as it is available. The data must be provided before the equipment is accepted.

CartêGraph ITS Inventory Database Fields General:

- ID
- TOC Location Description
- Installation Address
- Installation Phone Number
- Service Provider
- Service Provider Utility Account
- TOC Monitor ID
- Region
- TOC Type
- Maintaining Authority
- Maintaining Authority Contact
- Service Provider

Details:

- Events – Lists work orders and other events
- Detectors:
    - ID
    - Detector Number
    - Description

- Loop Location

- Aux Equip:
  - ID
  - Serial Number
  - Description
  - Manufacturer
  - Model

- Cabinets:
  - ID
  - Serial Number
  - Description

- Supports:
  - Bolt circle
  - Height
  - Lowering system

15.7.4 Deployment Inventory

An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60 ITS Software.

15.8.1 Maintenance

15.8.1.1 New CCTV Cameras

Once the State Traffic Operations Center Maintenance Contractor accepts the CCTV camera equipment per 15.6.2, the State Traffic Operations Center will accept the camera onto the Statewide Maintenance Contract.

15.8.1.2 Existing CCTV Cameras

If a contractor is working on an existing camera, the contractor is responsible for locates and any maintenance until seven days after the as-builts have been delivered to the State Traffic Operations Center. At that time, the State Traffic Operations Center will accept the camera onto the Statewide Maintenance Contract.

15.8.2 Reevaluation

In addition to periodic camera equipment updates, cameras should be evaluated for their effectiveness. Existing camera installations should be reviewed to determine if there are locations are as beneficial as they used to be. It may be beneficial to remove cameras that are no longer necessary.

20.1.1 Introduction

The guidance in Chapter 20 is intended for the placement of *new* dynamic message signs (DMS) as part of new constructions projects only. The STOC must be contacted if retrofitting a dynamic message sign to an existing system or in any other circumstance where the addition of a DMS is being considered.

Dynamic message signs (DMS) are traffic control devices used to provide motorists en-route traveler information. They are commonly installed on full span overhead sign bridges; post mounted on roadway shoulders, and overhead cantilever structures. The information is most often displayed in real-time and can be controlled either from a remote centralized location or locally at the site. DMS are designed to affect motorist behavior to improve traffic flow and operations. Traveler information displayed on DMS may be generated as a result of a planned or unplanned event, which is programmed or scheduled by operations personnel. Examples of traveler information include:

- Incidents affecting traffic
- Emergency situations requiring diversion
- Amber Alerts
- Recurrent traffic congestion
- Current roadwork
- Future roadwork (up to 10 days in advance)
- Special events
- Current travel times
- Static travel times
- Weather information specific to travel conditions

By State policy, DMS should not be used to display the following information:

- Advertising products or slogans, whether WisDOT related or not
- Safety messages
- Weather reports or temperature
- Time of day or date
- Directions for specific user groups

The objective of providing the information is to allow the motorist time to avoid an incident, prepare for unavoidable conditions, or to give travel directions. For all information displayed the goal is to have a positive impact on the motorist's travel time. Additional guidelines for when and how to use DMS, see TGM 17-1-1.

20.1.2 Needs Assessment

DMS can be located on stretches of highway to inform motorists traveling at high speed or along heavily traveled arterial roadways leading to the freeway system to be seen by motorist traveling at slower speeds. Refer to the Transportation Operations Infrastructure Plan for when DMS are needed.

20.1.2.1 Data Collection

Data collection required for DMS deployment is broken into two areas: preliminary data collection, and site-specific data collection. Under preliminary data collection, the following information will need to be obtained to determine the area, corridor and type of changeable message sign.

- Intended purpose of DMS
- Type of information to be displayed on DMS
- Alternate route diversion points

Under site-specific data collection, the following information will need to be obtained to determine the exact location of the changeable message sign.

- Base mapping with local roadway network linked to the segment under review for the DMS
- Existing roadway horizontal alignment
- Roadway vertical information
- Existing sign inventory
- Location of power facilities along roadway segment

20.1.2.2 Types

There are multiple types of DMS technology currently deployed, such as flip disk, fiber optic and light emitting diode (LED); however, LEDs have become the dominant DMS technology choice.

20.1.2.3 Determination of DMS Type

Prior to locating DMS along a roadway segment some engineering decisions need to be made, and DMS type selected. The five types DMS on the Statewide Procurement include:

- OVERHEAD FREEWAY DYANMIC MESSAGE SIGN, FULL MATRIX (3 LINES, 18-INCH)
- SIDE MOUNTED FREEWAY DYNAMIC MESSAGE SIGN, FULL MATRIX (3 LINES, 14-INCH)
- ARTERIAL DYNAMIC MESSAGE SIGN, FULL MATRIX (3 LINES, 12-INCH)
- ARTERIAL DYNAMIC MESSAGE SIGN, FULL MATRIX (2 LINES, 10-INCH)
- PORTABLE DYNAMIC MESSAGE SIGN (3 LINES, 18-INCH, FULL MATRIX)

The MUTCD requires a minimum character height of 18 inches for any DMS that is placed on a roadway where speeds exceed 55 MPH as stated in MUTCD 2E.21. While DMS larger than the minimum size may be acceptable from the perspective of the MUTCD, the larger signs can have negative impacts on the surrounding area depending on the characteristics of existing surrounding area. Particularly, they can contribute significantly to light pollution near residential areas.

Freeway and arterial DMS are used for permanent applications. These signs require an engineered concrete base and structure. A State Licensed structural engineer must design the sign structure and foundation. WisDOT Central Office reviews and approves all DMS structure and foundation plans. Portable CMS are used for temporary applications (see Chapter 35 PCMS).

DMS Matrix Displays

Messages are limited by the type of DMS used and its display space configuration or matrix. There are three typical types of matrix displays, which are Character, Line, and Full. In a character matrix a separate display space is made available for each letter of the text message. A character matrix of 8 horizontal by 3 vertical has only 24 display spaces available. In a line matrix there is no physical separation between the characters in a single line of text. However, in a line matrix there still remains a separation between different lines of text. In a full matrix no physical separations exist between individual characters or lines in the message. A message can be shown at any size and location as long as it is within the display space. The exhibit below demonstrates the differences between the matrix types.

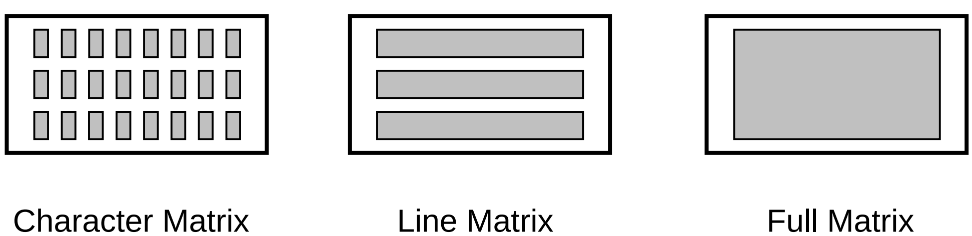


Figure 5-2: Dynamic Message Sign Matrix Displays

Messages displayed on a DMS are done by using one or two phases. A phase is defined as the limits of the display area available for text, bitmaps, or animation. According to WisDOT TGM policy 17-1-1, DMS shall have no more than two phases per sign.

For specific procurement product information, see Chapter 70.5 State Supplied List. Contact the STOC for product information.

Follow the DMS Design Process checklist shown in Table 20.1

Table 20.1 DMS Design Process Checklist

1. Collect preliminary data required for the proposed dynamic message sign location	
2. Determine DMS type	
3. Determine corridor placement for DMS implementation	
4. Collect site-specific data required for the proposed DMS location	
5. Select the DMS site required for design	
6. Determine cabinet placement for the DMS	
7. Perform underground infrastructure	
8. Determine the communications medium used for the proposed location	
9. Revisit steps 4 through 8 until final design is complete	
10. Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location.	
11. Determine the construction details needed for the proposed design, details which need to be modified, and new details which need to be created to provide a complete construction plan.	
12. Determine the special provisions needed for the proposed design, special provisions that need to be modified, and new special provisions, which need to be created to provide a complete construction plan.	
13. Determine the standard specification bid items and procurement items that will need to be included in the estimate and miscellaneous quantities to provide a complete construction plan.	

20.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format of sequential by region with the county ID. For example, for the 20th dynamic message sign (DMS) in the SE Region that is installed in Milwaukee County (40), the number for the device should be DMS-40-0020 (i.e., DMS-County number-next sequential four digit number). The device number and related information will be stored in the ITS inventory management system.

If the device requires a TELCO (landline phone line), a street address must be established during this process.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at: http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

20.2.2 Communications Assignments

Refer to Chapter 50, ITS Communication Systems for information regarding the appropriate communication network to use for DMS. Contact the STOC to discuss communication requirements.

20.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

20.3.1 Design Process

In the DMS design process, the designer must follow several steps to ensure successful implementation and proper operational capabilities. Many of these steps, such as power and communication requirements, must be addressed early in the design process.

1. Collect preliminary data required for the proposed dynamic message sign location
2. Determine DMS type
3. Determine corridor placement for DMS implementation
4. Collect site-specific data required for the proposed DMS location
5. Select the DMS site required for design
6. Determine cabinet placement for the DMS
7. Perform underground infrastructure
8. Determine the communications medium used for the proposed location
9. Revisit steps 4 through 8 until final design is complete
10. Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location.
11. Determine the construction details needed for the proposed design, details that need to be modified, and new details, which need to be created to provide a complete construction plan.
12. Determine the special provisions needed for the proposed design, special provisions that need to be modified, and new special provisions, which need to be created to provide a complete construction plan.
13. Determine the standard specification bid items and procurement items that will need to be included in the estimate and miscellaneous quantities to provide a complete construction plan.

20.3.2 Sign Placement

Using data and information collected during the previous step, site selection is now possible. If possible, signs should be placed so that nearby CCTV cameras can view the DMS message. The following demonstrates how that information is utilized when selecting sites for possible deployment.

20.3.2.1 Alternate Route Diversion Points

In an urban roadway network, DMS should be located in advance of alternate route access points on the network to allow motorists to take action in response to the message on the sign. In an urban setting there are typically many other signs that compete for motorists' attention, and DMS should be placed for maximum visibility and impact. On an arterial roadway segment, the distance may vary based on issues such as speed limit, local factors, and right of way constraints. The designer should review each site individually and utilize proper engineering principles to determine locations.

20.3.2.2 Existing Horizontal Alignment Data

To insure proper viewing of the DMS message sites must be located on tangent roadway sections. The introduction of even minor curves along the roadway can impact visibility. Current DMS technology used limits a pixel's cone of visibility to only a few degrees. Because of this, minor changes in the roadways horizontal alignment may make the message unreadable. The designer should look for sites that are located on tangents and allow a motorist at least 900 to 1000 feet to view the sign while traveling 55 mph or faster. If the motorist is traveling between 30-45 mph, the minimum distance needed should be 500 feet. If no site is available on a desirable tangent section, overhead DMS may be placed on gradual horizontal curves; however, the structure design must be modified to focus the sign to a point on the roadway 900 to 1000 feet upstream of the sign to enhance its legibility.

20.3.2.3 Existing Vertical Alignment Data

Vertical alignment along the roadway also impacts the visibility of the DMS. The cone of visibility (discussed previously) limits the visibility of the DMS in these areas. If there are a limited number of potential locations available, an upward grade is desirable. Ideal site locations on roadway segments are where the grade is 1% or less. DMS should not be placed along grades exceeding 4 percent.

20.3.2.4 Existing Sign and Traffic Control Inventory

DMS should not compete with other existing signs or interfere with traffic control devices. The designer must take inventory of all signs and traffic control along a roadway segment to properly place the DMS. Based on this inventory, existing signs may need to be relocated to accommodate proper DMS placement. On the freeway, the minimum distance between Type I guide signs and a DMS is 800 feet. On arterial streets the distance allowed between Type I signs and a DMS is approximately 400 feet. Since the DMS signs are typically installed in elevated positions care should be taken by the designer to also identify possible conflicts with the DMS blocking other existing traffic control devices. Care should also be taken that existing trees do not block the view within the 800 or 400 feet viewing distance.

20.3.2.5 Location of Power Along Roadway Segment

Locating existing power along a roadway segment helps a designer understand how difficult it might be to power a potential DMS site. It is desirable to locate the cabinet and electrical service as close together as possible. All power service locations will require approval from the utility company prior to installation.

20.3.3 Geometric Considerations

Some of the geometric considerations will require some level of engineering judgment by the designer. In any case, all DMS site locations shall be approved by and coordinated with the STOC ITS Engineer. Placement of equipment for DMS sites involves the controller cabinet, sign structure, and electrical service.

20.3.3.1 DMS Supports/Location

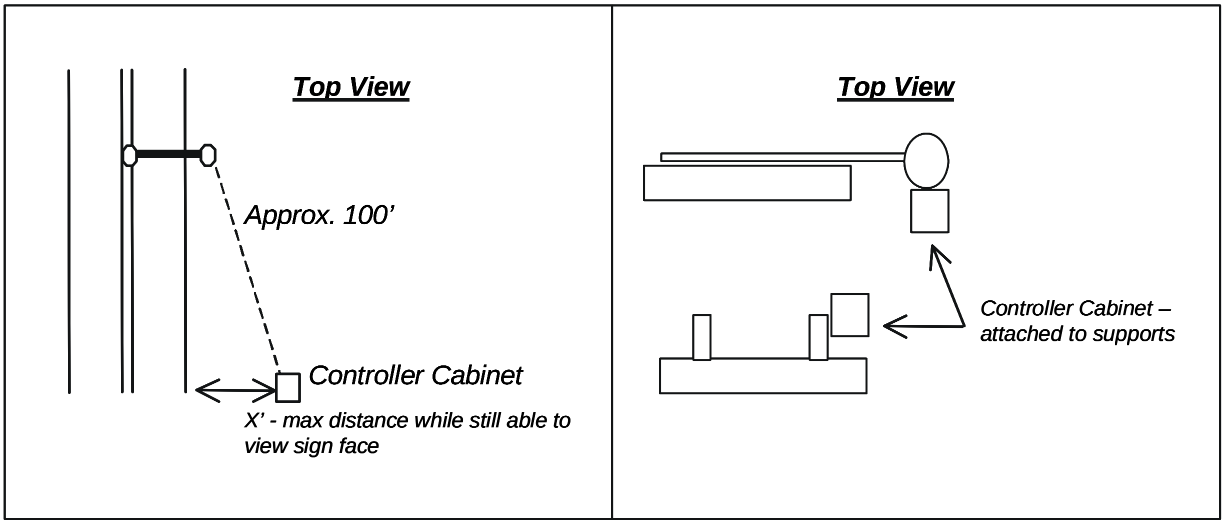
Design the sign bridges and sign structures per the FDM, Standard Specifications, and Structures Manual.

20.3.3.2 DMS Height Requirements

Per the MUTCD, the minimum distance from the roadway to the bottom of a freeway or arterial DMS shall be a minimum of 18 feet (19 feet maximum) above high point of road. Design the sign bridges and sign structures per the FDM, Standard Specifications, and Structures Manual.

20.3.3.3 Cabinet Location

Locating controller cabinets at DMS sites is done differently for freeway and arterial deployments. Due to right of way constraints, arterial DMS controller cabinets are typically located in close proximity to the sign or mounted directly on the support structure. The freeway DMS controller cabinets, however, should be located at a distance of 100 feet from the front of the sign at a location at which an individual can view the sign from the cabinet and provide a safe location outside the clear zone. The 100 feet is a typical deployment distance that is favorable to most DMS manufacturers. Figure 20.3-1 provides graphical representation of controller cabinet locations for various types of DMS deployment.



Freeway DMS Controller Cabinet – Overhead Sign Bridge Structure

Arterial DMS Controller Cabinet Cantilever and Shoulder Mounted

Figure 20.3-1: DMS Controller Cabinet Locations

20.3.3.4 Underground Infrastructure

When the controller cabinet, electrical service and DMS have been placed, the underground conduit infrastructure can be designed. Issues to keep in mind when designing the conduit infrastructure include:

- Pull Box Spacing - Pull boxes should be spaced within 200 feet.
- Terrain - Conduit infrastructure should be designed on relatively flat (4:1 slope or flatter) terrain. For steeper sloped terrain (3:1 or greater) , conduit may be run perpendicular to (i.e., up or down) the slope to locations where the terrain is more suitable for conduit installation.
- Conduit Size - 4-Inch conduit is typically used for detector station raceways. 2-inch conduit must be used when entering electrical service (meter) pedestals.
- Conduit Fill - The size and number of conduits along a run is dependent on percentage of fill as established by the National Electric Code (NEC). For new conduit installation, the percent fill must not exceed 31%. For installation of cable in existing conduit, 40% of the available area may be used.
- Conduit in Concrete Base – Two 4-inch conduits, and one 2-inch conduit or three 2-inch conduits should be placed in the concrete foundation. This will allow one conduit for electrical wire, one conduit for communication wire, and one conduit for other cables needed.

20.3.3.5 Electrical service

The power distribution wires running between the electrical service and the controller cabinet consist of stranded copper single conductors, cross-linked polyethylene (XLP), USE rated. Section 655 of the standard specifications provides guidance on additional requirements. The bid items for Electrical Wire Traffic Signals (gauge #) AWG or Electrical Wire Lighting (gauge #) AWG will meet the requirements. The gauge of conductors must be calculated per the requirements of the National Electrical Code.

Consistent with the design practice recommended in the National Electric Code, the power distribution system should be designed for a maximum of a 3% voltage drop between the electrical service location, which may be a utility connection point or a dedicated circuit in an adjacent installation such as a lighting distribution cabinet, and the DMS or other field cabinet. When calculating the voltage drop, it is important that the ultimate potential power draw is considered. The sum of the size of the circuit breakers within the cabinet should be used as the potential draw. This will mean a 50-Amp power draw should be used as most ITS cabinets come with 2-25-Amp circuit breakers.

Depending on the availability and location of electrical service locations, these requirements may dictate the use of step-down voltage transformers adjacent to field cabinets. Refer to the SDD and specification for use of step-down voltage transformers.

20.3.3.6 Electrical Wire Routing

The conduit system for DMS sites needs to be bonded together, due to the fact that power cables are running within the system. Bonding all metallic components of the system together assures that there will be no difference in voltage potential across two points in that system. In addition, grounded conductor needs to be run with current-carrying cables (such as traffic signal conductors, power distribution wires, etc.), which returns the circuit's current at zero voltage. The bonding/grounding wires in system typically use Electrical Wire Traffic Signals 10 AWG (Item 655.0515) in the State's Standard Specifications. The gauge of grounded conductor must be calculated per the requirements of the National Electric Code.

The pull boxes do not require grounding if the total voltage encountered in the pull box is 50 volts or less. In some Districts, a policy has been made to bond and ground all conduit systems, since equipment is frequently added to various locations in the future. For assistance in bonding and grounding of underground systems, consult the State Electrical Engineer.

20.3.3.7 Cable Routing

Cable routing for dynamic message signs typically involves the connection of communication and power to the controller cabinet from the sign and from the cabinet to the power and communication resources. Communication cable from the cabinet to the DMS is typically proprietary to the DMS manufacturer. Outside of the DMS Communication cable the current standardized cables are utilized. The power distribution wires running between the controller cabinet and the electrical service should be in a separate conduit. Power and communication cables should not be mixed together. In addition, the power and communication cables for the dynamic message sign should also be kept in separate raceways.

20.3.3.8 Safety Considerations

A site must be designed to allow for safe maintenance and operation of the DMS and its controller cabinet. To address safety issues the following questions should be asked:

- Does the site allow safe and easy access to the sign for maintenance vehicles?
- How exposed will maintenance vehicles and personnel be to live traffic while at the site?
- Can personnel access the controller cabinet without having to use the roadway shoulder?

Answering these questions the designer may choose to make additional site modifications. Safety considerations should always be considered in the site's design.

20.4 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

20.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

20.5.2 Communication Requirements

Communication between the DMS and control center allows information to be disseminated on a real-time basis, providing up-to date information to the motorist. The Operations Center can communicate with the DMS via a voice-grade telephone line, either standard wire based or cellular. Dedicated communications, such as a state owned fiber optic cable, state owned copper twisted pair cable, spread spectrum radio, or a combination of the three, could also be used to provide communications between the DMS and the Operation Center. Chapter 50, Communication Systems provides additional information on communication types and requirements.

20.5.3 Power Requirements

Consistent with the design practice recommended in the National Electric Code, the electrical service and power distribution system should be designed for a maximum of a 3% voltage drop between the electrical service location, which may be a utility connection point or a dedicated circuit in an adjacent installation such as a lighting distribution cabinet, and the DMS or other field cabinet. When calculating the voltage drop, it is important that the ultimate potential power draw is considered. Good design practice dictates that the sum of the size of the circuit breakers within the cabinet be used as the potential draw. In most cases for ITS design this will mean a 50-Amp power draw should be used as most ITS cabinets come with 2-25-Amp circuit breakers.

A 100 Amp, 2-Circuit, 120/240 volt, single phase, three wire underground electrical service is the most commonly used and preferred electrical service for DMS cabinets, or any ITS field cabinet; however, other systems must be considered in instances where the electrical service location is of such a distance from the field cabinet that maintaining the above described 3% maximum voltage drop is not possible.

Power distribution conductors must be sized appropriately to design for the above-mentioned 3% maximum voltage loss with a maximum conductor size of 1/0 AWG.

Due to WisDOT safety regulations, voltage in excess of 120V must not be brought into ITS field cabinets. Rather, step-down transformers must be installed adjacent to the field cabinets with only the 120V conductors installed into the cabinet. For further clarification, it is not acceptable to "split" the 240V service into two 120V circuits in the field cabinet.

The electrical service will be furnished and installed by the local power company up to a demarcation point, typically an electrical service (meter) pedestal. The electrical service must conform to the requirements of the local power company. **The location of the electrical service pedestal must receive approval from the utility company.** The electrical service will include two 50-amp circuit breakers rated at 22,000 AIC. The requirements for power cable between the electrical service and controller cabinet can be found in 20.3.3.7 Cable Routing.

At locations which require a remotely located electrical service or which require an adjacent step-down transformer, a 100 Amp outside rated breaker box with space for 6 circuits, but no main breaker, will be attached to the side of the cabinet so that the cabinet may be shut down without entry into the higher voltage step-down transformer. Also, a 50 Amp single circuit breaker rated at 22,000 AIC will be installed within the breaker box to serve as a local electrical service disconnect point. Remote service should be labeled in the field as ITS with State Traffic Operations Center's phone number.

20.5.4 DMS Construction Standards

Construction details, Standard Detail Drawings, and Special Provisions can be found in Appendix 70.

20.6.1 Testing

20.6.1.1 Controllers and Detectors

Reference Standard Specifications 675.3.(14) through 675.3.(20) for testing procedures. In 675.3(15), traffic flow information includes volume and speed data.

20.6.1.2 Field System Integrator

Refer to Standard Specification 670.3.2.1 for field system integrator duties.

Contractor-furnished equipment and materials, refer to Standard Specification 670.3.3.1.

Department-furnished equipment and materials, refer to Standard Specification 670.3.3.2

20.6.2 Acceptance

Notify the State Traffic Operations Center after testing is complete. The State Traffic Operations Center Maintenance Representative will do the final concurrence of acceptance before the State Traffic Operations Center accepts ownership and maintenance of the DMS.

20.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

20.7.2 Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as "GPS data points". The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
  - Latitude (Y-coordinate) in decimal degrees
  - Longitude (X-coordinate) in decimal degrees
  - Altitude (Z-coordinate) in feet
  - Date (day, month, year) of point collection
  - Time (24 hour format) of point collection
  - Initials of field personnel collecting data points
  - Abbreviation for Element Type (see table of elements below)
  - Location description (for example, street and cross street)
  - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 95% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

Relevant Elements

Abbreviation	Description
CAM	CCTV poles (capture point at pole location)
CAB	Field equipment cabinets (unless attached to pole that is already being located)
PB	Pull boxes (when used with a fiber optic infrastructure installation, or when connected to in-pavement loops)
MH	Manholes (when part of fiber infrastructure)
JB	Junction boxes (such as on a bridge)
CV	Communication vaults (when part of fiber infrastructure)
MBP	Meter breaker pedestals
HUT	Equipment shelters (i.e. fiber optic communication huts)
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YF	Yellow Flashers (ramp metered when flashing signs)
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RWIS	RWIS sites (including tower, pull boxes and meter breaker pedestal)
GTE	Ramp closure gates
PG	Point Generic (fiber access/splice locations and other infrastructure not described above)
MD	Microwave detectors/detector poles (capture point at pole location)

20.7.3 Deployment Inventory

An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60 ITS Software.

20.8.1 Maintenance

20.8.1.1 New DMS

Once the State Traffic Operations Center Maintenance Contractor accepts the DMS equipment per 20.6.2, the State Traffic Operations Center will accept the DMS onto the Statewide Maintenance Contract.

20.8.1.2 Existing DMS

If a contractor is working on an existing DMS, the contractor is responsible for locates and any maintenance until seven days after the as-builts have been delivered to the State Traffic Operations Center. At that time, the State Traffic Operations Center will accept the DMS onto the Statewide Maintenance Contract.

20.8.2 Reevaluation

In addition to periodic DMS equipment updates, DMSs should be evaluated for their effectiveness. Existing DMS installations should be reviewed to determine if there are locations are as beneficial as they used to be.

25.1.1 Introduction

The guidance in Chapter 25 is intended for the placement of ***new*** dynamic trailblazers as part of new construction projects only. The STOC must be contacted if retrofitting a dynamic trailblazer to existing systems or in any other circumstances where the addition of a dynamic trailblazer is being considered.

Dynamic trailblazer assemblies are used to guide motorists along alternate routes to a freeway segment during major incidents and ramp closures. **Under a "bypass" condition**, the assemblies may be routing people exiting the freeway, either voluntarily or involuntarily, or may be informing motorists already traveling the alternate route to continue bypassing the freeway to entrance points further downstream. **Under the "default" condition**, the "bypass" sign is blank, and the directional arrow assembly is pointed in the same direction, as would a standard static route marker.

Figure 25.1-1: Typical Dynamic Trailblazer Assembly

25.1.2 Needs Assessment

Dynamic trailblazers may be used when there is a frequent need to divert arterial traffic going to the highway from the primary route to an alternate route. Dynamic trailblazers could be activated for a variety of reasons including, planned special events, recurrent incidents, and other varying traffic conditions. Diverting traffic to the alternate route with the dynamic trailblazers alerts drivers to the shortest route to the freeway and optimizes the road network. Prior to starting the actual site design of dynamic trailblazers, the designer must collect pertinent data relating to corridor-wide and site-specific issues and develop a corridor operations plan. Examples of the data to collect in the needs assessment may include the following:

- Alternate routes and diversion strategies - A detailed map of the project corridor needs to be obtained, showing system interchanges and approaches to the alternate routes.
- Inventory of local agencies - An inventory of local agencies that are present in the project corridor needs to be compiled. This inventory will be used under outreach and coordination with these agencies.
- Inventory of existing signs and signals - A detailed inventory of existing signs and signal displays must also be compiled. This information will be critical in determining trailblazer assembly placement.
- Inventory of existing utilities - For local intersection design, all utilities must be inventoried and shown on the design plan. This information must be obtained via actual Digger's Hotline locate services, since most utility plant maps show utilities in general rather than specific locations. This information is critical in determining trailblazer assembly placement.
- Site-specific issues or concerns based on initial site visit (e.g., right-of-way, utilities, landscape)

25.1.2.1 Developing a Corridor Operations Plan

In determining where individual trailblazers should be placed throughout the corridor, a corridor operations plan must be developed to determine the intended use of the trailblazers. An example of an operations corridor plan is shown in Figure 25.1-2. If the use is intended specifically to **not** direct motorists off the freeway, but to provide guidance to motorists already on the parallel route, then a plan as shown may be appropriate. If, however, the implementation were intended to provide guidance to motorists traveling along the parallel route and being diverted from the freeway, would require additional assemblies along the eastbound approaches.

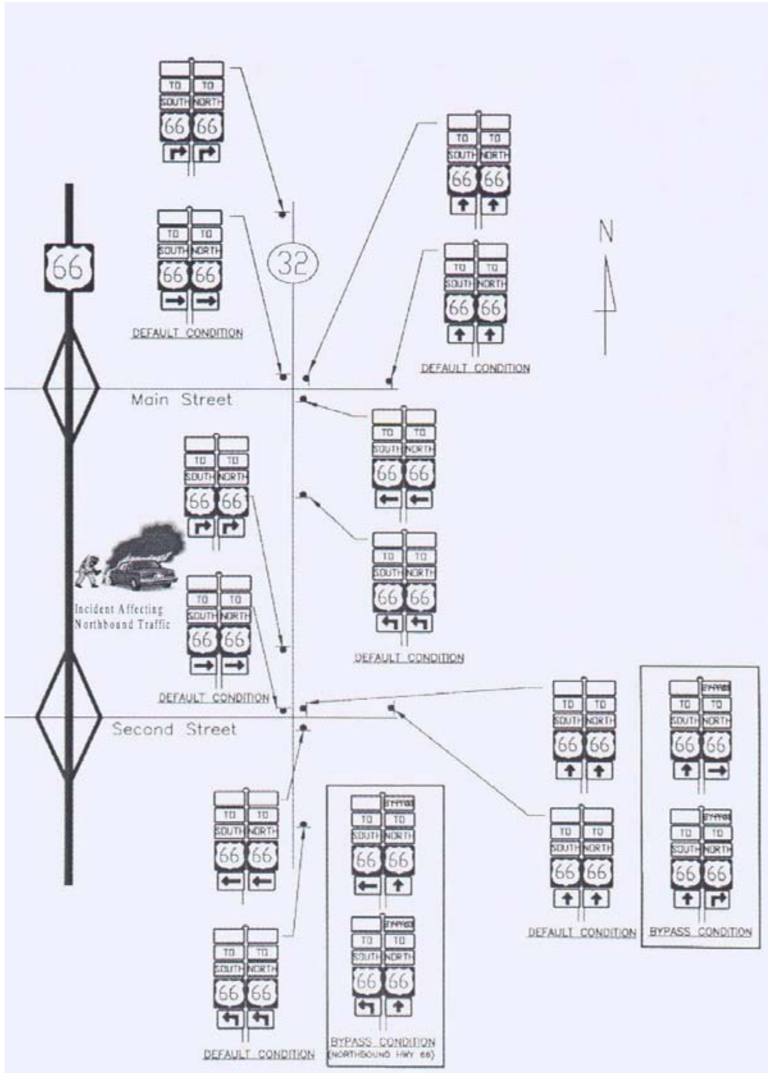


Figure 25.1-2: Typical Corridor Operations Plan for Dynamic Trailblazer Planning

25.1.2.2 Local Agency Outreach and Coordination

When implementing dynamic trailblazer assemblies, outreach to and coordination with local agencies within the corridor needs to be conducted. Questions that the designer must be prepared to answer include:

- Is the operational intent of the system to divert traffic away from the freeway under routine congestion? Severe congestion? Incidents?
- Will the alternate route be capable of carrying the additional traffic as a result of freeway diversion?
- What type of operational improvements (e.g., traffic signal timing) do you plan to implement to carry this additional traffic?
- What affect will these operational improvements have on cross-street traffic throughout the corridor?

If these questions are not investigated, and outreach with local agencies not conducted, the project may receive political and/or institutional opposition.

25.1.2.3 Dynamic Trailblazer Design Process

In the dynamic trailblazer design process, the designer must follow several steps to ensure successful implementation and proper operational capabilities. Some of these steps, such as power and communication requirements, must be addressed early in the design process and not after design for the proposed location has been completed. Each of these steps is detailed further in subsequent sections of this chapter.

Table 25.1-1 Dynamic Trailblazer Design Process Checklist

1. Collect initial data required for the proposed dynamic trailblazer design location (see 25.1.2)	
2. Establish corridor operations plan for proposed trailblazer deployment (see 25.1.2.1)	
3. Assign Name to Dynamic Trailblazer Device (see 25.2.1)	
4. Determine the location of the dynamic trailblazer assemblies and controller cabinet. (see 25.3.1 and 25.3.2)	
5. Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location.	
6. Prepare the underground infrastructure, including conduit and pullboxes (see 25.3.3)	
7. Perform cable routing to provide hardwire interconnection between the controller cabinet and trailblazer devices such as signals, electrical service, etc. (see 25.3.4)	
8. Determine the communications medium used for the proposed location (see 25.5.3)	
9. Revisit steps 3 through 8 until final design is complete	
10. Coordinate and conduct outreach with local agencies surrounding the proposed corridor.	
11. Determine the construction details, special provisions, and standard specification bid items need for the proposed desgn along with thos that need to be modified and created to provide a complete construction plan (see 25.5.4 and appendix 70)	

25.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format. For example, for the 20th Dynamic Trailblazer that is installed in the State in Milwaukee County (40), the number for the device should be DTS-40-0020 (i.e., DTS-County number-next sequential four digit number). The device number and related information will be stored in the ITS inventory management system.

If the device requires a TELCO (landline phone line), a street address must be established during this process.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at:

http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

25.2.2 Communications Assignments

This chapter, Ch 25 – Dynamic Trailblazers, discusses the appropriate communication network to use for dynamic trailblazers. Contact the STOC to discuss communication requirements.

25.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

25.3.1 Design Process

In the dynamic trailblazer design process, the designer must follow several steps to ensure successful implementation and proper operational capabilities. Some of these steps, such as power and communication requirements, must be addressed early in the design process and not after design for the proposed location has been completed. Each of these steps is detailed further in subsequent sections of this chapter.

1. Collect initial data required for the proposed dynamic trailblazer design location (see 25.1.2)
2. Establish corridor operations plan for proposed trailblazer deployment (see 25.1.2.1)
3. Assign Name to Dynamic Trailblazer Device (see 25.2.1)
4. Determine the location of the dynamic trailblazer assemblies and controller cabinet. (see 25.3.1 and 25.3.2)
5. Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location.
6. Prepare the underground infrastructure, including conduit and pullboxes (see 25.3.3)
7. Perform cable routing to provide hardwire interconnection between the controller cabinet and trailblazer devices such as signals, electrical service, etc. (see 25.3.4)
8. Determine the communications medium used for the proposed location (see 25.5.3)
9. Revisit steps 3 through 8 until final design is complete
10. Coordinate and conduct outreach with local agencies surrounding the proposed corridor.
11. Determine the construction details, special provisions, and standard specification bid items need for the proposed design along with those that need to be modified and created to provide a complete construction plan (see 25.5.4 and appendix 70)

25.3.2 Site Design and Equipment Placement

When the initial data collection and corridor operations plan is complete, the site design and equipment placement can be performed. Typically, two separate static route markers are placed on an approach to the intersection. Dynamic trailblazer assembly placement follows this static sign placement methodology. Per approach, one assembly is placed upstream of the intersection, with a second assembly placed at the intersection. This placement is indicated in Figure 25.1-2, with photo examples of each placement shown in Figure 25.3-1 and Figure 25.3-12.

Figure 25.3-1: Trailblazer Placement at Intersection

Figure 25.3-2: Trailblazer Placement Upstream of Intersection

25.3.2.1 Assembly Layout and Housing

Dynamic trailblazer assemblies consist of three components: a static route marker sign, an electronic “BYPASS” blank-out sign, and an electronic sign which has directional arrows that change dependent upon the current condition of operation in the corridor. An example of a dynamic trailblazer assembly is shown in Figure 25.3-3.

Housing design will vary dependent on size and type of assembly under consideration.

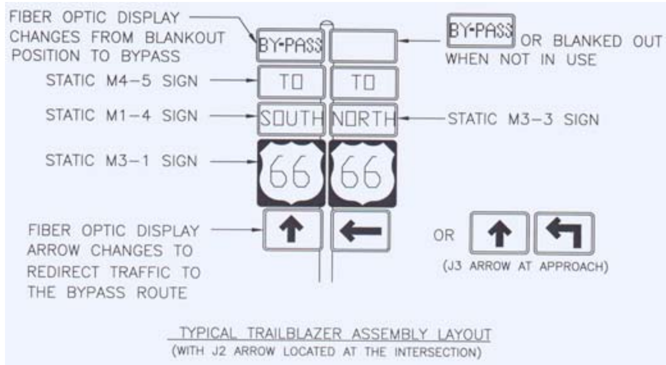


Figure 25.3-3: Dynamic Trailblazer Assembly Layout

It is important that the following site design issues be taken into account when placing the trailblazer assemblies:

- **Existing Utilities** - Using the utility information gathered under the data collection step of the design process, **proper clearance between the pole foundation (base) and existing utilities must be maintained.** It is important to note that standard utility locate tolerances are +/- 18-inches from the located paint mark.
- **Clearance** - A minimum of 18-inches must be maintained from the vertical plane of the existing curb and the closest portion of the sign assembly. In addition, if placing the assembly between existing curb and sidewalk, clearance of the sidewalk must also be maintained. In narrow installation areas, a mounting configuration as shown in Figure 25.3-4 can be used.
- **Existing Signal Displays** - Clear line-of-sight on traffic signal displays must also be maintained when placing these assemblies. It is very important that the designer carefully review this issue, since it may not be evident initially that the placement of the trailblazer assembly will occlude the traffic signal display. This issue is important not only for the intersection placement, but also for the upstream placement.
- **Existing Pole Mounting** - When mounting trailblazer assemblies to existing poles (as shown previously in Figure 25.3-1), a thorough structural review must be conducted. This review **must be coordinated through the Region Structural Engineer**.

Figure 25.3-4: Alternate Mounting Configuration in Narrow Clearance Areas

25.3.3 Cabinet Placement

The placement of the controller cabinet includes the following:

- Distance between the controller cabinet and the trailblazer.
- Accessibility for maintenance vehicles whenever possible.
- Safety of the cabinet location.
- Grades.

The slope of the terrain for cabinet placement must be no steeper than 4:1. Placement of the cabinet on 3:1 slopes or steeper require grading provisions to provide a level area around the cabinet.

Pole Mount Cabinets may be used if a controller cabinet size or capability is not needed. These cabinets are mounted directly to the pole. The pole mount cabinet has enough space to house electric service, a video encoder, and other communication equipment. Conduit is run from the bottom of the pole mount cabinet to the nearest pullbox or vault.

25.3.4 Underground Infrastructure

When the controller cabinet and trailblazer assemblies have been placed, the underground conduit infrastructure can be designed. Issues to keep in mind when designing the dynamic trailblazer conduit infrastructure include:

- Conduit Size - 3-Inch conduit is typically used for sign cables, since a) cost savings between 3-inch and smaller diameter conduits is minimal, and b) 3-inch conduit may provide for greater future expansion depending on the number of cables and % fill of the conduit. 2-inch conduit **must be used** when entering electrical service (meter) pedestals.
- Conduit Fill - The size and number of conduits along a run is dependent on percentage of fill as established by the National Electric Code (NEC). For new conduit installation, the percent fill must not exceed 31%. For installation of cable in existing conduit, 40% of the available area may be used.
- Pull Box Spacing - Pull boxes should be spaced approximately 200 feet apart. If
- Directional Bore - For conduit installation across paved areas, two methods of installation can be used, open-cut or directional bore. Open-cut conduit is strongly discouraged (and at times prohibited) due to new pavement conditions and roadway integrity. When designing **directional bore crossings**, consideration must be given to the installation process. When directionally drilling (bore), an auger is sent first underneath the pavement between two points, and then pulled back with the assembled conduit. In consideration of this, conduit must be assembled and laid out prior to being pulled back. In order to perform this task, adequate room must be available to “lay out” the conduit.

25.3.5 Cable Routing

Cable routing for dynamic trailblazers involves the connection of all equipment to the controller cabinet, including the signs and electrical service electrical service. Other devices such as cameras (see Chapter 15) may be added to a dynamic trail blazer site and require cable routing as described in their respective chapters. The size and type of service conductors to the sign are largely dependent on the sign requirements and distance from the power source (cabinet). If running communication cable in the same conduit system as the service conductors or power distribution wires, these should not be mixed together in the same conduit.

25.4 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

25.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

25.5.2 Communication Requirements

Dynamic Trailblazer controllers (i.e. Model 2070 processor assemblies), contain 1200 to 14,400 baud (bits per second) modems internal to the processor unit. The communication medium selected for ramp meter design can include spread spectrum radio, Ethernet over fiber (with an Ethernet to serial converter), dedicated twisted pair copper, or leased telephone circuit. Contact the State Traffic Operations Center to discuss communication requirements.

25.5.3 Power Requirements

A 100 Amp, 120/240 volt, single phase, three wire underground electrical service is required for electrical service installation. Typically, two controller cabinets can be powered by a single 100-amp service. The electrical service will be furnished and installed by the local power company up to a demarcation point, which consists of an electrical service (meter) pedestal. The electrical service must conform to the requirements of the local power company. The location of the electrical service must receive approval from the utility company. The electrical service will include two 50-amp circuit breakers rated at 22,000 AIC. The requirements for power cable between the electrical service and controller cabinet can be found under the Cable Routing section of this chapter.

At locations which require a remotely located electrical service, a 100 Amp outside rated breaker box with space for 6 circuits, but no main breaker, will be attached to the side of the cabinet. Also, a 50 Amp single circuit breaker rated at 22,000 AIC will be installed within the breaker box to serve as a local electrical service disconnect point.

25.5.4 Communications System Construction Standards

Construction details, Standard Special Provisions, and Special Provisions can be found in Appendix 70.

25.6.1 Testing

25.6.2 Controllers and Other Equipment
Reference Standard Specifications 675.3.(14) through 675.3.(20) for testing procedures.

25.6.3 Field System Integrator
Refer to Standard Specification 670.3.2.1 for field system integrator duties.

- **Contractor-furnished equipment and materials**, refer to Standard Specification 670.3.3.1.
- **Department-furnished equipment** and materials, refer to Standard Specification 670.3.3.2

25.6.4 Acceptance
Notify the State Traffic Operations Center after testing is complete. The State Traffic Operations Center Maintenance Representative will do the final concurrence of acceptance before the State Traffic Operations Center accepts ownership and maintenance of the communications system.

25.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

25.7.2 Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as "GPS data points". The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
    - Latitude (Y-coordinate) in decimal degrees
    - Longitude (X-coordinate) in decimal degrees
    - Altitude (Z-coordinate) in feet
    - Date (day, month, year) of point collection
    - Time (24 hour format) of point collection
    - Initials of field personnel collecting data points
    - Abbreviation for Element Type (see table of elements below)
    - Location description (for example, street and cross street)
    - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 965% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

Relevant Elements

Abbreviation	Description
CAM	CCTV poles (capture point at pole location)
CAB	Field equipment cabinets (unless attached to pole that is already being located)
PB	Pull boxes (when used with a fiber optic infrastructure installation, or when connected to in-pavement loops)
MH	Manholes (when part of fiber infrastructure)
JB	Junction boxes (such as on a bridge)
CV	Communication vaults (when part of fiber infrastructure)
MBP	Meter breaker pedestals
HUT	Equipment shelters (i.e. fiber optic communication huts)
ANT	Antenna poles (capture point at pole location)
OHS	Dynamic message signs (capture at base of sign support with connections to power and/or communications)
YF	Yellow Flashers (ramp metered when flashing signs)
HAR	Highway advisory radio transmitters (at antenna location)
SGN	Highway advisory radio signs (at sign location)
RMS	Ramp meters (capture point at pole location)
RWIS	RWIS sites (including tower, pull boxes and meter breaker pedestal)
GTE	Ramp closure gates
PG	Point Generic (fiber access/splice locations and other infrastructure not described above)
MD	Microwave detectors//detector poles (capture point at pole location)

25.7.3 Documentation

A listing of all the devices installed and the associated serial numbers, as-built CAD files, and testing and calibration results should be provided to BHO-STOC.

The following fields are used in the ITS inventory system. This data should be provided to the BHO-STOC as soon as it is available. The data must be provided before the equipment is accepted.

CartêGraph ITS Inventory Database Fields General:

ID
TOC Location Description
Installation Address
Installation Phone Number
Service Provider
Service Provider Utility Account
TOC Monitor ID
Region
TOC Type
Maintaining Authority
Maintaining Authority Contact
Service Provider

Details:

- Events – Lists work orders and other events
- Detectors:
  - ID
  - Detector Number
  - Description

Loop Location

- Aux Equip:

- ID
- Serial Number
- Description
- Manufacturer
- Model

- Cabinets:

  - ID
  - Serial Number
  - Description

- Supports:

    - Bolt circle
    - Height
    - Lowering system

25.7.4 ***Deployment Inventory***

An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60, ITS Software.

25.8.1 Maintenance

25.8.2 New Dynamic Trailblazers

Once the State Traffic Operations Center Maintenance Contractor accepts the Dynamic Trailblazer equipment per 25.6.2, the State Traffic Operations Center will accept the Dynamic Trailblazer onto the Statewide Maintenance Contract.

25.8.3 Existing Dynamic Trailblazers

If a contractor is working on an existing Dynamic Trailblazer, the contractor is responsible for locates and any maintenance until seven days after the as-builts have been delivered to the State Traffic Operations Center. At that time, the State Traffic Operations Center will accept the dynamic trailblazer onto the Statewide Maintenance Contract.

25.8.4 Reevaluation

Dynamic Trailblazers should be evaluated for their effectiveness periodically. Existing Dynamic Trailblazer installations should be reviewed to determine if there are locations where Dynamic Trailblazers are no longer as beneficial as they used to be. It may be beneficial to remove Dynamic Trailblazers that are no longer necessary.

30.1.1 Introduction

Road Weather Information Systems (RWIS) are a key part of maintenance operations and traffic management systems. The roadside weather stations, known as Environmental Sensor Stations (ESS) are used by county highway department personnel and traffic operations staff to continuously monitor a variety of road and atmospheric parameters. These include:

- Air temperature and relative humidity
- Wind speed and direction
- Precipitation
- Visibility
- Road surface temperature
- Road surface state (dry, wet, etc.)
- Amount of deicing chemical present

These systems were originally designed for winter maintenance use, but are now used year-round and by traffic operations as well.

The live, real time, RWIS system can be viewed online at http://www.dot.wisconsin.gov/travel/gis/rwis.htm

RWIS operations manuals and annual reports are available on the internal WisDOT intranet site and may be requested.

30.1.2 Needs Assessment

Normally, new installations are planned as part of highway improvement projects. However, if funding is available, they can be installed as a stand-alone project. Personnel involved in the decision on whether a new ESS site is justified include:

- WisDOT RWIS Program Manager (Bureau of Highway Operations)
- WisDOT Regional Area Supervisors
- County highway department patrol superintendents
- Project Engineer

These agencies will discuss the need for the new ESS site. If it is determined that an ESS site is required, they will then decide upon the appropriate sensor configuration for the new location. This includes locations for in-pavement sensors, non-contact pavement sensors, and atmospheric sensors.

30.1.3 Sensor Selection

Once the tower location is determined, the next step is to decide upon the sensor configuration. At a minimum, all sites will consist of an air temperature/relative humidity sensor, a wind speed/direction sensor, and some combination of the following:

- Precipitation sensor. Options range from basic yes/no to more advanced technologies that determine precipitation type as well as visibility.
- Road surface sensors. Determination must be made as to which specific lanes they will be installed in, as well as whether or not to install bridge deck sensors.
- Non-contact sensors. In areas where lane closures are not feasible to accomplish regular maintenance and repairs of roadway sensors, consideration should be given to installing non-contact (remote) roadway sensors.
- Subsurface temperature probes. They measure the temperature of the ground 18 inches below the surface.
- Roadway cameras.
- Traffic sensors. These can be integrated into the RWIS, which can result in savings on infrastructure costs.

Table 30.1-1 RWIS Design Process Checklist

1. Collect initial needs assessment (see 30.1.2)	
2. Determine ESS sensor needs (see 30.1.3)	
3. Determine location of ESS tower, cabinet, and sensors (see 30.3.2 and 30.3.3)	
4. Establish corridor operations plan for proposed trailblazer deployment (see 30.1.2.1)	
5. Assign name to ESS site (see 30.2.1)	
6. Determine the location of the dynamic trailblazer assemblies and controller cabinet. (see 30.3.1 and 30.3.2)	
7. Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location. (see 30.3.6)	
8. Prepare the underground infrastructure, including conduit and pullboxes (see 30.3.4)	
9. Perform cable routing to provide hardwire interconnection between the controller cabinet and ESS devices such as electrical service, etc. (see 30.3.5)	
10. Determine the communications medium used for the proposed location (see 30.5.2)	
11. Determine the construction details, special provisions, and standard specification bid items need for the proposed design along with those that need to be modified and created to provide a complete construction plan (see 30.5.4 and appendix 70)	

30.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format. For example, for the 20th Road Weather Information System that is installed in the State in Milwaukee County (40), the number for the device should be RWIS-40-0020 (i.e., RWIS -County number-next sequential four digit number). The device number and related information will be stored in the ITS inventory management system.

If the device requires a TELCO (landline phone line), a street address must be established during this process.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at:

http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

30.2.2 Communications Assignments

This chapter, Chapter 30, Road Weather Information Systems, discusses the appropriate communication network to use for road weather information systems. Contact the STOC to discuss communication requirements.

30.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

30.3.1 Design Process

In the RWIS design process, the designer must follow several steps to ensure successful implementation and proper operational capabilities. Many of these steps, such as power and communication requirements, must be addressed early in the design process.

1. Collect initial data required for the proposed ESS location.
2. Determine the ESS sensors required for the design location.
3. Assign name to ESS tower for proper recording.
4. Determine the location of the ESS tower and meter service pedestal.
5. Prepare the infrastructure, including tower pad and underground cabling.
6. Perform cable routing to provide hardwire interconnection between the ESS processor and any road sensors.
7. Determine the communications medium used for the proposed location.
8. Revisit steps 3 through 6 until final design is complete.
9. Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location.
10. Determine the construction details needed for the proposed design, details that need to be modified, and new details that need to be created to provide a complete construction plan.
11. Determine the special provisions needed for the proposed design, special provisions that need to be modified, and new special provisions that need to be created to provide a complete construction plan.
12. Determine the standard specification bid items and procurement items that will need to be included in the estimate and miscellaneous quantities to provide a complete construction plan.

30.3.2 ESS Equipment Placement

Placement of equipment for ESS involves the controller cabinet/tower, roadway sensors, underground infrastructure, and electrical service.

30.3.3 ESS Tower and Cabinet

ESS placement is based on the requirements documented under Section 30.1.3 of this chapter. Site surveys by the WisDOT RWIS Program Manager are required. Site placement should adhere as closely as possible to standards outlined in the FHWA Road Weather Information System Environmental Sensor Station Siting Guidelines.

- **Foliage -** Whenever possible, the site survey should be done while trees are in full foliage. If this is not done, it is possible that foliage can interfere with the proper operation of the ESS equipment.
- **Right-of-way**- The ESS will always be placed in the WisDOT right-of-way.
- **Maintenance** – The ESS requires ongoing maintenance. Placement should be such that a maintenance technician has easy access to the tower location. The tower is a 30-foot foldover tower, so the orientation of the tower with regards to the direction it will fold down is critical. Proper clearance must be accounted for.
- **Permanent Structures** – It is acceptable to install the ESS cabinet on existing structures (poles, sign bridges, buildings, etc.) when power is available and stand alone options are not available, keeping in mind ease of maintenance concerns.

The controller cabinet will be located on the ESS tower. The following items will be considered in placement of the tower:

- Distance between the controller cabinet and the roadway sensors.

- Distance between the tower and the electrical service pedestal.
- Off-freeway accessibility for maintenance vehicles whenever possible.
- Safety/security of the cabinet location. If heavy pedestrian /all-terrain vehicle/snowmobile traffic is anticipated in the vicinity of the tower, a fence might be required around the tower.
- Grades. The ESS tower requires an eight-foot by eight-foot concrete pad. Thus, if possible, the tower should be located where the grade is minimal. The slope of the terrain for tower placement must be no steeper than 5:1.

30.3.4 Roadway Sensor Placement

If it is determined that roadway sensors are required, the next step is to decide the specific locations for each sensor. An ESS processor can ingest up to six sensors. The following locations should be considered, in this priority order:

- Bridge deck slow lane (if applicable)
- Roadway slow lane
- Bridge deck fast lane (if applicable)
- Roadway fast lane

Sensors can be placed in either direction of travel, but maintenance is generally easier if they are located on the same side of the highway as the ESS tower. In addition, if the proposed location is at an intersection of two state trunk highways, sensors can be placed on both.

30.3.5 Underground Infrastructure

When the controller cabinet, electrical service and ESS tower site have been placed, the underground conduit infrastructure can be designed. Issues to keep in mind when designing the conduit infrastructure include:

- <u>Pull Boxes</u>– Pull boxes are sometimes required between the tower and the roadway sensors.
- <u>Terrain</u> - Conduit infrastructure should be designed on relatively flat (4:1 slope or flatter) terrain. For steeper sloped terrain (3:1 or greater) , conduit may be run perpendicular to (i.e., up or down) the slope to locations where the terrain is more suitable for conduit installation.
- <u>Conduit Size</u> - 1-Inch PVC conduit is typically used for roadway sensor connection. Conduit entering electrical service pedestals must be sized per pedestal requirements.
- <u>Conduit Fill</u> - The size and number of conduits along a run is dependent on percentage of fill as established by the National Electric Code (NEC). For new conduit installation, the percent fill must not exceed 31%. For installation of cable in existing conduit, 40% of the available area may be used.
- <u>Conduit in ESS Tower Base</u> - Two 2-inch conduits, and one 1-inch conduit should be placed in the ESS tower's concrete base. This will allow one conduit for electrical wire, one conduit for communication wire, and one conduit for coaxial cable (which is sensitive to electric-magnetic fields).

30.3.6 Cable Routing

Cable routing for ESS sites typically involves the connection of all roadway sensors, electrical, and communications services to the ESS cabinet on the tower. Other devices such as cameras or system detector stations (Chapters 10 and15) may be added to an RWIS site, and require cable routing as described in their respective chapters. The power distribution cable running between the ESS controller cabinet and the electrical service should be in a separate conduit. Power and communication cables should not be mixed together.

30.3.7 Electrical service

The power distribution wires running between the electrical service and the controller cabinet consist of stranded copper single conductors, cross-linked polyethylene (XLP), USE rated. Section 655 of the standard specifications provides guidance on additional requirements. The bid items for "Electrical Wire Lighting (gauge #) AWG will meet the requirements. The gauge of conductors must be calculated per the requirements of the National Electric Code.

30.3.8 Electrical Wire Routing

The conduit system for ESS sites needs to be bonded together, due to the fact that power cables are running within the system. Bonding all metallic components of the system together assures that there will be no difference in voltage potential across two points in that system. In addition, grounded conductor needs to be run with current-carrying cables (such as traffic signal conductors, power distribution wires, etc.), which returns the circuit's current at zero voltage. The bonding/grounding wires in system typically use Electrical Wire Traffic

Signals 10 AWG (Item 655.0515) in the State's Standard Specifications. The gauge of grounded conductor must be calculated per the requirements of the National Electric Code. There is a distinct method required for the bonding system. Examples of this method can be found in Chapters 2 and 3.

The pull boxes do not require grounding if the total voltage encountered in the pull box is 50 volts or less. In some Districts, a policy has been made to bond and ground all conduit systems, since equipment is frequently added to various locations in the future. For assistance in bonding and grounding of underground systems, consult the State Electrical Engineer.

30.3.9 Roadway/Bridge Deck Sensor Cabling

Roadway sensors are supplied with 150 or 300 feet of Type IIA cable. When possible, this cable will be run directly into the ESS cabinet. It will be installed in the road surface in a saw kerf ½ inch wide by 1½ inches deep. This kerf will then be filled with flexible sealant once the cable has been installed.

The cable will then be run through 1-inch conduit into the ESS cabinet. If a pull box is required to extend the cable length, the sensor cable will run into the pull box, then a Type V cable will connect to the ESS cabinet.

For bridge deck installation, coordination with the State Bridge Engineer is required in order to determine whether the sensor cable will run in a saw kerf to the side of the bridge or through a hole in the deck to conduit. Once the cable is run to the side of the bridge by one of these methods, it will run through 1-inch PVC conduit to the ESS cabinet.

30.4.1 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

30.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at

http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

Communication Requirements

Road Weather Information Systems controllers (i.e. Model 2070 processor assemblies), contain 1200 to 14,400 baud (bits per second) modems internal to the processor unit. The communication medium selected for ramp meter design can include spread spectrum radio, Ethernet over fiber (with an Ethernet to serial converter), dedicated twisted pair copper, or leased telephone circuit. Contact the State Traffic Operations Center to discuss communication requirements.

30.5.2 Power Requirements

A 100 Amp, 120/240 volt, single phase, three wire underground electrical service is required for electrical service installation. Typically, two controller cabinets can be powered by a single 100-amp service. The electrical service will be furnished and installed by the local power company up to a demarcation point, which consists of an electrical service (meter) pedestal. The electrical service must conform to the requirements of the local power company. The location of the electrical service must receive approval from the utility company. The electrical service will include two 50-amp circuit breakers rated at 22,000 AIC. The requirements for power cable between the electrical service and controller cabinet can be found under the Cable Routing section of this chapter.

At locations which require a remotely located electrical service, a 100 Amp outside rated breaker box with space for 6 circuits, but no main breaker, will be attached to the side of the cabinet. Also, a 50 Amp single circuit breaker rated at 22,000 AIC will be installed within the breaker box to serve as a local electrical service disconnect point.

30.5.3 Communications System Construction Standards

Construction details, Standard Special Provisions, and Special Provisions can be found in Appendix 70.

30.6.1 Testing

30.6.1.1 Controllers and Detectors

Reference Standard Specifications 675.3.(14) through 675.3.(20) for testing procedures. In 675.3.(15), traffic flow information includes volume and speed data.

30.6.1.2 Field System Integrator

Refer to Standard Specification 670.3.2.1 for field system integrator duties.

- **Contractor-furnished equipment and materials**, refer to Standard Specification 670.3.3.1.
- **Department-furnished equipment** and materials, refer to Standard Specification 670.3.3.2

30.6.1.3 Acceptance

Once the road weather information system testing is complete, the RWIS Project Manager in BHO maintains and operates the equipment.

30.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as "GPS data points". The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
  - Latitude (Y-coordinate) in decimal degrees
  - Longitude (X-coordinate) in decimal degrees
  - Altitude (Z-coordinate) in feet
  - Date (day, month, year) of point collection
  - Time (24 hour format) of point collection
  - Initials of field personnel collecting data points
  - Abbreviation for Element Type (see table of elements below)
  - Location description (for example, street and cross street)
  - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 965% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

Relevant Elements

Abbreviation	Description
CAM	CCTV poles (capture point at pole location)
CAB	Field equipment cabinets (unless attached to pole that is already being located)
PB	Pull boxes (when used with a fiber optic infrastructure installation, or when connected to in-pavement loops)
MH	Manholes (when part of fiber infrastructure)
JB	Junction boxes (such as on a bridge)
CV	Communication vaults (when part of fiber infrastructure)
MBP	Meter breaker pedestals
HUT	Equipment shelters (i.e. fiber optic communication huts)
ANT	Antenna poles (capture point at pole location)
OHS	Dynamic message signs (capture at base of sign support with connections to power and/or communications)
YF	Yellow Flashers (ramp metered when flashing signs)
HAR	Highway advisory radio transmitters (at antenna location)
SGN	Highway advisory radio signs (at sign location)
RMS	Ramp meters (capture point at pole location)
RWIS	RWIS sites (including tower, pull boxes and meter breaker pedestal)
GTE	Ramp closure gates
PG	Point Generic (fiber access/splice locations and other infrastructure not described above)
MD	Microwave detectors//detector poles (capture point at pole location)

30.7.2 Documentation

A listing of all the devices installed and the associated serial numbers, as-built CAD files, and testing and calibration results should be provided to BHO-STOC.

The following fields are used in the ITS inventory system. This data should be provided to the BHO-STOC as soon as it is available. The data must be provided before the equipment is accepted.

CartêGraph ITS Inventory Database Fields General:

ID
TOC Location Description
Installation Address
Installation Phone Number
Service Provider
Service Provider Utility Account
TOC Monitor ID
Region
TOC Type
Maintaining Authority
Maintaining Authority Contact
Service Provider

Details:

- Events – Lists work orders and other events
- Detectors:
  - ID
  - Detector Number
  - Description

Loop Location

- Aux Equip:

- ID
- Serial Number
- Description
- Manufacturer
- Model

- Cabinets:

  - ID
  - Serial Number
  - Description

- Supports:

- Bolt circle
- Height
- Lowering system

30.7.3 Deployment Inventory

An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60 ITS Software.

30.8.1 Maintenance

30.8.1.1 New Road Weather Information Systems

Once the RWIS Project Manager accepts the communication systems equipment per 50.6.2, the Project Manager will operate and maintain the communication systems for RWIS.

30.8.1.2 Existing Road Weather Information Systems

If a contractor is working on an existing Road Weather Information System, the contractor is responsible for locates and any maintenance until seven days after the as-builts have been delivered to the RWIS Project Manager. At that time, the RWIS Project Manager will accept the system and operate and maintain the system.

30.8.2 Reevaluation

Road Weather Information Systems should be evaluated for their effectiveness periodically. Existing Road Weather Information Systems installations should be reviewed to determine if there are locations where Road Weather Information Systems no longer are as beneficial as they used to be. It may be beneficial to remove Road Weather Information Systems that are no longer necessary.

35.1.1 Introduction

Currently PCMS are available and deployed by Regions, typically through county highway departments and contractors, for various uses. The use of these signs shall conform to the following guidelines. PCMS are official traffic control devices and NOT a public information tool. Since they are dynamic signs, PCMS must only be used to display "real-time" or changing traffic condition or traffic control information. TGM Policy 17-2-1 provides guidance for when to use PCMS.

35.1.2 Needs Assessment

PCMS are used for work zone temporary traffic control, incident management, special events, and unusual/hazardous road conditions due to weather. This could include expected delay times in queue situations, warning of stopped traffic, ramp or lane closures, advisory speeds and alternate route advisories. They may also be used to provide advance notice (up to 10 days) prior to projects or events expected to cause congestion or that will require drivers to use alternate routes. PCMS should not be used to replace static warning or regulatory signs; they may be considered as a supplemental device to a required static sign. In the case of a ramp or lane closure, the PCMS would supplement the static warning signs informing motorists of the closure. It is at the discretion of the Region whether static or changeable message signs are more appropriate for specific applications.

The Department reserves the right to use/deploy signs from its inventory on an improvement project to improve safety and optimize the operational efficiency of a construction work zone. Contractor provided signs should be used for aforementioned purposes if they could be made available and deployed expeditiously and cost effectively.

35.1.3 Types

PCMS are available in various types, including fiber optic, light emitting display diodes (LED), bulb matrix and various hybrids of light source/disk technology. The standard for the industry is a 3-line sign with eight characters per line. The Bureau of Highway Operations maintains current literature on various manufacturers and specifications for PCMS.

35.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format. For example, for the 20th portable changeable message sign (PCMS) that is installed in the state will be in Milwaukee County (40), the number for the device should be PCMS-02-2004 (i.e., PCMS - Old District Number - Old District Number+next sequential three digit number). The device number and related information will be stored in the ITS inventory management system.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at:

http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

35.2.2 Communications Assignments

Refer to Chapter 50, ITS Communication Systems for information regarding the appropriate communication network to use for PCMS. Contact the STOC to discuss communication requirements.

35.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

35.3.1 Sign Placement

PCMS must be placed to allow drivers enough time to comprehend the message and decide what action to take.

When the PCMS is used to warn of stopped or slowed traffic, place it far enough in advance of the longest anticipated queue of traffic so drivers have adequate distance to stop. If used to provide information on delays, current ramp closures or to inform of alternate routes, place the PCMS in advance of exits to alternate routes so drivers have adequate time to decide whether or not to exit without making erratic maneuvers.

When used to provide lane closure warning and there is an interchange between the sign and the lane closure, include enough information about location of the lane closure so exiting traffic is not encouraged to make unnecessary lane changes prior to the interchange.

It is possible to use multiple PCMS for adequate warning or if one PCMS cannot safely display enough information. When anticipated queue lengths vary, and queues could extend beyond an interchange, PCMS may be needed on each side of the interchange and should provide current information.

For advance notice (up to 10 days) of ramp or lane closures, PCMS may be placed at the actual closure location to give notice to repeat drivers.

35.3.1.1 Lateral Placement

Signs should be placed as far away from the live traffic lanes as possible without hampering visibility. In advance of Interstate construction projects, the signs should be placed on the backslope beyond the ditch. The location selected should be at or slightly above the elevation of the roadway. This improves the visibility, minimizes the chance of a vehicle hit, and also improves safety for the sign maintenance worker. For intermittent work such as freeway lane closure, or where site conditions do not allow otherwise, the signs may be placed on the shoulder. The site should be visited to assure visibility, safety and maintenance considerations. A taper of reflectorized drums, cones or barricades should be placed ahead of PCMS placed on the shoulder if it is not shielded by a barrier.

35.3.1.2 Electrical service

PCMS are powered with solar power technologies; so hard wiring the device to an electrical service is not necessary.

35.4.1 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

35.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at

http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

35.5.2 Communication Requirements

Communication between the PCMS and control center allows information to be disseminated on a real-time basis, providing up-to date information to the motorist. Signs are capable of having manual on-site control or remote control. The manual on-site control allows a project engineer or maintenance supervisor to program the sign using the on-board computer keyboard. However, this does not supercede the requirements for compliance with message guidelines. There are at least three methods of remote control; (1) Utilizing a cellular telephone, (2) utilizing a central base computer, and (3) utilizing Jam Logic Controller through the state patrol radio network.

PCMS owned by the State of Wisconsin can be identified with a large, reflective number placed on the back of the sign. The number will start with PCMS, followed by the two-digit region number, and a four-digit number. (e.g. PCMS-04-4001).

All state PCMS have a JamLogic controller and IP radio installed, as illustrated in Figure 35.5-1. The signs controller works with the JamLogic to change the message displayed. An IP radio is connected to the JamLogic Controller to communicate with the State Patrol Network tower. The message from the tower then goes to the servers at Traffic Technologies in Minnesota. Traffic Technologies currently has the contract to provide these services to the state, Traffic Technologies operators a website called JamLogic, which is where the PCMS messages can be controlled and viewed for each of the signs. This configuration allows for control of all State owned PCMS though the JamLogic website or on-site at the sign. The JamLogic system also has the capability to monitor a sign's health and history remotely. For instance, messages, voltage levels, and signal strength can be tracked over time through the JamLogic website.

The communications configuration through the State Patrol Network came about as a solution to the unreliable cellular communication coverage in many parts of Wisconsin.

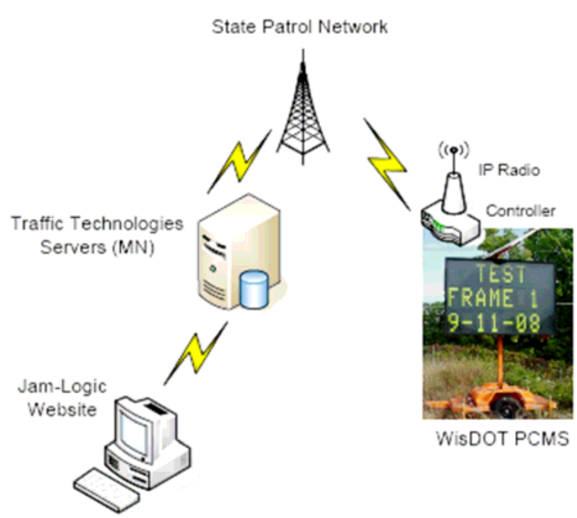


Figure 35.5-1. State PCMS Communication Network

Other signs may be found in the right of way that not owned by the State of Wisconsin. For example, a specific project may have a number of PCMS associated with it as part of its traffic management plan. Those signs will not have the communications network illustrated in Figure 35.5-1. It is up to the contractor to operate and maintain those signs as specified by that project's contract.

Chapter 50, Communication Systems provides additional information on communication types and requirements.

35.5.3 Power Requirements

PCMS are designed to operate independent of external power for extended periods of time and have solar power technologies installed. Hard wiring the device to an electrical service is not required.

35.5.4 PCMS Construction Standards

Construction details, Standard Detail Drawings, and Special Provisions can be found in Appendix 70.

35.6.1 Testing

35.6.1.1 Controllers and Detectors

Reference Standard Specifications 675.3(14) through 675.3(20) for testing procedures. In 675.3(15), traffic flow information includes volume and speed data.

35.6.1.2 Field System Integrator

Refer to Standard Specification 670.3.2.1 for field system integrator duties.

Contractor-furnished equipment and materials, refer to Standard Specification 670.3.3.1.

Department-furnished equipment and materials, refer to Standard Specification 670.3.3.2

35.6.2 Acceptance

Notify the State Traffic Operations Center after testing is complete. The State Traffic Operations Center Maintenance Representative will do the final concurrence of acceptance before the State Traffic Operations Center accepts ownership and maintenance of the PCMS.

35.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

35.7.2 Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as "GPS data points". The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
  - Latitude (Y-coordinate) in decimal degrees
  - Longitude (X-coordinate) in decimal degrees
  - Altitude (Z-coordinate) in feet
  - Date (day, month, year) of point collection
  - Time (24 hour format) of point collection
  - Initials of field personnel collecting data points
  - Abbreviation for Element Type (see table of elements below)
  - Location description (for example, street and cross street)
  - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 95% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

Relevant Elements

Abbreviation	Description
CAM	CCTV poles (capture point at pole location)
CAB	Field equipment cabinets (unless attached to pole that is already being located)
PB	Pull boxes (when used with a fiber optic infrastructure installation, or when connected to in-pavement loops)
MH	Manholes (when part of fiber infrastructure)
JB	Junction boxes (such as on a bridge)
CV	Communication vaults (when part of fiber infrastructure)
MBP	Meter breaker pedestals
HUT	Equipment shelters (i.e. fiber optic communication huts)
ANT	Antenna poles (capture point at pole location)
OHS	Dynamic message signs (capture at base of sign support with connections to power and/or communications)
YF	Yellow Flashers (ramp metered when flashing signs)
HAR	Highway advisory radio transmitters (at antenna location)
SGN	Highway advisory radio signs (at sign location)
RMS	Ramp meters (capture point at pole location)
RWIS	RWIS sites (including tower, pull boxes and meter breaker pedestal)
GTE	Ramp closure gates
PG	Point Generic (fiber access/splice locations and other infrastructure not described above)
MD	Microwave detectors/detector poles (capture point at pole location)

35.7.3 Deployment Inventory

An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60 ITS Software.

35.8.1 Maintenance

35.8.1.1 New PCMS

Once the State Traffic Operations Center Maintenance Contractor accepts the PCMS equipment per 35.6.2, the State Traffic Operations Center will accept the PCMS onto the Statewide Maintenance Contract.

35.8.1.2 Existing PCMS

An MOU shall be developed for any county highway department operating state-owned PCMS on the state highway system. A sample MOU is included at the end of this guideline. For state or county supplied signs, arrangements should be made using state or county forces to maintain the signs while in use. For newly purchased signs, a warranty period is usually provided, requiring the supplier to repair any failures or breakdowns of the sign. When the county performs maintenance work on state-owned signs, charge project number 00XX-01-07 (non-Interstate) or 00XX-01-08 (Interstate), Activity Code 032. When the county provides county-owned PCMS, all maintenance responsibility rests with the county and is covered under the rental rate.

35.8.2 Reevaluation

In addition to periodic PCMS equipment updates, PCMSs should be evaluated for their effectiveness at their current locations since they should only be used on a temporary basis.

40.1.1 Introduction
The guidance in Chapter 40 is intended for the placement of smart work zone equipment as part of construction projects. The use of smart work zone devices should be discussed with BHO Traffic Engineers prior to planning and deployment. Smart work zones are designed to mitigate construction related impacts, such as delay, increased travel times, and congestion-related crashes.

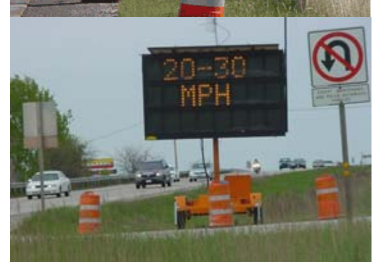
40.1.2 Needs Assessment
As part of the Transportation Management Plan (TMP) process, smart work zones are one alternative identified as a traffic mitigation strategy.

40.1.2.2 Criteria
Initial screening criteria to determine if a smart work zone is needed are provided below.

1. The Backbone user delay spreadsheets in the Lane Closure System (LCS) show delay, queues, and user costs for one and two lane closures along statewide freeways. If a particular work zone shows recurring delays of more than 15 minutes and/or sustained traffic volumes that exceed typical work zone capacity of 1,500 vehicles per hour per lane, then a smart work zone may be considered. Consider smart work zone cost in comparison to the anticipated user delay cost for the construction project.
2. It may be beneficial to install the permanent ITS equipment prior to the project so that it may be used as part of a smart work zone. Refer to the TOIP for proposed locations of permanent ITS as part of upcoming construction projects.

40.1.2.3 Types and Design Considerations
If one or more of the criteria are met, the designer can determine the type of smart work zone to implement. All smart work zone alternatives and placement should be discussed with BHO Traffic Engineering Section and the STOC.

- **Travel Time and/or Delay System**
  This portable, automated, real-time smart work zone system informs drivers what the estimated travel time and/or delay is between drivers' current location and a specific destination beyond them. The system collects real-time traffic flow data using roadside non-intrusive sensors, calculates travel time and delay between different points, and displays the travel time and delay information on portable changeable message signs at pre-determined locations. This information will allow drivers to decide whether to change routes, provides them opportunity to notify others of their estimated arrival time, and generally provides drivers sufficient information to calm tempers. Consideration should be given to posting an alternate route. The system should be carefully monitored for accuracy and adjusted accordingly so accurate information is being given to drivers. PCMS can also be used to notify the driver of the current speed range within the work zone, known as itellizone.



- **Dynamic Late Merge**
  When properly designed and deployed for a specific project, a DLM System should alert drivers of an upcoming traffic slow-down and inform them to use both lanes until the merge point. By encouraging use of all available lanes until the merge point, the system will reduce the length of a queue by around 40%. Reduced queue length allows better access to upstream interchanges. The DLM system also promotes more orderly merging, which may improve capacity at the merge point, reduce road rage incidents, and reduce the speed differential between lanes.

- **"Your Speed " Signs**

Also know as radar speed display signs. This is a work zone strategy that attempts to influence drivers to reduce their speed. The speed limit is displayed along with the detected speed of an approaching vehicle. Some studies have shown it to reduce average and 85th-percentile speeds by 3 – 7 miles per hour, but the sign may lose effectiveness over time if left in place at the same location for a prolonged period.

- **Variable Speed (pre-determined speed limit changes)**
  Can be used to easily lower the speed limit during construction hours and increase the speed limit when construction is not taking place, such as on weekends. This helps to eliminate the need to cover and uncover static signs and also helps to eliminate driver confusion if two different speed limit signs are accidentally left visible for drivers. Use of such device shall be discussed with the Regional Traffic Engineer.

- **Variable Speed (automatically changed speed limit)**
  This system advises drivers of an appropriate vehicle speed to allow them to travel through the work zone with minimal braking. The system determines the average speed of downstream traffic and advises upstream traffic of an optimum speed to approach the queue. It is anticipated that the system will smooth the transition between faster and slower moving traffic, and provide an increase in capacity of the roadway through the work zone area. Automatic variable regulatory speed limits have not been used in Wisconsin due to potential conflict with State Statutes, but a speed advisory system using similar technology has been used with good results. Use of such device shall be discussed with the Regional Traffic Engineer.

- **PCMS**
  Portable Changeable Message Signs are useful for displaying traveler information to the traveling public about work zone conditions. See Chapter 35 for more information.

- **Surveillance**
  Portable surveillance can be used to view traffic conditions in a work zone. These images may be helpful in changing messages on PCMS according to traffic conditions

- **Detection**
  Volume and speed data can be collected in a work zone using Wavetronix units. This data is useful in collecting work zone capacity data and speeds, which could help determine if other smart work zone strategies are needed. For more information on system detector stations, see Chapter 10 of this manual.

- **Moveable Barrier**
  If there is a directional split of peak traffic demand (60% or more of the traffic in one direction), moveable barrier may be a good option. Moveable barrier provides the ability to change the number of lanes (capacity) according to directional traffic demand during construction.

Table 40.1 Smart Work Zone Design Process Checklist

1. **Complete TMP** to determine if smart work zones are recommended as a mitigation strategy (see 40.1.2)
2. Review **criteria** to determine if a smart work zone is needed (see 40.1.2.2)
3. Determine the **smart work zone type and placement** best suited for the location (see 40.1.2.3 and consult with BHO-TES and BHO-STOC).
4. Discuss the **power, communications, and any integration** needs with BHO-STOC (see 40.2).
5. Discuss **purchasing** options with BHO-TES and BHO-STOC to determine if it's best to have the contractor provide the equipment, utilize existing state owned equipment, or purchase the equipment through BHO-STOC (see 40.3).
6. Determine the **construction details, special provisions, and standard specification bid items** needed for the proposed design, along with those that **need to be modified** and **created** to provide a complete construction plan (Appendix 70).

40.2.1 Naming Convention

If the smart work zone device require a TELCO (landline phone line), a street address must be established during this process.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at: http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

40.2.2 Communications Assignments

Refer to Chapter 50, ITS Communication Systems for information regarding the appropriate communication network to use for smart work zones. Contact the STOC to discuss communication requirements.

40.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

40.3 Procurement Process

Coordinate with the BHO Traffic Engineering Section and STOC to determine if it is best to have the contractor provide the smart work zone equipment, utilize existing state owned smart work zone equipment, or have BHO purchase the equipment. The BHO-STOC provides the management of the purchasing process. All questions relating to equipment orders and delivery dates should be directed to the Bureau of Highway Operations – STOC.

40.4 Maintenance

If the smart work zone equipment is provided by the contractor, the contractor is responsible for all maintenance during the construction project. If the smart work zone equipment is State provided, the STOC is responsible for maintenance.

45.1.1 Introduction

The guidance in Chapter 45 is intended for the placement of portable HAR devices. The STOC must be contacted if retrofitting a device to an existing system or in any other circumstance where the addition of a traveler information device is being considered.

The HAR system is a low-powered AM or FM radio station which broadcasts messages to motorists who receive signals through standard automobile radios. HAR provides motorist information similarly to VMS but can provide more detailed information. The information broadcast can include:

- Congestion reports,
- Hazardous conditions,
- Travel times,
- Alternate routes,
- Special event information,
- Parking locations,
- Weather and road conditions, and
- Construction information.

HAR systems can be permanent or portable, however WisDOT will only continue to maintain permanent HAR and will not be installing any new permanent HAR. FCC licensing is required, and each HAR site is limited to a maximum of 10-watts of power, unless a special permit is granted. HAR can broadcast either AM or FM radio signals, and the typical message length is up to two minutes.

A HAR installation is made up of six separate components:

- Audio Source
- Radio Transmitter
- Antenna System
- Ground System
- Communication System
- Synchronization System

60.1.1 Needs Assessment

Prior to determining the type and location of a portable HAR, various data needs to be collected, such as:

- Current FCC Licensing Requirements - The designer must obtain the latest copy of the FCC rules (section 90.242)
- Frequency availability - Existing HAR frequencies (airports, convention and visitors bureaus, stadiums, etc.) must be documented, in addition to all other radio frequencies. This list will be used upon determining usable frequencies.
- Availability of alternate routes - An inventory of alternate routes and diversion points is necessary to assist in proper placement of a HAR transmitter.
- Speed limits on HAR routes - The speed limit of a candidate route for HAR will determine the spacing required between the HAR flasher and HAR transmitter
- Site Specific Conditions - Soil properties, terrain, and obstructions for the site in question must be gathered. Uses for this information are explained in further detail in the following sections.

60.1.2 Types

There are three different systems within the HAR category; the one typically used is the 10-watt “Traditional” HAR. This type of HAR is typically used in Wisconsin. For this application, HAR consists of individual transmitter sites (or stations) located along an expressway, with each transmitter broadcasting at a range of 3 to 5 miles. Communications with each transmitter are typically through dial-up telephone, which is a permanent deployment.

45.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format. For HAR locations, the naming convention is HAR-County Number-Next sequential 4-digit number. For example, for the 4th HAR system that is installed in the state will be in Milwaukee County (40), the number for the device should be HAR-40-0004. For HAR flasher sign locations, the naming convention is TFS-County Number-Next sequential 4-digit number. The device number and related information will be stored in the ITS inventory management system.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at: http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

45.2.2 Communications Assignments

Refer to Chapter 50, ITS Communication Systems for information regarding the appropriate communication network to use for HAR. Contact the STOC to discuss communication requirements.

45.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

Enhanced HAR can transmit at a range of 8 to 12 miles. The transmitter site has a more advanced antenna and pole and broadcasts at more than 10 watts. A special permit is required from the FCC in order to use an enhanced HAR and this permit is harder to obtain than the 10-watt license. This is a permanent deployment. An extended ground plane is needed for enhanced HAR.

Portable HAR transmitters are typically trailer-mounted, with the antenna and grounding plane adapted for a portable application. Portable HAR is typically used for highway construction, incident management and special events with each consisting of a wireless solar power array and cell-phone control. Portable HAR is capable of being transferred from site to site, and has a broadcast range near that of permanently built stations (3-5 miles). Portable HAR is licensed by governmental entities for noncommercial broadcasts that relate to travel, safety and weather.

Synchronized HAR has increasingly become a popular deployment type, using traditional 10-watt transmitters (3-5 mile radius) systematically placed to create a regional "synchronization zone". Motorists hear the same message anywhere within the synchronized zone. Properly deployed, this type of deployment eliminates interference and delivers a universal broadcasts to a synchronized area.

A recent development in HAR technology allows widespread HAR coverage of an entire metropolitan area, with a single transmission from a central source (typically a PC). The central source broadcasts one message to the HAR transmitters in an entire coverage area, but only motorists on affected freeway segments are alerted to the HAR message through use of advisory signage equipped with HAR-activated flashing beacons. These messages are typically generated one of two ways: a computer-generated voice produced from system/HAR software, or via human voice that is recorded on a message-by-message basis, or on a "template" basis where the system software organizes the messages as programmed.

Follow the HAR Design Process checklist shown in the table below:

Table 45.1. HAR Design Process Checklist

1.	Collect initial data required for the proposed HAR implementation (see 45.1.1)
2.	Obtain licensing and permits. This step must be addressed early in the HAR design process due to frequency requirements, site issues, and duration of the application process. If designing an additional HAR site to an existing system, the designer should crosscheck with FCC requirements to ensure compliance with all regulations. (see 45.3.2)
3.	Determine the HAR type required (see 45.1.2)
4.	Conduct a HAR site selection analysis (see 45.3.1.2)
5.	Conduct final design of the HAR location (see 45.3.1.2)
6.	Begin the process to establish electrical service for the proposed location with the local power company. This should be done early in the design process to establish an acceptable electrical service location. (see 45.5.3)
7.	Determine the construction details needed for the proposed design, details which need to be modified, and new details which need to be created to provide a complete construction plan. (see 45.5.4)
8.	Determine the special provisions needed for the proposed design, special provisions which need to be modified, and new special provisions which need to be created to provide a complete construction plan. (see 45.5.4)
9.	Determine the standard specification bid items and procurement items that will need to be included in the estimate and miscellaneous quantities to provide a complete construction plan. (see 45.5.4)

45.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. The device numbering system follows a standardized naming format. For HAR locations, the naming convention is HAR-County Number-Next sequential 4-digit number. For example, for the 4th HAR system that is installed in the state will be in Milwaukee County (40), the number for the device should be HAR-40-0004. For HAR flasher sign locations, the naming convention is TFS-County Number-Next sequential 4-digit number. The device number and related information will be stored in the ITS inventory management system.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at: http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

45.2.2 Communications Assignments

Refer to Chapter 50, ITS Communication Systems for information regarding the appropriate communication network to use for HAR. Contact the STOC to discuss communication requirements.

45.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

45.3.1 Design Process

In the HAR design process, the designer must follow several steps to ensure successful implementation and proper operational capabilities. For AM broadcast HAR portable sites, site selection is critical to the success of the installation. Sufficient time must be allowed for and adequate data must be collected to ensure an adequate design, follow the steps in Table 45.1 for the design process.

45.3.1.1 Determination of Type

The typical HAR type for Wisconsin application is the 10-watt AM HAR installation and Portable HAR.

10-Watt HAR is used for permanent installations, and portable HAR is used for temporary HAR applications, such as construction management and special events. Portable HAR has less broadcast range than 10-Watt HAR.

HAR Synchronization should be considered if there are possibilities that two or more HAR deployments will overlap in broadcast areas. This is an added feature to any HAR transmitter, and is not affected by site placement.

45.3.1.2 Site Selection

The site selection issues discussed in this section are intended to provide the Wisconsin DOT with appropriate guidelines to follow when designing and implementing HAR stations. These guidelines will provide techniques to best utilize each HAR station, as well as the entire network of stations. Cost reduction procedures will be detailed pertaining to HAR implementation.

45.3.1.3 Alternate Routes and Diversion Points

When locating new HAR transmitter sites, two primary site selection criteria are typically considered: the availability of alternate routes (ideally parallel routes to the freeway) and the presence of diversion points (easy entrance and exit points to the alternate routes). These considerations are similar to site selection considerations for VMS.

There are two different types of alternate route possibilities, limited access freeway and local streets.

- Limited Access Freeways - A primary alternate route should be a freeway parallel to the principal route. An example of this situation would be the IH-94/894/43 central loop in Milwaukee. A motorist traveling from the Zoo Interchange to the airport has two freeway options: I-894 around the west and south legs of the loop, or I-94 to downtown, then south to the airport
- Local Streets - Secondary alternate routes include US highways, state highways, county highways, or local city streets. Such routes would probably be more prevalent than alternate routes on limited access freeways

For the alternate route to be successful, the alternate route must be able to accommodate the additional capacity needed due to the HAR message recommendation, and use of the recommended alternate route should cause savings in travel time. The following guidelines should be followed to assess travel time/distance comparisons between primary and alternate routes:

- Under free-flow conditions, the travel time along the alternate route should not be more than double the free-flow travel time along the diversion section.
- The travel distance of an alternate route along limited access freeways should not be more than double the distance of the diversion section.
- The travel distance of the alternate route along a local street should not be more than 1.5 times the distance of the diversion section.

Following these guidelines increases the probability that the motorist will be willing to use the alternate route. Appropriate local agencies must be involved when the alternate route involves local streets to build consensus that the alternate route is appropriate and to ensure that appropriate traffic signal timing modifications are developed and stored for implementation when circumstances warrant.

45.3.1.4 Additional Site Criteria

More detailed, site-specific criteria are involved in the final design of an AM HAR transmitter sites. These criteria address the ground system, ground plane, and antenna location. When designing an AM HAR site, the main objectives are to minimize interference and maximize the range of the HAR station. While those same objectives exist for an FM HAR site, satisfying those objectives is much simpler due to the different transmission characteristics of FM radio.

45.3.1.5 Ground System

The ground system is the area from the HAR antenna upstream and downstream along the roadway for approximately 3 miles. Well-selected sites, with good ground system properties, are a significant part of a successful HAR site.

Two types of waves propagate radio energy: surface and space. Surface waves travel along the earth's surface, and are heavily influenced by the ground system, specifically the earth's conductivity and proper grounding. Space waves travel through the atmosphere and are primarily a function of the antenna's efficiency and height. The most significant part of a HAR ground system is soil condition, with the following guidelines offered to aid in the evaluation of soil condition for a specific site:

- Conductive soil contributes to better performance of a monopole antenna;
- Cable antennas are recommended for sites with low soil conductivity;
- Fill dirt does not make a good antenna ground plane; and
- Undisturbed soil is preferred when locating a HAR antenna site.

45.3.1.6 Ground Plane

The ground plane of a HAR station is the copper wire part of the antenna system buried beneath the antenna support. Proper design and installation of the ground plane also influences the range over which the station can be heard. HAR design taking into account the following considerations can maximize its transmitting range:

- Locate the site at least 100 feet from overhead power lines, since AM broadcast is adversely affected by AC noise.
- Locate the site at least two (2) miles from large buildings that block the AM signal.
- Locate the HAR installation on a flat site clear of trees, shrubs, poles, and small buildings for a 100-foot radius from the antenna.

45.3.1.6 Antenna Location

The primary factor contributing to the quality of an antenna location is the effect that re-radiating structures has on coverage. The best antenna site will be located farthest away from a potentially re-radiating source. Re-radiating structures reflect radio energy, which distorts the coverage pattern otherwise expected. Too-close proximity to re-radiating structures results in dead spots, or unexpected areas of non-coverage. Potentially re-radiating structures consist of steel frames, copper wiring, iron, or copper plumbing and would have minimum sizes of:

- Greater than 1/8 the wave length in height (71 meters / 233 feet at 530 kHz; 23 meters / 75.5 feet at 1610 kHz)
- Greater than 1/4 the wave length in length (142 meters / 466 feet at 530 kHz; 47 meters / 154 feet at 1610 kHz)

In addition to influencing the ground plane, tall buildings, water towers, radio towers, and smokestacks are examples of vertical structures that can cause interference. Horizontally, power lines, bridge superstructures, guardrails, and metallic fences can vary field strengths, limiting the effectiveness of HAR. If site selection alternatives are inadequate and such sources of interference are unavoidable, field strength tests should be performed at the site under a temporary HAR operating license to assess the quality of HAR transmissions before committing resources to design and permanent installation.

HAR antennas may require approval from the Federal Communications Commission (FCC) and the Federal Aviation Association (FAA). The maximum height permitted by the FCC without special permitting for HAR antennas is 15 meters (49 feet) from the tip of the antenna to the ground, whether mounted on its own structure, or on an existing building or structure. FAA clearance may be required if the antenna site is within a five (5) mile radius of an airport or other aircraft landing area. However, notification may be needed if a vertical antenna greater than 6.1 meters in height is

a) Erected on an airport or heliport

b) Erected within a distance of 100 times antenna height of the nearest point of the nearest runway of an airport with at least one runway more than 975 meters long.

c) Erected within a distance of 50 times antenna height of the nearest point of airports with all runways less than 975 meters long.

d) Erected within a distance 25 times the antenna height of a heliport landing/takeoff area.

If any of these conditions exist, the applicant must submit an FAA form 7460-1 to the applicable regional FAA office. This should be submitted simultaneously with the FCC application. A second form, FAA form 7460-2, is required when construction begins. These forms may be obtained from the Federal Aviation Administration, Washington D.C., 20591, or any of its regional offices.

45.3.1.7 HAR Design and Installation Requirements

Proper installation procedures are critical to the optimum operation of Highway Advisory Radio. Installation procedures are typically encompassed in the specifications and other contract documents. Consequently, this section discusses the installation recommendations and techniques concerning the following aspects of HAR installation:

- Transmitter Housing and Protection
- Antenna System
- Grounding Systems
- HAR Advance Signing
- Underground Infrastructure
- Adjacent Frequency Consideration
- Synchronization Systems

Inappropriate installation of these devices can affect the HAR transmission quality and range, and can also decrease the life of the equipment.

45.3.1.8 Transmitter Housing and Protection

Using a standard Model 332 or 334 cabinet for HAR transmitter enclosure best addresses environmental concerns. Preferably, a transmitter is located as close as possible to its antenna. With the Model 332 or 334 cabinet, the transmitter is secured directly to the antenna structure, providing the site with a more electrically reliable system. If situations dictate otherwise, any NEMA Type 3 enclosure may be used to provide a weatherproof enclosure of the transmitter.

The FCC mandates that no unauthorized person may have access to a radio transmitter. Vandalism is also a HAR security concern. The cabinet locks on 332/334 cabinets are likely adequate to satisfy both security concerns, but the cabinet handles also accommodate the addition of a padlock to provide additional security, if deemed necessary.

45.3.1.9 Antenna System

As discussed above, it is possible that a HAR site might use either a monopole or a cable antenna. Both antenna systems have installation requirements that are detailed below. In Wisconsin, HAR has been deployed exclusively using the monopole antenna installation.

For monopole antenna HAR (10 Watt Application):

- Antennas shall not exceed 15.0 meters (49.2 feet) in height from ground level.
- Only vertical polarization of the antennas is permitted.
- Transmitter RF output shall not exceed 10 watts.
- At a distance of 1.5 km (0.93 miles), emission field strength shall not exceed 2 mV/m.
- The antenna should be mounted to the side of the field enclosure.
- If the support structure is metallic, the antenna shall be electrically insulated from the structure.
- The antenna shall be able to withstand winds of up to 80 mph, and shall be all-weather resistant, including icing.
- The antenna shall have a grounding system as described below.

For cable antenna HAR:

- Cable antennas shall not be longer than 3.0 km (1.9 miles)
- The transmitter RF output shall not exceed 50 watts

* At a distance of 60 meters (197 feet), emission field strength shall not exceed 2 mV/m.

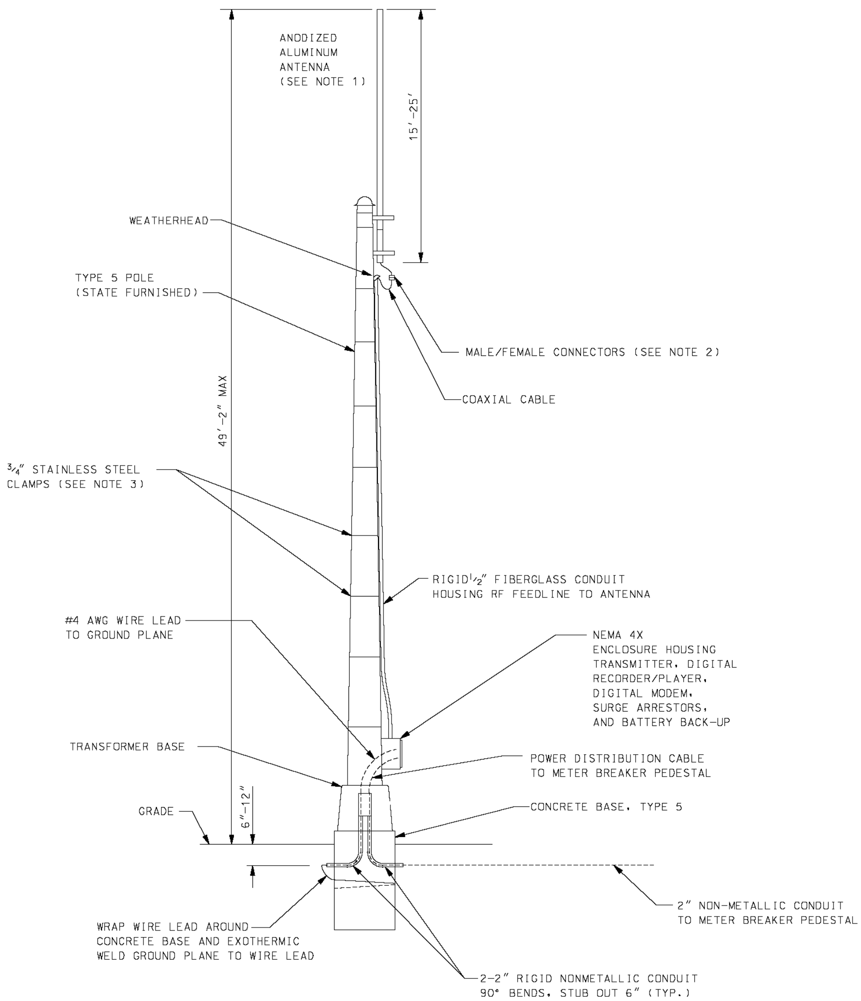


Figure 45.3-1: Typical Highway Advisory Radio Monopole Installation

45.3.1.10 Grounding Plane System

Testing should be performed to ensure that there is proper soil conductivity to afford the proper grounding plane for the antenna. A typical ground plane system may consist of twenty radials of No. 10 or 12 AWG copper wire, each approximately 30 meters (98 feet) in length. A 3/4 - inch by 4-foot copper grounding electrode should be connected to each end of the radial and driven into the ground. The entire ground plane system is typically buried 6 to 12 inches below ground level, which serves to minimizing damage and vandalism. Regardless of exact number, length, and size, ground plane radials are mostly installed in a symmetrical pattern. The radials are then connected at the antenna base where leads are grounded inside the enclosure. Because of the indeterminate nature of soil conditions, additional lengths or radials can be installed to improve signal transmission. An example of a ground plane installation is shown in Figure 45.3-2.

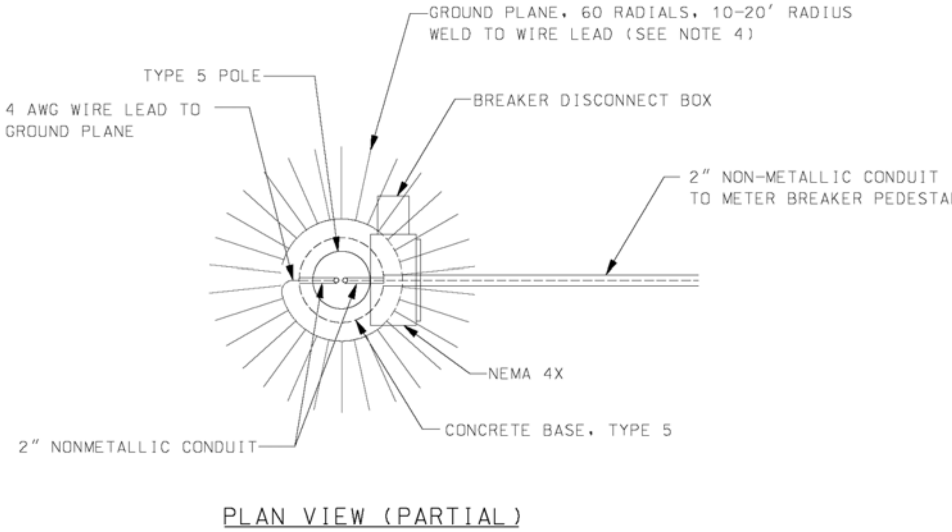


Figure 45.3-2: Typical Ground Plane Installation

45.3.1.11 HAR Advance Signing

Signs indicating both the presence of and the frequency at which the HAR is being broadcast should be installed at the beginning of each HAR broadcast area to alert motorists of its presence. Flashing beacons should be installed at each sign, actuated to flash when a special traffic message (other than default) is being broadcast. While other types of technology can be used in placed of beacons, such as blank out or other dynamic message signs, flashing beacons are reasonable for motorist expectation, and cost-efficient and easy to maintain. In designing advance signing for highway advisory radio, a signing inventory must be performed along the corridor. A minimum of 800-ft spacing must be maintained between the HAR advance sign and other standard Type I signs within the corridor. Placement of these signs must be approved by and coordinated with the Regional Signing Engineer and Regional Traffic Operations Engineer.

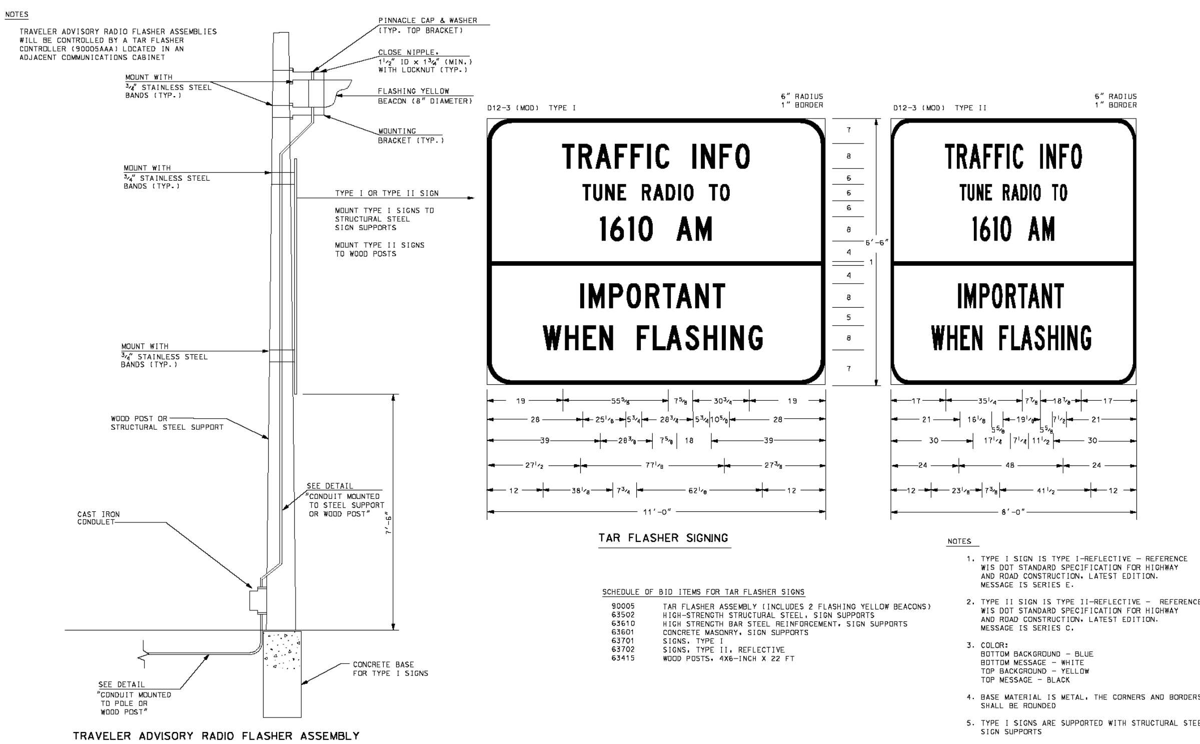


Figure 45.3-3: Typical HAR Advanced Signing

These advance notification signs should be placed at the outer edges of the transmission zone, and should conform to the appropriate freeway guide sign guidelines as described in the MUTCD. While there are not specific guidelines to the placement of these signs, it is recommended that signs be placed at the fringe of but within the broadcast zone. Such a location would allow for reasonable perception/response/reaction time for the motorist to tune to the frequency and listen to the entire message.

If necessary, another notification sign could be placed in the middle of the broadcast zone. To broaden the coverage area, HAR signing could be installed on city streets in advance of the freeway. This might involve modifying the sign design to better-fit local street right of way restrictions, if the sign is roadside mounted. Such a sign installation requires close coordination with local agencies.

Flashing beacons should be activated for all non-recurring congestion that may affect traffic along the corridor of travel. Activation of these beacons can be accomplished by radio, mainline communications cable, or leased telephone. Consequently, sighting these advance signs must take into account the availability of AC power and appropriate communications.

45.3.1.12 Underground Infrastructure

When the transmitter cabinet, pole, ground plane, and advanced signing assemblies have been placed, the underground conduit infrastructure can be designed. Issues to keep in mind when designing the HAR conduit infrastructure include:

- Conduit Size - 4-Inch conduit is typically used for raceways. Conduit entering electrical service pedestals must be sized per pedestal requirements.
- Conduit Fill - The size and number of conduits along a run is dependent on percentage of fill as established by the National Electric Code (NEC).
- Pull Box Spacing - Pull boxes should be spaced no greater than 200 feet. If a conduit run contains only one or two lightweight cables, this distance can be stretched to approximately 300 feet.
- Terrain - Conduit infrastructure should be designed on relatively flat (4:1 slope or flatter) terrain. For steeper sloped terrain (3:1 or greater), conduit may be run perpendicular to (i.e., up or down) the slope to locations where the terrain is more suitable for conduit installation.

45.3.1.13 Adjacent Frequency Considerations

When establishing a 10-watt HAR, WisDOT must follow several limitations concerning interference with adjacent radio frequency issues. Interference is primarily signal disturbance caused by other transmitters on an adjacent radio frequency. One signal, being broadcast on too close a frequency to another signal, will take on the characteristics of the second signal.

- HAR broadcasts cannot interfere with adjacent AM broadcast stations.
- New HAR sites cannot interfere with existing HAR sites.

AM HAR stations can broadcast at any frequency within the 530-1710 kHz band. To decrease the likelihood of interference, a number of restrictions are included in the FCC rules. The most significant restriction is that the HAR signal source must be located at least 15 km outside the measured 0.5 mV/m daytime contour of any AM broadcast station operating on a first adjacent channel. (540 kHz for a 530 kHz station, 1600 or 1620 kHz for a 1610 kHz station.) These contours are field measured and typically are completed by HAR vendors.

A second restriction is that the HAR must be located far enough away from any AM station operating either on the second or third adjacent to avoid interference in AM receivers tuned to the AM broadcast station frequency. Some guidance can be obtained from the FCC for separation requirements as given in section 73.37 (a) of the FCC rules. The following criteria are set forth as the basis for separation between a new and an existing AM station:

For stations separated by 20 kHz:

- The 2-mV/m contours of a new station may not overlap the 25-mV/m contours of an existing station.
- The 25-mV/m contour of a new station may not overlap the 2-mV/m contours of an existing station.

For stations separated by 30 kHz:

- The 25-mV/m contour of a new station may not overlap the 25-mV/m contours of an existing station.

Due to the low power of HAR stations, the 25 mV/m contour will be relatively small and close to the antenna site. The above criteria will generally be met if the antenna site is located outside the 2-mV/m contour of a conflicting second adjacent channel and outside the 25-mV/m contour of a conflicting third adjacent channel. If there are no second or third adjacent channels within approximately 160 km (257 miles), no further proof of non-interference is required.

45.3.1.14 Synchronization Systems

If there is two or more HAR within a close proximity, a synchronization system should be utilized to minimize the interference between the broadcast stations. Even though the criteria for broadcast range is between 3-5 miles, this can vary greatly with terrain and interference.

45.3.2 Licensing and Permits

Obtaining appropriate licensing for HAR operations occurs under the jurisdiction of the Federal Communications Commission (FCC). Various issues must be considered in the licensing procedure:

- FCC licensing options
- License Application Procedure
- Other Permits and Requirements
- License Upkeep and Renewal Procedures

45.3.2.1 FCC Licensing Options

Three different types of licenses can be issued by the FCC for HAR operations:

- Permanent licenses (10-watt HAR and Enhanced HAR)
- Temporary licenses
- Experimental licenses

Permanent licenses are the most common HAR license type, presuming adequate satisfaction of all FCC rules and regulations. If the HAR supplier files the application, then the agency usually needs to complete a questionnaire provided by the supplier. The supplier will then fill out the FCC application based on the questionnaire. Obtaining the license through a supplier is the most common procedure in today’s market, given their expertise and familiarity with the application process.

If the agency plans on completing the application, it is necessary to gather all of the information to meet the requirements covered under section 90.242 of the FCC rules. In addition, an FCC form 574, Application for Private Land Mobile and General Mobil Radio Services, needs to be completed.

A permanent HAR (or TIS, as called by the FCC) license is issued for 5 years. A station must be placed in operation within eight months from the date of the license grant. If that does not occur, the license becomes invalid and must be returned to the FCC for cancellation.

Further, within 60 days after station authorization or station construction, whichever occurs latest, the licensee must submit to the FCC a map showing a 2 mV/m contour based on actual “on-the-air” measurements. A sufficient number of points must be selected to determine the distance at which the attenuated field of 2 mV/m exists, as measured with a calibrated standard field strength meter. This may be done in 5 to 8 radial directions to create a plot of the 2-mV/m coverage contours on the map. If the measured field exceeds 2 mV/m at a distance of 1.5 km, the transmitter output power must be decreased accordingly. For stations employing cable antennas, the measured field strength of 2 mV/m must not be exceeded at a distance of 60 meters from any portion of the antenna.

For a station to remain in operation, the station must be operated on a reasonably continuous basis. Any station that has not been operated for one year or more is considered to have been permanently discontinued. This requires that the license be returned to the FCC for cancellation. A licensee planning to continue operations beyond the expiration date may request a license renewal. Renewals are regularly granted, provided the licensee has no outstanding citations for rule violations. A renewal application must be submitted up to 30 days after the license expires, and operation may continue on an interim basis during this period. It is recommended that the renewal be submitted 30 days prior to the expiration date of the license. If the renewal form is not postmarked within 30 days after the expiration date, the license is invalid and further operation is illegal. Any further authorization would require an original station application.

Temporary licenses, or Special Temporary Authority (STA) are granted for up to 1 year, and are not typically renewable. STA’s are usually granted under short terms of unusual circumstance. A STA can be obtained for HAR operation while the permanent license is being processed, or to provide for testing of a site to assess its operational characteristics. An STA can be requested in the form of a letter providing essential information as listed in section 90.145 of the FCC rules.

Experimental licenses are not granted for standard HAR operations. Typically, experimental licenses are granted for:

- Conducting scientific and technical radio research,

- Equipment demonstration by manufacturers, and
- Testing of equipment.

Eligibility for this type of license is based on the qualifications of the applicant to conduct the proposed experiments or test. Experimental licenses are issued for a 2-year period, and renewals can be granted if necessary. While it is not likely that WisDOT would use experimental licenses, such licenses may be used if WisDOT chooses to evaluate new HAR technologies on-site. Given that circumstance, the owner or demonstrator of the new HAR technology would likely be responsible for licensing.

45.4 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

45.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at

http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

45.5.2 Communication Requirements

Cellular or conventional dial-up communications are typically required to the HAR site for purposes of transmitting messages to the HAR. Either dial-up or direct communications is required to the advance warning beacons. Chapter 50, Communication Systems provides additional information on communication types and requirements.

45.5.3 Power Requirements

A 100 Amp, 120/240 volt, single phase, three-wire underground electrical service is required for HAR electrical service installation. The electrical service will be furnished and installed by the local power company up to a demarcation point, which consists of an electrical service. The electrical service must conform to the requirements of the local power company. The location of the electrical service must receive approval from the utility company. The electrical service will include two 50-amp circuit breakers rated at 22,000 AIC. The requirements for power cable between the electrical service and controller cabinet can be found under the Cable Routing section of this chapter.

At locations which require a remotely located electrical service, a 100 Amp outside rated breaker box with space for 6 circuits, but no main breaker, will be attached to the side of the cabinet. Also, a 50 Amp single circuit breaker rated at 22,000 AIC will be installed within the breaker box to serve as a local electrical service disconnect point.

The power distribution wires running between the electrical service and the controller cabinet consist of stranded copper single conductors, cross-linked polyethylene (XLP), USE rated. Section 655 of the standard specifications provides guidance on additional requirements. The bid items for "Electrical Wire Lighting (gauge #) AWG will meet the requirements. The gauge of conductors must be calculated per the requirements of the National Electric Code.

45.5.4 HAR Construction Standards

Construction details, Standard Detail Drawings, and Special Provisions can be found in Appendix 70.

45.6.1 Testing

Reference Standard Specifications 675.3(14) through 675.3(20) for testing procedures. In 675.3(15), traffic flow information includes volume and speed data.

45.6.1.1 Field System Integrator

Refer to Standard Specification 670.3.2.1 for field system integrator duties.

Contractor-furnished equipment and materials, refer to Standard Specification 670.3.3.1.

Department-furnished equipment and materials, refer to Standard Specification 670.3.3.2

45.6.2 Acceptance

Notify the State Traffic Operations Center after testing is complete. The State Traffic Operations Center Maintenance Representative will do the final concurrence of acceptance before the State Traffic Operations Center accepts ownership and maintenance of the traveler information systems.

45.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

45.7.2 Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as "GPS data points". The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
  - Latitude (Y-coordinate) in decimal degrees
  - Longitude (X-coordinate) in decimal degrees
  - Altitude (Z-coordinate) in feet
  - Date (day, month, year) of point collection
  - Time (24 hour format) of point collection
  - Initials of field personnel collecting data points
  - Abbreviation for Element Type (see table of elements below)
  - Location description (for example, street and cross street)
  - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 95% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

45.7.3 Deployment Inventory

An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60 ITS Software.

45.8.1 Maintenance

WisDOT will only continue to maintain permanent HAR and will not install new permanent systems on the state system. On the other hand, portable HAR will continue to be used for construction projects and special events.

45.8.2 Reevaluation

In addition to periodic equipment updates, traveler information devices should be periodically evaluated for their effectiveness at their current locations.

50.1.1 Introduction

The guidance in Chapter 50 is intended for the placement of ***new*** communication systems as part of new construction projects only. The STOC must be contacted if retrofitting a communication system to existing systems or in any other circumstances where the addition of a communication system is being considered.

An intelligent transportation system is comprised of many different elements — field components such as variable message signs, detector stations, ramp meters, and CCTV cameras; central equipment such as computers, workstations and monitors; and the human element (i.e., system operators and maintenance personnel). For the system to function properly, it will be necessary for each of these components to exchange information with other system elements. It is the communications network that provides the connecting link for this information. This section discusses the options and recommendations for the design of a communications network.

The communications network is an integral part of any ITS design in that it will affect (and be affected by) system architecture, configuration, and the operational strategies. Moreover, if thought of as a single expense, the communications network will likely be the costliest item in the vast majority of ITS related systems.

The most important consideration in designing a large communications network is that it must provide reliable service for 10 – 20 years or more to ensure economic viability. At this period in the communications industry and continuing into the foreseeable future, the extent of technological change and market restructuring presents both difficulties and opportunities. The difficulties are in the real possibility of equipment obsolescence. As with computers, the communications industry is going through a rapid evolution of available equipment. The opportunities may involve partnering with the many new communications companies that the deregulated environment is producing.

Although the design of the communication elements within individual projects may not involve system assessments and large scale concepts as indicated above, it is important that individual designers be aware of potential changes in communications network equipment and structure brought about by either of the above difficulties and/or opportunities.

The Department’s freeway modernization programs offer excellent opportunities for installing the conduits required for the ITS communications networks and for the control cables. Performing this work during freeway rehabilitation work will result in reduced installation costs, as well as minimize disruption to traffic flow. Moreover, given its long life expectancy, conduit can be installed several years before it is actually needed. Assuming that the conduit network is designed and constructed properly, any rehabilitation effort during system implementation will be minimal - at the very worst, the existing conduits may require cleaning.

50.1.2 Needs Assessment

Communication system design is typically a highly complex process. The telecommunications industry is technologically dynamic, with new technologies and enhancement of existing technologies constantly evolving. This chapter sets forth some basic information on communication systems in general. Emphasis is placed on communication conduit infrastructure and wireless spread spectrum design issues. Most applications involving the design of wire line or wireless communication systems will require additional information that is not currently found in this manual. However, for the design of basic communication infrastructure, such as conduit systems or spread spectrum infrastructure, this chapter provides the designer with fundamental guidelines to use in the design of these systems.

Prior to final design of communication system elements, a strategic communication plan must be developed for the region, indicating uses, communication types, configuration, topology, equipment, and other issues beyond the scope of this document. This strategic plan will provide the blueprint for how the overall system communicates, and will provide direction to the designer when implementing various types of communication infrastructure.

Aside from the basic physical components of a communication system (such as cable, modems, etc.), “how” an intelligent transportation system communicates between various components revolves around issues such as element protocols and formats. Older systems may have strict communications protocol guidelines (as defined by existing system software) that must be followed. Newer systems require communication design following “NTCIP” standards. NTCIP stands for the National Transportation Communications for ITS Protocol. It establishes an array of standards that provides:

- Rules for communicating (called protocols), and
- Vocabulary (called objects) necessary to allow electronic traffic control equipment from different manufacturers to operate with each other as a system.

The NTCIP is the first set of standards for the transportation industry that allows traffic control systems to be built using a "mix and match" approach with equipment from different manufacturers. Therefore, NTCIP standards reduce the need for reliance on specific equipment vendors and customized one-of-a-kind software. Bringing together representatives from equipment manufacturers and system users, NTCIP is a joint product of the National Electronics Manufacturers Association (NEMA), the American Association of State Highway and Transportation Officials (AASHTO), and the Institute of Transportation Engineers (ITE).

50.1.3 Communication Types

Communication network equipment for intelligent transportation systems can be divided into two different categories: analog and digital. Analog technology conveys data as electronic signals of varying frequency or amplitude that are added to carrier waves of a given frequency. Broadcast and phone transmission has conventionally used analog technology. Digital describes electronic technology that generates, stores, and processes data in terms of two states: positive and non-positive. Positive is expressed or represented by the number 1 and non-positive by the number 0. Thus, data transmitted or stored with digital technology is expressed as a string of 0's and 1's. Each of these state digits is referred to as a binary digit, or “bit” in short. A string of bits that a computer can address individually as a group is a byte.

Within each of these categories are

- **Voice** – typically radio communications, but can include PBX telephone type systems between centers,
- **Data** - elements from system detector stations, ramp meters, dynamic trailblazer assemblies, and variable message signs, which do not require large bandwidth (i.e., small packages of data).
- **Video -** elements such as closed-circuit television cameras or local agency video which require transmission of full-motion video (large bandwidth/transmission requirements) for incident verification and traffic surveillance.

In terms of carrier technologies for communications, there are numerous options available to use. This ranges from regular telephone service, one of the most basic forms of communication, to optical carrier (OCx) levels up to OC-48 There are numerous types of carrier technologies. This ranges from regular telephone service, one of the most basic forms of communication, to optical carrier (OCx) levels up to OC- 48. A sampling of various communication types, data rates, and media are discussed in this section and summarized in Figure 50.1-1. In discussions of “carrier systems”, the following definitions are presented:

- **T-Carrier** - The T-carrier system, introduced by the Bell System in the U.S. in the 1960s, was the first successful system that supported digitized voice transmission. The original transmission rate (1.544 Mbps) in the T-1 line is in common use today in Internet service provider connections to the Internet. Internet service providers also commonly use another level, the T-3 line, providing 44.736 Mbps. Another commonly installed service is a fractional T-1, which is the rental of some portion of the 24 channels in a T-1 line, with the other channels going unused. The T-carrier system is entirely digital, using pulse code modulation and Time-Division Multiplexing. The system uses four wires and provides duplex capability (two wires for receiving and two for sending at the same time). The T-1 digital stream consists of 24 64-Kbps channel that are multiplexing. (The standardized 64 Kbps channel is based on the bandwidth required for a voice conversation.) The four wires were originally a pair of twisted pair copper wires, but can now also include coaxial cable, optical fiber, digital microwave, and other media. A number of variations on the number and use of channels are possible.
- **Synchronous Optical Network** - SONET is the U.S. (American National Standards Institute) standard for synchronous data transmission on optical media. The international equivalent of SONET is synchronous digital hierarchy (SDH). Together, they ensure standards so that digital networks can interconnect internationally and that existing conventional transmission systems can take advantage of optical media through tributary attachments. SONET provides standards for a number of line rates up to the maximum line rate of 9.953 gigabits per second (Gbps). Actual line rates approaching 20 gigabits per second are possible. SONET is considered to be the foundation for the physical layer of the broadband ISDN (Broadband Integrated Services Digital Network). SONET defines a base rate of 51.84 Mbps and a set of multiples of the base rate known as "Optical Carrier levels (OCx)." Asynchronous transfer mode (ATM) runs as a layer on top of SONET as well as on top of other technologies.
- **Optical Carrier Levels (OCx) -** SONET includes a set of signal rate multiples for transmitting digital signals on optical fiber. The base rate (OC-1) is 51.84 Mbps. OC-2 runs at twice the base rate, OC-3 at three times the base rate, and so forth. Planned rates include OC-1, OC-3 (155.52 Mbps), OC-12

(622.08 Mpbs), and OC-48 (2.488 Gbps). Asynchronous transfer mode (ATM) makes use of some of the Optical Carrier levels.

- **Asynchronous Transfer Mode (ATM)** - ATM is a dedicated-connection switching technology that organizes digital data into 53-byte cell units and transmits them over a physical medium using digital signal technology. Individually, a cell is processed asynchronously relative to other related cells and is queued before being multiplexed over the transmission path. Because ATM is designed for easy implementation by hardware (rather than software), faster processing and switch speeds are possible. The pre-specified bit rates are either 155.520 Mbps or 622.080 Mbps. Speeds on ATM networks can reach 10 Gbps. Along with (SONET) and several other technologies, ATM is a key component of broadband ISDN. A sampling of various communication types, data rates, and media are shown in Table 50.1-1.

Carrier Technology	Data Rate	Primary Medium
Voice-grade telephone	56 kbps	twisted pair
T-1	1.544 Mbps	twisted pair or fiber optic
T-3	44.736 Mbps	twisted pair or fiber optic
OC-1	51.84 Mbps	fiber optic
OC-3	155.52 Mbps	fiber optic
OC-12	622.08 Mbps	fiber optic
OC-48	2.488 Gbps	fiber optic

Table 50.1-1 - Communication Data Rates

Various communication system mediums (types) are associated with ITS deployment, and include the following:

- **Fiber optic communication - Fulfills communication requirements for either data or video** devices
- **Twisted-pair communication cable** - Typically reserved for communication with data devices only
- **Spread-spectrum radio** - Most applications of spread-spectrum radio are reserved for data devices, however higher bandwidth technologies of spread-spectrum radio may apply to video devices
- **Leased communications** - Depending on the type of leased communication chosen, either data or video device communications may apply. Typically, leased video communication alternatives are substantially higher in cost than those available for data devices.

The overall communications network architecture has a major impact on the design of communications network. Network architecture falls into two main categories: centralized and distributed.

- **Centralized Communications** – All processing is performed at the control center. Communications in this manner are handled directly from trunk lines, and connected directly to each surveillance and control element in the field. This concept allows the greatest control over the system, and permits all communications trouble-shooting and maintenance to be handled at one physical location. Its primary disadvantage is that direct connections between the control center and the ever-expanding amount of field equipment require an extremely complex and expensive communication network. Moreover, the system is slightly more susceptible to wide-area disruptions.
- **Distributed Communications** – This network uses a concept identical to that of the central system, in that most information and control is processed at a single point (i.e., control center). The major difference is that the communications network is distributed to several key locations (i.e., "hubs") throughout the network. A local distribution network is used for each section of a freeway, and all of the communications for that area are concentrated at the "hub" within the area. At the communications hub, the data are concentrated (i.e., multiplexed) for transmission to the control center over long-haul, high-speed, large bandwidth trunks. Similarly, trunk communications from the control center are split into multiple low-speed channels at the hubs, and then transmitted over the local distribution network to the field devices. (NOTE - Depending on the distance involved and the data concentrations, a distributed network may include multiple tiers of hubs. For example, at the first level, the data may be concentrated into T-1 or T-3/OC-3 channels and transmitted to a second level node. At this hub, the T-1/T-3/OC-3 channels from several first nodes may be concentrated into higher bandwidth channels (e.g., OC-24 or OC-48); and so on until the data reach the control center.)

The distance requirements of the system area, coupled with cost and reliability considerations, dictate the distributed configuration with one or two tiers of hubs; although higher-level tiers may also be required if the video transmissions are digitized using CODEC hardware

The distributed configuration will require the placement of communication hubs at locations in the field to gather/distribute field data. These hubs divide the network topology into two basic divisions:

- **Trunk circuits** (i.e., "backbone network") for hub-to-hub and hub-to-control center communications. The data transmissions are high-speed conforming to T-carrier or SONET standards. Analog video communications (if used) will be multiplexed at the hub, providing multiple video images on a single trunk channel. If digital video communications are used, they too will be multiplexed at the hub and combined with the digital data, thereby requiring a larger bandwidth trunk and multiple tiers of hubs.
- **Distribution circuits** are used for the exchange of digital data messages between the hubs and field elements. These are typically low-speed channels (i.e., 1200-9600 baud). The hardware devices are usually aggregated on multidrop lines in a polled network, both to take advantage of the connectivity economics and to have the system in control of the timing.

Several segments will consist of WisDOT-owned fiber optic and twisted-pair cables -- the fiber optic cable being used for video transmissions and for high-speed data trunks between communication "hubs" and the control center; and the twisted-pair cable being used for low-speed data transmissions between the hubs and the various field components, although fiber or alternate communications methods (wireless) may also be used for this function. The communications cables are all installed in conduit. Additionally, conduit will be necessary for control cables between field components and their respective field devices (e.g., between ramp signals and the ramp meter controller), and for 120 VAC power feeds. This design manual primarily addresses the configuration of the network's main trunk line.

50.1.4 Inter-Agency Considerations

The STOC should be involved in the decision-making process for acquiring inter-agency communication networks.

50.2.1 Naming Convention

The STOC is responsible for maintaining all new equipment on the state system. Early in the design process, contact the STOC for a number for the device. However, communications equipment is often considered a component of the type of equipment and may not be named as a separate type of equipment on the state system. Check with the BHO-STOC for information on if a naming convention is required for the type of communications equipment being integrated into the system.

If the device requires a TELCO (landline phone line), a street address must be established during this process.

Standard ITS CAD cells have been developed and should be used in all plans. For more information, refer to FDM 15-5, Plan Preparation Methods. ITS and fiber optic CAD cell libraries can be downloaded at:

http://www.dot.wisconsin.gov/business/engrserv/roadway-design-files.htm.

50.2.2 Communications Assignments

This chapter, Ch 50 – ITS Communication Systems, discusses the appropriate communication network to use for communications equipment. Contact the STOC to discuss communication requirements.

50.2.3 System Integration

Contact the STOC for assistance in system integration of all ITS devices. WisDOT staff will provide assistance and expertise to the contractor in the areas of equipment installation, operations, integration with existing equipment, testing, and network management. This will ensure that all equipment installed operates as the plans show.

Communications systems may require inter-agency connections and agreements. Contact BHO-STOC for additional information.

50.3.1 ITS Equipment Communications Requirements

50.3.1.1 ITS Equipment Communications Channels

In telecommunications in general, a channel is a separate path through which signals can flow. The existing communication system assigns a *channel* and *drop* to each individual field device. Each channel is capable of carrying 16 drops (device). As a general rule, 12 drops are initially assigned per channel, allowing for increased system reliability and future expansion. While multiple data devices can be placed on a single channel, **variable message signs (freeway or arterial) must be placed on a channel separate from other data devices such as ramp meters, detector stations, etc.** For additional information on data channel and drop assignments, consult the Statewide Traffic Operations Center.

For fiber optic communications, fiber allocation is critical when designing a system. For each individual fiber, the fiber optic system operates as follows for both of these types of devices:

- **Data Devices** - 2-way data communication, with 2 fibers per data channel allocated across the system. Each channel carries up to 12 drops, with each drop consisting of 1 data device (ramp meter, detector station, etc.)
- **Video Devices** - 1-way video communication with 2-way data control communication. Each camera (or video sharing) site requires only 1 fiber for video and data communication.

50.3.1.2 Detection and Ramp Meter Controls

Typically, both the detector stations and ramp meters use the same processing/controller hardware and controlling software. These are the most numerous field devices in the current system being located at on-ramps and at nominal 1/2-mile intervals along the freeway — approximately 3 or 4 per mile in the “high-density” segments. These types of equipment currently require 1200-baud data circuits in a multi-dropped configuration, with up to 12 controllers on one channel. Communication between hubs and field processors are regularly polled therefore require full time availability.

In addition to the vehicle detectors for measuring volume, occupancy, and speed, additional detectors have been and will continue to be installed along the freeway for vehicle classification (i.e., number of axles) and pavement condition (e.g., dry, wet, ice, etc.). Each type of detector communicates over separate low-speed channels to the hub or control center on a regular polled basis. Accordingly, these channels will require full-time availability.

50.3.1.3 Dynamic Message Signs

Dynamic Message Signs (DMS) use field controllers furnished by sign vendors and implement the communications protocol that is compatible with the central system DMS protocol and format. DMS communications typically use the same type of data channels as detectors and ramp meters, but on channels separate from the vehicle detectors and ramp meters. There is a requirement for 100 percent availability for “instantaneous” message display when required and verification purposes, though there is actually less than 25 percent actual use.

50.3.1.4 CCTV Cameras / Video

The primary purpose of video surveillance is incident verification, requiring only short duration visual information. However, during the verification process, the video must have resolution and sharpness near broadcast quality video. The video network, MONITOR, has cameras throughout the state that are available 100 percent of the time for incident verification and other surveillance functions, though the time that most of the cameras will be used for that purpose will be relatively small. The exception to this general rule might be construction areas where the detectors are disabled, and it becomes necessary for the system operators to constantly monitor the freeway (via CCTV) for congestion management and incident detection.

The MONITOR system has been whether the video signals will be full-motion analog or digital using CODEC hardware. This has involved a trade-off between video quality, communication costs (both capital and recurring), and the capabilities of future compression technologies. For the initial implementation stages, the video communications has been analog; communications media and methods have been followed which allows such a mode of transmission. Initially, video communications was provided through leased analog video services. However, as digital services became available and capable of producing significant revenue for the provider, the pricing structure for the leased analog video created a situation that a State-owned fiber optic communications system became cost effective. CODEC hardware and compression techniques continue to become more standardized, equipment costs are decreasing, and quality of the digitized video will equal and likely surpass current "broadcast" quality in the future. As such, ITS video transmissions will ultimately be digital. Since the State-owned fiber optic network is capable of both analog and digital configurations, the future transition from current analog video to digital will be straightforward — replacing analog communications hardware with the improved digital equipment (e.g., CODECs, multiplexers) with minimal configuration of the fiber optic cabling and conduit network itself.

50.3.2 State Owned ITS Communications Design Standards & Guidelines

State-owned communication design standards and guidelines can be broken down into the categories of conduit design, wired communication design, and wireless communication design.

50.3.2.1 Conduit Design Standards

State-owned communication conduit design standards can be broken down into the following categories:

- General installation considerations
- Trenched communication conduit guidelines
- Directional bore guidelines, and
- Structure mount conduit guidelines

Guidelines for each category are presented in the following sections.

50.3.2.1.1 General Design Considerations

When designing communication conduit systems, the following general issues should be considered:

- As a general rule, multicell conduits should be **installed on a single side of the freeway.** The conduit path is to provide a continuous system. The various components of ITS deployments will likely be located on both sides of the freeway, and therefore lateral conduits (described below) will be necessary to access equipment locations. The designer should avoid conduit design which switches back and forth on either side of the freeway whenever possible. This is not always possible due to obstacles or constructability concerns, however minimizing the amount of cross-over will make it easier for future maintenance, locating, and system record-keeping.
- **More than one conduit per run is desirable**, particularly if the Department wishes to lease conduit space to other public agencies or private concerns. Under such an arrangement, one conduit would be used by the system, the other conduit would be leased. The majority of installation expense (especially with trenched conduit) is in digging and back filling the trench, not just in the material cost.
- For multi-cell conduit design, all inner ducts should **include a pre-lubricated woven pull tape**.

50.3.2.1.2 Trenched Conduit Design Guidelines

When designing trenched communication conduit, the following general issues should be considered. Illustrations of both trenched multicell conduit and plowed and trenched HDPE conduit are provided in Figure 50.3-1 and Figure 50.3-2.

- Communication conduit consists of two different types: multi-cell conduit or high-density polyethylene (HDPE) conduit. **Multi-cell conduit** consists of 3 or 4 *innerducts* (1¼ inch diameter each) within a 4 ½ -inch conduit, whereas HDPE conduit comes in varying sizes. Multi-cell conduit is installed via "in-trench" installation, where a trench is opened, the conduit is assembled, placed in the trench, and back-filled. With **HDPE conduit**, reels are placed on a plowing machine, where the trench, placement, and back-fill are performed in one operation rather than three. For this reason, in addition to material costs, the cost to install four 1¼-inch HDPE conduits is approximately half the cost to install 1 multi-cell conduit.
- **HDPE conduit must be UL listed**.
- **HDPE conduit must be installed in one continuous run** between access points.
- Freeway conduits should be generally **a minimum of 36 inches below finished grade**.
- Installation of **conduits in grass freeway medians should be avoided**. This limits the potential for communication system disruption under future additions of acceleration, deceleration, or auxiliary lanes.
- The **most desirable location of communication conduit is near the right-of-way edge** (typically a right-of-way fence), as far from the traveled way as possible.
- Conduit designed in sloped terrain with a 4:1 or steeper slope should be designed to run longitudinally to (i.e., up/down) the slope, not along the slope.
- **Underground warning tape** should be laid above all underground conduits, 12 inches below grade.

- A **copper wire (10 or 12-awg typ.) should be installed** in one of the conduits between access points. This locate wire is to be electrically connected between conduit runs to allow for continuous locate signal transmission throughout the conduit network.
- Communication conduit may be installed in the same trench as other conduit systems, such as freeway lighting. However, the freeway conduit should never enter the street light foundations, hand holes, or pullboxes. Similarly, the street light conduit should never interfere with the communication conduit. In essence, the conduit network for street lighting and the conduit network for the freeway system should be totally separate and independent of one another, even though they are collocated in the same trench.

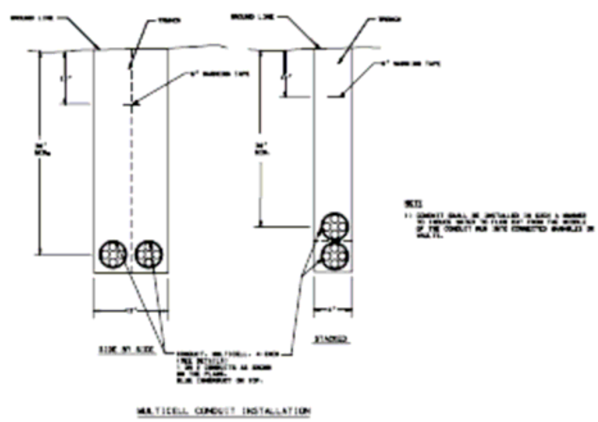


Figure 50.3-1 Typical Multi-cell Conduit Installation

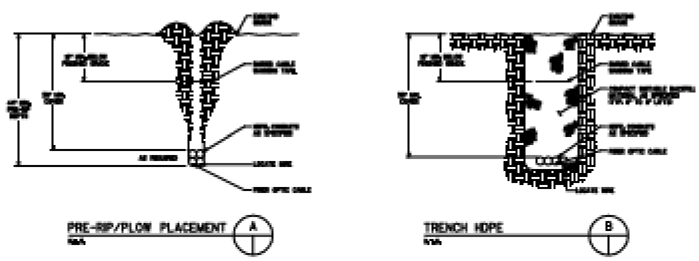


Figure 50.3-2 Typical HDPE Conduit Installation

50.3.2.1.3 Directional Bore Conduit Design Guidelines

When designing communication conduit under paved surfaces, the following general issues should be considered:

- **Lateral conduits** should be **installed at all interchanges, as well as all existing and potential future equipment locations.** For estimating future locations, a nominal 0.5-mile interval, depending on the spacing of interchanges, is typically adequate.
- Directional bore locations **require adequate room for conduit assembly and layout for "pull-back" operation.** This distance must allow for assembly of the entire length of conduit for the directional bore installation. During directional boring operations, multi-cell conduit is assembled, and a cable/wire rope is installed in one of the cells and is attached to a pullback assembly plate at the far end of the conduit run. This is done to prevent conduit separation during the pullback operation.
- Directional bore **installations under railroad tracks** require a minimum depth of 5- feet or as required by the railroad company. In addition, railroads typically require use of metallic conduit underneath railroad tracks.

50.3.2.1.4 Structure-Mount Conduit Design Guidelines

Guidelines for designing and installing the conduit network are summarized below:

- If a bridge (or other elevated section) is to be included as part of the reconstruction project, **four to eight 1-¼ inch conduits matching the inner duct should be incorporated within the barrier wall and parapets**. (See Figure 50.3-3) If this is not feasible, or if a multiple conduit network is being installed, 4½-inch fiberglass multi-cell conduits should be attached to the structure of the overpass (i.e., surface mounted) in accordance with WisDOT Standards.

- **Expansion fittings** should be installed wherever surface mounted 4 ½ inch conduit crosses an expansion joint in the freeway structure to provide a sliding joint, in addition to matching the expansion requirements of the conduit.
- All **structure-mounted multi cell conduit should be constructed of fiberglass**. All other conduit should be PVC constructed.
- **For each bridge or structure** requiring exterior-mounted conduit, **a separate construction detail must be provided**. (An example is provided in Figure 50.3-4) The designer should avoid providing "typical" construction details for a wide variety of bridge types, since mounting methods and installation requirements will vary greatly.
- Junction boxes should be installed opposite manholes on concrete parapet walls in which fiber optic conduit is being installed. A 4-inch sleeve should be provided connecting the fiber optic cabinet to the pull box.
- Two junction boxes should be installed, one on either end of the bridge, allowing access to the conduits on either side of the bridge.
- Each junction box should be equipped with a cable rung assembly allowing 20-30 ft. of fiber optic cable to be looped around inside the box.
- Junction boxes should conform to NEMA 4 or 4X, with a nominal dimension of 36 inches wide by 30 inches high by 12 inches deep.

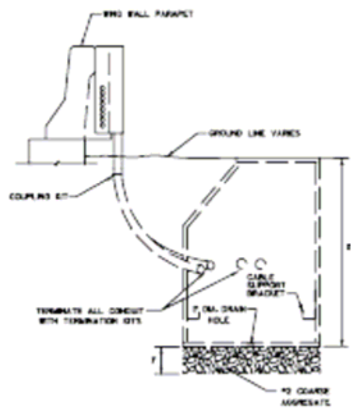


Figure 50.3-3: Conduit Transition From Trenched to Interior Parapet Conduit Systems

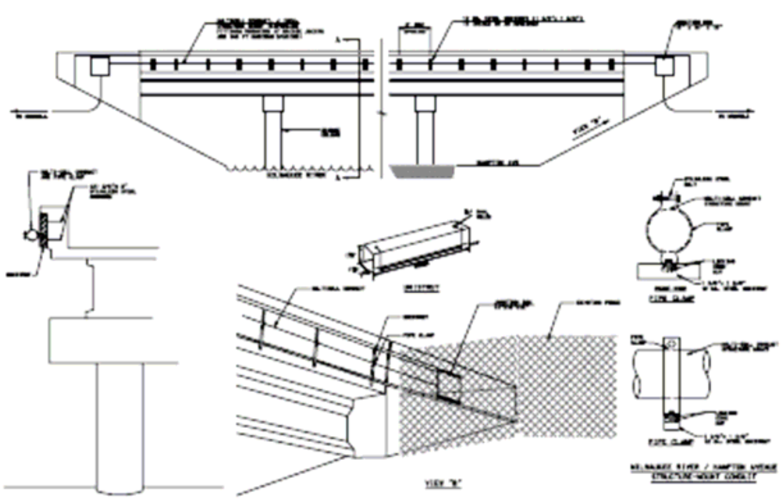


Figure 50.3-4: Bridge-specific Structure Mount Conduit Detail Example

50.3.2.1.5 Communication Manhole Design Standards

Guidelines for designing and installing the communication manholes are summarized below. A typical manhole installation detail is provided in Figure 50.3-5.

- Fiber optic manholes should be spaced at recommended intervals of 2500 feet, with the maximum allowable interval being 3500 feet allowing access to the multi-cell conduit at regular intervals.
- Fiber optic manholes should be installed at all locations wherever the conduit bends (as measured cumulatively from the last manhole) exceeds 360 degrees (180 degrees preferred).
- Manhole installation is not required whenever there is a change in the conduit installation method (e.g., from "in-trench" to "on-structure").
- Fiber optic manholes should not be installed along on-ramps, rather there should be a minimum of one manhole at each interchange where the distribution communication cabling transitions from multi-cell conduit to normal PVC conduit.
- The minimum dimensions of the manholes should be 36 inches (diameter) x 60 inches (depth). Manholes deeper than 60 inches may be considered "confined spaces" thereby adding complexly to persons entering the manholes.
- Manholes should be equipped with heavy-duty covers as they will be subject to occasional passage of heavy vehicles and cable rungs to allow excess cable to be coiled and raised off the ground.
- Final installed elevation for manhole, including cover, should be noted on plan when placed in the areas where roadwork (ramp widening, etc.) will be performed simultaneous with manhole installations.
- Two "knock-outs" should be provided on each sidewall of the manhole where the conduit does not enter.
- Manholes should be located to avoid drainage swells. Manholes located on slopes should be designed to not expose the side of the manhole that might be a hazard to traffic.
- Wherever applicable, the multicell conduit will be beneath the lighting conduit. Therefore, the manholes will have to be offset from the long axis of the conduit run. It is recommended that this offset be 24 inches.

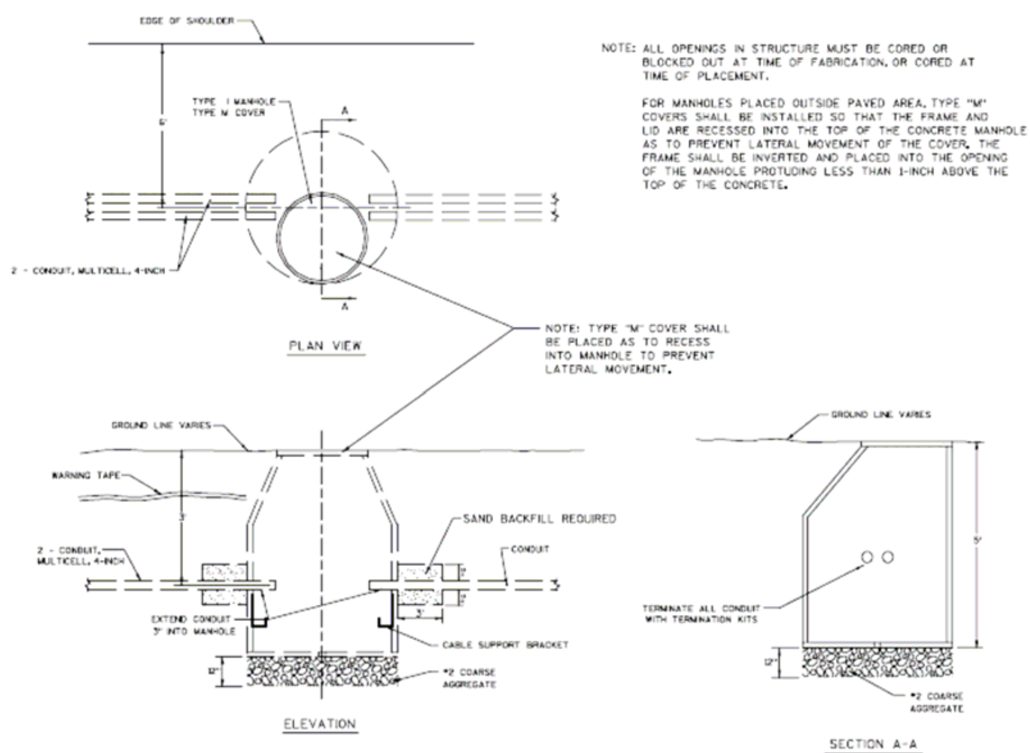


Figure 50.3-5: Typical Communication Manhole Installation

50.3.2.2 Wired Communication Design Standards

In most cases, there are two options available for wired communication, fiber optic cable or twisted pair cable.

50.3.2.2.1 Fiber Optics

Fiber optic cable has numerous advantages when considered for a dedicated communications network. These advantages include large capacity, immunity to electromagnetic and RF interference, a small flexible lightweight cable, and the capability to transmit data, voice, and video. The electronic equipment required (e.g., fiber muxes, video transceivers, etc.) is commonly available in a robust market with a good future.

The use of fiber optics typically requires a dedicated, WisDOT-owned communications network. This requires right-of-way and conduit throughout the network. Right-of-way is usually the limiting factor for private companies, but not for the State. The cost of installing conduit, however, can be significant. The backbone fiber optic network that runs throughout Wisconsin is often referred to as ITSNet.

Design criteria for fiber optic cable installation are as follows:

- Use cable with the correctly rated outer jacket material. Outdoor rated for underground installation in conduit, riser rated for vertical installations, and plenum rated for indoor installation.
- Design cable segments such that maximum pulling tension for individual cables is not exceeded. Different types and sizes of cabling have different maximum pulling tension.
- Design cable segments and access points (e.g., pull boxes, vaults, cabinets, etc.) such that minimum bending radius is not exceeded. Designers need to be aware that there are different bending radii depending upon loaded (during pulling, under tension) and unloaded (long term, at rest) conditions.
- Design cable segments and access points with nominal and maximum cable reel sizes in mind. Typical nominal reel sizes are 3,000 to 10,000 feet, with maximums upwards of 25,000 feet. Both the nominal and maximum reel sizes are dependent upon the type and diameter of the specific cable.
- Cables should not be pulled through any intermediate access point without the correct equipment and procedure. All tension must be eliminated at each access point. Alternately, the cable must be completely pulled from one access point to the next and safely stored in a figure-8 pattern.
- Excess fiber optic cable (100-ft typical) should be provided in each manhole in the system. This cable is coiled and fastened to cable support brackets. (See Figure 50.3-6)

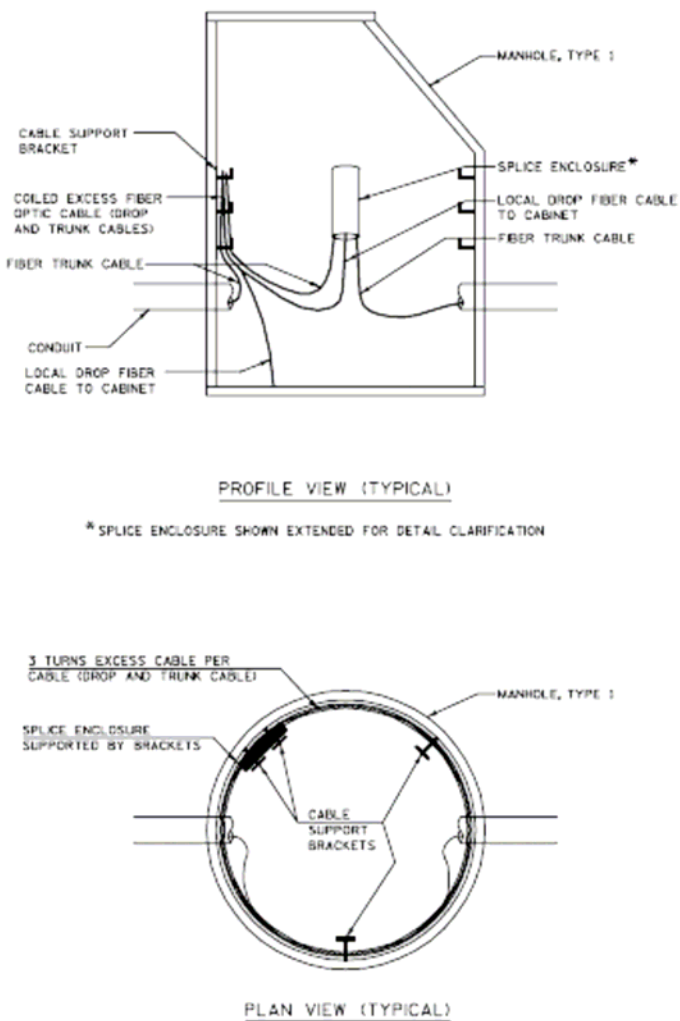


Figure 50.3-6: Communication Cable Installation in Manholes

To assist in record keeping and other system configuration and maintenance activities, a standardized naming convention for fiber optic cables is necessary. Figure 50.3-7 provides guidance on proper designation of fiber optic cables. This method is based from industry standard nomenclature.

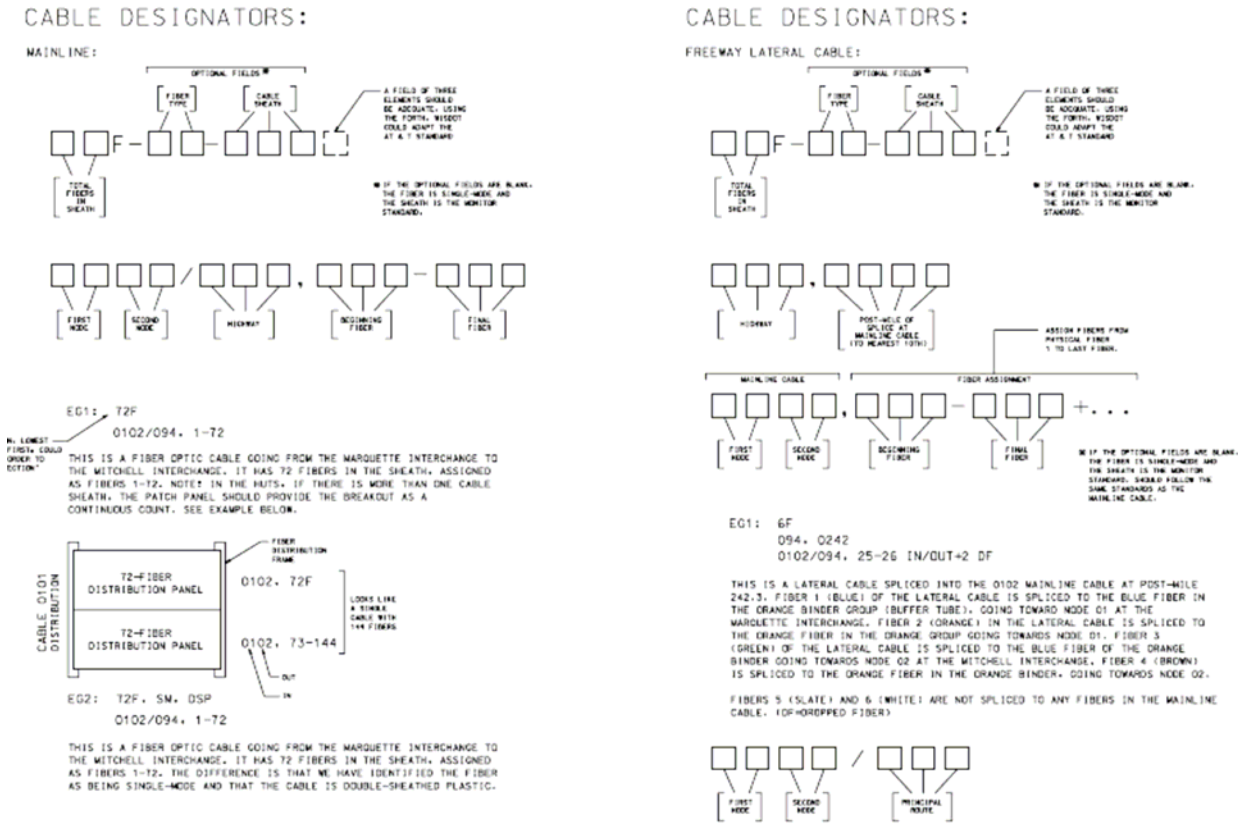


Figure 50.3-7: Fiber Optic Cable Designation and Naming Convention

50.3.2.2.2 Twisted Pair Cable

WisDOT-owned twisted pair cable has been widely used for the low-speed transmission of data in traffic signal systems, and between hubs and field elements within freeway management systems, with the network configured with between 8 and 12 field drops on each two-pair (4-wire) channel. The exact number of drops depends on the amount of data to be transferred between the hub and the field locations, and the rate of transfer. Twisted pair cable can support transmission distances of 8-10 miles before repeaters become necessary.

Twisted pair cable is a reliable and proven technology with established standards for cable and modems. A properly designed and installed twisted-pair communications system features reasonable low maintenance requirements in terms of average time between failures, the average time to repair, and the necessary levels of skill and equipment. Like fiber optics, it does require right-of-way and conduit, the latter often resulting in significant costs.

Design criteria for twisted-pair cable installation are as follows:

- Use cable with the correctly rated outer jacket material. Outdoor rated for underground installation in conduit, riser rated for vertical installations, and plenum rated for indoor installation.
- Design cable size and number of pairs taking into account the smallest diameter conduit or inner-duct the cable must pass through. A 25-pair cable has a nominal outer diameter of 1 inch.
- For interchanges consisting of multiple data devices, consider the use of smaller numbers of twisted pairs (e.g., 6-pair cable) to consolidate these devices to one of the local cabinets. For example, if three cabinets exist within a localized area, interconnect these cabinets with a 6-pair cable while bringing the mainline twisted pair cable into only one cabinet.
- In each manhole, provide for a service loop (one loop around the perimeter) of excess twisted pair cable

50.3.2.3 Wireless Communication Design Standards

One of the chief advantages of a radio-based communications subsystem is that no physical connection is required between the transmitter and receiver. This can translate into a significant cost savings over the capitalintensive cost of installing a cable conduit network, or the unpredictable ongoing costs for a leased facility. A proven radio alternative is the use of a spread-spectrum radio.

With spread-spectrum radio, the entire band (i.e., 902-928 MHz) is available for use by all users. Instead of subdividing the band, the FCC charged that each device operating in this range not exceed 1 Watt output power and be able to tolerate any interference generated in the band. This is accomplished by "spreading" the signal over the entire 26 MHz (in the 902-928 MHz band), and requiring that the receiver "know" where to look for the pieces of the signal.

Due to the spreading of the signal over a wide frequency range, electromagnetic noise (interference typically generated at a very narrow bandwidth) has less effect on signal integrity. Any noise interfering with a spread spectrum signal will tend to obscure only a very small fraction of the entire band and, since the signal is divided and spread over the entire spectrum, the transmitted signal can still be reliably reconstructed at the receiver.

Several low-speed spread-spectrum products are currently on the market, providing the following capabilities:

- Channel data rates of 9600 bps - 56 kbps
- Multiple channel capability
- Nominal range of 5 miles in open or over unobstructed ground (i.e., line-of-sight), with antenna
- RS-232 serial interface
- No FCC license required (although the manufacturer must have operation authorization)

Spread-spectrum radios transmitting at fractional and full T-1 rates (i.e., 512 kbps to 1.44 Mbps) over the frequency range of 5725 to 5850 MHz are also available. Both of these devices have a nominal range (with directional antenna) of 10 miles.

Design criteria for spread spectrum radio and antenna installation are as follows:

- Antennas can be mounted on standard poles, such as WisDOT Type 5 poles (30-ft), light poles, or camera poles.
- For large-diameter antenna (coaxial) cables, conduit installation between the local controller cabinet, pull boxes, and pole bases require the use of a 45-degree bend, a straight section, and another 45-degree bend to ease the installation sweep. (Typical installations into signal poles make use a single 90-degree bend.)
- Clear line-of-sight between antenna locations is not mandatory, but is preferred. Transmission quality is affected through significant changes in terrain elevations, trees, or tall buildings. If clear line-of-sight is indeterminable, engineering judgment should be used to determine the amount of terrain change or blockage between the two antenna locations.

50.3.3 Leased Communication System Considerations

Leased telephone circuits possess the flexibility and speed for application to ITS Deployment communications network as both low-speed and trunk connections. A wide variety of circuits are available from the telecommunications provider, including Type 3002 voice-grade data channels providing full-duplex multi-point analog service at 1200 - 9600 bps. These circuits can be used to provide analog communications between the control center and the VMS, ramp meters, and detector stations, and for camera control.

The telecommunications provider also offers digital services, which provide two-way digital data channels transmitting at rates between 2.4 (2400 bps) and 64 kbps. These circuits can be used for low-speed multi-point data channels operating at rates between 2400 and 9600 bps. These circuits thus can also be used for data trunking in which several low-speed channels are collected at a “hub”, multiplexed together in a higher speed Digital Services trunk, and transmitted to the control center. They may also be used for digital video transmission with a proprietary 56 kbps CODEC.

- ISDN channels each transmitting at 144 kbps (i.e., dual 64-kbps switched with 16 kbps data packet. These circuits can be used for data trunking, as well as for digitized video transmissions. for the video applications, 3 ISDN circuits would be used for each camera/CODEC to provide the appropriate video quality.
- DS1 (T-1) channels can also be used for digitized video. As compared to multiple ISDN circuits, the video quality would be significantly better, but at a greater monthly cost.
- DSL channels can also be used for both digital data and digitized video. Comparable to ISDN circuits, the video quality would be similar, but at a lower monthly cost.
- Fiber optic cables are also available from the telecommunications provider. It is noted that telephone companies throughout the United States make extensive use of fiber optic cables; but these networks are typically utilized solely for digital communications. The telecommunications provider is an exception

in that they will offer fiber optic cables for analog video. This approach provides “broadcast quality” video images.

Leased telephone is a very reliable communications solution in that there is a grid redundancy element due to the general coverage of the carrier’s network. One potential advantage over a dedicated network is that maintenance responsibilities are shifted from WisDOT to The telecommunications provider. Moreover, the service can generally be abandoned at any time, thereby providing flexibility to change the communications media should the need or opportunity arise. At the same time, the potential drawbacks associated with a leased approach must also be considered, including:

- Freeway Access - WisDOT is typically required to provide the telephone company with a conduit between the field cabinet and the nearest telephone facility. Along some segments, this distance may be significant and could result in an extensive conduit network being installed. This is not a major concern for the Milwaukee MONITOR in that the telecommunications provider only requires a conduit between the field cabinet and the freeway right-of-way.
- Cost - The costs for a leased network are not limited to the installation of the conduit. There are recurring expenses associated with the monthly cost of the circuits. Additionally, there is no guarantee that recurring charges will not significantly increase in the future unless WisDOT, and the telephone company enter into a contract. Several systems have converted from leased telephone to a jurisdiction-owned communications because of previous rate increases and the uncertainty of future hikes.
- Video Transmission - As a result of the improvements in CODEC technology during the last few years, the transmission of video over leased telephone is not as significant of an issue as it once was. Nevertheless, use of leased digital facilities for video requires a circuit capable of a data rate of 384 kbps (minimum for relatively good quality), a CODEC unit with CSU/DSU at both ends of the circuit, and an environmental enclosure (with heat and air conditioning) to house the field CODEC.

50.3.4 Communication Hut Design Requirements and Standards

Communication hub requirements for the state of Wisconsin have been established under previous ITS implementation projects. While these requirements are necessary to establish a basis for uniformity across the system, communication shelter manufacturers will have varying manufacturing processes materials which may or may not be acceptable.

Huts are not to be confused with communications hub. Hubs are points where fiber and/or other communications are connected through switches and routers, but do not have a physical location other than a cabinet or pull box.

Placement

- Communication hubs should be placed near logical crossing points of a communication network. Typically, system interchanges are ideal locations for communication hubs.
- The communication hub should be placed in a relatively flat area (4:1 slope or less)
- Hubs should be located in an area that is ultra-safe from vehicular travel.
- Communication shelters should be placed in a secure area, typically inside freeway right-of way fences with access via a locked gate.

Size

- Minimum interior dimensions of 8 feet (W) x 12 feet (L) x 9 feet (H)
- Frame type construction with both interior and exterior walls perpendicular to the floor

Structural Parameters

- Minimum roof live load 40 pounds per square feet
- Minimum side-wall live load 100 mile per hour wind load
- Minimum uniform floor load 150 pounds per square ft (over entire area)
- Minimum concentrated floor load 300 pounds per square ft (over one sq. ft)

The floor deck should be supported on a structural steel base / frame designed to permit the entire structure, complete with floor load, to be relocated. The base / frame shall incorporate full perimeter structural members, which protect and close off the complete building perimeter. The perimeter members shall accommodate lifting, anchoring, and support of the building. Skid-type base / frames shall not be acceptable. A concrete slab suspended between the perimeter members will provide necessary floor support. The entire underside of the base / frame shall be closed with a seam-welded steel plate to provide permanent barrier against moisture, insects, rodents, and vermin.

The base / frame shall be suitable for installation on a foundation system that provides multipoint support and anchoring along the long side of the base/frame structural members. Four concrete pier type foundations extending a minimum of 12 inches below normal frost line shall meet the requirements of the communication hub manufacturer. Piers shall be sized to accommodate an assumed soil bearing capacity of 3000 pounds per square feet.

An 8 feet (W) x 12 feet (L) x 12 inch (D) crushed aggregate base coarse pad shall be placed within the footprint of the fiber optic communications hub. Crushed aggregate base course shall adhere to the requirements of Section 304 in the Standard Specifications.

Anchoring shall permit repositioning, adjustment, and leveling of the building on the foundation during installation. Pre-cast anchor bolts shall not be allowed. Lifting and anchoring points shall be integral. No open holes shall be left in the perimeter of the base / frame after anchoring.

Insulation and Weather Proofing

- Insulation value – Floor, R11
- Insulation value – Sidewall, R11
- Insulation value - Ceiling / Roof, R19
- Maximum air filtration, 300 cubic feet per hour
- All areas insulated shall include a vapor barrier
- The communication hub shall be protected against the entrance of blowing rain or snow
- All door and conduit/cable openings shall be suitably protected and sealed

Heating-Ventilation-Air Conditioning

- Electric, forced air heating
- Operations controlled by environmental control panel
- Two speed ventilation system
- Exhaust fan with gravity damper
- Thermostatic control of the exhaust fan and exhaust damper shall be provided at the environmental control panel
- One (1) window type air conditioner (30,000 BTU per hour)
- Air conditioner unit shall permit the fan to cycle on and off with the compressor
- Air conditioner operation will be controlled by the environmental control panel

Environmental Control Panel (ECP)

- Provides remote thermostatic control of heating, ventilation, air conditioning, and emergency ventilation stages functions
- All environmental components shall be switched or otherwise controlled by devices properly rated and UL-listed
- Each environmental function shall be electrically interlocked to prevent simultaneous operation of multiple functions
- ECP shall have a five degree temperature differential between the ventilation and air conditioning stages to ensure the air conditioning does not conflict with outside ventilation, and vice-versa
- ECP shall contain visible indications of 1) Power ON, 2) Heat ON, 3) Vent ON, 4) Air Conditioner ON, 5) Emergency Vent ON; as controlled by the panel.
- Functional controls and internal terminal blocks shall be labeled with engraved plastic nameplates (dymo-type labels are not acceptable)

Safety, Security, and Remote Alarms

- Fire extinguisher
- Smoke detector
- Entrance intrusion
- High temperature
- Emergency Ventilation

Electrical

- Comply with National Electric Code
- All wiring will be surface mounted with straps in EMT conduit or other approved raceway
- All conduit will run horizontal or vertical
- 120/240 volt, single phase, 200 amps, with 30 branch circuits
- 100 amp auxiliary receptacle with manual transfer switch

Miscellaneous

- Four (4) 19 inch, non-enclosed racks, 7 feet in height, anchored to floor, wired complete with power with a minimum six (6) 120 VAC outlets along the rack
- One (1) 12 inch wide by 10 feet long cable tray
- One (1) 4 feet x 8 feet x ¾ inch plywood backboard

50.4.1 State Supplied Materials

The Department has secured bids to supply various electrical and traffic operations materials by specification at the time of construction or installation. A listing of state supplied materials can be found in Appendix 70.5 of this manual.

The Bureau of Highway Operations - STOC provides the management of the purchasing process. All questions relating to state supplied materials, equipment orders, and delivery dates should be directed to the Bureau of Highway Operations – STOC.

50.5.1 Contractor Supplied Materials

Following specifications 651.2 and 670.2, all products supplied by the contractor should conform to specification requirements on the department's approved product list. The list of approved contractor supplied materials and construction products for electrical work can be found at

http://www.dot.wisconsin.gov/business/engrserv/approvedprod.htm. For materials not on the approved list, refer to Standard Specification 670.3.3.1.

50.5.2 Communication Requirements

As discussed in section three of this chapter (55.3), communications requirements can vary between each different type of ITS equipment. The communication mediums selected can include spread spectrum radio, Ethernet over fiber (with an Ethernet to serial converter), dedicated twisted pair copper, leased telephone circuit, wireless communications, among others. Contact the State Traffic Operations Center to discuss specific communication requirements.

50.5.3 Power Requirements

A 100 Amp, 120/240 volt, single phase, three wire underground electrical service is required for most electrical service installations. Typically, two controller cabinets can be powered by a single 100-amp service. The electrical service will be furnished and installed by the local power company up to a demarcation point, which consists of an electrical service (meter) pedestal. The electrical service must conform to the requirements of the local power company. The location of the electrical service must receive approval from the utility company. The electrical service will include two 50-amp circuit breakers rated at 22,000 AIC. The requirements for power cable between the electrical service and controller cabinet can be found under the Cable Routing section of this chapter.

At locations that require a remotely located electrical service, a 100 Amp outside rated breaker box with space for 6 circuits, but no main breaker, will be attached to the side of the cabinet. Also, a 50 Amp single circuit breaker rated at 22,000 AIC will be installed within the breaker box to serve as a local electrical service disconnect point.

50.5.4 Communications System Construction Standards

Construction details, Standard Special Provisions, and Special Provisions can be found in Appendix 70 of this manual.

50.6.1 Testing

50.6.1.1 Controllers and Other Equipment

Reference Standard Specifications 675.3.(14) through 675.3.(20) for testing procedures. In 675.3.(15), traffic flow information includes volume and speed data.

50.6.1.2 Field System Integrator

Refer to Standard Specification 670.3.2.1 for field system integrator duties.

- **Contractor-furnished equipment and materials**, refer to Standard Specification 670.3.3.1.
- **Department-furnished equipment** and materials, refer to Standard Specification 670.3.3.2

50.6.2 Acceptance

Notify the State Traffic Operations Center after testing is complete. The State Traffic Operations Center Maintenance Representative will do the final concurrence of acceptance before the State Traffic Operations Center accepts ownership and maintenance of the communications system.

50.7.1 As-Builts

The Bureau of Highway Operations is responsible for maintaining all Traffic Operation ITS equipment and fiber optic network (ITSNET) on the state system. A comprehensive statewide as-built can be found at http://transportal.cee.wisc.edu/. A password for the TransPortal system can be obtained by following the instructions on the TransPortal webpage.

50.7.1.1 Geographic Information Requirements for As-Builts

The contractor shall collect geographic information for all Intelligent Transportation Systems (ITS) and Fiber Optic infrastructure installed in the project, hereafter referred to as “GPS data points”. The characteristics of the data points are outlined below along with acceptable procedures for collection and documentation of the data.

Data Formats

Physical

Data points will be delivered to the Engineer in an archival physical media format such as CD-ROM or DVD-ROM. Data may also be delivered as a download (FTP or HTTP) or through e-mail attachment, however physical media must be provided as part of as-built documentation.

Electronic

- Data points shall be submitted as a comma or tab delimited ASCII text file.
- Each data point shall be a single line in the text file.
- Each line shall be one data record containing the following fields:
    - Latitude (Y-coordinate) in decimal degrees
    - Longitude (X-coordinate) in decimal degrees
    - Altitude (Z-coordinate) in feet
    - Date (day, month, year) of point collection
    - Time (24 hour format) of point collection
    - Initials of field personnel collecting data points
    - Abbreviation for Element Type (see table of elements below)
    - Location description (for example, street and cross street)
    - WisDOT-assigned system ID number (when available)

Data Properties

The GPS data points shall be collected with the precision and accuracy requirements listed below. GIS quality equipment is typically needed to meet these requirements. For example, the Trimble GeoXT GPS unit meets these requirements.

Precision

- Degree coordinates shall be expressed using five decimal places of precision (1.2 meter precision)
- Altitude shall be expressed to the nearest whole foot
- Time/date information shall be expressed to the nearest minute

Accuracy

- Data points shall have a lateral accuracy of 1 meter for 965% of collected points
- Data points shall have a vertical (z-coordinate) accuracy of three (3) meters.
- Post-processing of collected points is permitted provided the contractor delivers a report containing meta-data describing the processing method, data sources, and expected accuracy.

Data Types

Data points shall be collected for each of the ITS and Fiber Optic infrastructure listed in the table below (if present) within the project area. The points shall be coded according to the abbreviation provided in the table.

Relevant Elements

Abbreviation	Description
CAM	CCTV poles (capture point at pole location)
CAB	Field equipment cabinets (unless attached to pole that is already being located)
PB	Pull boxes (when used with a fiber optic infrastructure installation, or when connected to in-pavement loops)
MH	Manholes (when part of fiber infrastructure)
JB	Junction boxes (such as on a bridge)
CV	Communication vaults (when part of fiber infrastructure)
MBP	Meter breaker pedestals
HUT	Equipment shelters (i.e. fiber optic communication huts)
ANT	Antenna poles (capture point at pole location)
OHS	Dynamic message signs (capture at base of sign support with connections to power and/or communications)
YF	Yellow Flashers (ramp metered when flashing signs)
HAR	Highway advisory radio transmitters (at antenna location)
SGN	Highway advisory radio signs (at sign location)
RMS	Ramp meters (capture point at pole location)
RWIS	RWIS sites (including tower, pull boxes and meter breaker pedestal)
GTE	Ramp closure gates
PG	Point Generic (fiber access/splice locations and other infrastructure not described above)
MD	Microwave detectors//detector poles (capture point at pole location)

50.7.2 Documentation

A listing of all the devices installed and the associated serial numbers, as-built CAD files, and testing and calibration results should be provided to BHO-STOC.

The following fields are used in the ITS inventory system. This data should be provided to the BHO-STOC as soon as it is available. The data must be provided before the equipment is accepted.

CartêGraph ITS Inventory Database Fields General:

ID
TOC Location Description
Installation Address
Installation Phone Number
Service Provider
Service Provider Utility Account
TOC Monitor ID
Region
TOC Type
Maintaining Authority
Maintaining Authority Contact
Service Provider

Details:

- Events – Lists work orders and other events
- Detectors:
  - ID
  - Detector Number
  - Description

Loop Location

- Aux Equip:

- ID
- Serial Number
- Description
- Manufacturer
- Model

- Cabinets:

  - ID
  - Serial Number
  - Description

- Supports:

- Bolt circle
- Height
- Lowering system

50.7.3 Deployment Inventory

An inventory of all ITS equipment and fiber optic network components is maintained at the BHO-STOC. The software CarteGraph is described in Chapter 60 ITS Software.

50.8.1 Maintenance

50.8.1.1 New Communications Systems

Once the State Traffic Operations Center Maintenance Contractor accepts the communication systems equipment per 50.6.2, the State Traffic Operations Center will accept the communication systems onto the Statewide Maintenance Contract.

50.8.1.2 Existing Communication Systems

If a contractor is working on an existing communications system, the contractor is responsible for locates and any maintenance until seven days after the as-builts have been delivered to the State Traffic Operations Center. At that time, the State Traffic Operations Center will accept the communication systems onto the Statewide Maintenance Contract.

50.8.2 Reevaluation

ITS Communication Systems should be evaluated for their effectiveness periodically. Existing communication systems installations should be reviewed to determine if there are locations where communication systems no longer are as beneficial as they used to be. It may be beneficial to remove Communication Systems that are no longer necessary.

60.1.1 Introduction

Traffic management systems are composed of hardware and software system as well as communications and networking systems. Computers play a primary role in controlling and managing the Wisconsin system using a client-server approach.

Servers provide services to client workstations allowing operators to work with software that performs important system functions while hiding much of the implementation and details from the user. It is the server that handles where data is stored and in what format, handles communication to a dynamic message sign per the sign manufacturer's requirements, handles changes to ramp meters or providing a web page that an authorized user can utilize to control/manage the system.

Servers save money by consolidating and managing these issues. They also provide scalability and economics of scale by reducing the need for additional computing equipment.

Software for traffic management systems are not the type of software you can purchase "off-the-shelf" and use immediately. There are many system configuration choices and requirements based on the system design that require a level of customization. Software needs to support many different types of field equipment (e.g. dynamic signs, 2070 controllers, low power AM transmitters, flashing beacons, cameras, etc.) from many different manufacturers.

There are generalized needs like database management, video and communication systems but the majority of the systems are specific to traffic management and have different requirements than typical office environments.

60.1.2 Needs Assessment

When new software and servers are being considered a needs assessment is typically completed to determine the functional requirements of the equipment needed. The types of needs being assessed can vary, but at a minimum the data management needs, end user needs, and business/reporting needs are reviewed.

60.1.3 Types

Guidelines for choosing the type of software and related hardware are highly dependant on the complexity of the project. For specific procurement product information, see Chapter 70.5 State Supplied List. Contact the STOC for product information.

60.2.1 Servers

In computing, a file server is a computer attached to a network that has the primary purpose of providing a location for the shared storage of computer files (such as documents, sound files, photographs, movies, images, databases, et cetera) that can be accessed by the workstations that are attached to the computer network.

Servers also provide shared service to the equipment in the field and simplify how that equipment is accessed. For example, each of the computers in the STOC can operate any of the dynamic message signs, regardless of the sign's model, firmware, etc.

The term server highlights the role of the machine in the client-server scheme, where the clients are the workstations using the storage. A file server is usually not performing any calculations, and does not run any programs on behalf of the clients. It is designed primarily to enable the rapid storage and retrieval of data where the heavy computation is provided by the workstations.

Milwaukee is the primary traffic operations center and referred to as the State Traffic Operations Center but a secondary traffic operations center is maintained in the Southwest region.

60.2.1.1 Data Servers

There are two general types of data servers on the network, data base servers and Statewide Incident Notification System (SINS) servers. Database servers utilize Oracle as the current database management system (DBMS) used by the STOC. This is one of the core servers used by the TransCore supplied system software (TransSuite). SINS servers provide database services for the SINS application used by control room operators to record infrastructure and traffic incidents.

60.2.1.2 Communication Servers

The following types of communication servers are on the network:

- Traveler Information System (TIS) – this server controls access to dynamic message signs (DMS) and highway advisor radio (HAR). This is one of the core servers used by the TransCore supplied system software (TransSuite).
- Freeway Management / Central Communications (FMS/CCS) – controls communications with controllers of various designations (ATR, CS, RM and SDS) used either as count stations or to operate system ramp meters. This is one of the core servers used by the TransCore supplied system software (TransSuite).
- Web – web interface – provides access to system software for approved off-site users. This is one of the core servers used by the TransCore supplied system software (TransSuite).

These data servers are duplicated and otherwise backed up at multiple locations throughout the state.

60.2.1.3 Video Servers

There are currently ten video servers on the network, eight in Milwaukee and two in Madison. The video servers primarily provide access to the images captured by the CCTV cameras and control to those cameras located along the freeway throughout the state.

- IVC (referred to by the manufacturer's name – Industrial Video Control)
    - Servers 1-8 in Milwaukee and Servers 1-2 in Madison
    - 24 cameras per server on most servers
    - IVC #5 has 100 cameras – this is the server that records 15 minute blocks of video for the previous 72 hours.

60.2.2 Security

The servers and field equipment and outside agencies connected via network to the BHO STOC center are separated by a firewall from the State Enterprise network. The firewall is jointly managed by BHO and BITS.

User accounts, authentication and authorization are handled by BHO STOC IT staff located in Milwaukee and Madison. A project to be completed by Fall 2009 will move from the current Primary/Backup Domain Controllers to an Active Directory installation.

Requests for user accounts and authorization for those accounts to use BHO STOC workstations, servers and field equipment should go to BHO STOC IT unit.

In general terms, server and software selection are managed by BHO. BHO staff will assess the benefits of the equipment as well as the risk of additions to the network.

60.2.3 Network

Advanced Traffic Management System (ATMS) is one term used to describe the overall system used to manage Intelligent Transportation System (ITS) components. An important part of an ATMS infrastructure, and any involved system, is the network. This basic network structure exists in both Madison and Milwaukee operations center.

The ATMS network is a separate BHO STOC maintained network and is firewalled from the Wisconsin DOT enterprise network for several reasons:

- Networked field equipment extends along the freeway and provides multiple dispersed connection points
- Enhance system security
- Provide a barrier to viruses

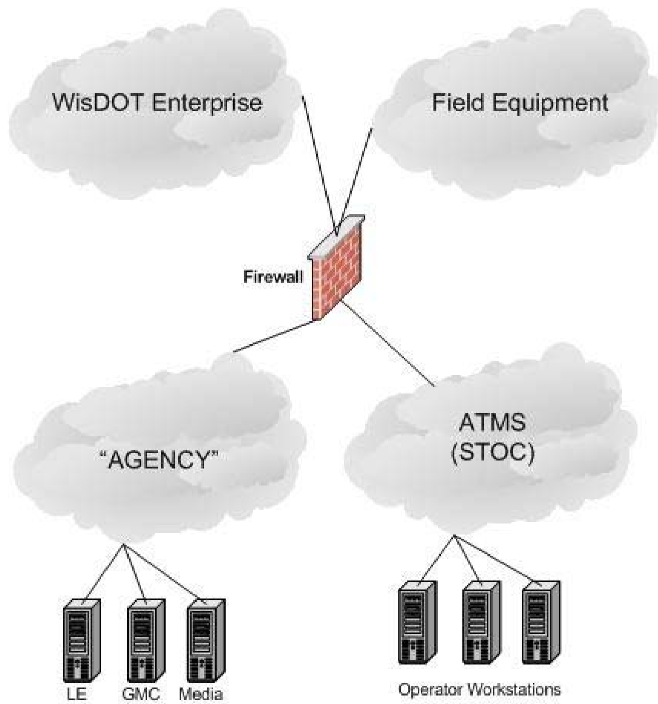


Figure 60.2-1 General Network Diagram

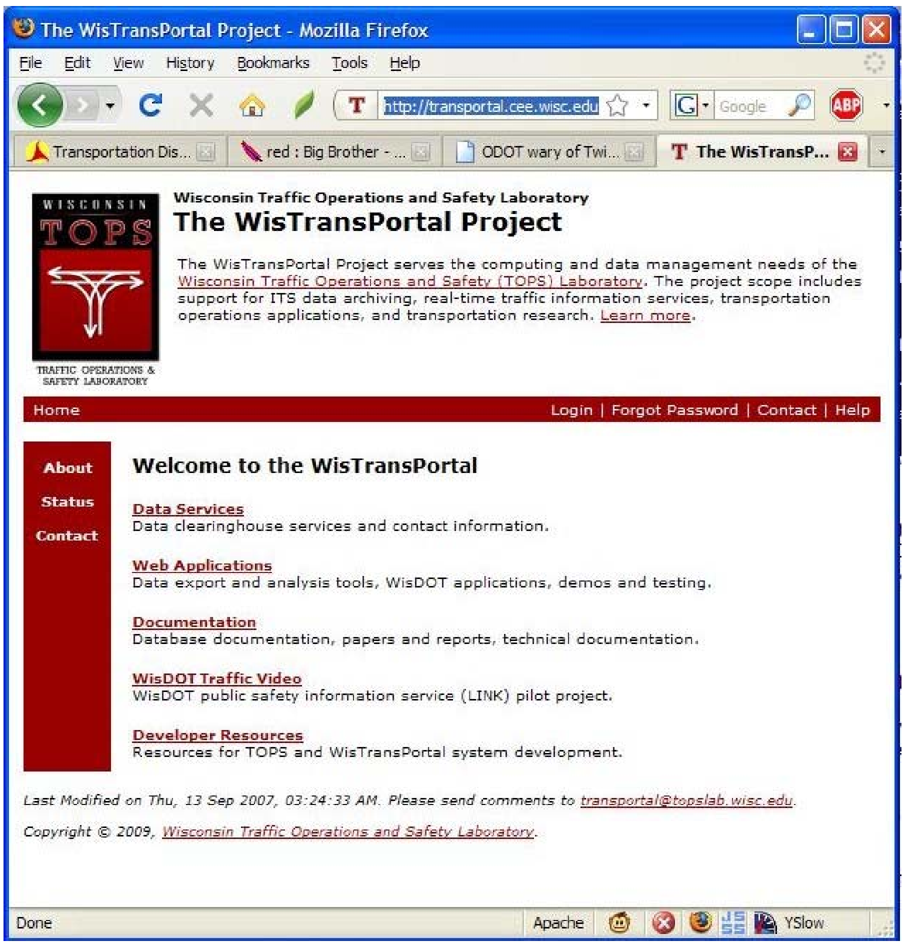
60.2.4 Fiber Network

Extending the network out to field equipment and interconnected multiple sites and agencies is achieved through the fiber network infrastructure.

60.3.1 Custom Software

When needed, the STOC uses a custom software packages were developed “in-house” by STOC IT staff or customized by the software developer. This is due to the unique nature of the data received and needing to be processed, as well as the unique needs of the end users. The following are a list of custom software utilized by developers and various users of the ITS network’s data. A brief description is given for each custom software listed and the primary contact is also provided. Contant BHO-STOC for more information about custom software.

- WisTransPortal – Large database that stores detector data, crash information, as-built drawings, construction and maintenance closures and CAD incident info. The WisTransPortal is housed at UW-Madison’s Engineering Hall.



See the WisTransPortal Project website to apply for a Login name and password.

- WisTrafPoster – posts traffic data for 511 use in XML format (http://www.511wi.gov/). This is a service that runs on Milwaukee’s TransCore WebServer. The BHO STOC IT staff is the primary contact.
- TrafficXML – post traffic data in XML format on web for 3rd parties. Written by HNTB as part of the Marquette Interchange website rollout, it provides XML data for many 3rd party developers but will be replaced by the 511 XML feed. Contact BHO STOC IT staff for access and use of XML data published by the STOC.
- TT – Travel Time program – publishes travel times to DOT website (http://www.dot.state.wi.us/travel/milwaukee/times.htm). Runs on Milwaukee’s TransCore Web Server. The BHO STOC IT staff is the primary contact.

- LCS – Posts lane closure data to Wisconsin DOT Website. This is a service that runs on Milwaukee's IVC #1 server. The BHO STOC IT staff is the primary contact.
- Snapper – takes snapshots from cameras and posts them to DOT website. Runs as a service on all IVC servers (Milwaukee and Madison) except for IVC #5 (Media server). The BHO STOC IT staff is the primary contact.
- SINS – tracks all infrastructure issues. Access database and web interface that runs on Milwaukee servers and control room workstations (http://miltocwp2.dot.state.wi.us/SINS/sins.html). The BHO STOC IT staff is the primary contact.
- STOC Exchange – message posting system for workstations. Runs on Milwaukee workstations. The BHO STOC IT staff is the primary contact.
- Control Room Issues – web software/Access database to track issues operations have with operating the "system" and/or with hardware or software used to run the "system" software (http://miltocwp1.dot.state.wi.us/CRM_Issues/Open.aspx). Runs on Milwaukee's TransCore web server. The BHO STOC IT staff is the primary contact.
- Mr. Freeze – "Operator Switchboard" software to control which camera is viewed. Generally used for outside users of WisDOT video such as law enforcement or media. The BHO STOC IT staff is the primary contact.

60.4.1 Commercial Software

There are a number of commercial off-the-shelf and custom software used by the BHO STOC. The typical DOT Enterprise Workstation software like Microsoft's Office 2007 is utilized on control room workstations with the exception of Microsoft Outlook.

The core system software used by the STOC is provided by TransCore. It is not an "off the shelf" (OTS) software but rather a custom designed and constructed software specific to Wisconsin ITS efforts but built on a common (software) infrastructure that TransCore utilizes for all ITS software clients.

- TransSuite (Transcore)
  - ATMS – Map for display and control of equipment
  - TIS – controls messages on dynamic and portable signs, HAR
  - IMS – Tracks incidents (crashes) on freeways
  - CCS – Central communication server
  - FMS – Freeway management server (aka "CCS")
  - Intranet application – web application to sue software remotely

  TransSuite®:
  * Traffic Control System
  * ATMS Map
  * ATMS Explorer
  * Traveler Information System (TIS)
  * Video Control System (VCS)
  * Incident Tracking and Management System/MICE
  * Freeway Monitoring and Management System/FTMS

  This is the system software for the STOC and Madison TOC.

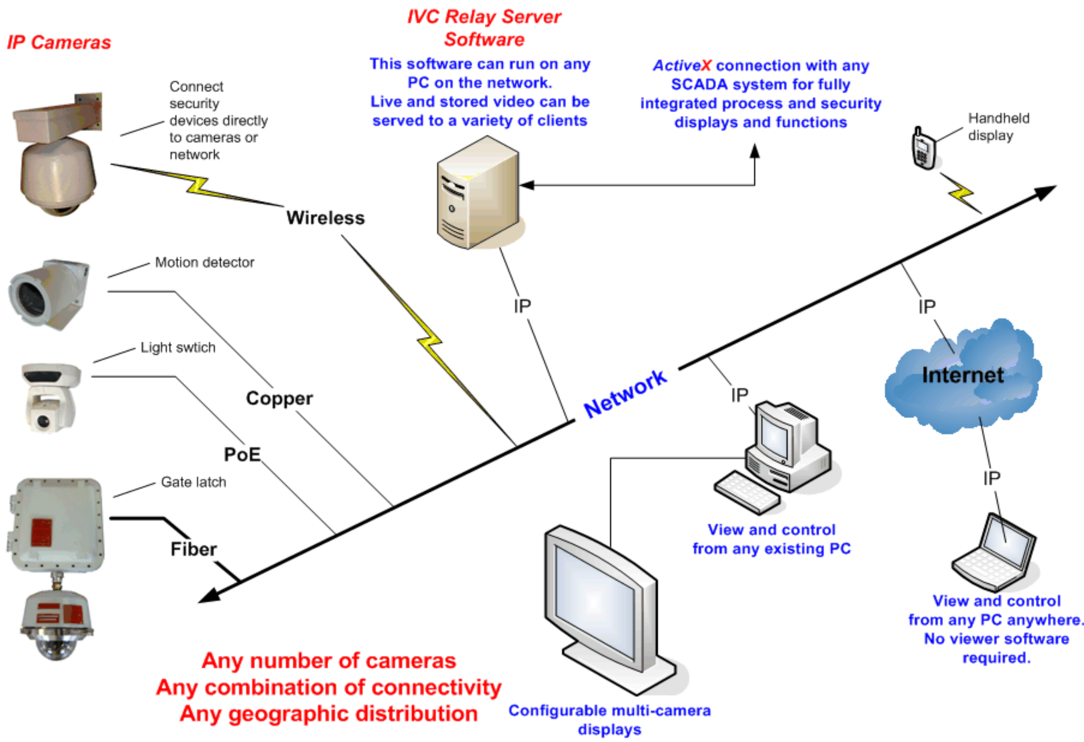
- Cartegraph
  - Signal View – Inventory of equipment in field (cameras, signs, and controllers) SIGNALview gives traffic engineers and technicians a powerful tool for maintaining and managing all components of your signal system. You can use SIGNALview to accurately show a signal group or intersection. It also tracks supports, head units, detectors, controllers, conflict monitors and auxiliary equipment. The easily customized SIGNALview interface enables you to access forms, online libraries and other data fields. And SIGNALview integrates seamlessly with other CartêGraph applications to create a complete public works solution that empowers you to manage with ultimate efficiency.
  - Work Director – ticketing system to track field equipment and maintenance requests WORKdirector gives you the functionality to manage all of the work activities performed by your organization – all in an easy-to-master interface. From an initial request for work to the scheduling of routine maintenance through the completion of each project, WORKdirector tracks and maintains data on activities, materials, employees and equipment. With its customizable interface, including forms, libraries and reports, WORKdirector has virtually unlimited potential to seamlessly automate your daily tasks. You can quickly and easily modify field names, design on-line work orders to match current paper forms, create reports to output information, and more. WORKdirector works with other CartêGraph programs to create a powerful, high-level public works management system.

- Industrial Video Control (IVC)
  - IVC Relay – Web server/video server software – bring in many camera/video to many users.
  - Viewstation – workstation software to watch video
  - Tour Server – Control video tours – runs on server.

  Each of the IVC cameras and the Relay Server has its own IP address. Just connect them to your network and the installation is complete. To view and control any of the cameras simply enter the IP address for the Relay Server on any PC. No viewer software is required.

  The IVC Relay Server provides Click-to-Point steering on the video and panoramas, precise preset views triggered by security and/or SCADA events, automatic video storage and snapshots, dynamic bandwidth management to insure that other applications on the network are not slowed, preconfigured multiple camera views, unlimited camera and viewer capacity, and much more.

IVC systems can consist of any combination of fixed-view cameras, PTZ cameras, indoor, outdoor, zoom-only, thermal, IR cameras, etc. Operators can instantly view and control cameras located at multiple locations anywhere in the world, securely via password access. The camera count and feature set can be changed at any time, usually without hardware additions or adjustments. IVC systems require no wiring apart from LAN connections, or hardware apart from the cameras.



- Coretec
  - Watchdog – video viewing software used in Madison.

    Watchdog™ System is a robust software system built upon a set of very powerful software modules in the form of reusable libraries and ActiveX controls. The package can be tailored to meet customer requirements, such as custom logos and custom hardware integration. These software modules can be easily incorporated into 3rd party software under licensing agreement, either individually or as an entire system.

- Microsoft
  - Office – Word, Excel, Access

    Microsoft Office is the most efficient suite of applications for document creation, communication and business information analysis. For many functions, the business platform has evolved from paper to the Web. Microsoft Office extends desktop productivity to the web, streamlining the way you work and making it easier to share, access and analyze information so you get better results. Office 2000 offers a multitude of new features. Of particular importance for this release are the features that affect the entire suite. These Office-wide, or shared features hold the key to the new realm of functionality enabled by Office. It makes it easier to use an organization's intranet to access vital business information and provides innovative analysis tools that help users make better, timelier business decisions. Office delivers resiliency and intelligence, enabling users and organizations to get up and running quickly, stay working and achieve great results with fewer resources
  - Windows Encoder – encode video for distribution (by UW – TOPS) to others (emergency service shared video)

- Logic Tree (511)
    - o Web-based interfaces for managing the dynamic sections of the 511 website such as floodgate messaging and road/weather conditions.

- Fleet Probe

60.4.2 Commercial Open Source

- Big Brother – web app to manage network equipment
  Big Brother is an application that monitors System and Network-delivered services for availability. Your current network status is displayed on a color-coded web page in near-real time. When problems are detected, the system can immediately notified by e-mail, pager, or text messaging.
- MRTG – Multi router Traffic Grapher – graph network bandwidth utilization
  You have a router; you want to know what it does all day long? MRTG can provide this information. It will monitor SNMP network devices and draw pretty pictures showing how much traffic has passed through each interface.
- Routers are only the beginning. MRTG is being used to graph all sorts of network devices as well as everything else from weather data to vending machines.
- MRTG is written in perl and works on Unix/Linux as well as Windows and even Netware systems. MRTG is free software licensed under the Gnu GPL.
- Nagios – new web app to manage network equipment
  Nagios is the industry standard in enterprise-class monitoring for good reason. It allows you to gain insight into your network and fix problems before customers know they even exist. It's stable, scalable, supported, and extensible. Most importantly, it works.

  What does Nagios provide?

  Comprehensive Network Monitoring
  * Windows
  * Linux/Unix
  * Routers, Switches, Firewalls
  * Printers
  * Services
  * Applications

  Immediate Awareness and Insight
  * Receive immediate notifications of problems via email, pager and cellphone
  * Multi-user notification escalation capabilities
  * See detailed status information through the Nagios web interface

  Problem Remediation
  * Acknowledge problems through the web interface
  * Automatically restart failed applications, services and hosts with event handlers

  Proactive Planning
  * Schedule downtime for anticipated host, service, and network upgrades
  * Capacity planning capabilites through usage monitoring

  Reporting Options
  * SLA availability reports
  * Alert and notification history reports
  * Trending reports through integration with Cacti and RRD-based addons

  Multi-Tenant/Multi-User Capabilites
  * Multiple users can access the web interface
  * Each user can have their own unique, restricted view

  Integration With Your Existing Applications
  * Trouble ticket systems
  * Wikis

Easily Extendable Architecture
* Over 200 community addons are available to enhance Nagios

Stable, Reliable, and Respected Platform
* 10 years in development
* Scales to monitor 100,000+ nodes
* Failover protection capabilities
* Winner of multiple awards
* Constant media coverage

Customizable Code
* Open Source Software
* Full access to source code
* Released under the GPL license

- VLC – used to watch video
  VLC media player - the cross-platform media player and streaming server.
  VLC media player is a highly portable multimedia player for various audio and video formats (MPEG-1, MPEG-2, MPEG-4, DivX, mp3, ogg, ...) as well as DVDs, VCDs, and various streaming protocols. It can also be used as a server to stream in unicast or multicast in IPv4 or IPv6 on a high-bandwidth network.

- Wireshark – to inspect network traffic and issues
  Wireshark is the world's foremost network protocol analyzer, and is the de facto (and often de jure) standard across many industries and educational institutions.
  Wireshark development thrives thanks to the contributions of networking experts across the globe. It is the continuation of a project that started in 1998.

  Features
  Wireshark has a rich feature set which includes the following:

  - Deep inspection of hundreds of protocols, with more being added all the time
  - Live capture and offline analysis
  - Standard three-pane packet browser
  - Multi-platform: Runs on Windows, Linux, OS X, Solaris, FreeBSD, NetBSD, and many others
  - Captured network data can be browsed via a GUI, or via the TTY-mode TShark utility
  - The most powerful display filters in the industry
  - Rich VoIP analysis
  - Read/write many different capture file formats: tcpdump (libpcap), Pcap NG, Catapult DCT2000, Cisco Secure IDS iplog, Microsoft Network Monitor, Network General Sniffer® (compressed and uncompressed), Sniffer® Pro, and NetXray®, Network Instruments Observer, NetScreen snoop, Novell LANalyzer, RADCOM WAN/LAN Analyzer, Shomiti/Finisar Surveyor, Tektronix K12xx, Visual Networks Visual UpTime, WildPackets EtherPeek/TokenPeek/AiroPeek, and many others
  - Capture files compressed with gzip can be decompressed on the fly
  - Live data can be read from Ethernet, IEEE 802.11, PPP/HDLC, ATM, Bluetooth, USB, Token Ring, Frame Relay, FDDI, and others (depending on your platfrom)
  - Decryption support for many protocols, including IPsec, ISAKMP, Kerberos, SNMPv3, SSL/TLS, WEP, and WPA/WPA2
  - Coloring rules can be applied to the packet list for quick, intuitive analysis
  - Output can be exported to XML, PostScript®, CSV, or plain text