FDM 11-5-1 Scope of Construction Projects

November 17, 2020

1.1 Discussion

Construction projects can frequently be organized into a series of separate contracts by major items of work or combined into "package" contracts. Some types of contract composition have proven to be more economical than others. It is generally beneficial to the State, and usually preferred by the contractors, to let separate contracts for each major type of work, i.e., grading, structures, base course, surfacing, or specialty work. When contracts include only items the contractors consider to be within their prime area of expertise, the savings are usually significant enough to warrant structuring projects around those abilities, whenever feasible.

The Region should develop an understanding and concurrence with the appropriate Central Office Design Coordinator on whether to package the project, early in the project's development.

Combinations of major work items into package contracts may be advantageous to the State when the project requires unusual considerations, such as complex traffic handling.

Combining box culverts or other small structures with grading work is desirable because of the closely interrelated scheduling of construction operations required.

Large structures should be let as separate contracts. Steel structures should be let to contract six months or more in advance of construction, to allow time for fabrication. When several small structures are to be built in the same general area, including those in adjacent Regions, they may be combined into one contract. Future construction project schedules should be examined to determine whether it would be advantageous to reschedule a project to the same fiscal year or otherwise make an adjustment to allow packaging the project.

The use of separate contracts also allows the opportunity to schedule contracts for letting at appropriate times, as may be required for stage construction.

Contracts for signing and signalization should be let at least six to nine months in advance of the anticipated installation date, to allow adequate time for fabrication. Normally, signing work should be let before the paving contract.

Urban highway and street projects should be let early enough in the year to assure that by the end of the construction season, the condition of the project is suitable to carry traffic during the winter months.

Asphaltic concrete paving contracts should not be scheduled for letting during the months of June through October. This is the period when paving contractors are busy with construction, there is a limited construction season remaining, bids are speculative and must reflect anticipated costs for the following year, and experience has shown that bids during this period are least favorable to the state. Off-season lettings for paving contracts allow the contractors ample time to prepare bids which normally results in more competitive bidding. Asphalt paving contracts should generally require completion of construction during the same calendar year as the fiscal year used for funding the project, i.e. during one construction season.

An economic advantage may be realized through utilization of the alternate proposal bidding procedures, as presented in Chapter 19 under Consideration of Proposals. By using the provisions contained in that procedure, the Department may solicit bids for project A, project B, and project A and B combined.

It should be emphasized that there is no substitute for engineering judgment and common sense. When there is any uncertainty, questions relating to contract format should be directed to the appropriate Central Office Design Coordinator.

1.2 Collaboration with Industry

The construction industry can play a role in providing valuable information during the design process. WisDOT can provide industry with information early in the design process that can help prepare for future lettings.

Design teams can reach out to industry, through Bureau of Project Development (BPD) working with contracting associations, to get feedback on potential construction methods for a particular operation or for gathering information for a unique or non-typical bid item. Contact BPD Construction Oversight Chief if it there is a need to outreach to industry during the design of process.

Preliminary plans can be shared with industry through the HCCI projects page on projects with substantial grading, unique structure components, complex staging, high-cost projects ($20 million in estimated construction costs), and any other project the region deems appropriate. These plans can be posted at any time during the design process. Postings can consist of full or partial plans or roll plots, models, special provisions, or other project documents as appropriate. Coordinate through BPD Proposal Management section to have preliminary plans posted to the HCCI website prior to PS&E. Follow the procedure in FDM 19-10-15.1.23 for posting preliminary plans at the time of PS&E.

FDM 11-5-2 Traffic Demand Forecasts — August 17, 2020

2.1 Traffic Forecasts General

This section discusses traffic forecasting including forecast uses, when a forecast is required, the types of forecasts, and how to request a forecast.

Traffic forecasts are used throughout the project life cycle in several ways, including but not limited to:

- Determining appropriate highway and bridge design criteria.
- Designing pavement structures.
- Evaluating levels of service for improvement needs and project alternatives.
- Analyzing environmental issues like air quality and noise.
- Evaluating alternative alignments.

The Transportation Planning Manual (TPM) is a document that outlines traffic forecasting policies, procedures, data and travel demand model use. The TPM is maintained by the Traffic Forecasting Section. See TPM section 1.4 for a summary of traffic forecast requirements.

WisDOT completes two types of forecasts: *project-level* and *planning-level*.

Project-level traffic forecasts are developed or reviewed by the Traffic Forecasting Section. The TRAFFIC FORECAST REQUEST form (DT1601) shall be used to request a project-level forecast. The project schedule should allow sufficient time for the preparation of traffic forecasts as stated in the DT1601 form.

Consultants or Metropolitan Planning Organizations (MPO's) may complete traffic forecasts for State Highway projects in some rare instances, and in those instances the Traffic Forecasting Section shall review the completed forecast. The FORECAST REVIEW REQUEST form (DT1594) shall be used to request a traffic forecast review.

Planning-level traffic forecasts are developed by region staff with data maintained and provided by the Traffic Forecasting Section. Contact the appropriate WisDOT Region forecast liaison to request a planning-level forecast; TPM section 70.1. See the Planning-Level Forecast SharePoint page for more information.

Contact the Traffic Forecasting Section at DOTTrafficForecasting@wi.dot.gov with questions.

FDM 11-5-3 Highway Capacity — August 17, 2020

3.1 General

This chapter discusses the evaluation of highway capacity and Level of Service (LOS). The analysis of existing and future operating characteristics of a facility can be measured using Level of Service to provide an indication of the ability of the facility to satisfy both existing and future travel demand. Level of Service is a nationally recognized quantitative measure that is used to describe the quality of travel on a transportation facility. LOS can be measured for various travel modes that include automobile (autos, trucks, buses, and motorcycles), pedestrian, bicycle and transit modes. This FDM chapter will discuss LOS that applies to the automobile mode. In addition to LOS, there are other measures of effectiveness that can be used to enhance the evaluation of mobility needs for the automobile mode (see FDM 11.5-3.2.1).

The LOS measure is stratified into six letter grades, "A" through "F" with "A" representing excellent operating conditions with traffic flowing freely and "F" representing extremely congested conditions. The capacity of a roadway represents the maximum number of vehicles that can pass a point on a roadway in a given amount of time. Each roadway type has a defined method for assessing capacity and level of service, which is based on a set of performance measures. For example, LOS on a freeway is characterized by the traffic speed, proximity to other vehicles, and the freedom to maneuver within the traffic stream. LOS on a rural two-lane highway is defined by the traveler's speed and the ability to pass slower moving vehicles. LOS on urban arterials is defined by the average travel speed, which includes delay incurred at the controlled intersections.

When evaluating the LOS and capacity of a highway, follow the procedures in the 'Highway Capacity Manual 6th Edition' (HCM6): A Guide for Multimodal Mobility Analysis, published by the Transportation Research Board. For further information on how to obtain this document, write or call:

Transportation Research Board Business Office

500 Fifth Street, NW

Washington, D.C. 20001

(202) 334-3213

www.trb.org

Other references on capacity and LOS include: (1) "A Policy on Geometric Design of Highways and Streets," AASHTO 2011. (2) "A Policy on Design Standards Interstate System", AASHTO 2005.

3.2 Congestion and LOS

3.2.1 Congestion and Facility LOS

The LOS thresholds shown in Table 3.1 are considered desirable degrees of design year congestion on Wisconsin facilities. Facilities are lengths of freeways, multilane highways, two-lane highways and urban streets, which are defined by two endpoints. Table 3.1 does not apply to controlled intersections. Intersection LOS is discussed below in subsection FDM 11-5-3.2.2.

When substantial portions of a facility have a current or projected LOS that is more congested than that shown in Table 3.1 the Department may consider improving the LOS preferably through incremental improvements or capacity expansion. Table 3.1 provides desirable LOS values; however, it may not always be feasible to improve congested facilities to the desirable LOS values shown. For example, consider the case where the primary purpose of an improvement project is system preservation. During the scoping phase of this project it is determined that the design year LOS exceeds the desirable LOS threshold. In this case, safety should be the primary reason to make improvements outside of the existing footprint. The Department may elect to address system preservation with no capacity expansion, due to financial, environmental, or community input considerations.

The Department intends to use the mobility performance information to guide State Highway System improvement planning efforts. Such improvements enhance the economy, reduce congestion, improve safety, avoid and minimize environmental impacts, and serve community objectives.

The designer should strive for the best operating performance conditions practical for the facility. A LOS and capacity analysis can be used by designers to assist in determining the design features, including roadway cross-section, which will allow a facility to operate at the desired LOS. There may be situations where an evaluation of capacity or operational improvements supports a higher quality of service due to safety and operational impacts. There may be other situations where an evaluation of capacity or operational improvement supports a lower quality of service due to environmental or economic considerations. When the study involves an evaluation of a highway expansion, adjustments to the LOS thresholds should be approved by the WisDOT Bureau of State Highway Programs, Program Development and Analysis Section. Coordination with FHWA should be made on any Interstate or NHS NEPA project that evaluates capacity improvement elements or expansion alternatives.

Although the LOS analysis and the Table 3.1 LOS thresholds should be part of the decision to consider capacity and operational improvements, there may be other mobility measures of effectiveness that could be used to demonstrate needs and enhance the roadway design, which include but are not limited to:

- Average Travel Speed
- Vehicle Density
- Hours and Cost of User Delay
- Queue
- Travel Time Reliability

In addition to these measures, there may be other operational and safety factors to consider when evaluating projects for capacity or operational improvements. These important factors listed below could also be considered when determining the purpose and need, or criterion to use for the alternative analysis evaluation in the environmental study.

- Projects being considered for system preservation where the LOS is within a reasonable range of the LOS threshold in the design year and the benefits of the improvements (related to factors such as operation and safety) are greater than the marginal cost of the improvements.

- Projects with substantial safety problems that may not be addressed by spot improvements.
- Short highway segments that provide lane continuity and logical connections to major facilities or areas.

The measures selected to evaluate the operational improvements should be consistent with a project's purpose and need. The environmental document should include an explanation of the measures selected to evaluate purpose and need as well as the criteria used to evaluate the alternative improvements.

Table 3.1 Desirable Levels of Service

STH Sub-System	Rural and Small Urban Areas [1]	Urbanized Areas [2] with Population > 50,000
C2030 Backbone and Connector Routes [3]	LOS C (≤ 4.0)	LOS D (≤ 5.0)
National Highway System (NHS) Routes [4] (Non-NHS Backbone and Connector Routes)	LOS D (≤ 5.0)	LOS D (≤ 5.0)
Non-NHS Routes [5] (Other Principal Arterials, Minor Arterials, Collectors and Local Functionally Classified Roads)	LOS D (≤ 5.0)	Mid LOS E (≤ 5.5)

The highest LOS thresholds are applied to the Interstate system routes and other Corridors 2030 system routes in recognition of their importance from a mobility and economic development perspective. The Interstate system within Wisconsin is included in the C2030 Backbone system. Wisconsin C2030 Backbone routes also include a number of other important freeways and expressways. On Corridors 2030 routes, "minimal to moderate" congestion is allowed. Some "severe" congestion is allowed on non-NHS routes in highly urbanized areas. See Table 3.2, which shows the relationship between the LOS alpha value and the numeric value.

3.2.2 Congestion and Intersection LOS

As with roadway facilities, designers should strive to achieve the best intersection level of service (LOS) that is practical given the local land use, economic, social, and environmental characteristics. The designer should aim to balance the level of service for all users of the intersection (e.g., vehicles, pedestrian, bicycles, etc.).

Where practical, on C2030 and NHS routes, strive to provide LOS D or better operations for all movements at the intersection (left, through and right turning movements for each approach) during the peak hours of travel. On non-NHS routes, where practical, strive to provide mid-LOS E or better operations for all movements at the intersection (left, through and right turning movements for each approach) during the peak hours of travel.

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[1] 23 USC 101 (a): "(33) URBAN AREA. The term ''urban area'' means an urbanized area or, in the case of an urbanized area encompassing more than one State, that part of the urbanized area in each such State, or urban place as designated by the Bureau of the Census having a population of 5,000 or more and not within any urbanized area, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by *the Secretary*. Such boundaries shall encompass, at a minimum, the entire urban place designated by the Bureau of the Census, except in the case of cities in the State of Maine and in the State of New Hampshire."

[2] 23 USC 101 (a): "(34) URBANIZED AREA. The term ''urbanized area'' means an area with a population of 50,000 or more designated by the Bureau of the Census, within boundaries to be fixed by responsible State and local officials in cooperation with each other, subject to approval by *the Secretary*. Such boundaries shall encompass, at a minimum, the entire urbanized area within a State as designated by the Bureau of the Census." https://www.gpo.gov/fdsys/pkg/USCODE-2012-title23/pdf/USCODE-2012-title23-chap1-sec101.pdf. The Wisconsin Urbanized Area Boundaries are found at:

http://wisconsindot.gov/Pages/projects/data-plan/plan-res/boundaries.aspx

[3] The Corridors 2030 Map is found at:

http://wisconsindot.gov/Documents/projects/data-plan/plan-res/corr2030.pdf

[4] The National Highway System Routes are found at:

http://wisconsindot.gov/Pages/projects/data-plan/plan-res/nhs.aspx

[5] The National Highway System Routes are found at:

http://wisconsindot.gov/Pages/projects/data-plan/plan-res/nhs.aspx

Where it is not practical to achieve these levels of operation, a reduced LOS may be acceptable for minor street movements or major street non-through movements.

Common scenarios where a reduced LOS may be appropriate include, but are not limited to, the following:

- The minor street is not part of the State Trunk Network (STN)
- The 95th percentile queue for the movement with the reduced LOS is less than four vehicles, or approximately 100 feet, and will not block another major intersection or access point
- Nearby alternate routes are available for drivers to self-divert to a location with lower delay
- The intersection is minor street stop-controlled and centered between two signalized intersections on the major street
- Fewer Impacts to other modes of travel (motorized and non-motorized).

An example of a case where a reduced LOS may not be appropriate includes movements at ramp intersections that impact the mainline Interstate or other freeway operations.

WisDOT will consider reduced LOS operations for specific intersection movements during the design year on a case-by-case basis to determine the most practical level of service. The Bureau of Traffic Operations will review the use of a reduced LOS for intersection or turning movement operations.

Describe the rationale for justifying and accepting the lower LOS for these intersection movements. Document the rationale and decision in the Design Study Report or other capacity evaluation reports (e.g., ICE report). WisDOT shall obtain FHWA acceptance for federally-funded new construction, reconstruction and projects that include capacity improvements, on the NHS or on intersections that can impact interstate movements, such as ramp terminals.

3.2.3 Converting LOS Letter Value to Numeric Value

Table 3.2 shows the relationship between the traditional alpha value for LOS and the numeric value for level of service at WisDOT. The LOS is converted from the alpha-character scale to a numeric scale in order to facilitate a more detailed comparison between segments and to compare segment values with threshold values.

Table 3.2 LOS Alpha/Numeric Value Comparison

LEVEL OF SERVICE (Alpha Value)	LEVEL OF SERVICE (Numeric Value)
A - (Excellent conditions)	1.01 to 2.00
B - (Very good conditions)	2.01 to 3.00
C - (Good conditions)	3.01 to 4.00
D - (Moderately congested conditions)	4.01 to 5.00
E - (Severely congested conditions)	5.01 to 6.00
F - (Extremely congested conditions)	≥ 6.00

The numeric value is calculated using the measure that defines the LOS alpha value. For example, the measure used to define LOS on basic freeway segments is density. For the basic freeway segment, the density range for a given LOS alpha value is equal to the numeric range shown in Table 3.2 (e.g., the density range for LOS E is > 35 to 45 passenger cars per mile per lane (pc/mi/ln) and equates to the numeric range of 5.01 to 6.00). Interpolation is used to calculate the numeric LOS value for a density value that falls between the density ranges for a given LOS alpha value, (e.g., a density of 40 pc/mi/ln is halfway between the LOS E minimum and maximum density range and equates to a numeric value of 5.50). The LOS F range can be difficult to estimate. Therefore, it may be appropriate to show a numerical value of 6+ for conditions that exceed the LOS F threshold.

3.3 Incremental Improvements for Non-Interstates and Non-Freeways

One of the most cost effective and safe ways to make highway improvements is through advanced planning and providing incremental improvements to the system. Evaluate incremental improvements for projects that include capacity improvements in the scope of work. Coordinate the evaluation of all phased alternatives with the region environmental staff as outlined in FDM 20-10.

In rural areas consider the following incremental improvements:

- Passing lanes - providing a passing lane on a two-lane rural corridor could improve the LOS. Passing lanes are advantageous where passing opportunities are limited because of traffic volumes, roadway alignment or a high proportion of slower vehicles. FDM 11-15-10 contains design criteria and guidance on potential locations for passing lanes.

- Truck climbing lanes.
- Turn lanes at intersections.
- Intersection sight distance impacts and geometric improvements.
- Vertical and horizontal alignment improvements,
- Widen lanes and shoulder improvements.
- Access Control.

In urbanized areas consider:

- Access control and review traffic operations at intersections.
- Adding left or right turn bays or extending the length of existing turn bays.
- Review island locations.
- Upgrade the signal timing and phasing.
- Upgrade signal equipment.
- Signal coordination and actuated signal control.
- Conversion to a one-way street, from two-way street.
- Selective removal of on-street parking.

3.4 Incremental Improvements for Interstates and Freeways

Evaluate incremental improvements for projects that include capacity improvements in the scope of work. The evaluation of phased alternatives should be coordinated with the environmental staff as outlined in FDM 20-10. Below is a partial list of potential improvements:

- Add auxiliary lanes between ramps.
- Lengthen exit or entrance ramps.
- Provide additional ramp lanes for turning movements at the ramp terminal intersection.
- Provide collector-distributor roads.
- Extend the length of weaving sections where possible.
- Where heavy volumes of bus or truck traffic exist, evaluate dedicated bus or truck lanes.
- Consider incident management sites to reduce congestion and delay.
- Implement appropriate ITS strategies.
- Part-time use of shoulder
- Travel Demand Management

Facilities which experience occasional severe congestion (such as routes with high flows a few days a year resulting from seasonal tourism or special events) may be candidates for temporary operational strategies such as enhanced motorist assistance patrols, deployment of portable variable message signs, or extra bus service. These mitigation strategies may forestall the need for high-cost capacity improvements for a number of years. Implementation of these measures may require coordination between the DOT, local officials, and the businesses or organizations that generate the extra-ordinary demand. Permanent operational strategies should be considered where recurrent congestion occurs.

3.5 Level of Service Analysis

Conduct a level of service analysis to evaluate the need for incremental improvements, or to determine if alternatives with additional lanes should be included in a project’s range of alternatives. The following list provides examples of types of projects or project tasks that include a LOS analysis.

- Environmental analysis (EA, PEL, EIS) for a potential Major or Mega project
- A corridor study that includes an operational needs evaluation
- Traffic Impact Study (TIA)
- Intersection Control Evaluation (ICE) (See FDM 11-25-3 for further guidance)
- Project scoping when operational problems are projected to occur.
- Design Study Reports

The types of projects that do not require an operational analysis include, but are not limited to:

- activities that do not lead to construction
- utility installation
- activities included in the state's highway safety plan
- installation of noise barriers, fencing or pavement markings.

LOS can be measured for applications that range from the highly detailed to generalized planning applications. The design criteria tables in FDM 11-15-1 and FDM 11-20-1 contain planning level AADT thresholds that could be used for first glance planning applications. The AADT thresholds in the Arterial Design Criteria Tables in FDM 11-15-1 are based on Highway Capacity Manual analyses using conservative data for typical 2-lane and multi-lane roadway configurations. The AADT and DHV thresholds in the Urban Streets Criteria in FDM 11-20-1 provide a general indication of when capacity improvements may be needed. These tables are based on the HCM arterial analysis using the assumptions provided. The dynamics of all the factors used in the urban LOS analysis makes the LOS of individual urban roadways complex and highly variable depending upon the geometric and traffic control conditions.

The WisDOT Meta-Manager model output provides LOS information using site-specific forecasts and roadway information that can be used for more specific planning level evaluation of the need for incremental and capacity improvements. The Meta-Manager mobility model output provides LOS information for existing and proposed traffic conditions under current roadway and geometric conditions. This LOS information is provided for through movements on mainline freeways, rural multilane highways, rural two-lane facilities and urban arterials. The Meta-Manager LOS information should not be used to analyze individual signalized intersections, connections with side roads and freeway ramps. The urban arterial analysis uses system averages for traffic signal timing characteristics and should only be used for a planning and preliminary design level analysis of the corridor. The LOS data, traffic forecasts and roadway conditions are stored in an excel table, within the mobility sheet, located in the "Meta Manager" folder on each Highway Region's local area network. The Meta-Manager document (\\mad00fpH\N8public\BSHP\Meta-manager data\Metadata.doc) provides more specific information about the location of the data and the LOS calculations. For questions about the Meta-Manager LOS information, contact the Bureau of State Highway Programs (See the contact information for mobility data on page 2 of the Meta-Manager document).

WisDOT supported traffic analysis software should be used for more specific traffic analysis or design applications. See TEOpS 16-10 for an overview of available traffic analysis tools that can be used to evaluate traffic operations on WisDOT facilities and intersections. The use of the Highway Capacity Manual for the operational analysis of projects on the NHS is not required if another traffic analysis method is determined to be more appropriate by WisDOT to fully identify and evaluate the performance and impacts of the proposed project alternatives. (See FHWA May 6, 2016 LOS Letter https://www.fhwa.dot.gov/design/standards/160506.cfm).

If HCM or other or microscopic simulation analysis is performed for the evaluation and design of transportation improvement projects, a peer review process should be conducted. The Traffic Model Peer Review process is outlined in the Traffic Engineering, Operations and Safety Manual, Chapter 16, Section 25 (TEOpS 16-25).

Traffic analyses can be conducted by WisDOT, consultant, or local unit of government trained in the use of the Highway Capacity Analysis methodology. In general, begin a traffic analyses by evaluating the existing operation of the project using existing data collected in the field such as traffic volumes, roadway geometrics, traffic control operations (i.e., signal timing plans) and other features (i.e. parking stalls and maneuvers, driveway operations, etc.). Once the existing traffic analyses are calibrated and the results are validated, the existing traffic analyses can be modified to model future traffic volumes, operations and geometric improvements to meet an agreed to level of service.

The level of service analysis of a facility should consider traffic characteristics, roadway conditions, and control conditions of the facility.

3.5.1 Design Hour Volume

The level of service analysis focuses on the existing or projected traffic along a highway or intersection during a particular peak hour. The amount of traffic occurring during this hour is called the Design Hour Volume (DHV). The DHV is one of the most important criterion used in the level of service evaluation. The selection of an appropriate hour for planning, design and operational purposes is a compromise between providing an adequate LOS for most hours of the year and providing economic efficiency. Document the rationale and supporting data for determining the DHV in the DSR or capacity evaluation report. Refer to FDM 11-5-3.5.1.1 for guidance with WisDOT DHV approval on Wisconsin facilities. FHWA approval of the DHV should be requested for federally-funded new construction and reconstruction projects on the NHS.

3.5.1.1 Design Hour Volume for Freeways, Multilane Highways, and Two-Lane Highways

WisDOT policy is to use the 30th highest hour volume of the year as the Design Hour Volume for mainline freeways, mainline multilane highways, and rural two-lane facilities. The 30th-highest design hour may be used when the facility has a small number of hours in the year with higher volumes and has many hours that experience only a small reduction in volumes. However, in cases where traffic patterns are significantly different, other design hour volumes can be justified.

For example, there may be circumstances where the 30th highest design hour is not realistic to use because of exceptionally high hourly volume peaking characteristics. These conditions may occur on routes with a higher level of recreational traffic or routes that are near a stadium, seasonal shopping mall or other special event traffic generator. These routes tend to have higher volumes on a few select weekends or in other peak periods, and traffic during the rest of the year has much lower volumes, even during the week-day commute times.

A higher design hour may be justified when the LOS using the 30th highest design hour cannot be achieved because of social and environmental constraints, or if the project is financially cost prohibitive. When higher design hours are justified, the LOS evaluation should also consider the 100th highest design hour for rural or small to medium urban areas and 200th or 250th highest hour for highly urbanized areas (>200,000 population) with heavy daily traffic. Higher design hours (e.g., 200th or 250th highest hours) may also be justified in urban areas where there is usually little difference between the 30th and the 200th or 250th highest hour. In urban areas, a higher design hour may be justified to be consistent with daily AM or PM peak periods.

A project specific evaluation of the appropriate design hour and associated volumes must be made for all LOS evaluations on projects that include lane additions for a roadway facility. The design hour evaluation should be made by analyzing the traffic volume data from the most applicable continuous traffic count site locations. Additionally, other data sources may be used to supplement the determination of the design hour volumes. A summary of the findings, recommended design hour, and associated volumes should be reviewed and approved for those projects that include lane additions, by the WisDOT project team, in conjunction with the Bureau of State Highway Programs, the Bureau of Traffic Operations, and the Traffic Forecasting Section. The Federal Highway Administration must approve deviations from the 30th highest design hour on interstate projects.

The traffic forecast provides the annual average daily traffic (AADT). The K factor and the design hour directional distribution (D) are located on the Traffic Forecast webpage. The K factor is defined as the design hour volume divided by the annual average daily traffic (AADT) that occurs for the design year. Refer to FDM 11-5-2 for guidance on how to obtain traffic forecasts.

If the directional design hour volume (DDHV) is to be computed using the K factor, one of the following formulas can be used:

$$DDHV = AADT * K_{(both\ directions)} * D$$

Where:

DDHV = directional design hour volume (veh/hr)

AADT = annual average daily traffic in both directions (veh/day)

$K_{(both\ directions)}$ = proportion of AADT occurring in the design hour for both directions combined

D = proportion of traffic in the highest direction during the design hour

If the analysis of DDHV includes data from continuous count site locations, the K factor may be computed by direction rather than for both directions.

$$DDHV = AADT * K_{(one\ direction)}$$

Where:

DDHV = directional design hour volume (veh/hr)

AADT = annual average daily traffic in both directions (veh/day)

$K_{(one\ direction)}$ = proportion of AADT occurring in the design hour for one direction only

3.5.1.2 Design Hour Volume for Urban Streets, Intersections and Ramp Terminals

The design hour volume used for a detailed analysis of urban arterials, intersections, ramps, and ramp terminals should be based on the AM or PM peak hour volume for individual turning and through movements. In some cases where significant traffic is occurring on the weekend or mid-day, it may also be appropriate to consider mid-day peaking. In urban corridors, directional traffic patterns and intersection turn volumes are seldom the same in the AM and PM peak hours, so it is usually necessary to analyze the traffic operations for at least two different time periods. Additionally, other data sources may be used to supplement the determination of the design hour volumes.

The traffic forecast provides the AADT and turning movement projections for intersections if needed. The K factor and the design hour directional distribution (D) are located on the Traffic Forecast webpage. Refer to FDM 11-5-2 for guidance on how to obtain traffic forecasts.

3.5.2 Peak Hour Factor (PHF)

The peak hour factor is the ratio of the total hourly volume to the rate of flow during the highest 15-minute period within the hour and is computed by the following equation.

$$PHF = \frac{V}{4\,x\,V_{15}}$$

Where:

PHF = peak hour factor

V = hourly volume (veh/h)

V_{15} = volume during the peak 15 minutes of the analysis hour (vehicles in 15 min)

After the PHF is calculated, it can be used to convert a peak hour volume to a peak hour flow rate (v), using the following formula:

$$v = \frac{V}{PHF}$$

The PHF for controlled intersections is calculated at the intersection level and then the intersection PHF is applied to each of the movements.

3.5.2.1 Facility Segments

The PHF for the existing conditions can be based on existing field data. If field data does not exist, the recommended HCM default can be used. For design year conditions use a PHF of 1.0.

3.5.2.2 Intersections

In most cases, use the PHF derived from the existing field data for intersection LOS analyses. If the existing field-derived PHF is less than 0.92 (the recommended HCM default), however, it may be appropriate to utilize a higher PHF for the analyses of design year conditions. Use of any value other than the field-derived PHF requires coordination with and approval from the regional traffic engineer or the Bureau of Traffic Operations.

In general, apply the PHF to all turning movements and approaches at the intersections. In those cases where one approach to the intersection has significantly different peaking characteristics than the rest of the intersection (e.g., one approach provides direct access to a school), coordinate with region traffic operations or BTO to determine whether it is appropriate to use a different PHF for that one approach.

3.5.3 Percent Heavy Vehicles in the Design Hour

In general, the percentage of trucks in the design hour is lower than the percentage of trucks over an average day. This lower percentage is because there is a higher percent of total vehicles in the design hour. Sometimes trucks try to avoid traveling in peak conditions, thus care must be taken when estimating heavy trucks.

Mainline design hour truck percentages can be found at http://wisconsindot.gov/Pages/projects/data-plan/traf-fore/default.aspx.

3.5.4 Driver Population Factor

The capacity can be adjusted to account for unfamiliar drivers in the traffic stream, using the capacity adjustment factor (CAF). In general, the factor for driver population should be set to 1.0, which assumes the traffic stream is comprised of regular drivers. A lower number may be justified if sufficient empirical data is used to support that a significant amount of the drivers are unfamiliar with the corridor. In those cases where the corridor contains a higher percentage of recreational or unfamiliar drivers, the driver population factor should range between 0.9 and 1.0.

3.5.5 Rural Roadway Conditions

Capacity and LOS on rural highways are at a minimum affected by the following:

- Number and widths of travel lanes
- Shoulder widths
- Percent no-passing zones
- Number of access points or interchange density per mile
- Terrain type
- Free flow speed

Wisconsin highways use only the level and rolling terrain classifications. Level terrain generally includes corridors that contain grades of no more than 3 percent. These corridors include any combination of horizontal and vertical alignment permitting heavy vehicles to maintain approximately the same speed as passenger cars. Within level terrain corridors there may be isolated sections on two-lane highways that require climbing lanes to mitigate the speed variance between passenger cars and trucks. Rolling terrain generally includes grades of significant length greater than 3 percent grade and will cause heavy vehicles to reduce their speed substantially below the speed of passenger cars. Typically, rolling terrain corridors are similar to those found near the Wisconsin River Valley, in the southwestern part of the State. Mountainous terrain is not used in Wisconsin. The Meta-Manager database provides an estimate of segments with rolling terrain that can be used for a planning level analysis.

3.5.6 Urban Roadway Conditions

Capacity and LOS on urban streets are at a minimum affected by the following:

- Presence of exclusive turn lanes.
- Number and lengths of exclusive turn lanes.
- Presence of medians.
- Level of access control.
- Presence of parking and bus stalls and frequency of maneuvers within those stalls.
- Number and widths of travel lanes.
- Free flow speed

3.5.7 Intersection Control Conditions

Capacity and LOS at an intersection will be affected by as the following control conditions:

- Type of intersection control (stop condition, traffic signals, or roundabouts).
- Traffic signal timing characteristics and level of coordination between adjacent traffic signals or within a system of traffic signals.

Refer to FDM 11-26 for guidance on roundabouts. Refer to FDM 11-50-50 for guidance on traffic signals or the "Traffic Signal Design Manual" (TSDM). The Region traffic personnel typically use the TSDM.

3.6 Level of Service Evaluation for Environmental Documentation

The design year LOS and supporting information shall be completed for highway improvement projects that involve the following environmental documents:

- Environmental Report (ER)
- Environmental Assessment (EA)
- Environmental Impact Statement (EIS).

A traffic summary matrix (refer to Basic Sheet 4, Traffic Summary Matrix found at https://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/environment/formsandtools.aspx) is required for projects that require a ER or an EA.

The environmental evaluation should be coordinated with the region environmental staff as outlined in FDM 20-10.

The Meta-Manager model output can be used to determine the LOS under existing conditions and proposed conditions for environmental documents, when no substantial geometric or operational changes are proposed. For example, the Meta-Manager output should not be used to determine the project's LOS when adding or reducing the number of thru lanes, adding or eliminating medians or two-way left turn lanes (TWLTLs), adding or eliminating left or right turn lanes, adding or removing parking lanes, installing or retiming traffic signals, improving signal coordination, and significantly adding or eliminating the number of access points. (See the previous Level of Service Analysis section of this FDM chapter for the location of the Meta-Manager LOS data).

Projects that include significant geometric or operational changes should have a project specific traffic analysis completed to determine the LOS. The following section on Traffic Analysis Software provides guidance on the appropriate analysis software that could be used for those evaluations.

3.7 Traffic Analysis Tool Selection

The following provides a general overview of the available traffic analysis tools. Guidance on selecting the specific traffic analysis tool software is available in the Traffic Engineering, Operations, and Safety Manual, Chapter 16, Section 10 (TEOpS 16-10).

3.7.1 Overview of Available Analysis Tools

Several traffic analysis tools are available to assist transportation professionals in evaluating traffic operations on WisDOT facilities. Most studies, including traffic impact analysis, intersection control evaluations, traffic signal timing, design reports, turn lane warrant assessment, work zone delay analysis, corridor studies, and system level analyses include an evaluation of operational conditions.

There is no “one size fits all” traffic analysis tool. The tools used for each analysis vary in their data requirements, capabilities, methodology, and output. Tools that are more powerful require greater time and effort, so it is important to match the analysis methods with the scale, complexity, and technical requirements of the project. A project may require the use of a combination of multiple traffic analysis tools. Document the rationale for choosing the selected traffic analysis tool(s) in the Traffic Analysis Tool Selection memoranda and submit to the WisDOT regional traffic staff for approval.

3.7.2 Capacity Analysis

WisDOT accepts the use of HCM6, methods in order to meet the planning, operational, and design analysis needs of most traffic studies. For project analysis initiated prior to November 2017, it may be acceptable to continue to follow the HCM 2010 methodologies for the duration of the project. Coordinate with the regional traffic engineer or BTO-TASU to verify whether to continue using the HCM 2010 methodologies or whether to update to the HCM6 methodologies.

The methodologies of the HCM should be the primary way of determining the performance measures required for a variety of traffic study projects reviewed or commissioned by WisDOT. Refer to TEOpS 16-15 for additional guidance on the specific methodological components for the core facility types addressed by the HCM.

Analysts should recognize and account for the limitations of the HCM methodology. When the analysis falls outside the confines of the HCM methodology, the project manager should specify the use of an alternative tool, such as microsimulation. Refer to TEOpS 16-20 for additional guidance on the use of microsimulation.

3.7.3 Model Calibration and Validation

All traffic analysis tools require some degree of calibration and validation to assure that their outputs match actual field conditions. For both deterministic and simulation tools, WisDOT supports changes to default and input parameters to best replicate observed conditions. For example, TEOpS 16-15 provides guidance on adjustments to saturation flow rate and right-turn on red parameters for HCM-based deterministic analysis of traffic signals. Calibration is particularly important in microsimulation models, where there are many assumptions and parameters that can affect the simulation. Provide clear documentation of the model development and calibration process to identify the model input parameters and any adjustments made to default values to reflect field measured or otherwise expected conditions.

Calibration and validation is essential for the validity of the analysis process and the project manager should assure that the project schedule and budget devote sufficient time and resources to this crucial step. Additional guidance on the calibration and validation of microsimulation models is available in TEOpS 16-20.

To ensure the integrity of the calibration process and model results, the region shall conduct a peer review of all traffic models (microsimulation and deterministic models) as outlined in the TEOpS 16-25.

FDM 11-5-5 Access Control

May 15, 2019

5.1 Introduction

According to the TRB Access Management Manual[6], “Access management is the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway. It also involves roadway design applications, such as median treatments and auxiliary lanes, and the appropriate spacing of traffic signals. The purpose of access management is to provide vehicular access to land development in a manner that preserves the safety and efficiency of the transportation system.”

Both the AASHTO GDHS and the TRB Access Management Manual describe Access Management Principles:

[6] See p.3 in (*1)* Introduction and Concepts. In *Access Management Manual* Transportation Research Board, 2003, ch. 1, pp.3-11.

Table 5.1 Access Management Principles

AASHTO[7]	TRB[8]
Classify the road system by the primary function of each roadway Limit direct access to roads with higher functional classifications Locate traffic signals to emphasize through traffic movements Locate driveways and major entrances to minimize interference with traffic operations Use curbed medians and locate median openings to manage access movements and minimize conflicts	Provide a specialized roadway system Limit direct access to major roadways Promote intersection hierarchy Locate signals to favor through movements Preserve the functional area of intersections and interchanges Limit the number of conflict points Separate conflict areas Remove turning vehicles from through-traffic lanes Use nontraversable medians to manage left-turn movements Provide a supporting street and circulation system

See FDM Chapter 7 for additional guidance on Access management and control.

5.2 State Access Management Plan (SAMP)

Chapter 9 of WisDOT's Connections 2030 Statewide Long-Range Transportation Plan revised the State Access Management Plan (SAMP) and increased the number of tiers from two to five. All STH routes are assigned to one of the tiers.

- Tier 1 maximizes Interstate/Statewide traffic movement
- Tier 2A maximizes Interregional traffic movement
- Tier 2B maximizes Interregional traffic movement
- Tier 3 maximizes Regional/Intra-urban traffic movement
- Tier 4 balances traffic movement and property access

See FDM 7-5-1 for additional guidance.

5.3 Spacing

These guidelines are intended as a tool in relating access to facility type, functional type, and traffic volume of both the route under study and intersecting routes. Attachment 5.1 shows rural arterial access spacing. The access spacing determined from Attachment 5.1 is the minimum distance between that intersecting facility and adjacent similar type or higher type access points (private, public, at-grade, or interchange) without regard to functional classification of the adjacent access points.

Refer to FDM 11-30-1 regarding ramp terminal spacing

Urban charts are not part of this guide. Since urban areas are unique, other controls such as existing development and street spacing usually require varying degrees of access. See FDM 11-25-2 for guidance on corner clearance to driveways. See FDM 11-25-2, FDM 11-25-5 and FDM 11-25-20 for guidance on median openings.

Also, no recommendation is given for "Routes Under Study" functionally classified lower than arterial. Lower classified routes vary considerably.

Consider the possibility of changes in the degree of access control of a highway whenever modernization is contemplated. The investigation should consider both the immediate effects of changes and the impact of future development. Changes in land use patterns and intensity that occur during the ultimate life of the right-of-way

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[7] See p.90 in (*2) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

[8] See pp.7-10 in (*1*) Introduction and Concepts. In *Access Management Manual* Transportation Research Board, 2003, ch. 1, pp.3-11.

will have a great effect upon the traffic patterns and highway obsolescence. It is desirable to control access according to conditions expected to exist during the latter part of the road's life expectancy.

By 2010 Wisconsin communities, including counties, should have adopted comprehensive plans which are required in order to make valid local zoning and land division decisions. Public utilities base their plans for future expansion of services on predicted population growth and movement. All of these are good sources of information about the future land uses that could affect state highways.

The proximity of adjacent intersections to locations that are or may be signalized should be maintained at a minimum of 1200-ft, unless a greater distance is shown in Attachment 5.2. See Traffic Signal Design Manual (TSDM) at:

https://wisconsindot.gov/Pages/doing-bus/local-gov/traffic-ops/manuals-and-standards/tsdm/tsdm.aspx

5.4 Intersecting Roadways

Determine the extent of access control to apply around intersecting roads. The degree and length of this control depends, for the most part, on the design of the intersection (stop or free-flow design), traffic volumes using the intersecting highway, and traffic generated by the adjacent property. Factors generally considered are the number and speed of vehicles approaching an intersection and the conditions of entrance to the major highway (i.e., stop, yield, unmarked). Other considerations may include intersection sight distance and vision corners addressed in FDM 11-10-5; or functional area and corner clearance addressed in FDM 11-25-2. Further extension or expansion of access control along intersecting roadways must be evaluated on a project-by-project basis.

5.5 Interchange Areas

Interchanges are expensive to build and to upgrade. Therefore, it is essential that they be designed and operated as efficiently as practical. To preserve their intended function, adequate geometry at ramp termini and appropriate access control along the crossroads are essential.

Many older interchanges have been designed with only limited access control on the intersecting crossroad. As a result, considerable development may occur near the intersection of the ramp terminus and the crossroad. Over time, such ramp termini, as well as several nearby access connections, may require signalization or roundabouts, thereby causing increased delay on the crossroad.

In urbanized areas, high turning volumes and close spacing between adjacent ramp termini and access connections can create operational problems on the crossroad that can cause; extensive queuing, delay, heavy weaving volumes, and poor traffic progression. Ultimately, these types of problems at the ramp termini can affect traffic on the ramp and may cause spill back onto the mainline freeway. These problems consist of queue spillback, stop-and-go travel, heavy weaving volumes, and poor traffic progression.

To ensure efficient operations along the crossroad at an interchange, adequate lengths of access control need to be a part of the overall design of an interchange. This minimizes potential for queue spill back on the ramp and cross road approaches to the ramp terminus. Increased spacing between access points will also provide adequate distances for weaving on the crossroad, provides space for merging maneuvers, and provides space for storage of turning vehicles at access connections on the crossroad.

Access control at interchanges should be coordinated with local zoning authorities.

For additional guidance, see pp. 749-752 of the AASHTO GDHS[9], “Access Separations and Controls on the Crossroad at Interchanges.”

5.5.1 Access Control on Interchange Crossroad

Access control at an interchange along the crossroad shall comply with Table 1 of Attachment 5.2, but not be less than intersection corner clearance as defined in FDM 11-25-2.

- Do not allow new access between the interchange ramp and the public road.
- If private access already exists on the crossroad between the ramp and the public road, evaluate the potential cost of either removing that access or restricting it to right-in, right-out only. It may be justifiable to allow interim access until the access use changes or until the traffic volume from the access point justifies a higher level of intersection control than a stop condition. The access is then re-evaluated for removal. Consider what costs and impacts there may be if it is necessary to go back at some time in the future and acquire or close access due to serious operational problems. Do not allow

[9] (*2) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

a median opening between the interchange ramp and the Public Road.

- Do not allow access on the cross road in the transition area (merge or diverge condition) from 4-lanes down to 2-lanes.

Refer to the Transportation Research Board, Access Management Manual 2003, pages 158-162, for additional guidance on interchange area management.

5.5.2 Access Control Along an Expressway at an Interchange

Access control at an interchange along an expressway shall extend from the merge/diverge point of entrance/exit ramps as shown in Attachment 5.2 and shall comply with the distances shown in Table 2 of Attachment 5.2.

5.6 Traffic Impact Analysis

On both expressways and their cross roads, an approved traffic impact analysis is required to justify a less-than-upper range distance of access control. This analysis shall be included in the project file. Consider the following factors when evaluating access control distance:

1. Mainline, ramp and side road projected design year AADTs, including turning movements to and from the side road.
2. Intersection geometry, including turn lane lengths
3. Weaving and deceleration distances.
4. Posted speeds
5. Sight distance (horizontal and vertical)
6. Intersection sight distance
7. Zoning
8. Estimated cost of real estate acquisition to achieve access control,
9. Estimated cost of roadway improvements to achieve access control

5.7 References

1. TRB Committee on Access Management (ed.). Introduction and Concepts. In *Access Management Manual*. Transportation Research Board, Washington, DC, 2003, ch. 1, pp. 3-11.

2. *A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, Washington, DC, 2004.

LIST OF ATTACHMENTS

Attachment 5.1	Access Spacing Guidelines
Attachment 5.2	Access Control for Typical Interchange

FDM 11-5-10 Earthwork *August 17, 2020*

Careful consideration of the design elements affecting earthwork quantities and distribution is necessary for both economic and environmental reasons. (See FDM 19-7-1 for guidance on rock excavation.)

10.1 Preliminary Design

During the preliminary design phase several alternative grade lines and alignments should be evaluated. Earthwork quantities, including the required distribution of earthwork, should be developed for each alternative. It is desirable that the final alternative chosen result in balanced earthwork quantities, but this is not always feasible because of other controlling factors.

For urban projects the primary consideration is to minimize property damage by designing the street or highway to match, as nearly as possible, the elevations of the adjacent development. Because of this requirement earthwork may have to be wasted or borrowed.

For rural projects an alignment and grade line can often be developed that will satisfy the principal controlling features (e.g., clearance under structures, meeting crossroad elevations, adequate fill height over marsh, adequate drainage ditches, etc.) and yet provide balanced earthwork quantities. Design of the grade line should include a detailed analysis of earthwork distribution considering haul lengths, haul direction, and the capabilities of typical earthmoving equipment. Distances to potential borrow or waste sites should also be considered.

10.2 General Considerations

In general, long cuts and fills should be avoided, as larger and more expensive grading equipment becomes necessary for efficient earthmoving operations. Track or wheel type bulldozers are most efficient when material is moved less than 200 feet or steeply downhill. For longer hauls scrapers become necessary. Very long hauls or hauls on public highways require the use of dump trucks loaded by front-end loaders, power shovels, or belt conveyors.

Analysis of earthwork distribution, including the locating of earthwork divisions and the plotting of a mass diagram, can be accomplished by computer methods. The mass diagram can be a valuable tool in the planning or understanding of a grading operation, as it provides a convenient graphic display of cumulative volume over an entire project. It is not necessary to include the mass diagram in the plans, but the earthwork divisions and mass ordinates should be shown.

Design of grading projects must include provisions for the removal of undesirable or loosely compacted materials. Undercutting the mouths of cuts should be specified to remove the topsoil and humus material, which if left could result in settlement or frost heave in the transition from cut to fill.

Similarly, other sections of the grade may contain material that should be removed to assure adequate compaction can be achieved. Excessively wet or supersaturated soil should be removed and placed where it can be drained. The material itself may be adequate once it is dry.

The shaping and rounding of cut slopes should always be specified, especially in the transition to fill, as this significantly improves the highway's appearance and is less susceptible to erosion.

10.3 Project Scheduling

Earthwork issues must be analyzed carefully whenever a grading project is built in stages. There are times when the earthwork quantities for an overall project will either be in balance or be a waste project. In either case the overall project does not require borrow material. If, however, the project is built in stages, there may not be enough cut material available to meet the fill needs of a particular stage. Designers must evaluate the cut-versus-fill situation for each stage of the overall project.

10.4 Total Volume Concept for Project Earthwork.

The Department employs the “Total Volume Concept” for project earthwork. For earthwork purposes, the project is considered a single entity unless physical barriers (such as river crossings, railroads, highways and etc) or staging needs require separation into two or more divisions. Within each division, the total excavation volume is compared to the total embankment volume to determine borrow volume or waste volume for that division. Payment for all excavation and for all borrow within a division is at the established unit cost with no adjustments for haul distances. This concept involves:

1. A running total of earthwork volume showing excess or deficiencies is included in the plan. This is done on the earthwork data sheets immediately preceding the cross sections on a plan. (an EXCEL spreadsheet: FDM 11-5 File 1)
2. No balance points or references to these are shown in the plan. If a project has two or more divisions, each division is identified in the earthwork data sheets and the earthwork summary sheet.
3. Borrow or waste volumes are determined by a summary of all earthwork demands within each specific division. Each determined division of the project is considered a separate entity. If a contractor elects to use the “waste” identified in one division as “borrow excavation” in another division, the contractor will be paid, both, “common excavation” in one division and “borrow” in the other division. **Note to the designer: the designer must specify in the special provisions if the contractor is prohibited from using the waste from one division as borrow in another division.**
4. The item of overhaul has been eliminated. If there are significant changes in conditions or character of work, the contractor may be justified in seeking payment for additional hauling cost under standard spec 104.2.2 (Issuing Contract Change Orders).
5. Grading operations are conducted in the manner that best fits the operational needs of the contractor while fulfilling contract requirements. This may include wasting common excavation in one portion of the project division and replacing it with borrow in another portion of that division. However, this does not change the contract borrow volume and the Department only pays for borrow needed in excess of suitable available excavation.
6. The engineer may authorize the contractor to obtain material for embankment construction from areas

within the right of way, but outside of the grading limits. The Department will pay for borrow material obtained from within the project right-of-way limits but outside project excavation limits at a price determined under standard spec 109.4 (Price Adjustments for Contract Revisions).

7. Common excavation materials determined by the engineer to be unsuitable for the embankment construction will be wasted and replaced by borrow paid at the established unit price. If no item for borrow is included in the contract, payment will be as extra work.

10.5 Borrow

The designer should strive to eliminate or at least minimize the use of borrow because of its cost and potential to delay project completion. Contractors are required to pay increasingly higher prices for borrow material, especially in areas of the state where acceptable sites are difficult to find. Environmental, archaeological, and historical considerations can prevent the use of otherwise acceptable sites. Even with apparently acceptable borrow sites, there is the potential for delay of the excavation if significant archaeological or historical materials are uncovered. WisDOT has a cooperative agreement with the Wisconsin State Historical Society to advise them of any such finds. (See Chapter 20 for details of this agreement.)

Earthwork designs that result in small borrow quantities, say, less than several thousand cubic yards, should be avoided. Small borrow quantities often result in high unit bid prices; then if actual borrow quantities greatly exceed the estimates, the cost of the item becomes excessive.

10.6 Earthwork Quantities

Earthwork quantities should be included on each cross-section sheet unless a separate “Earthwork data” sheet, identified in FDM 15-1-40, is included in the plan.

10.7 Earthwork Computations

The end areas and volumes used in earthwork computations should be the end areas and volumes with all adjustment applied. The expansion and reduction factor for all earth materials should be obtained from the soils report for the project or from the regional soils engineer.

During the process of grading, rock excavation is normally the only excavation item that expands and occupies a greater volume in the fill than it did in its original location. Cut and borrow excavation shrinks and occupies less volume in the fill than it did in its original location.

The marsh expansion factor indicates the percent that the marsh excavation quantity should be increased to determine the amount of marsh backfill required. This factor accounts for; the shrinkage of the backfill material placed in the marsh, the displacement of the marsh during the excavation and backfilling process and one (1) foot of granular backfill or select borrow material placed above the marsh (if granular backfill or select borrow is specified).

If the marsh or EBS will be used as part of the embankment, the earthwork summary sheet should indicate the volume of marsh or EBS and the estimated reduction factor for the embankment. When marsh or EBS is used as part of the embankment, outside of the 1:1 slopes, the designer must include a construction detail identifying the area where the material is designated to be used. The soils engineer should be consulted to confirm that the marsh or EBS is suitable for use in the embankment and to provide the estimated reduction factor.

The following are some of the volume correction factors that are used in earthwork computations:

1. Fill Expansion (>1): applied to the true fill volume to account for only the shrinkage of the cut and borrow material placed in the embankment.
2. Rock Expansion (>1): applied to the rock excavation volume to account for the volume of rock material after it is excavated and placed in the embankment. Rock excavation expands as it is excavated to be used in the embankment. This may also be referred to as “rock swell”.
3. Marsh Backfill Expansion (Typically >1): applied to the volume of marsh that is excavated to account for; the shrinkage of the backfill material, the displacement of the marsh during the excavation and backfilling process, and one (1) foot of granular backfill or select borrow placed above the marsh (if granular backfill or select borrow is specified). This factor is used to determine the volume of marsh backfill that is required. This volume is used in the mass ordinate computations only if cut or borrow is used as backfill material. If select borrow or granular backfill is specified, then this volume is not used in the mass ordinate.
4. Marsh Reduction (<1): applied to the volume of marsh excavation to account for the true volume of marsh material after it is excavated and placed in the embankment. Marsh excavation shrinks considerably as it goes from its natural state to its compacted state in the embankment. If marsh

excavation is utilized in the construction of the embankment, it is typically used outside of the 1:1 slope and may be restricted in height of fill. The designer may elect to waste the marsh excavation, in which case this factor is not used in the earthwork computations.

5. EBS Backfill Expansion (>1): applied to the true volume of EBS to account for the shrinkage of the backfill material used to backfill the EBS. This factor is usually close to, or the same as, the fill expansion factor on a given project, depending on the backfill material specified. Frequently, this is assumed to be the same as the fill expansion factor and the EBS backfill volume may be computed separately or as part of the fill in the mass haul computations. If select borrow or granular backfill is specified for EBS backfill, then this volume is not part of the mass ordinate.
6. EBS Reduction (<1): applied to the true volume of EBS excavation to account for the reduced volume of EBS as it is placed in the embankment. EBS typically shrinks as it goes from its natural state to its compacted state in the embankment. The appropriate factor can vary widely depending on what type of EBS material is encountered on a project. If the material is utilized in the construction of the embankments, it is typically placed outside the 1:1 slopes and may be restricted in height of fill. The designer may wish to waste the EBS material, in which case this factor is not used in the earthwork computations.

There are two methods that are used to determine the volume of earthwork quantities. These two methods are referred to as the “shrink the cut” and the “expand the fill” method.

The “expand the fill” method of earthwork computations requires the user to visualize the fill as expanding in order to account for the actual shrinkage of the cut or borrow material placed in the fill. The fill does not actually expand. The expansion factor applied to the fill is an estimated value that accounts for the percent increase in the volume of cut or borrow excavation, as measured in its original location that is needed in the fill.

The earthwork calculations shall use the “expand the fill” method. The “expand the fill” method involves the following process:

Step 1

Determine the usable volumes of all excavation and fill materials as well as the expansion/reduction factors for each material.

Step 2

If rock excavation is present, expand the rock volume and deduct this from the unexpanded fill.

Step 3

If marsh excavation is present, and the excavated marsh will be used in constructing the embankment slopes, reduce the marsh excavation volume and deduct this from the remaining unexpanded fill.

Step 4

If EBS is present, and the EBS material will be used in constructing the embankment slopes, reduce the EBS excavation volume and deduct this from the remaining unexpanded fill.

Step 5

Expand the fill volume that remains after completing steps 2 -4.

Step 6

If marsh is present, expand the marsh excavation volume to determine the required volume of marsh backfill. If common or borrow is used to backfill the marsh, it is part of the mass ordinate. (Note: if select borrow or granular backfill is specified for marsh backfill, this volume is expanded to determine the volume of select borrow or granular backfill but is not used as part of the mass ordinate.)

Step 7

If EBS is identified, expand the EBS excavation volume to determine the volume of EBS backfill. If common or borrow is used to backfill the EBS, it is part of the mass ordinate. (Note: If select borrow or granular backfill is specified for EBS backfill, this volume is expanded to determine the volume of select borrow or granular backfill but is not used as part of the mass ordinate).

Step 8

Determine the remaining volume of cut, after the marsh or EBS is backfilled, by deducting the marsh or EBS backfill determined in steps 6 and 7 from the cut. (Note: if select borrow or granular backfill is specified for marsh or EBS backfill, the marsh or EBS backfill does not affect the cut volume and would have a value of zero

(0) in this equation).

Step 9

Determine the required borrow (minus value) or waste (plus value) by subtracting the expanded fill, determined in step 5 from the remaining volume of cut, determined in step 8.

Earthwork will normally be designed and computed using the Civil 3D earthwork process. However, it is recommended that, as a minimum, the designer perform manual computation checks at each segment and each earthwork division identified in the earthwork summary table in the miscellaneous quantities section of the plan.

Two examples of earthwork calculations are included in Attachment 10.1.

10.8 Excess Incidental Excavation

Excess excavation material from the construction of storm sewer, bridges, retaining walls, etc. should be placed in embankments if the material is suitable for that purpose. On projects where the quantity of unclassified excavation or borrow is small and excess incidental excavation is large, the designer should investigate the adequacy of the incidentally excavated soil for use as fill. If it is acceptable, show such quantities in the plan in the earthwork balance tables or earthwork summaries. If this material is not suitable for embankment construction, it shall be incorporated into the project or disposed of in accordance with standard spec 205.3.11.

10.9 Soil Compaction

Attachment 10.2 is a set of guidelines concerning soil compaction. It explains some of the factors which should be considered when choosing between standard compaction, special compaction, and QMP Earthwork for individual projects.

The Region Soils Section is responsible for analyzing soils and recommending the proper soil compaction inspection method for region designed projects. Region designers should confer with their soils unit to determine which method should be applied to individual projects. Consultants are responsible for analyzing the soils for the projects they are designing and for recommending the proper soil compaction inspection method to use.

10.10 Bridge Approach Embankments

Bridge approaches represent a special earthwork situation. They should be constructed using one of the techniques shown in Attachment 10.3. The recommended procedure is shown in Attachment 10.3, Detail A. The 10:1 slope will permit concrete trucks to approach the bridge site while the 20-foot section provides contractors with adequate room to use standard compaction equipment.

Attachment 10.3, Detail B is an alternative embankment construction procedure. It is best suited for sites having non-cohesive, uniform particle size granular materials. It calls for overfilling the abutment back slope, then cutting it back only that distance necessary to construct the abutment. If possible, this surcharge embankment material should be left in place for at least six months prior to bridge construction if the foundation material is compressible. Sheet piling may be needed to retain granular embankment material.

Designers should seek the advice of their region soils section concerning which method of approach embankment construction to use. Designers should provide their soils staff with tentative grades and foundation site information. Site soils reports should also be reviewed before making a decision.

10.11 Geosynthetics

10.11.1 General

Different types of geosynthetics, geotextiles and geogrids, are used in transportation projects for the following applications:

Table 10.1 Applications for Geosynthetics

GEOTEXTILES (type)		GEOGRID (type)
Subgrade Aggregate Separation (SAS)	Modified SAS(C)	Subgrade Reinforcement (SR)
Subgrade Reinforcement (SR)	Embankment Stabilization (ES)	Marsh Reinforcement (MR)
Riprap (R)	Heavy Riprap (HR)	Slope Stability Reinforcement (SSR)
Drainage Filtration (DF)	Marsh Stabilization (MS)	

Standard spec 645 includes bid items for various applications. Most of these bid items have complete specifications for typical applications, but several require project specific customization and are specifically designed to require associated special provisions.

10.11.2 Items Requiring Project Specific Customization

Designers need to consult the Regional Soils Engineer or Bureau of Technical Services Geotechnical Engineering Unit for assistance with the design of type MS, SR, and ES geotextiles; and for type MR and SSR geogrids. Modify the standard bid items for individual projects; do not develop SPV bid items.

Geotextile types MS, SR, and ES require a project specific special provision modifying the standard spec bid items to specify required material properties. In addition, other materials and construction provisions may be required to fit the individual project requirements.

Geogrid types MR and SSR require an STSP modifying the standard spec bid items to specify both materials and construction requirements. These STSPs contain the framework for additional contract requirements, but the designer must come up with the actual requirements.

- For Geogrid Type MR use STSP 645-024 "Geogrid Type MR"
- For Geogrid Type SSR use STSP 645-026 "Geogrid Type SSR"

LIST OF ATTACHMENTS

Attachment 10.1	Earthwork Calculation Examples
Attachment 10.2	Compaction of Soils
Attachment 10.3	Bridge Approach Construction Techniques

FDM 11-5-15 Select Materials in Subgrades

December 5, 2017

The following policy will be in effect for rural state trunk highway projects and urban freeway projects constructed after 2006. In the interim, designers are encouraged to use this policy on a selective basis on applicable projects. However, funding for such applications of select materials must come from established project allocations or from other region program allocations. This policy will not affect the common practice of ordering the use of select materials during construction to correct site-specific problems.

15.1 Policy

WisDOT policy will require using select materials in the upper portions of subgrades developed from soils that are difficult for subgrade construction. These include:

- All silty soils,
- Most silty clay soils,
- Soft clay soils,
- Mineral soils with a high organic content, and
- Any other soil with a history of problems relating to subgrade construction.

The shaded portion of Attachment 15.1 is designated the Standard Inclusion Area. It shows those areas in the state where these soils predominate.

Select materials will be used in subgrades for projects located in the Standard Inclusion Area shown in Attachment 15.1 unless the project soils report recommends against such application and provides suitable justification for this recommendation.

The non-shaded portion of Attachment 15.1 is the Standard Non-Inclusion Area. Here better soils predominate and select materials are normally not needed for subgrade construction. Select materials may, however, be used on specific projects in the Non-Inclusion Areas if the soils report identifies significant areas of difficult soils and recommends such treatment.

15.2 Application

This requirement will apply to all projects with significant earthwork volumes. Select materials may be used in subgrades on safety improvement projects or other projects with minor volumes of earthwork if such use is warranted by project requirements, time constraints, or other considerations. The soils report should provide a recommendation for use on projects of this type. **The requirement for select materials will not apply to resurfacing projects, pavement replacement projects, or projects with incidental amounts of earthwork.**

Select materials may be applied to discreet segments of a project based on changes in soil conditions. Such selective use must be based on recommendations for specific areas contained in the soils report.

Select materials will be required in both cuts and fills unless otherwise recommended in the soils report. Cut areas may be excluded if the material at and below subgrade elevation is identified as stable material such as rock, gravel, sand, or dense till. Fill areas in which the top four feet of the subgrade is constructed from rock excavation may also be considered for exclusion.

15.3 Design

Attachment 15.2 shows specific materials and depths for ten different systems of select materials. These ten systems are considered to have equivalent performance and shall be used to provide the select materials for subgrades. The soils report should recommend which system or systems may be suitable for the specific project. This recommendation should be based on the materials available in the project area, the estimated cost of those materials, and past experience or performance. The designer shall review these recommendations and select the system best suited to the project.

For preliminary planning purposes, Table 15.1 provides estimated costs per mile for each of the ten select materials systems. The final cost to any project will depend on many factors that could result in significant variation from these estimated cost figures. These factors include local material costs and availability, transportation costs, earthwork adjustments, project staging, and project quantities.

***Table 15.1* Estimated Cost of Select Material Systems**

Select Material System	Estimated Cost per Mile
No.1 – Breaker Run Stone	$125,000
No. 2 – Breaker Run Stone with Geogrid	$130,000
No. 3 – Grade 1 Granular Backfill	$105,000
No. 4 – Grade 2 Granular Backfill or Select Borrow	$100,000
No. 5 – Pit Run Sand and Gravel	$100,000
No 6 – Pit Run Sand and Gravel with Geogrid	$115,000
No. 7 – Flyash, Lime, Cement Stabilization	$ 95,000
No. 8 – Salvaged Materials or Industrial By-Products	*
No. 9 – Select Crushed Material	$140,000
No. 10 – Select Crushed Material with Geogrid	$140,000
* = Highly variable depending on material and location.	

When included in project plans, show the chosen select materials system on the appropriate typical section(s). Determine quantities of each of the required materials and include them as separate contract bid items. Adjust other earthwork quantities as necessary to compensate for the inclusion of a select materials system.

When select materials are used as stated in this procedure, they will be considered as part of the subgrade and will be included in the contract for subgrade construction. Soil parameters for pavement design will continue to be those of the project soils as determined in the soils report.

To preserve the integrity of the select materials systems and to facilitate movement of local traffic, it is strongly recommended that the Base Aggregate Dense should be included as part of the same contract.

Breaker Run is quarried rock or concrete material processed through a primary crusher, is not further screened or crushed, and will meet the gradation requirements shown in Table 15.2.

***Table 15.2* Recommended Breaker Run Gradation**

Sieve	Percent Passing
6-inch **	100
** In at least one dimension.	

Select Crushed material is crushed and screened aggregate with particles predominately larger than 1 1/2 inches, free of unconsolidated overburden materials, topsoil, organic materials, steel, and other deleterious materials, and will meet the gradation requirements shown in Table 15.3.

***Table 15.3* Recommended Select Crushed Material Gradation**

Sieve	Percent Passing
5-inch	90 - 100
1 1/2-inch	20 - 50
No. 10	0 - 10

Pit Run is an unprocessed aggregate material obtained from a gravel pit and will meet the gradation requirements shown in Table 15.4.

***Table 15.4* Recommended Pit Run Gradation**

Sieve	Percent Passing
1 1/2 inch	0 - 50

Attachment 15.3 through Attachment 15.7 are schematic drawings showing how the select material is to be placed in various situations. The select materials form the uppermost portion of the subgrade. Drainage of the select material is accomplished with relief trenches at all sag points and at 250 ft intervals between sag points. The flow lines of ditches should be at or below the bottom of the select materials. This may require a special ditch. If this is not possible then Attachment 15.6 shows how a special trench and pipe underdrain system can be built to help drain the select material.

15.4 Other Design Considerations

The use of select materials could have a significant impact on excavation, waste, or borrow quantities. Consider carefully the distribution of any excess material and the impacts to the mass diagram resulting from the use of select materials.

LIST OF ATTACHMENTS