Section 3-01
General Concepts, Design Standards and Design Exceptions

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GENERAL CONCEPTS

General: This section is intended to provide a basic overview on a variety of general subjects associated with geometric design of highways. For detailed design information, consult the following references: *AASHTO A Policy on Geometric Design of Highways and Streets, WYDOT Design Guides, WYDOT Standard Plans, WYDOT Standard Specifications for Road and Bridge Construction,* the *AASHTO Roadside Design Guide*, *Highway Capacity Manual*, and other Transportation Department design manuals and AASHTO publications.

Design Vehicle: A design vehicle is a motor vehicle of standard dimensions that is used in establishing controls for geometric design. Design vehicles are grouped into three main classifications: passenger vehicles, buses/recreational vehicles, and trucks. Their dimensions and turning radii are used in setting roadway widths, turning radii, vertical clearances, etc.

The design vehicle is selected by the Traffic Program in accordance with criteria set forth in *AASHTO A Policy on Geometric Design of Highways and Streets*. In highway design, the largest standard design vehicle likely to use the highway frequently is used to design such critical features as corner radii at intersections and radii of turning roadways.

Driver Expectancy: Driver expectancy refers to the expectation, by the driver, of standard geometric, operational, and route characteristics. Departure from common design features or abrupt changes in their character may result in driver error, or increased response time, which may result in an increased risk of a crash.

An example of driver expectancy is the expectation that an off-ramp from a highway will be located on the right side of the road. Adequate informational signing may help offset the confusion a left-hand exit would cause, but wherever possible the normal and expected right-hand exit should be used. Another example of design features that violate driver expectancy is when abrupt changes are made in design speed or horizontal alignment. Such changes should be made gradually to allow the driver to make smooth transitions in driving actions.

Design Speed: Design speed is a selected speed used to determine various geometric features of the roadway. The selection of a design speed is influenced by topography, adjacent land use, and the functional classification. Design speed should be selected to attain a desired combination of safety, mobility, and efficiency, within the constraints of environmental quality, economics, aesthetics, and social or political impacts.

Sight Distances: A driver’s ability to see ahead is needed for safe and efficient operation of a vehicle on a highway.

Stopping Sight Distance

Drivers need to be able to see far enough ahead to react to hazardous objects on the roadway and to be able to stop before impact. Therefore, the design of the roadway must provide adequate stopping sight distance for the driver at all locations.

AASHTO's definition of stopping sight distance consists of two components: the distance traveled by the vehicle during the driver's brake reaction time and the actual braking distance. A brake reaction time of 2.5 seconds is used for all drivers and for all conditions, but does not account for situations requiring complex decisions by the driver. Braking distance is based on a conservative deceleration rate of 11.2 ft/sec^2 that accounts for wet pavements, worn tires, etc., but not for icy roads.

Stopping sight distances, according the 2011 AASHTO policy, are shown in EXHIBIT 1, Stopping Sight Distance on Level Roadways.

Metric					U.S. Customary				
Design Speed (km/h)	Brake Reaction Distance (m)	Braking Distance on Level (m)	Stopping Sight Distance		Design Speed (mph)	Brake Reaction Distance (ft)	Braking Distance on Level (ft)	Stopping Sight Distance	
			Calculat-ed (m)	Design (m)				Calculat-ed (ft)	Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60.0	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83.0	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147.0	153.6	300.6	305
80	55.6	73.4	129.0	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240.0	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.5	566.0	570
120	83.4	165.2	248.6	250	65	238.9	405.5	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	820
					80	294.0	614.3	908.3	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s^2 [11.2 ft/s^2] used to determine calculated sight distance.

EXHIBIT 1

STOPPING SIGHT DISTANCE ON LEVEL ROADWAYS

Drivers sometimes do not drive slower on wet or icy pavement. Therefore, providing longer sight distances when possible adds to the safety of the roadway under adverse conditions.

Passing Sight Distance

Passing sight distance is needed to safely provide for the passing maneuver on two-lane roadways where the faster vehicle must use the lane of opposing traffic. Because of the nature of the terrain in which the roads are constructed, it is not always possible or economically feasible to supply continuous passing sight distance. WYDOT attempts to fulfill the requirements for safe passing sight distance whenever practical. The more passing sight distance that can be provided for a roadway, the better and safer it will operate. See EXHIBIT 2, Passing Sight Distance For Design of Two-Lane Highways.

Detailed sight distance descriptions can be found in the *AASHTO A Policy on Geometric Design of Highways and Streets* including discussion on the effect of grades on stopping sight distance, decision sight distance, and how it applies to trucks.

Metric				U.S. Customary			
Design Speed (km/h)	Assumed Speeds (km/h)		Passing Sight Distance (m)	Design Speed (mph)	Assumed Speeds (mph)		Passing Sight Distance (ft)
	Passed Vehicle	Passing Vehicle			Passed Vehicle	Passing Vehicle	
30	11	30	120	20	8	20	400
40	21	40	140	25	13	25	450
50	31	50	160	30	18	30	500
60	41	60	180	35	23	35	550
70	51	70	210	40	28	40	600
80	61	80	245	45	33	45	700
90	71	90	280	50	38	50	800
100	81	100	320	55	43	55	900
110	91	110	355	60	48	60	1000
120	101	120	395	65	53	65	1100
130	111	130	440	70	58	70	1200
				75	63	75	1300
				80	68	80	1400

EXHIBIT 2
PASSING SIGHT DISTANCE FOR DESIGN OF TWO-LANE HIGHWAYS

Traffic Volumes: Traffic volumes are a measure of the traffic usage for a particular segment of a road or a highway. Different derived traffic volumes are used in design for selection of typical sections, design speeds, surfacing thickness, etc. For the purposes of highway design and planning, WYDOT commonly uses projected 20-year traffic volumes from when the project is first initiated.

ADT (Average Daily Traffic)

Derived from the total volume for a given time period divided by the number of days in that time period, and expressed in vpd (vehicles per day).

AADT (Annual Average Daily Traffic)

Total number of vehicles traversing a section of roadway in a year divided by 365, the number of days in a year. The AADT are the traffic volumes employed in selecting design criteria such as number of lanes, shoulder widths, design speed, and expressed in vpd (vehicles per day).

DHV (Design Hourly Volume)

Generally taken as the 30th-highest hourly volume of the year, or approximately 15 percent of the AADT, and is used to determine what level of capacity or service a road should be designed to accommodate, and expressed in a percentage of the ADT. This value balances the difference between adequacy of design and economy of design.

DDHV (Directional Design Hourly Volume)

Used in situations where traffic patterns, in different directions, vary significantly depending on time of day, such as high volume commuter traffic to and from a business center.

% of Trucks

The percentage of the traffic stream that is comprised of buses, single-unit trucks and truck combinations. Percentage of trucks does not include light delivery trucks.

Traffic volumes and design volume projections are collected and/or prepared by the Planning Program - Transportation Surveys Section.

For projects with long design duration, the traffic count and projections should be updated prior to final design, if the ones used to select design parameters are somewhat outdated. The design should be reviewed against the updated traffic counts for compliance. If any aspect of design would be changed by the updated counts, the Project Development Engineer should be advised.

Level of Service: Level of service (LOS) is the concept used to describe operational conditions within a traffic stream and their perception by motorists. The designated level of service compares the existing or proposed roadway to the "ideal" conditions for that type of roadway. Level of service is defined by a letter designation from A to F, with A representing the best operating conditions and F the worst operating conditions. This definition describes the conditions encountered in terms of such factors as speed, travel time, maneuverability, traffic interruptions, comfort, convenience, and safety.

The *AASHTO A Policy on Geometric Design of Highways and Streets* defines the general operating conditions for levels of service as follows:

A - free flow, with low volumes and high speeds.
B - reasonably free flow, but speeds beginning to be restricted by traffic conditions.
C - stable flow, but most drivers restricted in freedom to select their own speed.

D - approaching unstable flow, drivers have little freedom to maneuver.
E - unstable flow, may be short stoppages.
F - stop and go operation.

WYDOT uses a design year Level-of-Service (LOS) C as the appropriate LOS to warrant capacity improvements for Interstate mainline sections; a design year Level-of-Service (LOS) D has been selected as the appropriate LOS to warrant capacity improvements for Interstate interchange ramps and intersecting roads. A design year Level-of-Service (LOS) D has been selected as the appropriate LOS to warrant capacity improvements for NHS Arterial & Non-NHS State Highway rural and urban mainline sections. Achieving a specified LOS level in some situations may not be feasible, in such cases, a lower LOS may be acceptable. Further information on level of service can be found in the Highway Capacity Manual.

Capacity Analysis: A detailed discussion of capacity analysis can be found in the *Highway Capacity Manual*. The *Highway Capacity Manual* is defined as- "a set of procedures used to estimate the traffic carrying ability of facilities over a range of defined operational conditions. It provides tools for the analysis and improvement of existing facilities, and for the planning and design of future facilities." The Traffic Program will usually do the detailed capacity analysis required on a project.

Access Control: Access control is the regulation of ingress and egress from streets and highways by state or local authorities. Access ranges from fully controlled access on interstates and freeways, where preference is given to the mobility of through traffic, to partially controlled access on lower functional classification roads and highways, where the access needs of adjacent landowners receive nearly as much priority as mobility of the traveling public.

In general, access to state highways is regulated in accordance with the *WYDOT Access Manual*, and in accordance with WYDOT Operating Policy. All access points should be evaluated during the design. Access on non-interstate highways is permitted by the District and Traffic Program, and access on interstate highways may be allowed only with FHWA approval.

DESIGN STANDARDS

General: Design standards to be applied to the various combinations of roadway classification and project types (Preservation, Rehabilitation, Reconstruction) are the current editions of:

- *AASHTO A Policy of Geometric Design of Highways and Streets*
- *WYDOT Design Guide, Interstate Highways*
- *WYDOT Design Guide, NHS Arterial (Non-Interstate)*
- *WYDOT Design Guide, Non-NHS State Highways*
- *WYDOT Road Design Manual*
- *WYDOT County Road Fund Manual*

The *WYDOT Design Guides* are specific to the roadway's functional classification and project type. It is important that the applicable book and section be referenced to ensure that correct design standards are being applied.

Functional Classification: Functional classification of roads and highways is a system by which roads are grouped according to the general function they provide. Functions provided by roads and highways, both urban and rural, include main (through) movement, transition (e.g. freeway ramps), distribution, collection, access, and termination. For the purposes of design, WYDOT recognizes the following functional classifications for both urban and rural facilities:

- Interstate
- NHS Arterial (Non-Interstate)
- Non-NHS State Highways (arterial, collector, or local)

Definitions of the functional classifications for both urban and rural can be found in the *AASHTO A Policy on Geometric Design of Highways and Streets*. Functional classifications are established for the roadway by the Planning Program and are documented in the Reconnaissance Inspection Report. See EXHIBIT 3 for the National Highway System: Wyoming Map, and EXHIBIT 4 for the Design Functional Classification Map.

The website link to the National Highway System: Wyoming Map is:
http://www.fhwa.dot.gov/planning/national_highway_system/nhs_maps/wyoming/

The Design Functional Classification Map can be found as a downloadable PDF file on the Road Design Manual webpage.

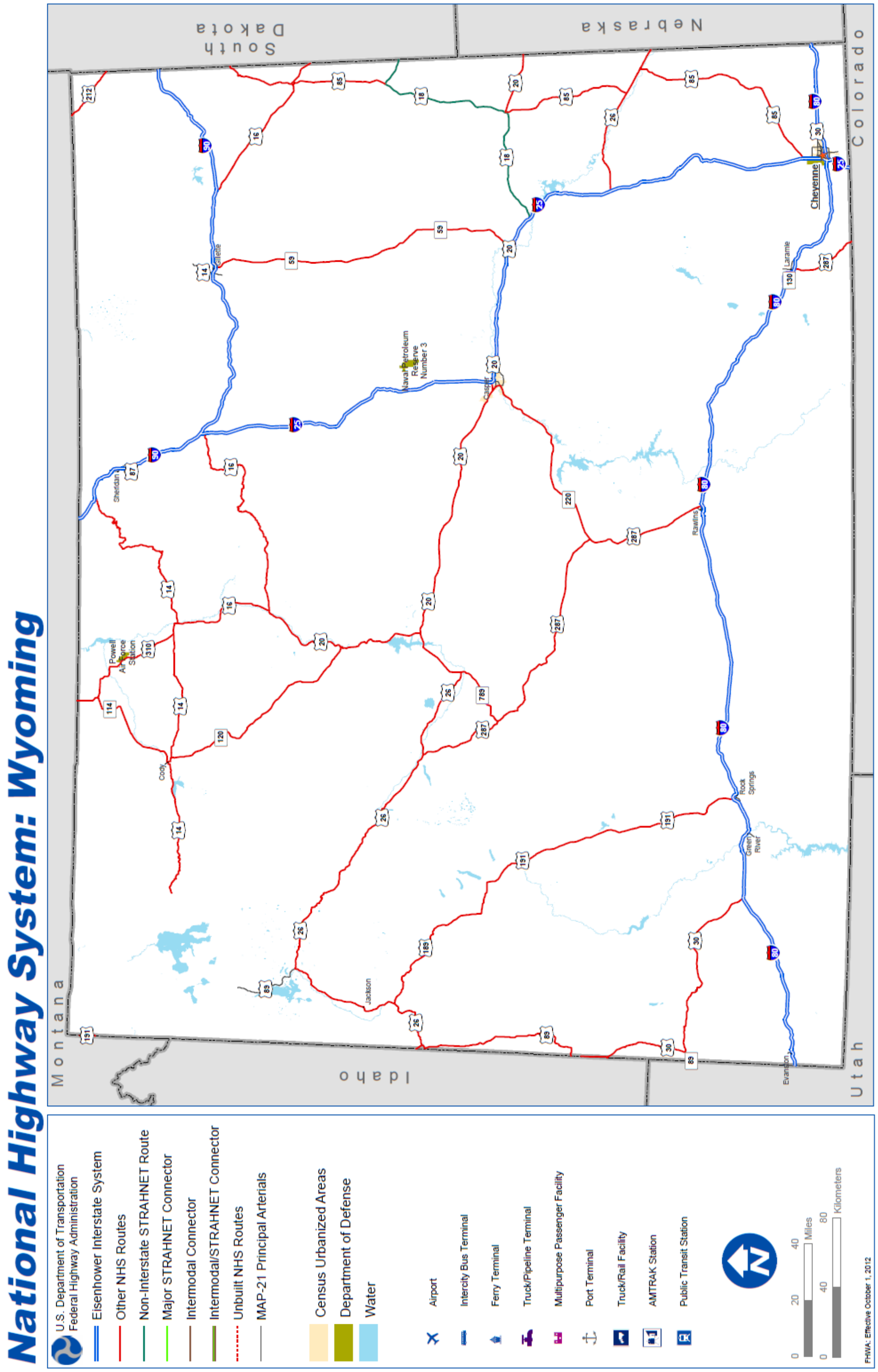

EXHIBIT 3

NATIONAL HIGHWAY SYSTEM: WYOMING

2021 JAN

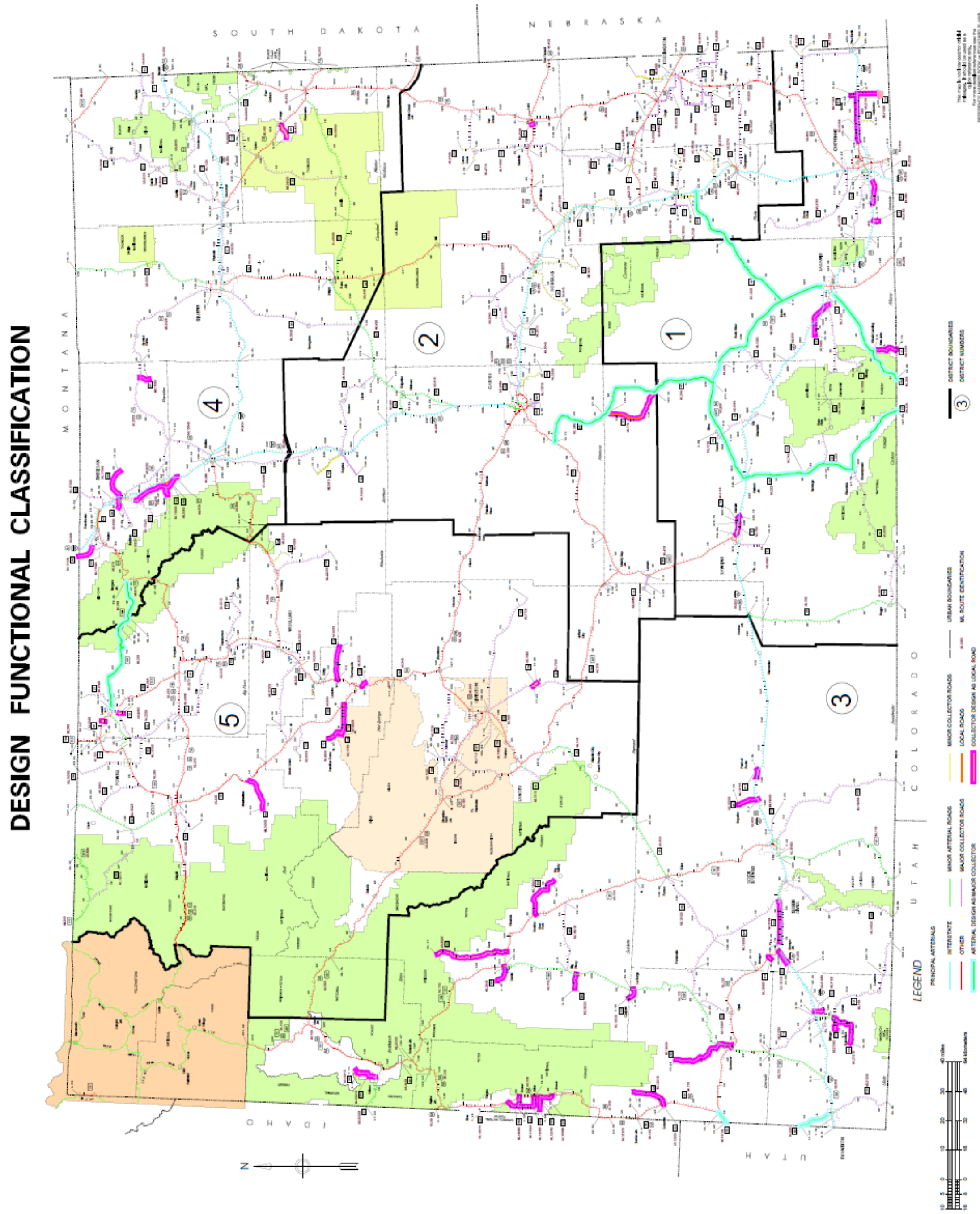

EXHIBIT 4

DESIGN FUNCTIONAL CLASSIFICATION

Project Types:

1. Preservation Project Type: Preservation of existing highways to allow for the construction of a) a range of pavement design strategies that extend the service life or serviceability of the roadway pavement structure as identified in the Pavement Management System, b) bridge structure preservation or maintenance strategies identified in the Bridge Management System, and c) selected location-specific roadway and roadside safety improvements supported by the Safety Management System and including location-specific roadway geometric improvements. This project type may also address corridor needs for (a) operational improvements including auxiliary lanes and intersections improvements, (b) roadway traffic control device upgrades including signs, signals, and markings and (c) areas of isolated reconstruction or rehabilitation to meet identified highway needs.

2. Rehabilitation Project Type: Rehabilitation of existing highways to allow for the construction of selected improvements including (a) pavement design strategies identified in the Pavement Management System, (b) highway geometric upgrades, (c) bridge structure replacement or rehabilitation strategies identified in the Bridge Management System, (d) roadway and roadside safety improvements supported by the Safety Management System, (e) operational improvements including auxiliary lanes, modifications to existing interchanges and intersections, and upgrades to roadway traffic control devices including signs, signals, and markings. This project type could include isolated areas of reconstruction to meet identified highway needs.

3. Reconstruction Project Type: New construction or reconstruction of existing highways to provide for (a) the full range of pavement design strategies identified in the Pavement Management System, (b) highway geometric criteria upgrades, (c) bridge structure replacement or rehabilitation strategies identified in the Bridge Management System, (d) a full range of roadway and roadside safety improvements supported by the Safety Management System, (e) added capacity for design year traffic including additional travel lanes and auxiliary lanes, new interchanges and modifications to existing interchanges and intersections, and (f) roadway traffic control devices.

   Detailed descriptions and procedures for each project type can be found in the current *WYDOT Design Guides.*

<u>Chapter 3 - Section 3-01 General Concepts, Design Standards, Design Exceptions</u>

Controlling Design Criteria: In 1985 the FHWA issued its policy regarding the 13 controlling criteria the FHWA identified as being of sufficient importance in highway design. In 2016 the FHWA streamlined the 13 controlling criteria to refine the focus on criteria with the greatest impact on road safety and operation. Research indicates that the controlling criteria are less influential on the traffic operation and safety performance of low-speed urban and suburban arterials than other features such as intersection design and access management strategies. Therefore, the FHWA has focused application of the controlling criteria on high-speed NHS roadways (design speed ≥ 50 mph). The FHWA reduced the number of controlling criteria from 13 to 10 for roadways with design speeds ≥ 50 mph, and applied only 2 of those criteria to low speed roadways with design speeds < 50 mph.

The development of the 10 controlling criteria was based on giving agencies the flexibility to balance the safety and operations of all modes of transportation, while reducing administrative requirements where they do not clearly result in improved safety and operations. The FHWA left it up to the States on how they want to implement the criteria. WYDOT will adopt the reduced amount of controlling criteria as listed below.

The following are controlling design elements that the FHWA has identified as being of sufficient importance in highway design for urban and rural roadways on the NHS. Refer to the 2014 WYDOT Design Guides for Preservation, Rehabilitation and Reconstruction project types, on and off the NHS, for the design values of the following 10 controlling criteria.

High Speed Roadways (design speed ≥ 50 mph)

1. Design Speed
2. Lane Width
3. Shoulder Width
4. Horizontal Curve Radius
5. Superelevation Rate(1)
6. Stopping Sight Distance (SSD)(2)
7. Maximum Grade
8. Cross Slope
9. Vertical Clearance
10. Design Loading Structural Capacity

Low Speed Roadways (design speed < 50 mph)

1. Design Loading Structural Capacity
2. Design Speed

(1) Superelevation Rate is for rate only and does not include transition length or distribution.
(2) Stopping Sight Distance at sag vertical curves is excluded from the controlling criteria.

When it is difficult or cost prohibitive to achieve full compliance with the controlling design criteria, either a design exception (for Reconstruction projects on the NHS) or documentation of the design decision (all other projects) needs to be written.

Based on the findings of recent research and FHWA's assessment and experience, a brief discussion on each of the proposed changes to the controlling criteria is provided below. *(From A Notice by the FHWA on 10/07/2015 in the Federal Register.)*

1. Design speed is proposed to be retained as a controlling criterion for all facilities on the NHS. Design speed is different from the other controlling criteria in that it establishes the range of design values for many of the other geometric elements of the highway. Because of its effect on a highway's design, the design speed is a fundamental and very important choice that a designer makes. In recognition of the wide range of site-specific conditions, constraints, and contexts that designers face, the design standards allow a great deal of design flexibility by providing ranges of values for design speed. For most cases, the ranges provide adequate flexibility for designers to choose an appropriate design speed without the need for a design exception. If a limited portion of an alignment must be designed to a lower speed, it is generally more appropriate to evaluate specific geometric element(s) and treat those as design exceptions, instead of evaluating an exception for the design speed of the roadway.

2. Lane width is an important design criterion with respect to crash frequency and traffic operations on high-speed and rural highways. The design standards provide the flexibility to choose lane widths as narrow as 10 feet on some facilities.

3. Shoulder width has substantial effect on crash frequency and on traffic speeds on rural highways.

4. Horizontal curve radius, previously called horizontal alignment, has a documented relationship to crash frequency on rural highways of all types. Curve radius also influences traffic operations on urban/suburban

arterials. Superelevation is the other main aspect of horizontal alignment and is being retained as independent controlling criterion.

5. Superelevation has a documented relationship to crash frequency on rural, two-lane highways and research suggests this would also be true on rural multilane highways and freeways. Superelevation is generally not provided on low-speed urban/suburban streets.

6. Stopping Sight Distance (SSD) is proposed to be retained as a controlling criterion because sufficiently long SSD is needed to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. Research found that SSD less than specified by the design standards for crest vertical curve design, combined with a hidden feature such as a curve, intersection, or driveway, resulted in increased crashes on high speed roadways. Retention of SSD as a controlling criterion will ensure that deviations from this criterion are examined on a case-by-case basis, to determine whether site characteristics and crash history are indicative of potential areas needing attention. From an operational perspective, SSD generally does not affect operations on freeways under free-flow conditions. However, when freeways operate at near-capacity, limited SSD may further reduce capacity below the levels expected based on current predictive models. These impacts are typically examined during project development.

7. Maximum grade is proposed as a controlling criterion but minimum grade is not. The existing controlling criteria of `grade' includes both maximum and minimum grade. Maximum grade is proposed to be retained due to its relationship to crash frequency on rural, two-lane highways and the effect of steep grades on traffic operations on high-speed roadways. Minimum grade is proposed to be excluded because while it does influence roadway drainage, minimum grade alone does not ensure sufficient drainage and does not rise to the level of the controlling criteria.

8. Cross slope is proposed to be retained as a controlling criterion to address drainage issues. While research has not been conducted to determine whether there is a relationship between the normal cross slope of roadway pavements and crash frequency, our experience is that inadequate drainage could contribute to vehicle loss of control under some circumstances. Due to the relationship between cross slope and drainage, especially when combined with minimum grades, cross slope is proposed to be retained as a controlling criterion.

9. Vertical clearance is proposed to be retained as a controlling criterion. While vertical clearance does not affect operations on the roadway other than for those vehicles that are taller than the available vertical clearance allows, vertical clearance crashes can have severe impacts on operations by damaging overpasses and other structures, resulting in extended road closures. In addition, inadequate vertical clearance on Interstate freeways impacts military defense routes and requires additional coordination with the Surface Deployment and Distribution Command Transportation Engineering Agency.

10. Design Loading Structural Capacity is related to the strength and service limit state designs, not to traffic operations or the likelihood of traffic crashes. Previously called `structural capacity,' FHWA proposes to clarify that the applicable criterion covered herein relates to the design of the structure, not the load rating. Design loading structural capacity is important in maintaining a consistent minimum standard for safe load-carrying capacity and deviations from this criterion should be extremely rare. Design loading structural capacity is proposed to be retained as a controlling criterion regardless of the design speed for the project. Exceptions to design loading structural capacity on the NHS could impact the mobility of freight, emergency and military vehicles, and the traveling public and requires additional coordination with the FHWA Office of Infrastructure.

DESIGN EXCEPTIONS

General: A formal design exception is required for reconstruction projects on the NHS when the controlling criteria are not met. The FHWA expects documentation of design exceptions to include all of the following:

1. Specific design criteria that will not be met.
2. Existing roadway characteristics.
3. Alternatives considered.
4. Comparison of the safety and operational performance of the roadway and other impacts such as right-of-way, community, environmental, cost, and usability by all modes of transportation.
5. Proposed mitigation measures
6. Compatibility with adjacent sections of roadway.

Design Speed and Design Loading Structural Capacity are fundamental criteria in the design of a project. Exceptions to these criteria should be extremely rare and

FHWA expects the documentation to provide the following additional information:

- Design Speed Exceptions:
  - Length of section with reduced design speed compared to overall length of project.
  - Measures used in transitions to adjacent sections with higher or lower design or operating speeds.
- Design Loading Structural Capacity Exceptions:
  - Verification of safe load-carrying capacity (load rating) for all State unrestricted legal loads or routine permit loads and, in the case of bridges and tunnels on the Interstate, all Federal legal loads.

Design Exception Requests are submitted to and approved by the delegated authority. The 2015 Fixing America's Surface Transportation (FAST) Act and the 2015 Stewardship and Oversight Agreement between the Wyoming Department of Transportation and Federal Highway Administration (FHWA) Wyoming Division, delegates the authority to approve design exceptions to WYDOT for all projects on and off the National Highway System (NHS). Request design exceptions in a letter addressed to the Assistant Chief Engineer for Engineering and Planning with the following signature blocks:

Concurred by:	Highway Development Engineer
Approved by:	Assistant Chief Engineer for Engineering and Planning
Approved by:	Assistant Chief Engineer for Operations

Design Documentation: All design decisions should be documented to demonstrate compliance with accepted engineering principles and the reasons for the decisions. Design decisions that meet the tolerable controls should be noted in the plan inspection report and/or the QC/QA Checklist. Design decisions that do not meet tolerable controls for Rehabilitation and Preservation projects, both on and off the NHS, as well as design decisions that exceed the tolerable controls need to have formal documentation.

The documentation of exceptions from the design standards will include written justification, including cost estimates and impacts to project delivery schedule, from the individual program and approval from executive staff and, when required, the Federal Highway Administration (See OP 7-1).

See attached "Sample Letter" for general format.