Part 511 – Design

Subpart A – Procedures

511.0 General

A. Engineering design is an organized and rational process that applies the natural laws of science for the enhancement of human welfare. Engineering design should be sensitive to the needs of people, their activities, and the landscape.

B. Engineering design is performed at many organizational and geographic locations. The designs prepared are of varying complexity and are often performed at locations some distance from the construction site. The design is performed by personnel having various levels of knowledge and skill. The designs often require review and approval by someone at a location other than the construction site or design office. Designs must be reviewed to ensure adequate performance and safety (see part 501 of this manual). Because of the diverse nature of the design activities in NRCS, some standardization of basic nomenclature and procedures is needed.

511.1 Scope

A. The principles defined in this part apply to all sizes and complexities of designs. The detail to which the procedures are to be followed varies according to the need. The simplest conservation practice may require only a few notes, computations, and drawings. Larger and more complex works may require numerous notes, computations, and drawings to complete all stages of the design. Likewise, the complexity of site conditions and engineering along with the number of alternatives and organizational units affects the intensity and duration of work at each design stage.

B. Engineering design must provide for the quality and durability required for the economic life of the practice or component at the least-total cost consistent with functional requirements. Engineering designs must be determined by comparative design studies and cost estimates prepared with full consideration of the landscape, environment, topography, foundation, and other site conditions and the economy and feasibility of construction, operation, and maintenance. Economic comparisons of alternative designs are determined by the amortized average annual cost of installation (including costs of land rights), operation, and maintenance. Environmental comparisons must consider ecological, cultural, and aesthetic values.

511.2 Design Stages

A. To provide standard terminology for orderly scheduling and coordination of work, three stages of design activity are defined. This terminology is to be used in all NRCS correspondence, publications, and documents relating to design. The design activities included in these stages may be further subdivided into phases or subphases as necessary to control NRCS work or to administer engineering services contracts and agreements.

B. On small and simple structural measures, all three stages of design can be accomplished in one brief period of time and in such a manner that they are nearly inseparable. On larger works, such as projects, much of the work in stages one and two may be completed during planning (see section 510.1 of this manual.). Items for which the final design data are known during planning, such as topographic, hydrologic, and hydraulic features, should be completed for final design purpose at that time. The planning data need only be reviewed before design commences to verify accuracy and adequacy. In this manner, data gathered during planning can be used to avoid duplication of effort

and ensure that there is little or no modification needed in the general layout during final design. Similarly, data should be gathered on the geology and foundation if assurance against significant cost changes is desired.

C. Stage one includes data collection and evaluation for all information on—

(1) Physical data, including topographic, hydrologic, visual, biologic, geologic, seismic, and archeological data.
(2) System and structure functional requirements and purpose, including capacity, controlled water level, and location.
(3) Site constraints, including information on ownership boundaries, easements, utilities, and water rights.

D. Stage two is the preliminary design, which consists of developing the general features of the works of improvement. It includes selecting the most suitable types of structures, the optimum layout and arrangement of the elements of the structural system in the landscape, the types and locations of appurtenant mechanical equipment, and, if applicable, the most feasible power source. Also, cost studies and an economic feasibility examination must be made. The conceptual phase of preliminary design is the point at which design alternatives and configurations for key elements have been developed but not selected.

(1) Hydraulic design must be sufficient to select alignment, grade, size, and critical elevations for each evaluated alternative.
(2) Foundation conditions must be analyzed and the embankments designed in sufficient detail to provide seepage control and stability requirements.
(3) Structural details of alternate designs are developed sufficiently to prepare reasonable quantity and cost estimates.
(4) Landscape resource objectives, preliminary landscape resource designs, and preliminary plans are sufficiently developed to determine feasibility and prepare preliminary cost estimates.
(5) Specifications of material and work requirements are outlined, and a schedule of work and payment items is to be included.
(6) Cost estimates are determined by estimating construction costs. Alternate designs must be compared according to the average annual cost of installation, operation, and maintenance, including costs of land, easements, rights-of-way, and relocation of roads, utilities, or both.
(7) A design report is to be compiled to include all information, either directly or in appendices, necessary for a technical review by others. Such review may be internal or by outside organizations.

E. Stage three is the final design, which consists of—

(1) Checking the adequacy of the surveys and investigations and the accuracy of the layout chosen in the preliminary design.
(2) Refining and revising the preliminary design information.
(3) Detailing the layout and hydraulic design.
(4) Completing the structural design.
(5) Refining the landscape resources design.
(6) Preparing the construction drawings, contract specifications, bid schedule, engineer's estimate, and construction schedule.
(7) Preparing the design report.
(8) Preparing the operation and maintenance plan.
(9) Preparing the quality assurance plan.

511.3 Operating Procedures

A. The operating procedures to be followed depend on the organizational level at which the design is done. If the design is done by many offices or by offices that are remote from one another, the need for an established documented procedure is greater. Designs made at field and area offices are usually processed by simple informal procedures.

B. The more complex designs often require technical assistance, peer review, and concurrence by the Director, Conservation Engineering Division (CED). The design may be prepared by—

(1) The NRCS State engineering staff (field, area, or State office).
(2) A multistate design team or the National Design, Construction, and Soil Mechanics Center (NDCSMC) using data collected by State staffs.
(3) The engineering staff of a sponsoring local agency under an agreement for engineering services.
(4) A private engineer under a contract for engineering services negotiated either by NRCS or the sponsoring local agency.

C. If it is anticipated that the design will require assistance, independent review by the NDCSMC or others, or concurrence by the Director, CED, the State conservation engineer (SCE) must prepare a realistic design and construction schedule. In addition, the SCE develops operating procedures for preparing designs, construction drawings, and specifications and for accomplishing their orderly and timely review and approval (see section 501.4 of this manual). Operating procedures must comply with the following:

(1) The State engineering staff is responsible for all surveys and investigations.
(2) The office providing the design assistance, independent review, or concurrence will be consulted at the conceptual phase to provide review and concurrence as needed, before key project elements and configurations have been selected or significant detailed design work has begun. Any significant changes in elements and configurations at later stages of the design must be made in consultation with those providing independent review and concurrence.
(3) The work must be completed by the State engineering staff if qualified design engineers are available.
(4) NDCSMC assistance may be requested at any stage in the preparation of the design.
(5) If designs prepared by local sponsoring agencies or by architect-engineer (A&E) contractors require independent review, the review must include task orders including independent Government estimates (IGE), specifications for engineering services, or agreements covering the work. Performance time must be adequate to permit the necessary review. The State will perform necessary quality assurance of deliverables before submitting for independent review.
(6) Construction drawings and specifications are prepared concurrently so that they can be properly coordinated.
(7) Contract specifications must be compiled by the office responsible for the design of the work.

D. Operating procedures for continuity between employees performing site investigations, design, and construction are not complicated for small or simple jobs if the work is prepared at one or two offices. However, if there are several offices and employees involved or segments of the work are prepared by specialists, maintaining continuity is much more difficult. In these more complex operations, coordination and communication must be facilitated between engineers, geologists, and others during stages two and three of design and during construction. This is coordinated by the designer, the soil engineer assisting the geologist in planning and evaluating the site investigation, or both. Field reviews during the investigation may be necessary to ensure all information needed for

the design is obtained. Likewise, the designer arranges for transfer of information to the construction inspection staff. For more complex projects, the design and soil engineers, geologist, construction engineer, and inspector may meet to exchange information. This preconstruction meeting should cover critical interpretation and assumptions dealing with design features and those items that need verification during construction.

511.4 Design Analysis

A. The design analysis defines the scope of the design and evaluates the relationships of the principles that determine the design. It consists of a step-by-step description of the procedures used. Each step must be described concisely and completely.

B. The design analysis must include the data used, criteria, and procedures. The design analysis must be technically sound, performed in a logical manner, and documented.

511.5 Design Checking and Review

A. Checking during design is essential. Checking consists of an examination of the narrative, computations, and drawings for accuracy, conformation with procedures, and consistency between the various parts of the design. The checker must be experienced in the type of design, the criteria, and the procedures. The checker initials each sheet completed and verifies that—

(1) The basic data were correctly applied and assumptions were applied appropriately and used in the computations.
(2) Mathematic computations are accurate.
(3) Details are consistent from sheet to sheet.
(4) Drawings comply with the design.
(5) Drawings comply with the specifications.
(6) Computed critical elevations, costs, and quantities are accurate.
(7) Construction drawings are complete.

B. Reviews must be made during the design to ensure technical quality. All designs, drawings, and specifications must be reviewed (see part 501 of this manual). Reviews must be made progressively by the responsible design office through an examination of narrative, computations, and drawings. The reviewer assumes responsibility with the designer for the functional adequacy and structural soundness of the structure or structural system. The reviewer's capability must be equal to that needed to do the design. The review must determine that the—

(1) Design provides for the planned purpose.
(2) Basic data are adequate.
(3) Design assumptions are valid.
(4) Methods of analysis are valid.
(5) Alternatives evaluated are equal in meeting minimum performance requirements.
(6) Solution is appropriate to the problem or site condition.
(7) Design complies with policy and criteria.
(8) Design is consistent with sound engineering practice.

C. The review procedures as outlined in section 501.05A(3) of this manual depend upon the operating procedures used for class I through VIII jobs. The review procedures for class VI and VII jobs are the responsibility of the SCE. Review procedures for class-VIII jobs are the responsibility of the SCE with concurrence by the Director, CED. The SCE must ensure that the design schedule provides enough time for review by the appropriate authorities at the various design stages. Review

schedules must reflect a realistic consideration of the locations of the reviewing offices, time needed to transmit material, and coordination of the work with the rest of the workload of the offices.

511.6 External Reviews

Consideration must be given to the need for an external review of dams and other engineering structures that, when installed, will become a potential hazard to human life in case of failure. See section 520.26 of this manual for the procedure to be used for dams. When necessary, a similar procedure should be used for other structures.

511.7 Design Criteria

A. Design criteria established by policy directives are often of a general nature. The criteria provide guidance in obtaining the quality of acceptable work. Designs must be prepared to satisfy the functional purpose in a safe and stable manner, which may often result in requiring more restrictive limits than the established minimum criteria. In other words, meeting minimum engineering criteria will not, in all cases, ensure adequate designs.

B. Minimum design criteria established by policy are to be met.

C. Criteria used in preparing project plans are normally used in the design and construction of structural measures. At the time of final design, the individual having the appropriate engineering job approval authority (see section 501.4 of this manual) must reaffirm that all aspects of the engineering plans are legally permissible and that the structure will perform its assigned function in a normal manner during its service life. The design criteria are to be changed from that used in planning if—

(1) The planned design is not acceptable in light of new engineering knowledge as reflected in the revised criteria. In this situation, the measure must be designed to meet new criteria.
(2) Downstream development requires a change in structure classification before construction. In this situation, the structure must be reclassified and designed in accordance with the latest criteria.

D. The sponsors or landowners must be informed of changes that increase the cost or require alterations in land rights.

511.8 Construction Drawings and Specifications

A. The preparation of construction drawings and specifications is the final step in the design process. The drawings are a graphical description, and the specifications are the narrative description of the works to be constructed. The construction drawings and specifications provide descriptive information on the quantity and quality of the completed work. The work must be clearly described so that the owner and constructor will understand the requirements. This provides a mutual understanding when the requirements are met.

B. Construction drawings must be prepared and assembled in a clear and logical manner. The minimum requirements are contained in part 541 of this manual.

C. Construction specifications must include both materials and construction methods. The minimum requirements are contained in part 542 of this manual. Requirements must be established in terms of a specified end product.

D. Construction drawings and specifications must be completed and approved prior to commencing of the work, unless directed by the SCE.