# Chapter Five
# DESIGN

## 5-1.0 DESIGN CONSIDERATIONS

The activities involved in the provision of pavements can be divided into three groups. First, there is the geotechnical design of the natural roadbed soil to obtain a suitable foundation for the pavement. Second is the design, construction, and upkeep of a pavement structure built on top of the foundation. Third is the design and provision of drainage facilities to direct surface and subsurface flows of water away from the pavement structure to prevent saturation of the pavement. These three aspects of the provision of a pavement are discussed in detail in the subsequent sections of this chapter.

In addition to the broad categories addressed above, a number of procedural factors must be addressed. These range from obtaining a source of funding for the project to identifying guidelines that must be followed depending on the urban or rural location of the project. To address such factors it is necessary to understand the functions and responsibilities of the Department as well as the various Federal, State, and local agencies that may have an influence on the design process.

Chapter 1 of Mn/DOT's Road Design Manual provides an overview of the different offices of the Department and their working relationships. Similar information is provided for the Federal, State, and local agencies that become involved in the process. Guidelines are also provided on the development process for highway projects, including information on the preconstruction role of Mn/DOT. Given the increasingly complex nature of the design process due to environmental concerns, government regulations, and difficult engineering, funding, and management decisions, this information is necessary to the engineer.

A background on the design controls and criteria for highways in Minnesota can also be found in Chapter 2 of Mn/DOT's Road Design Manual. This includes information on the classification systems used by the Department in the application of non-highway design criteria, the establishment of jurisdictional authority, and the determination of the available sources of funds for projects. Tier standards adopted by Mn/DOT for two-lane and multi-lane rural highways are also discussed in order to provide the dispensation of funds for the upkeep of the highest mileage of roadway structures at a high level of service. A working knowledge of this information is necessary for the design processes discussed in this chapter to be in accordance with the goals of the Department.

# 5-2.0 GEOTECHNICAL DESIGN

## 5-2.01 EXCAVATION AND EMBANKMENT CONSTRUCTION

It is the responsibility of the District Soils or Materials Engineer, in conjunction with the Design Engineer, to assure that the finished grade elevation is least five feet above the water table (or an amount equal to the maximum frost penetration) to minimize frost heaving and thaw weakening of the subgrade. The depth to water table must be significantly larger for silty materials. It is also the responsibility of the District Soils or Materials Engineer to evaluate and provide recommendations for the excavation and placement of embankment materials. The condition of existing soils and embankment treatments need to be considered and included in the recommendations. Each of these topics is discussed in the following sections.

In general, embankment materials and construction should comply with Mn/DOT's Specification 2105.

### 5-2.01.01 SOILS EVALUATION

It is the responsibility of the District Soils Engineer to evaluate and classify the materials that are to be used within an embankment. The following paragraphs discuss the types of soils that may be encountered along the proposed alignment.

1. Suitable/Unsuitable Materials. Materials classified as "suitable" for embankment fills generally consist of granular, select granular, and common materials with an R value of at least the design value. Borderline soils that would normally be suitable may be classified as unsuitable for a particular project if an abundance of better material is available.

   Topsoil, highly organic materials, debris, and other generally unstable soils are always classified as unsuitable, but may be utilized in certain portions of an embankment when suitable material is lacking (Section 5-2.02.03).

2. Excavated Soils. Soils excavated from cut sections should be used to the fullest extent practical if the excavated material is designated suitable with respect to the requirements of the project. See Mn/DOT's Specification 2105.3D.

3. Salvaged Materials. Existing aggregate and topsoil should be salvaged and reused in new construction wherever possible. See Mn/DOT's Specification 2105.2C.

4. Borrow. Borrow is material required for embankment construction that cannot be obtained from roadway cut sections. It is the responsibility of the District Soils or Materials Engineer to list, locate, test, and survey locations suitable for borrow when it is required on a project (Section 4-2.03.08). Borrow material should be classified as either select granular (Mn/DOT's Specification 3149), common, or topsoil (Mn/DOT's Specification 3877).

   The District Design Engineer is responsible for determining the required quantities of materials for embankment construction while making use of the shrink/swell factors provided by the District Soils Engineer. Shrink/swell factors are determined by locating the material source and then estimating their volume change from their undisturbed condition to their reworked and compacted condition. This change is referred to as the shrink (if the compacted density is larger than the in-situ density) or swell (if the compacted density is less than the in-situ density) of the material. The factor is particularly important when haul lengths are lengthy.

   A shrinkage factor of 100 percent means that a material will occupy the same volume when placed and compacted in the roadway that it did in the ground prior to excavation. A factor greater than 100 means that the natural material will shrink and more borrow or excavation material will be needed to build the planned embankment. A factor less than 100 percent indicates that the natural material will swell.

One complication to be considered when determining shrinkage factors is the consolidation of the underlying foundation soils by construction equipment. This consolidation can induce up to one foot of roadbed settlement in tilled fields, which would have a dramatic effect on the amount of fill needed on the project. The shrinkage factor is therefore the sum of the compaction factor plus other factors. If varying conditions are encountered, more than one shrinkage factor may be required.

The District Soils Engineer should indicate the method used to arrive at the shrinkage factors listed in the Design Recommendations Report. The preferred method is to obtain undisturbed soil samples from the borrow pit and measure their in-situ density and moisture content. These undisturbed soil samples can be taken either at the surface or in shallow excavations. In the case of plastic soils, District or Foundation Unit drill rigs can obtain undisturbed thin-wall tube samples at depth. Densities of deep granular soils are most commonly estimated from $N_{60}$ values.

The in-place density values should be compared against the Proctor density/moisture curves to arrive at a compaction factor. Although Mn/DOT's specifications may call for 95 or 100 percent of T99 (Method C) density, the as-built density will be larger than the specification density. Investigation 183 concluded that plastic fills are generally placed about three percent above specification density, while granular fills are generally about four percent higher.

After the compaction factor is calculated, it should be adjusted for foundation consolidation to arrive at an estimated shrinkage factor (Shrinkage Factor = Compaction Factor plus Other Factors).

Shrinkage factors have, in the past, included the disposal of unsuitable material: this practice is misleading and should be discontinued. A separate calculation should be made to determine the amount of unsuitable materials (primarily organic soils) that cannot be utilized on the job. Likewise, estimates of swamp shrinkage should be made separately due to complicating factors such as vertical subsidence and lateral compression. Guidance in this area may be obtained from the Foundations Unit (Office of Materials and Road Research).

The Geology Unit (Office of Materials and Road Research) should be contacted for an estimate of swell when rock cuts are being considered. Generally, rock shrinkage factors will be less than 100 percent.

It may not be necessary to make an estimate of the shrinkage factor for particularly small projects where exploratory resources are not available. In these situations, it is acceptable to use prior experience and outside sources to estimate the factors. One such source of in-place moist density data is the U.S. Natural Resources Conservation Service. A computer listing of the engineering properties of approximately 600 Minnesotan soils has been furnished to each District Materials Engineer, which are accurate to a depth of five feet. These data can be compared to Mn/DOT's Proctor data to arrive at a compaction factor.

Another source is an MHD study performed by W.W. Dreveskracht. A regression analysis of some 70 compaction versus depth of excavation calculations indicated the following compaction factors:

| Depth (feet) | Compaction Factor (%) |
|---|---|
| 1 | 122 |
| 2 | 116 |
| 5 | 108 |
| 10 | 102 |
| 15 | 98 |

| | |
|---|---|
| 20 | 96 |
| 25 | 94 |
| 30 | 92 |

Where $r^2$, an indication of the scatter in the data, is 0.48 and Standard Error is 8.6. The values given are compaction factors only and do not include other factors, such as equipment shrinkage, which must be considered to arrive at an estimated shrinkage factor.

There will always be some uncertainty in the selection of a design shrinkage factor due to variable natural soil properties, construction operations, and normal statistical variation. Obtaining adequate data and performing careful analysis before a design shrinkage factor is selected can reduce the uncertainty. The experience of district construction, maintenance, and design personnel who have worked with similar projects and soils should be utilized as much as possible.

An additional adjustment may be made to account for accidental loss or waste during hauling. This adjustment should change the final factor by no more than five percent.

Lastly, past Mn/DOT experience indicates that field conditions (e.g., depth, overburden and material type) impact the shrinkage or swell as shown in Table 5-2.1.

Table 5-2.1. Approximate shrinkage factors for depth, overburden and material type.

| Material and Application | Shrinkage Factor (%) |
|---|---|
| Rock | |
| Sandstone | 90 - 100 |
| Limestone, granite, basalt, etc. | 70 - 90 |
| Shale | 90 - 110 |
| Soil | |
| Deep cuts and high fills | 100 - 130 |
| Normal cuts and fills | 130 - 140 |
| Ditch cuts and shallow fills | 135 - 150 |
| Shoulder grading | 140 - 150 |
| Light shoulder grading | 150 - 165 |

Also see Table 5-2.13 for shrinkage factors for swamp backfill.

### 5-2.01.02 SOILS PREPARATION

Preparation of soils for foundation support and embankment placement typically involves reworking or enhancing the existing materials, promoting uniformity of the material's properties, and eliminating such problems as pockets of high moisture content or unstable or unsuitable subgrade soils.

1. Compaction. Compaction is the process of increasing the soil density by reducing its air voids (Figure 3-2.4) using artificial means, such as rolling or tamping. It is carried out to improve the material’s engineering properties such as strength, compressibility, permeability, and volume change characteristics.

   For a given compactive effort, there exists an optimum moisture content at which the highest density and best engineering properties are obtained. Therefore, it is advantageous to maintain a soil’s moisture content close to its optimum during compaction. This will allow for the greatest degree of compaction with the least amount of compactive effort.

2. Lime Treatment. The engineering characteristics of soils can be altered by the application of lime. Lime is typically utilized as a drying agent for wet soils. In addition, lime reacts with clay to improve its engineering properties in a number of ways. Lime may reduce the clay's plasticity and shrinkage characteristics, improve its workability, and increase its strength and stability. However, it may also increase the frost susceptibility of the soil and induce cracking, so it should be used with care.

   Construction with lime involves scarification of the existing subgrade, lime spreading and mixing, and compaction. Lime should be applied to the full width of the scarified surface across the grade. The lime and subgrade material should immediately be mixed with either rotary mixers or disc harrows to prevent loss due to wind. For this reason, lime should not be spread during windy conditions. Thorough mixing is also essential to distribute the lime uniformly throughout the soil. After satisfactory moisture and soil conditions are achieved, the material can be compacted as specified.

   Additional information may be obtained from Section 5-2.01.04 and Mn/DOT's Grading and Base Manual, Section 5-692.521.

3. Geotextiles. Geotextiles can effectively be used to provide separation and/or stabilization in locations where soft soils make placement of subsequent lifts difficult or density hard to achieve, such as culvert foundations or subcuts. Geotextiles should not be used to replace portions of the required granular material. Mn/DOT's Specification 3733, Type V is often referenced for this application.

   Geotextiles have also been used in embankment reinforcement to steepen slopes, improve bearing capacity, and spread the loaded area in swamp crossings. These applications require consultations with the Foundations Unit (Office of Materials and Road Research). Additional information may be obtained from Section 5-4.03.02 and Mn/DOT's Road Design Manual, Section 8-5.02.09.

## 5-2.01.03 SUBGRADE CORRECTION

Subcuts and culvert installations require minor excavations and treatment of the subgrade that will support the roadway.

1. Subcuts. Subcuts are made to ensure material uniformity and the stability of the upper portion of the roadbed. Specifically, they are utilized to eliminate unstable materials, frost-heave potential, differential moisture conditions, and other non-uniform subgrade conditions. Typical subcut depths range from two to four feet with a one-foot minimum. All subcuts should be backfilled with suitable grading materials.

   It is the responsibility of the District Soils Engineer to specify the subcut depth, which is often the calculated frost depth (Section 3-2.03.03). The subcut depth should extend to below the frost line in areas of the roadbed that have the potential to generate frost heaves with 20(H) to 1(V) tapers at each end. These transitional tapers are provided to prevent abrupt differential settlement caused by different types of soil (granular vs. non-granular, in most cases). The subcut should be backfilled with Select Granular Material (Mn/DOT's Specification 3149.2B), and perforated pipe should be placed in the bottom of the subcut according to the design standards (Fig. 5-4.2(e)). Special perforated pipe drains systems may be designed when the ground water levels is expected to rise into the subcut zone. The Geology Unit should be contacted for assistance with these designs.

   The shadow cast by a bridge may induce a frost heave in the subgrade of the roadway running beneath it if the subgrade contains plastic soils. In locations where this condition is possible, a subcut should be made and backfilled with granular material. This fix should extend at least 150 feet, plus tapers, on either side of the bridge.

Refer to Mn/DOT's Road Design Manual (Figures 4-2.01A and B) for subcut sections. Similar treatments may be performed in sidehill cuts in non-granular soils.

The following transitions should be provided when making subcuts or excavations:

- When connecting new surfacing, cut vertically to the bottom of the in-place surfacing (or to the bottom of the new surfacing design, whichever is deeper) then diagonally at a 1(H) to 1(V) slope to the bottom of the recommended subgrade excavation.
- When connecting to in-place roadways at the termini of proposed new construction, cut vertically to the bottom of the in-place surfacing (or to the bottom of the new surfacing design, whichever is deeper); then at a mild 20(H) to 1(V) taper to the bottom of the recommended subgrade excavation.
- When matching into in-place crossroads, cut vertically to the bottom of the in-place surfacing (or to the bottom of the new surfacing design, whichever is deeper) then at a 4(H) to 1(V) slope to the bottom of the recommended subgrade excavation.
- Provide mild 20(H) to 1(V) tapers when transitioning between subcut depths. Tapers between plastic and granular soils should be constructed so that the granular soil overlays the plastic soil.

Traffic lanes to be used during construction must be delineated to keep vehicles a safe distance from the adjacent excavation. The delineation should coincide with the projection of a 2(H) to 1(V) or flatter slope between the edge of the traffic surface and the near edge of the bottom of the excavation.

2. Culverts. Culvert excavations, particularly in rural settings, are generally open cut without bracing or shoring. It is advisable to slope the excavation away from the culvert at slopes of 4(H) to 1(V) or flatter. However, the actual excavation slope should be determined during construction by the Contractor, who should consider the in-situ soil properties and/or safety factors. The excavation slope lines indicated in the plans for pay quantity determinations are not necessarily adequate slopes from a safety standpoint. It is the contractor's responsibility to determine the proper slope necessary for safe construction practices at any particular site.

New culverts in plastic and non-uniform soils should be placed on a minimum of two feet of aggregate bedding. The excavation should be backfilled with granular material. A geotextile (Mn/DOT's Specification 3733, Type V) is often used below the aggregate bedding for separation/stabilization if soft and/or unstable soils underlay the bedding. Once again, 20(H) to 1(V) tapers between material changes should be constructed to help reduce the differential heave potential at the roadway surface.

The excavations for additions to existing culverts should be backfilled with soils that substantially match the in-place soils (relative to textural classification, layering, moisture, and density) if there are no signs of excessive heave in the existing culvert. If excessive heave is present, a complete granular treatment with 20(H) to 1(V) tapers is necessary. See Mn/DOT's Road Design Manual, Figures 8-6.02 A through E, for typical sections of culverts in plastic soils.

Using a culvert liner as opposed to installing a new culvert may adequately mitigate some culvert distresses. Such linings consist of smaller diameter pipes inserted within the existing culvert with the resulting annular space being grouted shut. The obvious advantage of this treatment is that the need for excavation is greatly reduced or eliminated, which may be particularly advantageous in an urban setting. The main caution when considering such an alternative is being certain that adequate flow capacity remains in the culvert liner.

When space limitations prohibit the use of open-cut trenches (usually near bridge approaches, culverts, and utilities) the design of shoring, bracing, and/or dewatering may be necessary. The Foundations Unit or Geology Unit (Office of Materials and Road Research) should be advised and consulted in such situations.

### 5-2.01.04 PLACEMENT OF EMBANKMENT AND BACKFILL MATERIALS

All necessary clearing and grubbing should be completed prior to proceeding with construction operations.

1. Uniformity, Layers, Transitions. Each layer of the roadbed should be constructed of a uniform material. If available soils are so varied that it is impractical to obtain a uniform material, the available material should be blended and mixed. In transitional areas where granular embankments or backfill join plastic soil embankments or backfill, 20(H) to 1(V) tapers should be used between the change in materials to prevent abrupt soil differentials and placed so that the granular overlays the plastic soil.

   Embankment material should be placed according to Mn/DOT's Specification 2105.3E in relatively uniform layers, approximately parallel to the profile grade. Layers in the upper three feet of the roadbed should not be more than eight inches in loose thickness, while those below the upper three feet should not be more than 12 inches in loose thickness, except as follows:

   a. For soft and unstable foundation soils that will not support construction equipment, the embankment may be constructed as a single layer to the lowest elevation at which construction equipment can operate without causing the underlying soils to intrude into the upper eight inches of the embankment. In no case should the top of this grade be fewer than three feet below the subgrade.

   b. For placement of granular material (not more than 20 percent passing the No. 200 sieve) in the upper three feet of the embankment, lift thickness may be increased to not more than 12 inches as long as proper compaction can be achieved.

   c. Predominantly stone, broken concrete, or rock fragment; embankment material of sizes that cannot be compacted can be placed in lifts, not exceeding a thickness of two feet, up to an elevation one foot below subgrade. Such material larger than three inches in the greatest dimension should not be placed within the upper six inches of the roadbed embankment. Materials should not exceed six inches in greatest dimension when placed within the upper three feet of embankment or backfill.

      Each such lift should be leveled prior to placing the next layer thereon, using suitable equipment in a manner that will provide even distribution of the larger rock or broken concrete and fill the voids with the spalls and finer material, so as to form a compact mass.

   d. Embankment materials adjacent to structures should be placed in lifts not more than eight inches in thickness for a distance of 50 feet on each side of pipes, 48 inches or less in diameter; and 100 feet on each side of other structures. The placement shall be for the full height, from the embankment foundation to the top elevation of the structure.

e. Layer construction is not required for channel fills, spoil banks, and berms that do not provide foundation support for structural features.

The upper two to four feet of the embankment/fill should be comprised of selected earth material or granular material. Granular materials, if used, should be placed in the uppermost portions of the embankment. Within 12 inches of the subgrade surface, granular materials should not be capped with non-granular materials.

At no time should embankment material be placed frozen or on soil that is frozen to a depth greater than four inches. No frozen material exceeding six inches in the greatest dimension should be permitted in the embankment. Frozen material less than six inches in the greatest dimension can only be placed outside of a 1(H) to 1(V) slope down and outward from the grading subgrade PI.

2. Compaction. Evaluation of embankment/fill material or base course compaction should comply with Mn/DOT's Specifications.

The Design Recommendation letter prepared by the District Soils Engineer should include recommendations for the method used to measure or evaluate the effectiveness of the compactive effort the contractor is using to place embankment/fill soils and aggregate base materials. Mn/DOT Spec. 2105, <u>Excavation and Embankment</u>, lists two methods to measure effectiveness of compactive effort, Specified Density and Quality Compaction (formerly termed Ordinary compaction); Mn/DOT Spec. 2211, <u>Aggregate Base</u>, lists three methods, Specified Density, Quality Compaction and Control Strip. Descriptions of these methods can be found in the Specifications and in the Grading and Base Manual.

Although these methods are <u>equally</u> effective in evaluating the results of a Contractor's efforts, there are circumstances when one method will be more practical than another.

For example, for a grading project, Specified Density <u>MAY</u> be best if there is a limited number of inspectors; if the planned embankment construction is over 50,000 cubic yards; or if the work involves a "large" number of culvert installations.

Quality Compaction <u>MAY</u> be best if the embankment construction is less than 50,000 cubic yards; if the inspectors available are <u>experienced</u> in all aspects of embankment construction and are numerous enough to <u>constantly</u> observe <u>all</u> of the contractor's operations that require Quality Compaction.

For the Aggregate Base part of a project Specified Density <u>MAY</u> be best if there is a limited number of inspectors available; if the project is considered "large" (over 3 miles long); and if the distance from the District headquarters is <u>MORE</u> than 60 miles or one hour travel time.

Quality Compaction is usually ok if the project is less than 3 miles long and the inspectors available are numerous enough to <u>constantly</u> observe <u>all</u> of the contractor's operations.

Control Strip <u>MAY</u> be used if the number of available inspectors is limited; if the project is considered "large" (over 3 miles long); and if the distance from the District headquarters is <u>LESS</u> than 60 miles or one hour travel time.

For Aggregate Surfacing (Mn/DOT Specification 2118) there is no compaction requirement unless the recommended surface thickness exceeds TWO (2) inches, in which case the aggregate is compacted and evaluated in accordance with the requirements of Mn/DOT Specification 2211.3, Quality Compaction.

Where the Specified Density Method is used, it is the project field inspector's responsibility to sample and test the materials to be used as fill; to determine their maximum dry densities and optimum moisture contents; and to perform density and moisture tests on the compacted embankment, to assure that specified density requirements have been attained. Materials placed within the upper three feet of the embankment, and those adjacent to structures, should be compacted to a dry density of not less than 100 percent of their maximum dry density. Materials placed below the upper three feet of the embankment, and not adjacent to structures, should be compacted to a dry density not less than 95 percent of their maximum dry density.

Quality compaction (visual inspection) may be specified for materials placed outside a 1-1/2(H) to 1(V) slope down and outward from the grading shoulder P.I. on fills over 30 feet in height, or outside of a 1(H) to 1(V) slope down and outward from the grading shoulder P.I. on fills of 30 feet or less in height. The embankment/fill should be compacted until there is no further evidence of consolidation.

Mechanical compaction is not required on portions of the embankment that are constructed with predominantly stone or rock fragments or placed in conjunction with topsoil covering or roadside grading. Density control should not apply to waste materials or non-rock material (topsoil, etc.) utilized for incidental drainage or landscaping outside the roadbed embankment. However, it is the responsibility of the project field inspector to approve that the placed material is a compact mass that is acceptably consolidated.

3. Moisture Control. Compaction moisture control should comply with Mn/DOT's Specification 2105.3F. For materials placed with specified density control, the moisture content of the embankment material should be not more than 115 percent of its optimum moisture content when 95 percent of the maximum density is specified, and should be within the range of 65 to 102 percent of its optimum moisture content when 100 percent of the maximum density is specified.

   Special moisture restrictions should be employed for problem soils. For expansive and lacustrine soils, the compaction moisture content should be within the range of 90 to 115 percent of the optimum moisture content for material placed below the upper three feet of the fill, and within the range of 90 to 102 percent within the upper three feet. The compaction moisture content for red drift soils should be within the range of 65 to 95 percent of its optimum moisture content.

4. Use of Lime. The decision on the use, type, and amount of lime is the responsibility of the District Soils or Materials Engineer. The amount of lime used depends upon the moisture content of the soil being dried, the plasticity, and/or the desired engineering properties to be attained.

   Quicklime and hydrated lime products are commonly used. Quicklime, or calcium oxide, is highly reactive, compared to hydrated lime. Hydrated lime is quicklime that has had part of its water demand satisfied by adding water in the slaking process. For drying of soils, in most cases, less than one percent hydrated lime is sufficient, but in no case should more than two percent be used. Quicklime may be substituted for hydrated lime on the basis of one percent quicklime being equal to 1.3 percent hydrated lime. Additional information may be obtained from Mn/DOT's Grading and Base Manual, Section 5-692.521.

5. Controlled Rate/Surcharge. Compressible silts, clays, and organic deposits may be improved by surcharging or pre-loading. The pre-load fill is applied in controlled lifts to the area to be treated and allowed to remain in place while foundation soils consolidate sufficiently to increase their strength or reduce their compressibility. After sufficient time for the required compression has occurred, either the pre-load is removed or additional fill may be placed. Pre-loading has proven to be a relatively inexpensive method of improving deep compressible deposits.

Monitoring of embankment settlements and movements is done through the installation of settlement plates (Figure 3-2.10), hub lines, and control points. Installation and location of settlement plates on, and hub lines and control points outside of, the embankment should be coordinated between the District Soils Engineer and the Foundations Unit (Office of Materials and Road Research).

6. Test Rolling. Evaluation of the load carrying capacity of a prepared subgrade with heavy rollers prior to the placement of the base course is called test rolling. The Department normally employs test rolling only on main lines of projects at least one mile in length. Areas which pump or rut excessively should be excavated and recompacted to provide adequate bearing material for the pavement. Test rolling should comply with Mn/DOT's Specification 2111.

### 5-2.01.05 EROSION CONTROL AND TURF ESTABLISHMENT

During construction, temporary erosion controls should be used in conjunction with permanent measures, with all forms of erosion control being placed as soon as permissible. Temporary measures are of particular concern with steep rolling topography, erosive subsoils (i.e., loamy sands, silt loams, and silty clay loams), and where most of the drainage from the construction limits may enter into streams, lakes, etc. Temporary measures consist of bale ditch checks, earth diversions, bale diversions, temporary drains, and sediment traps/basins. Additional details of these controls can be obtained in Mn/DOT's Road Design Manual, Section 8-5.0.

Erosion is controlled, on a permanent basis, through the placement of sod or the establishment of turf. In most situations erosion control sod should be provided on typical highway projects, even though a portion of the project may be in an urban setting. Erosion control sod is of good quality and usually blends in quite well with established lawns. Lawn and boulevard sod should be restricted to rest area lawns and building site lawns.

The following Table 5-2.2 summarizes the available types of sod and their usage.

Table 5-2.2. Sod types and usage.

| Sod Type | Predicted Use (%) | Quality | Usage |
|---|---|---|---|
| Lawn and boulevard | 5 - 15 | Premium | High maintained areas, such as rest areas and lawns. |
| Erosion control | 75 - 95 | Average to high | Areas with low maintenance, such as ditch bottoms, bridge end slopes, lawns, and behind curbs. |
| Pasture | 0 - 5 | Low to average, harvested from local areas where commercial sod may not be available | Very harsh roadsides and/or very sandy soils. |

When turf is to be established, it should be placed as soon as construction permits. This reduces the length of time areas are left unprotected and the area exposed is reduced. It is the responsibility of the District Soils Engineer to recommend types of turf establishment in the project Materials Design Recommendations Report. The components of successful turf establishment are discussed below.

1. Topsoil. The most critical element for successful turf establishment is the amount and quality of topsoil at the site. Therefore, it is extremely important to salvage as much of

the in-place topsoil as possible. All available topsoil should be salvaged and stockpiled during construction and then re-spread over the disturbed areas.

a. General Roadsides. The Department's goal for topsoiling roadsides is to provide six inches of topsoil over all disturbed areas. If there is a shortage of suitable topsoil, four inches may be provided. In no circumstances should less than three inches be recommended. If there is an insufficient quantity of salvageable topsoil to provide even three inches, then a topsoil borrow item should be recommended.

b. Rest Areas/Building Sites. For lawns on all rest areas and building sites, a minimum of six inches of topsoil should be provided. The Department's goal is to provide six inches of topsoil over the entire site. However, three to four inches can be recommended for the outlying areas (berms, ramps, drain fields, and exercise areas) if a shortage exists.

c. Excess Topsoil. If there is an excess of topsoil on a proposed project, then the depth of replaced topsoil should be increased as much as possible. No less than six inches should be placed on areas to be seeded. Inslopes may be built up with topsoil, and additional topsoil may be stockpiled for future use by maintenance.

d. Use of Peat as Topsoil. Because of shrinkage and stability problems, peat is generally not recommended for use as a topsoil medium. However, the District Soils Engineer should make a detailed review of the type of organic soils on the project and deal with each individual project or portion of a project. For instance, organic soils classified as muck, organic silt loams, and even peat loams may be used as topsoil. In some cases, sand could be mixed with peat loams to make a suitable growing medium. Semi-fibrous to fibrous peats should not be used to topsoil slopes. Fibrous peats have high shrinkage and low stability characteristics.

2. Lime. Lime aids in successful turf establishment on acidic type soils, which are generally found in the central, north central, and northeastern portions of the state. Usually, these soils are forest type soils and/or sands with a high degree of leachability. The degree of acidity is measured by the difference from a pH less than 7.0. For any particular project, the determination of lime requirements is made from soil test results and the information in Tables 5-2.3, 5-2.4, and 5-2.5, which follow. Areas 1 and 2 are delineated in Figure 5-2.1. The SMP buffer index test is conducted on mineral soils with less than 6.0 pH.

Table 5-2.3. Lime recommended for mineral soils when soil/water test is conducted.

| | Application (tons/acre) | |
|---|---|---|
| Soil-water pH | Area 1 | Area 2 |
| 6.4 and higher | 0.0 | 0.0 |
| 6.3 | 2.0 | 0.0 |
| 6.2 | 2.0 | 0.0 |
| 6.1 | 2.0 | 0.0 |
| 6.0 | 3.0 | 2.0 |

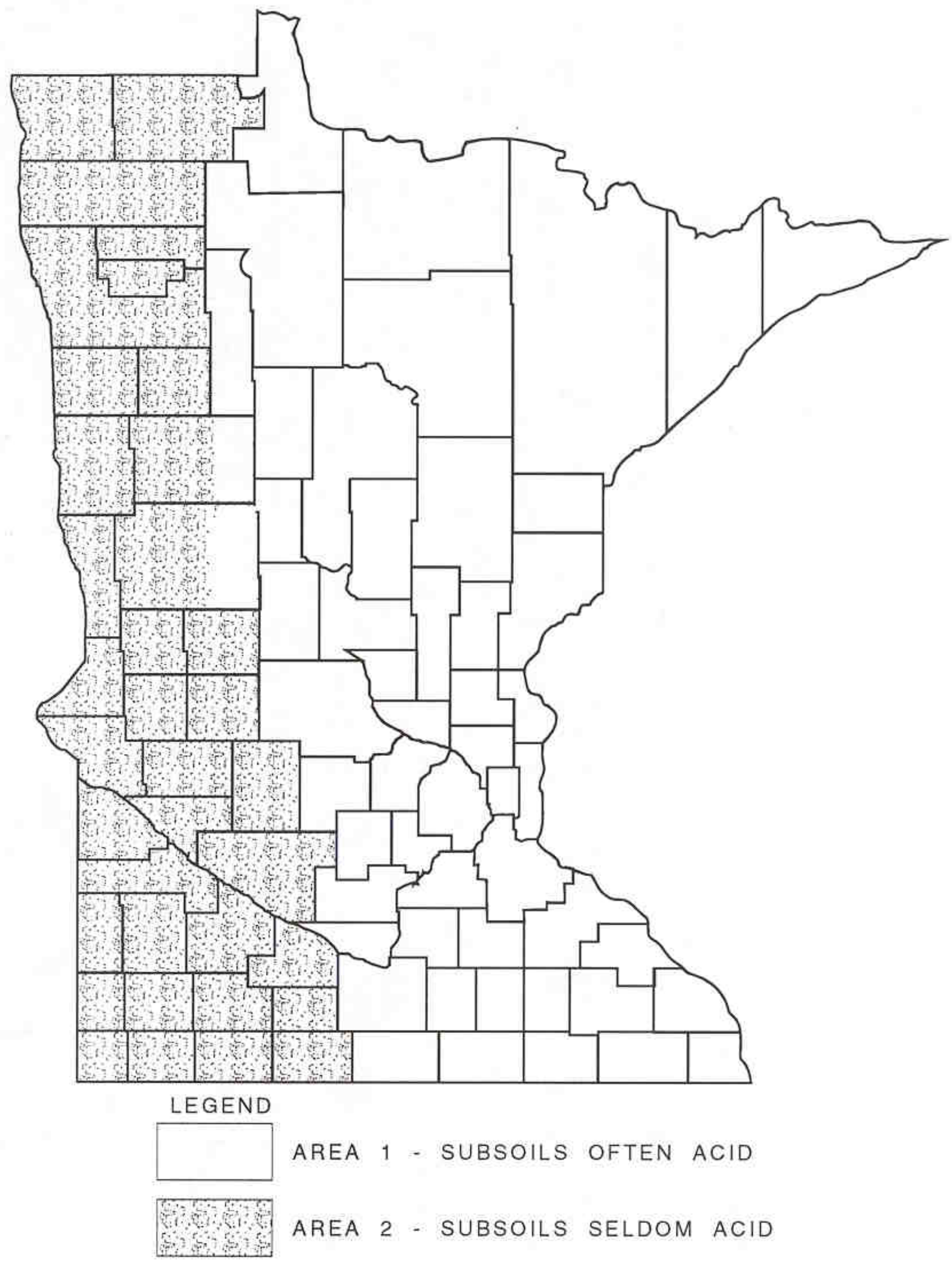
Table 5-2.4. Lime recommended for mineral soils when SMP test is conducted.

| SMP Buffer Index | Application (tons/acre) Area 1 | Area 2 |
|---|---|---|
| 6.8 | 3.0 | 2.0 |
| 6.7 | 3.0 | 2.0 |
| 6.6 | 3.0 | 2.0 |
| 6.5 | 3.5 | 2.0 |
| 6.4 | 3.5 | 2.5 |
| 6.3 | 3.5 | 2.5 |
| 6.2 | 4.0 | 3.0 |
| 6.1 | 4.0 | 3.0 |
| 6.0 | 4.0 | 3.5 |
| 5.9 | 4.0 | 3.5 |
| 5.8 | 5.0 | 4.0 |
| 5.7 | 5.0 | 4.0 |
| 5.6 | 5.0 | 4.5 |

Table 5-2.5. Lime recommended for organic soils.

| Soil-water pH | Application (tons/acre) |
|---|---|
| 5.5 and higher | 0.0 |
| 5.4 | 2.0 |
| 5.3 | 2.0 |
| 5.2 | 2.0 |
| 5.1 | 2.0 |
| 5.0 | 2.0 |
| 4.9 | 3.0 |
| 4.8 | 3.0 |
| 4.7 | 4.0 |
| 4.6 | 4.0 |
| 4.5 or less | 5.0 |

Figure 5-2.1. Map used to determine lime needs



3. Fertilizer

The determination of fertilizer requirements is made from soil test results. The amount of fertilizer to apply is dependent on the type of turf established, or seed mixture used, and the fertility level of the in-place soils. In order to make fertilizer determinations, Tables 5-2.6, 5-2.7, and 5-2.8 should be utilized with Figures 5-2.2 and 5-2.3.

Table 5-2.6. Nitrogen required for various seed mixtures.

| | Nitrogen Required (lb./acre) | |
|---|---|---|
| Organic Content of Soil (%) | Mixtures 400 - 700 | Mixtures 100 - 300 and 800 - 1,000 |
| 0 - 5 | 70 - 80 | 30 |
| 6 - 10 | 50 - 60 | 20 |
| > 10 | 40 | 20 |

Figure 5-2.2. Determination of phosphorous.

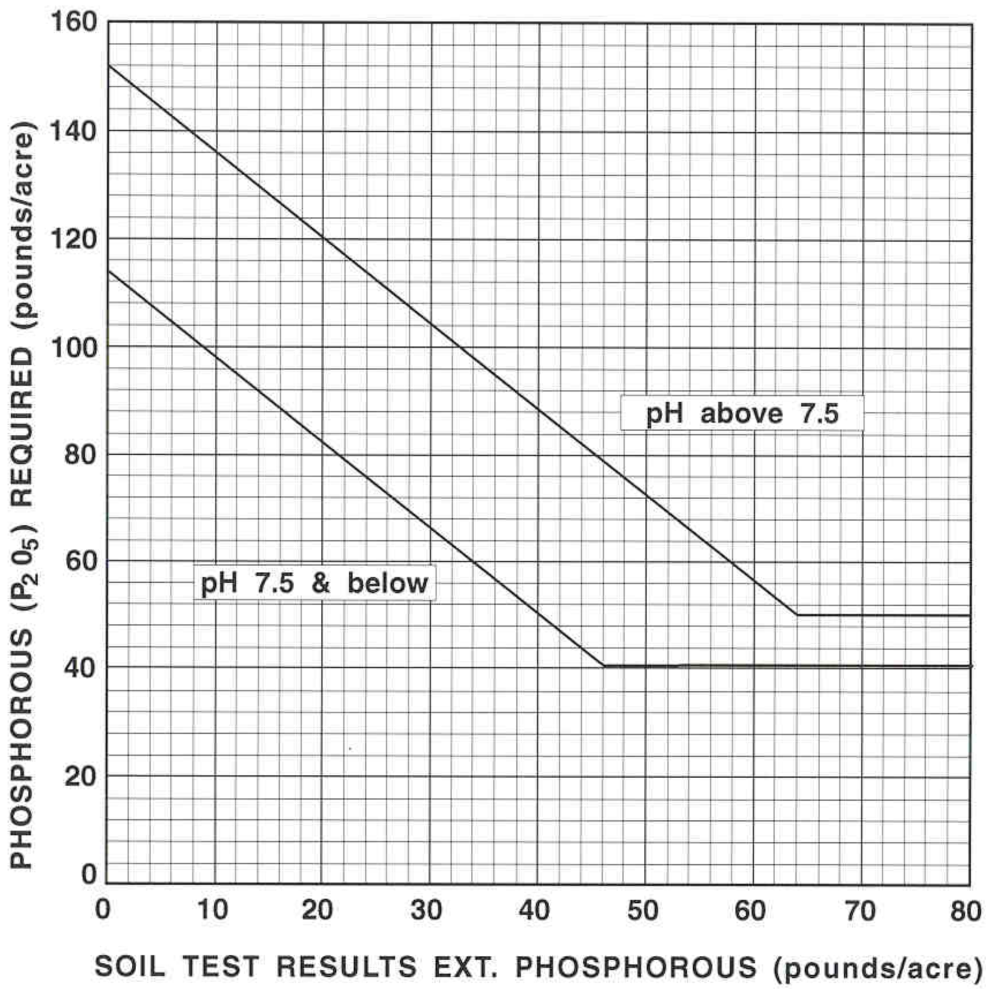


Figure 5-2.3. Determination of potassium.

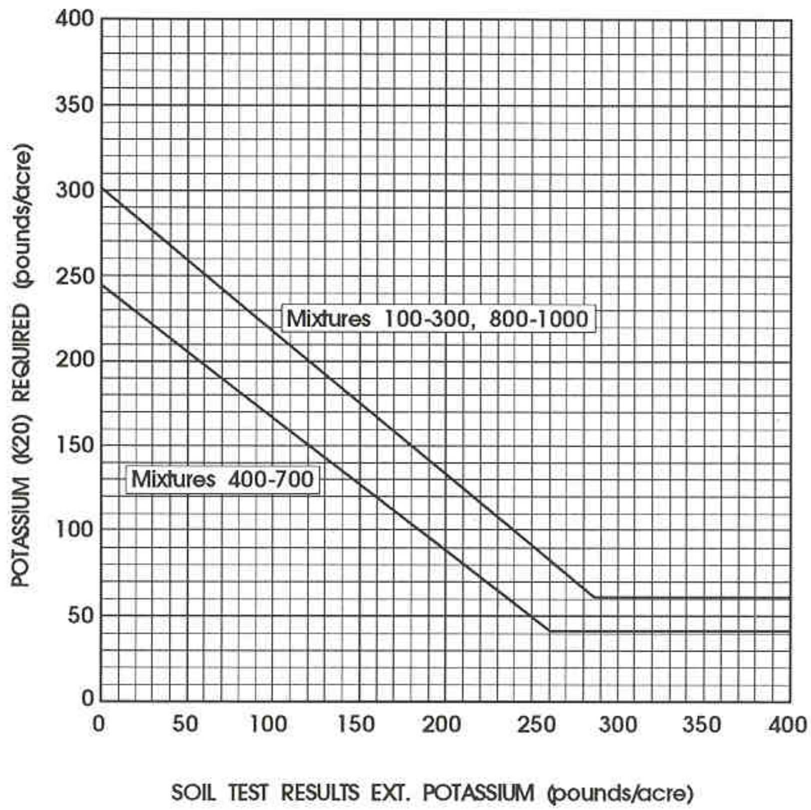


Table 5-2.7. Analysis of available fertilizers.

| Ratio | Analysis (N $P_2O_5$ $K_2O$) | Ratio | Analysis (N $P_2O_5$ $K_2O$) |
|---|---|---|---|
| 1:2:1 | 12-24-12 | 0:1:2 | 0-20-40 |
| 1:2:2 | 10-20-20 | 2:2:1 | 20-20-10 |
| | | | 16-16- 8 |
| 2:6:3 | 8-24-12 | | |
| | | 1:4:1 | 8-32- 8 |
| 1:4:4 | 6-24-24 | | |
| | 5-20-20 | 3:2:4 | 15-10-20 |
| 1:1:1 | 10-10-10 | 2:2:3 | 14-14-21 |
| | 12-12-12 | | 12-12-18 |
| | 14-14-14 | | |
| | 15-15-15 | 3:3:4 | 15-15-20 |
| | 16-16-16 | | 12-12-16 |
| | 17-17-17 | | |
| | | 2:3:3 | 12-18-18 |
| 1:4:2 | 8-32-16 | | 14-21-21 |
| | 7-28-14 | | |
| | 6-24-12 | 1:1:2 | 10-10-20 |
| 1:2:4 | 6-12-24 | 2:1:5 | 10- 5-25 |
| 1:3:9 | 4-12-36 | 2:1:2 | 24-12-24 |
| 2:1:1 | 20-10-10 | 9:23:0 | 18-46- 0 |
| | 16- 8- 8 | | |
| | | 1:1:0 | 25-25- 0 |
| 3:1:1 | 15- 5- 5 | | |
| | 24- 8- 8 | 1:3:3 | 8-24-24 |
| | | - - - | 9-23-30 |

Table 5-2.8. "Shotgun" fertilizer analysis and rates.

| Analysis | Rate (lb./acre) | Seed Mixtures | Soil Conditions |
|---|---|---|---|
| 12-12-12 | 500 | 500 - 700 | Average to favorable, medium, organic, dark colored, loams and heavier soils, average depths. |
| 12-12-12 | 700 | 500 - 700 | Lighter soils, forest soils, thin reddish soils, lighter colored, tan to gray. |
| 10-20-20 | 450 | 400 - 700 | Favorable soils, silty soils, darker colored salt contaminated soils. |
| 8-32-16 | 400 | 800, 900 | Alkaline soils, prairie-type soils found in southwestern Minnesota and through the Red River valley. |
| 12-24-12 | 400 | 500, 700 | Alkaline soils, prairie-type soils found in southwestern Minnesota and through the Red River valley when grass mixture is desired. |
| 6-24-24 | 500 | 800, 900, | Heavier soils, tan to dark colored, or when B horizon soils are to be seeded. |
| 20-10-10 | 400 | 650, 600, | Favorable soils when lawn- mixtures are seeded. |
| 6-24-24 | 200 | 100 - 300 | All soil types when native grasses are seeded. |

Following is an example of proper fertilizer selection:

Example. Determine fertilizer analysis and rate for a soil with an organic content of 3%, extractable phosphorous of 14 lb./acre, exchangeable potassium of 110 lb./acre, and a pH of 6.8. Seed Mixture 500 is to be used.

From Table 5-2.6, nitrogen required = 70 - 80 lb./acre.
From Figure 5-2.2, phosphorous required = 88 lb./acre.
From Figure 5-2.3, potassium required = 110 lb./acre.

The above nutrients are in an approximate 2:2:3 ratio. Thus, from Table 5-2.7, select 12-12-18 analysis. Next, determine an application rate by dividing the required nutrients by the percent active ingredient in the fertilizer, i.e., for nitrogen, 80 ÷ 0.12 = 666; for phosphorous, 88 ÷ 0.12 = 733; and, for potassium, 110 ÷ 0.18 = 611. Thus, an application rate of 650 lb./acre appears good.

Use 12-12-18 analysis at an application rate of 650 lb./acre.

When no soil samples have been taken for a particular project, and thus no laboratory test data are available, three methods may be used to determine the fertilizer needs requirement. These methods are as follows:

- Use the fertilizer recommendation from an adjacent project that has similar soil conditions.

- Obtain the approximate phosphorous and the approximate potassium concentrations of the in-place soils from Figures 5-2.4 and 5-2.5 and use these values as if they were test data. Nitrogen requirements can be obtained from Table 5-2.6 by assuming an organic content of the in-place soils (usually five percent or less). Then proceed with determining the fertilizer requirement as shown in the above example.

- Use the "shotgun" fertilizer analysis and rates listed in Table 5-2.8.

Figure 5-2.4. Relative soil phosphorous content.

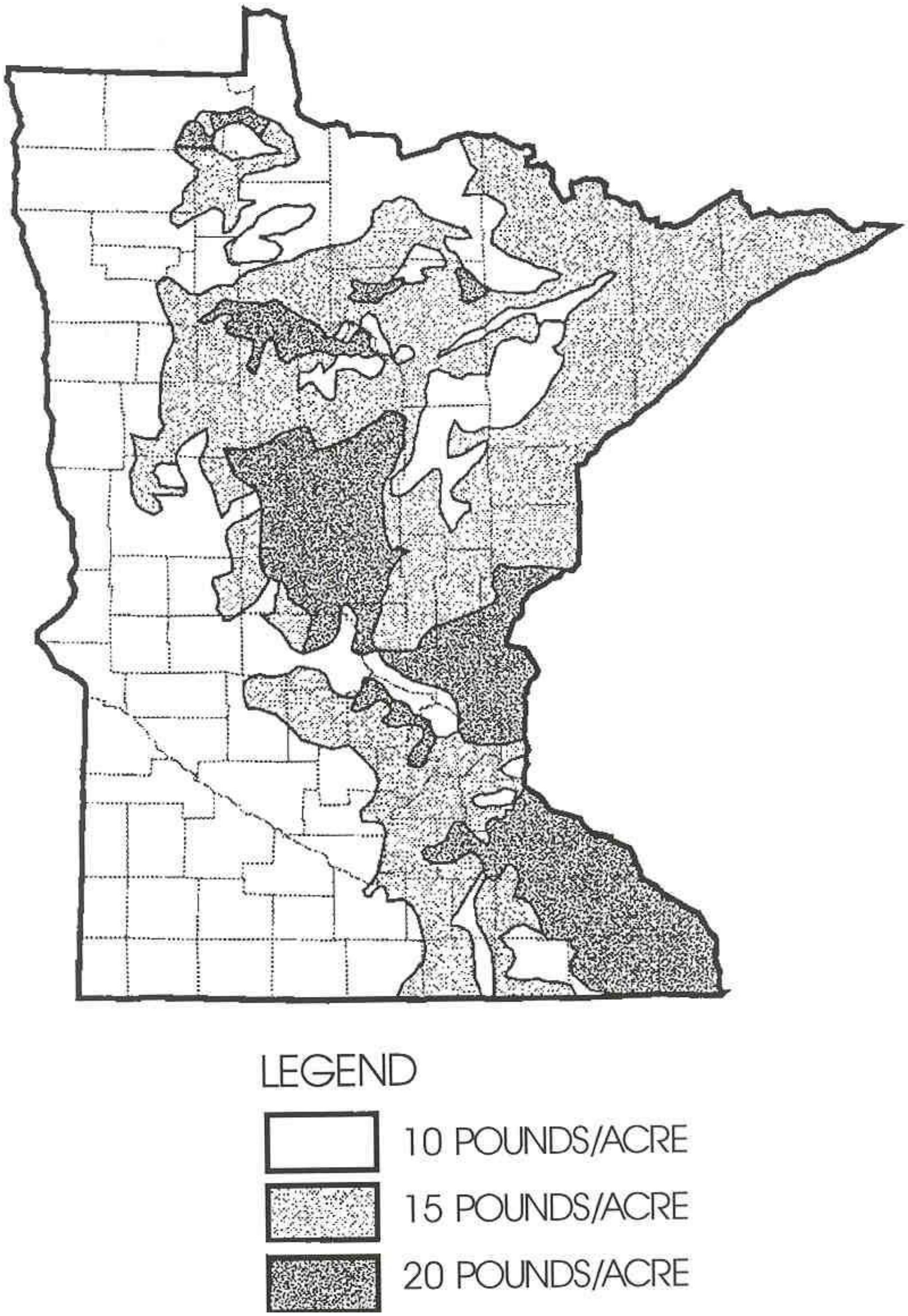
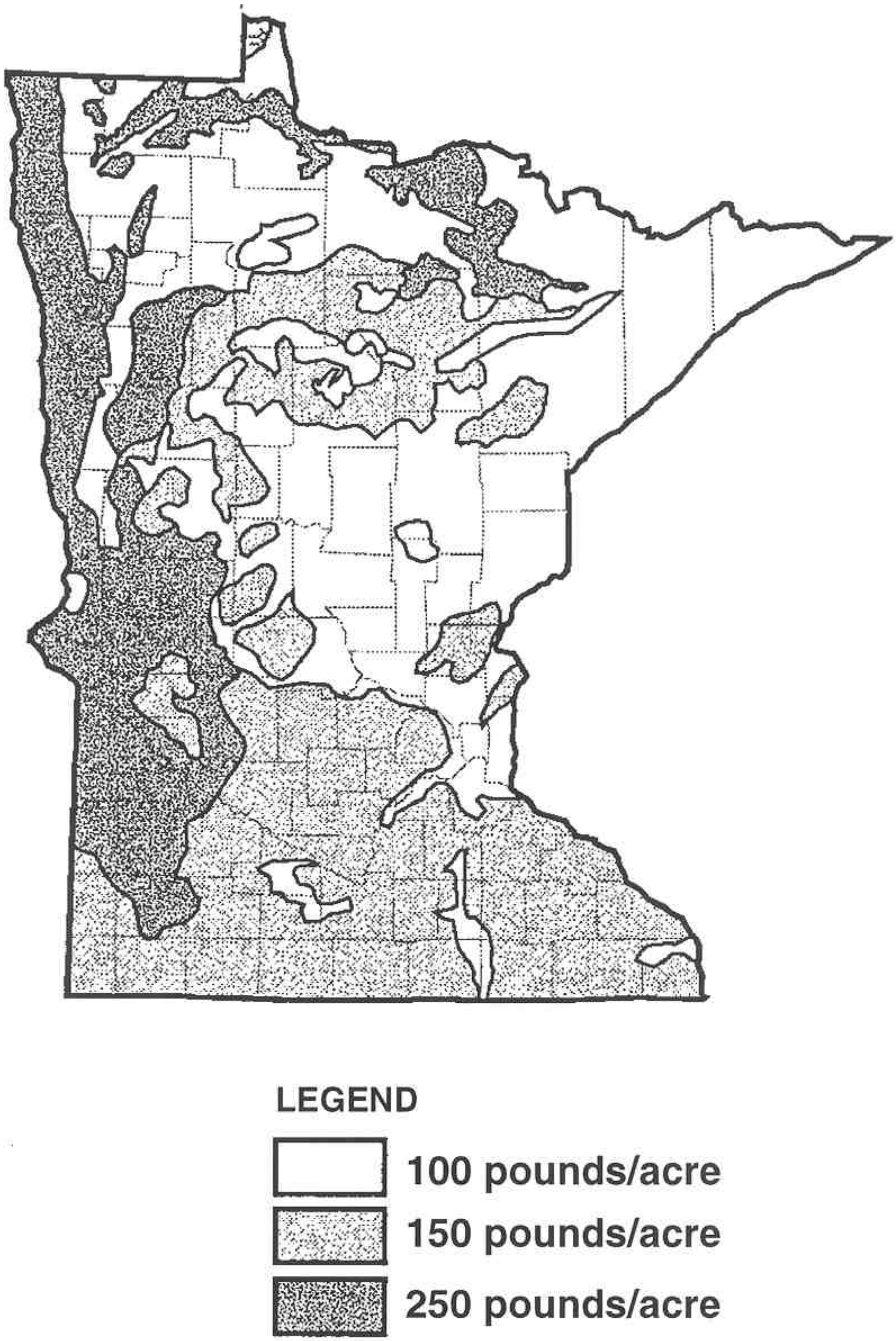


Figure 5-2.5. Relative soil potassium content.



An example using the above two Figures 5-2.4 and 5-2.5 to determine the fertilizer requirement follows:

Example. Determine the fertilizer requirement and rate for a turn lane project near Willmar. Seed Mixture 800 is to be used.

First, the in-place soil fertility level is determined. Assume a low organic matter content of in-place soil (0 - 5%). Then, from Figure 5-2.4, the soil phosphorous level is 10 lb./acre and from Figure 5-2.5, the soil potassium level is 150 lb./acre.

Second, the nutrients needed are determined. From Table 5-2.6, the nitrogen required is 30 lb./acre; from Figure 5-2.2, the phosphorous required is 96 lb./acre; and from Figure 5-2.3, the potassium required is 120 lb./acre.

Third, the fertilizer analysis and rate required is determined. From Table 5-2.7, select 9-23-30 analysis. Next, determine an application rate by dividing the required nutrients by the percent active ingredient in the fertilizer, i.e., for nitrogen, 30 ÷ 0.09 = 333; for phosphorous, 96 ÷ 0.23 = 417; and for potassium, 120 ÷ 0.30 = 400. Thus, an application rate of 400 lb./acre appears good.

Use a 9-23-30 analysis at an application rate of 400 lb./acre.

4. Mulch. Mulch performs a very important function in providing a proper environment for seed germination and controlling erosion while the seedling plants establish themselves. Several different mulching techniques are available for various types of projects. Therefore, it is important that the best mulching technique be selected to match project conditions.

   a. General. Available mulch types and their general usage are listed in Table 5-2.9.

Table 5-2.9. Mulch types and usage.

| Type* | Rate | Use | Remarks |
|---|---|---|---|
| 1 | 2 tons/acre | General - All soils types, flat to moderate slopes (3:1 or flatter) | Most effective and economical type. Include disc anchoring. |
| 2 | 0.18 gal/yd$^2$ | Drier sandy soils without much organic matter. Limit to small scattered areas such as roadway widenings (less than 10 ft.). | Does not work very well on soils high in organic matter. Water at a rate of 1,000 gal./acre should also be provided to pre-moisten the ground surface. |
| 3 | Not available at this time | | |
| 4 | 1-1/2 tons/acre of Type 1 plus 500 lb./acre of Type 5 | All soils types. General use on slopes steeper than 3:1 | Very economical mulching technique on slopes. |
| 5 | 1,500 lb./acre | Inaccessible areas such as overburden and weathered rock slopes. | Can also be used on small flat areas near traffic and buildings. |
| 6 | For use around landscape plantings only | | |

*Defined in Mn/DOT's Specifications

b. Shoulder Mulch Tacking. Shoulder mulch tacking is an additional technique for preventing erosion and establishing vegetation in the critical area immediately adjacent to paved shoulders. Basically, shoulder mulch tacking consists of applying an approximately three-foot wide band of asphalt emulsion with a distributor spray bar over the top of Type 1 mulch. Projects where shoulder mulch tacking would be very beneficial are those with heavier traffic volumes and/or those that are located in open wind-swept locations.

Shoulder mulch tacking is described in Mn/DOT's Specification 2575.3F10. It should be applied at a rate of two tons per acre of Type 1, oversprayed with 0.10 gallons per square yard of Type 2. It can be used on all soil types and is very effective in holding straw/seed in place next to bituminous shoulders. Also, provide for disc anchoring the Type 1 mulch.

c. Nettings and Blankets. Plastic nettings, consisting of Type 1 mulch with netting rolled out over the top of the mulch, or wood fiber blankets should be recommended for establishing vegetation and controlling erosion on slopes steeper than 3(H) to 1(V) where an erosion problem is anticipated. Nettings, which generally work better on cut slopes than they do on fill slopes because of better soil density. They should be used only where runoff does not pour over the top of the slope; whereas wood fiber blankets can be used in such situations. Wood fiber blankets are generally more effective at controlling erosion than the straw/netting combination because of better overall material density and better fastening capability.

Generally, wood fiber blankets are considered to be the best mulch available. They can also be used in lieu of sod around culvert apron ends.

Mn/DOT’s Specifications 3883 and 3885 cover plastic nettings and wood fiber blankets, respectively.

5. Seed. Perhaps the most difficult recommendation for the District Soils Engineer, relative to turf establishment, is the seed mixture to use on a specific project. However, standard mixtures have been formulated for just about all situations encountered throughout the state. Some of the situations and the potential for successful performance of the various seed mixtures are listed in Table 5-2.10.

Table 5-2.10. Seed mixtures performance.

| | Performance | | | |
|---|---|---|---|---|
| Factor | Very Poor | Poor | Good | Very Good |
| Adaptability to wet sandy soils | 800, 1,000 | 100, 150, 200, 300, 650 | 400, 500, 600, 700 | 900 |
| Adaptability to dry sandy soils | 800, 1,000 | 400, 500, 600, 700, 650 | 100, 150, 900 | 200, 300 |
| Adaptability to plastic soils, clays and silts | - | 650, 900 | 400, 500, 600, 700, 800 | 100, 150 200, 300, 1,000 |
| Adaptability to peat disposal | 100, 150 200, 300 400, 650, 800, 1,000 | 600 | 700, 900 | 500 |
| Tolerance to alkaline soils, pH > 7.5 | - | - | 500, 600, 650, 700, 800, 900, 1,000 | 100, 150, 200, 300, 400 |
| Tolerance to acidic soils | 800, 1,000 | 400, 600, 650, 900 | 100, 500, 700 | 150, 200, 300 |
| Tolerance to salt | 600, 650, 800, 900, 1,000 | 500, 700 | 300 | 400 |
| Adaptability to mowing | 100, 150, 200, 1,000 | 700, 800, 900 | 300, 500 | 400, 600, 650 |

a. General Roadside Seed Mixtures. General roadside seed mixtures are identified as Mixtures 500, 600, 700, 800, 900, and 1,000. These mixtures have a large range of adaptability and can be used statewide. However, each mixture is developed for a specific use and/or project soil condition. Historically, Mixture 500 has been used statewide and for all types of situations and/or soils. This does not mean, however, that Mixture 500 should be recommended as a "boiler plate" selection in the Materials Design Recommendations Report. One of the other mixtures may be more adaptable to the site and/or soils conditions, as indicated in Table 5-2.11.

Table 5-2.11. Seed mixtures and usage.

| Mixture | Use | Soil Types |
|---|---|---|
| 500 | General roadside use statewide. May be used on back slopes, inslopes, ditches, and waste areas. Can be mowed. | All soil types. Best on loams, tolerates most pH ranges and Fertility levels. |
| 600 | Roadsides in urban areas that are mowed. Can also be used on rural roadside shoulders | Good topsoils, medium organic and high fertility levels. |
| 700 | Rural mixture most widely used by counties. Area of use is similar to Mixture 500. | All soil types. Best on loams, most pH ranges. |
| 800 | Rural mixture used on heavy soils or for seeding plastic subsoils without without topsoil. Mainly used in agricultural areas of the state. | Clays, clay loams, silts, silt loams, plastic sandy loams. |
| 900 | Rural mixture used on sands, silts, and poorly drained soils. Does well on loams, loamy sands. red silty soils and gravelly areas. | Silts, silt loams, plastic sandy sandy |
| 1000 | Where it is desired to establish crown vetch. | Clays, clay loams, silts, silt loams, loams. |

b. Lawn Seed Mixture. Seed Mixture 650 is specially formulated for establishing a high-quality lawn. The mixture contains 75 percent bluegrasses. Some of the bluegrass components are low-maintenance types, while the remaining bluegrass components are dense, dark green colored, and luxuriant. Seed Mixture 650 should be used at building sites, at rest areas, and at other places a quality lawn is desired, but are not sodded. Whenever Mixture 650 is specified, at least six inches of quality topsoil should be placed.

c. Salt-tolerant Seed Mixture. Seed Mixture 400 is specially formulated for highway roadsides or boulevards that are subjected to heavy salt use. Species contained in the mixture are low growing (up to about eight inches high) and sod forming. The alkali grass contained in the mixture requires a salty environment in order to survive. Therefore, Mixture 400 should be recommended for shoulders and medians in urban areas of heavy salt use.

d. Mixtures for Temporary Cover. Seed Mixtures 1100 (Oats) and 1150 (Rye) are available to provide temporary cover. Oats should be used in the spring and summer. Rye should be used in the fall. Both oats and rye are annuals and provide vegetative cover for only one year. Specify Mixture 900 for projects that need a temporary cover crop lasting more than one year. Mixture 900 contains a considerable amount of legumes in it and, as a result, establishes quite easily, even without suitable topsoil.

e. Native Grass Mixtures. The use of native grasses is encouraged whenever possible, especially in rural areas of the state. The native grasses have proven to be extremely drought tolerant and hardy, and they do very well in poor soils. They also provide excellent wildlife habitat for birds that nest and forage on roadsides.

Mixtures 100, 150, 200, and 300 are native grass seed mixtures designed for specific areas of the state (Figures 5-2.6, 5-2.7, 5-2.8, and 5-2.9), or growing conditions described in Table 5-2.12.

Table 5-2.12. Native grass mixtures and usage.

| Mixture | Use | Soil Types |
|---|---|---|
| 100 | Specifically in western Minnesota where conditions are dry and soils are relatively poor. Suggested for use in ditch bottoms and back slopes. | Alkaline soils of western Minnesota. Clays, silty clays, and silts. |
| 150 | General mix that can be used nearly anywhere in the state. Suggested for use in ditch bottoms and back slopes. | All soil types, except peat. |
| 200 | Statewide, where soils are very sandy and well drained, especially for the Anoka Sand Plain Region, etc. Suggested for use in ditch bottoms and back slopes. | Sandy soils, sandy loams, loamy sands, and sands. |
| 300 | Statewide, composed of short grasses and intended for use on the inslopes of roadsides and in medians. | All soil types, except peat. |

Figure 5-2.6. Suggested planting region for Mixture 100.

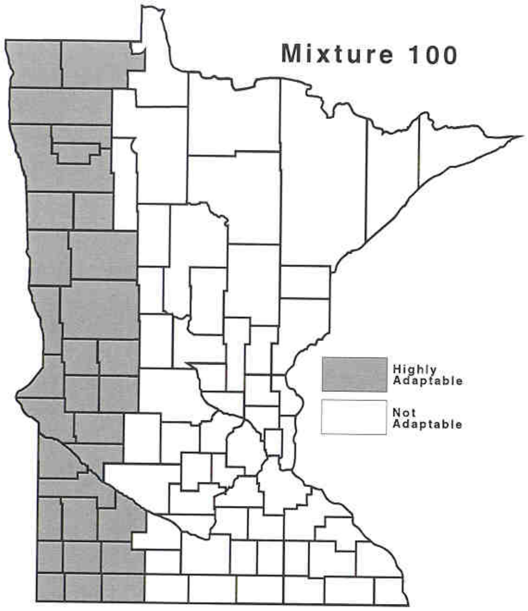



Figure 5-2.6

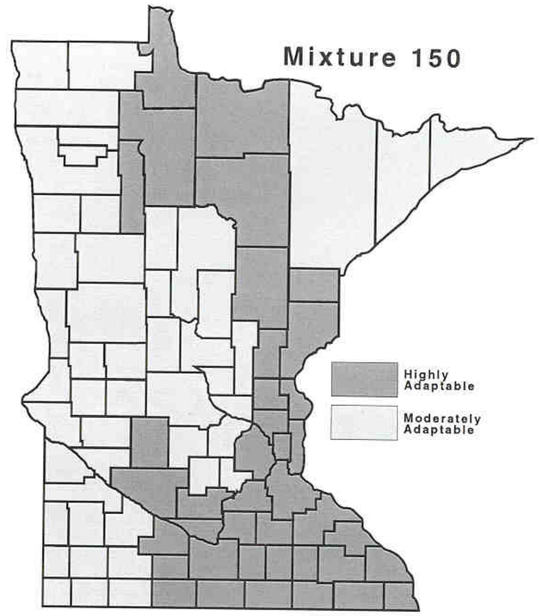



Figure 5-2.7

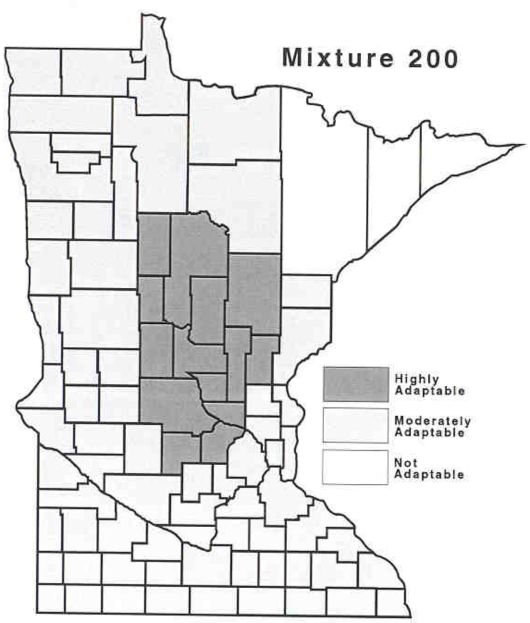



Figure 5-2.8

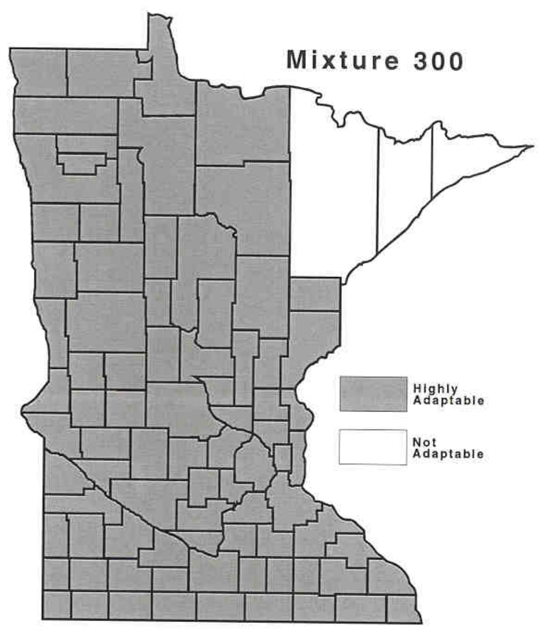



Figure 5-2.9

f. Wildflower Seed Mixtures. Wildflower seed mixtures are for specific situations. Basically, wildflowers have been seeded on rural projects and rest area sites. They can be used throughout the state. The goal of the Department is to match the species to be seeded with the species that grow naturally in the local project area. Therefore, most wildflower mixtures should be formulated as Special Seed Mixtures by the Agricultural Engineer.

Wildflower seed Mixture 1200 is a mixture that can be used for the southern half of Minnesota (south of St. Cloud).

## 5-2.02 SPECIAL TREATMENTS AND CONSIDERATIONS.

Special treatments and considerations are required for non-typical foundation materials and conditions. These are discussed in the following sections.

### 5-2.02.01 SWAMPS.

It is the responsibility of the District Soils Engineer to determine the depth of required swamp excavation, location and character of required backfill material, and associated shrinkage factors. Figure 5-2.10 shows typical swamp sections. The Foundations Unit (Office of Materials and Road Research) may also be contacted for recommendations.

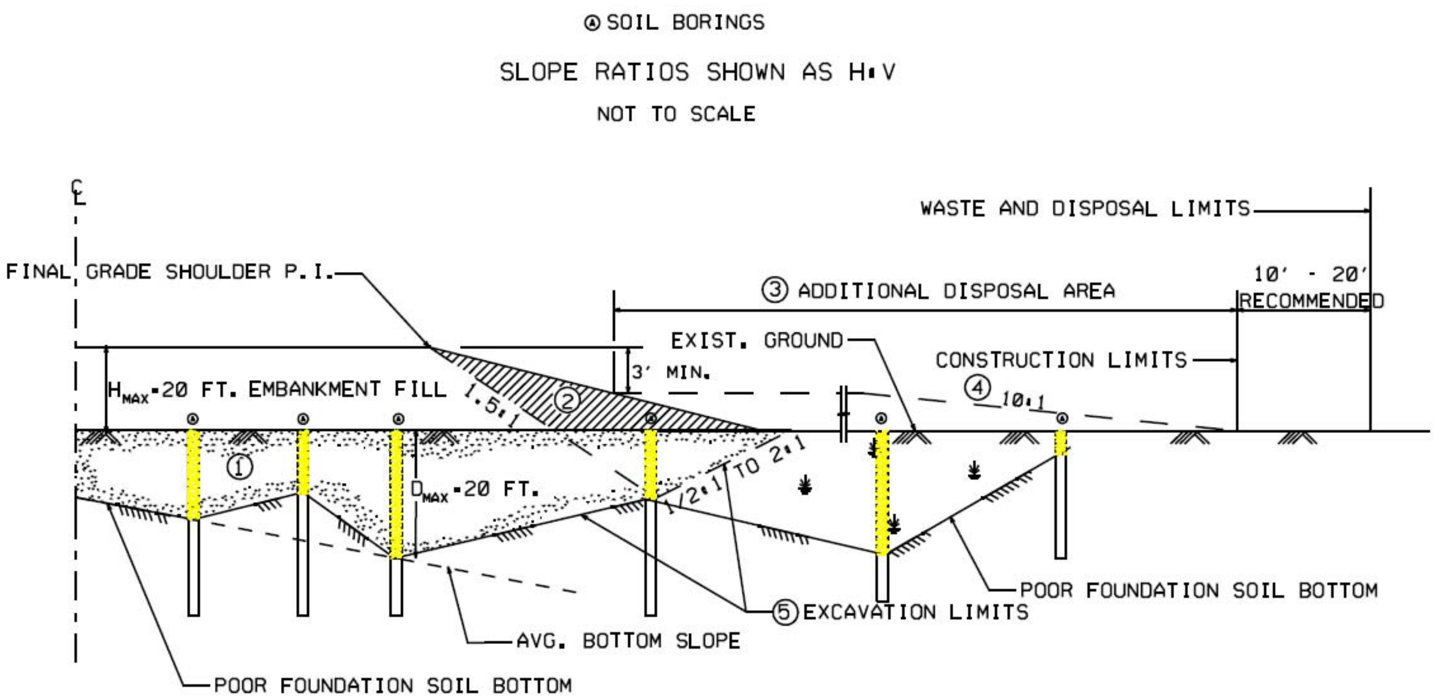
1. Excavation and Backfill. In this method, unstable swamp materials are excavated and replaced with suitable backfill. For fills of intermediate height (five to 20 feet), the typical section shown in Figure 5-2.10 should be used as a guide. In general, swamp material should be excavated outward (from the road centerline) and down from the point of intersection of the proposed side slopes and roadway surface (P.I.) to a depth of about two thirds the swamp thickness. From that point, the swamp material should be excavated on a slope of 1/2(H) to 1(V) outward and up to the existing grade and in and down to the bottom of the swamp. For shallow fills of less than about five feet, a floated embankment may be used; or the excavation may be made on a steeper slope of 1/2(H) to 1(V), but must extend outward and all of the way down to the bottom of the swamp. For high fills of more than about 20 feet in height, where more excavation is required to maintain stability, the typical section (1-1/2(H) to 1(V) slope), or even flatter, should be maintained and extend outward and all the way down to the swamp bottom.

Excavated swamp material may be disposed of along the completed toe of the roadway embankment. In general, disposal areas for swamp material should have 10(H) to 1(V) or flatter slopes, unless otherwise specified by the Foundations Unit.

Backfill material should consist of either granular or plastic borrow type materials. If the excavation is performed under water, the excavation should be backfilled with granular material to a level at least two feet higher than the local water level. If the excavation is performed in the dry (due to natural causes or the water having been removed from the excavation by sumps and pumping), the excavation may be backfilled with either plastic or granular soils. However, granular soils are generally the preferred swamp backfill material.

The placement of swamp backfill material should, in general, be in accordance with the recommendations in Section 5-2.01.04. Table 5-2.13 should be used as a guide in estimating the shrinkage factor for swamp backfill.

Figure 5-2.10. Typical swamp sections.




NOTES:

THIS TYPICAL SECTION MAY BE USED IF ALL OF THE FOLLOWING APPLY:

A. EMBANKMENT FILL IS 20 FT. OR LESS
B. POOR FOUNDATION SOILS DEPTHS (AS MEASURED BY DMAX) ARE 20 FT.OR LESS
C. POOR FOUNDATION SOIL BOTTOM SLOPES TOWARDS CENTERLINE OR IF THE BOTTOM SLOPES AWAY FROM CENTERLINE AT A 6:1 SLOPE OR FLATTER

FOR HIGHER EMBANKMENTS, DEEPER POOR FOUNDATION SOILS AND STEEPER SLOPING BOTTOMS, CONSULT THE GEOTECHNICAL ENGINEERING SECTION (OFFICE OF MATERIALS).

① EXCAVATE POOR FOUNDATION SOILS AND BACKFILL WITH SUITABLE MATERIAL (TO BE DETERMINED BY SOILS ENGINEER). POOR FOUNDATION SOILS CONSIST OF ORGANIC AND MINERAL SOILS WITH GREATER THAN 5% ORGANIC CONTENT BY WEIGHT AND MAY INCLUDE PEAT, MARL, OR OTHER SOILS AS DIRECTED BY THE SOILS ENGINEER

② DISPOSAL AREA AND SLOPE DRESSING. PLACE SUITABLE OR UNSUITABLE BACKFILL MATERIAL AS DIRECTED BY THE SOILS ENGINEER. PLACE A MAXIMUM OF 5 FT. OF EXCAVATED POOR FOUNDATION SOIL. DO NOT PLACE SUITABLE GRADING MATERIAL ON TOP OF ORGANIC SOILS.

③ ADDITIONAL DISPOSAL AREA. PLACE ADDITIONAL UNSUITABLE MATERIAL AND EXCAVATED POOR FOUNDATION SOILS. SPECIFICATION 2105 FURTHER DISCUSSES THE CONSTRUCTION REQUIREMENTS FOR EXCAVATED MATERIAL.

④ FOR DESIGN PURPOSES, USE 10:1 (H:V) SLOPE UNLESS OTHERWISE RECOMMENDED BY THE SOILS ENGINEER

⑤ EXCAVATION SLOPE COMING UP OUT OF BOTTOM SHALL BE 1/2:1 TO 2:1 AS RECOMMENDED BY THE SOILS ENGINEER. AS A MINIMUM, THE EXCAVATION SHOUL REMOVE POOR FOUNDATION SOILS TO THE FULL WIDTH OF THE EMBANKMENT.

Table 5-2.13. Approximate shrinkage factors for swamp backfill.

| Placement | Shrinkage Factor (%) |
|---|---|
| Removing small amount of topsoil | 130 |
| 5 ft. below natural ground | 135 |
| 10 ft. below natural ground | 140 |
| 15 to 20 ft. below natural ground, irregular bottom | 145 |
| About 30 ft. below natural ground, very irregular bottom | 150 |

Caution should be exercised if sumps and surface pumping are used, as such methods may decrease overall stability and result in flowing material or slides and damage to adjacent structures. In some swamp excavations it may be necessary to maintain the natural water level, even by pumping in water, to keep the sides of the excavation stable or to minimize possible settlement of adjacent structures.

The proximity of adjacent structures to the excavation should be a concern to the District Soils Engineer. The damage that would result from flowing material or slides should be addressed. Installation and monitoring of settlement plates, hub lines, or other instrumentation may be necessary, and should be coordinated with the Foundations Unit.

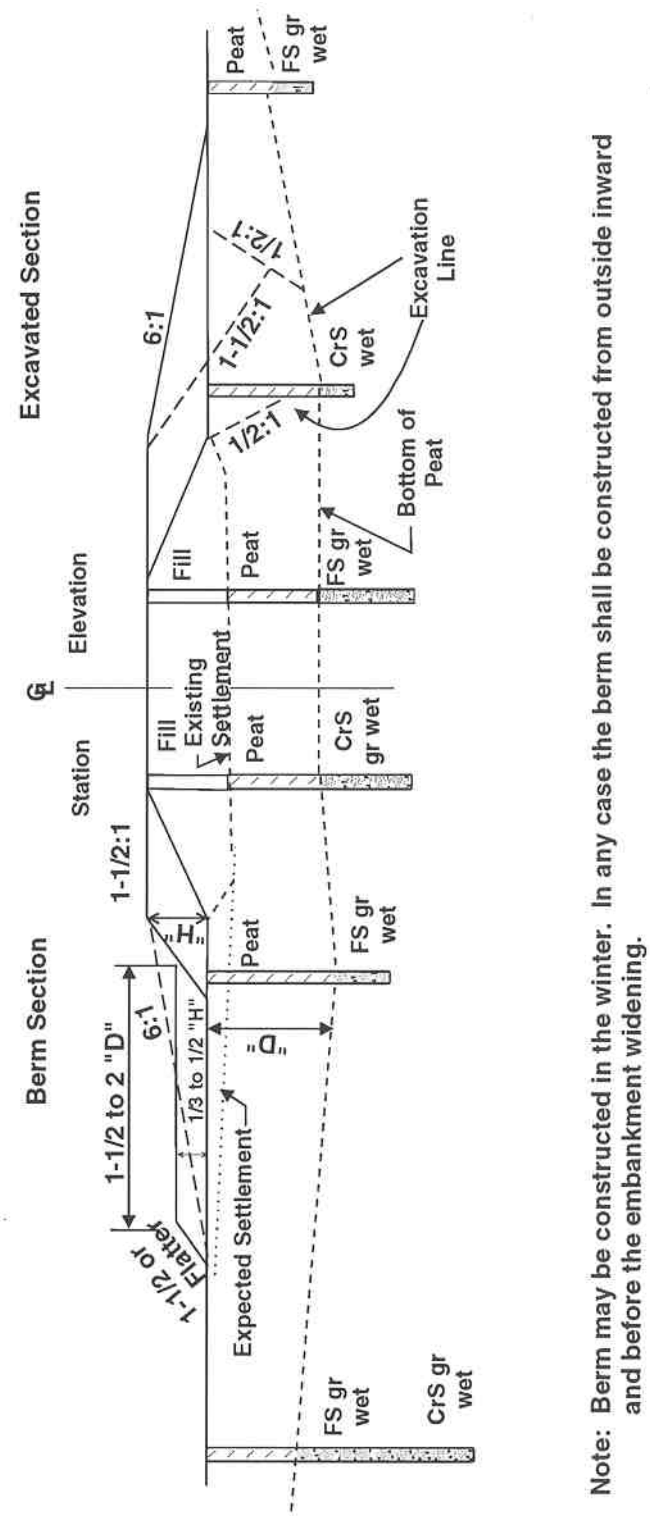
2. Floated Embankment. In the placement of a floated embankment, existing trees, brush, and other surface vegetation is clear cut with only minimal disturbance to the in-place vegetative mat. The embankment is then placed directly over the existing swamp, proceeding from the toes in toward the road centerline, with the slope width, including berms, exceeding twice the depth of the swamp. Typically, this method requires less fill material because the swamp material does not have to be dug out. Placement of geosynthetics (geotextiles or geogrids) between the swamp and placed embankment materials may be desirable in order to minimize ruts, expedite work, increase allowable stresses on the swamp subgrade and to allow the floated embankment to act as a cohesive whole. It should be noted that the use of geosynthetics would not eliminate settlement. They will tend to make it more uniform.

   It may also be desirable to use light weight fill (e.g., wood chips, shredded tires, etc.) for floating the embankment.

   The use of geosynthetics for earth reinforcement (Mn/DOT's Specification 3733, Type VI), or the use of light weight fill, should be coordinated with and studied by the Foundations Unit. (See Section 5-2.05 for additional information on geosynthetics.)

3. Widened Section. The placement of additional fill adjacent to an existing roadway may be accomplished by either excavation and backfill or use of a floated embankment. In either case, particularly if excavation and backfill is used, the stability of the old road core should be considered. Figure 5-2.11 depicts embankment widening over weak soils. This type of work should be studied by the District Soils Engineer and coordinated with the Foundations Unit and/or Pavement Design Unit (Office of Materials and Road Research).

Figure 5-2.11. Cross section of embankment over existing roadway in swamp.



## 5-2.02.02 ROCK EXCAVATION

Preliminary designs for rock excavation (subcuts and backslopes) should be based on Mn/DOT's Road Design Manual, Section 4-6.02.02. Final designs should be established only after completion of a detailed geologic investigation.

1. Subcuts. Subcut excavations require the determination of rock excavation method (mechanical or explosive) and transitions into and out of rock sections. Both transverse and longitudinal transitions should be provided in the design to minimize differential cracking. (Generally, rock designs provide for 6" of paid overbreak below the bottom of the rock subcut).

2. Rock Backslopes. Rock cuts averaging six feet or less in height should have the same backslope as the adjacent soil sections. Intermediate heights (about six to ten feet) should generally be laid back as soil slopes, but may be treated as a rock section if the rock is competent and not highly weathered, and especially if such cut heights lead into higher rock cuts. Cuts between 10 and 45 feet in height in competent rock generally require a backslope shaped by controlled excavation (such as presplitting or cushion blasting) and a ditch width of 12 feet. Rock cuts higher than 45 feet require similar controlled excavation methods, with a ditch width of 20 feet. The recommended ditch widths are based on minimizing rockfall onto the roadway, removal of fallen rock, and safety clear zone areas. The use of intermediate horizontal rock benches is not recommended. Rock backslope angles, which typically range between vertical and 1/4(H) to 1(V), should be based primarily on the rock mass characteristics, but may need to be modified due to right-of-way constraints. Assistance in determining the backslope angle, modification of ditch widths, or any special rock cut designs, is available from the Geology Unit (Office of Materials and Road Research).

   Blasting is normally required for the removal of rock and consideration must be given to the potential impact of blast vibrations on nearby structures and their occupants and waterwells. Under conditions where vibrations may have an adverse effect, they should be limited by contract language. Assistance in developing vibration controls should be obtained from the Geology Unit.

## 5-2.02.03 UNSUITABLE MATERIAL

Materials defined as unsuitable [topsoil, organic material (greater than 5% organic) debris, undesirable material, etc.] must be removed from the embankment foundation, unless otherwise designated. The unsuitable materials shall be disposed of in accordance with Mn/DOT's Specifications 2104 and 2105 (i.e., peat, muskeg, marl, muck, and other unstable materials that are not to be used in the roadbed embankments shall be deposited in the areas indicated in the Plans, or elsewhere as approved by the Engineer). All other materials, including bituminous and concrete waste, that are considered unsuitable for use in the upper portion of the roadbed shall be placed in embankments at least three feet below the subgrade surface, or outside of a 1(H) to 1(V) slope down and outward from the shoulder lines on fills under 30 feet in height, or outside of a 1-1/2(H) to 1(V) slope down and outward from shoulder lines on fills over 30 feet in height; used to flatten the embankment slopes; or disposed of elsewhere as approved by the Engineer (Mn/DOT's Specification 2105).

For embankments of three feet or less in height, unsuitable materials should be removed from the upper four feet of the roadbed between the shoulder lines. See Mn/DOT's Specification 2105.3D.

## 5-2.02.04 EXISTING STRUCTURES/PAVEMENTS

Abandoned structures and other obstructions within the right-of-way that have no salvage value should be demolished and removed from the project area, with their location and disposition indicated on the Plans. Those structures that interfere with new construction should be demolished and removed prior to construction of the affected work. Typical salvageable materials are aggregate, topsoil, debris, and rocks not exceeding three inches in the greatest dimension.

Removal operations should comply with Mn/DOT's Specifications 2102, pavement; 2103, buildings; 2104, pavement/miscellaneous structures: and 2442, removal of old bridges.

**5-2.02.05 SLOPE PREPARATION**

Embankments which are to be widened and have inslopes steeper than 4(H) to 1(V) require that the slopes be flattened to this slope, or flatter; or that steps (benches) be cut into the slope. See Mn/DOT's Specification 2105.3B. The material used for the embankment widening should substantially match the in-place embankment material in terms of textural classification, moisture and density.

**5-2.03 STRUCTURE FOUNDATIONS**

The foundation of a structure serves to transmit the weight of the building, bridge, or other structure to the supporting soil or rock below. Shallow foundations consist of spread footings, either continuous strips or individual pads, and are utilized when a soil stratum suitable for supporting the structure is located at a shallow depth. A continuous strip footing is one that supports a wall, while an individual pad footing is one that supports a single column.

When soft soils overlie a suitable supporting stratum at depth, the foundations are required to be extended to and supported by the deeper material by use of deep foundations - piles and/or drilled shafts. Piles are structural members of timber, concrete, and/or steel, with a small cross-sectional area when compared to their length, and are usually driven into the ground by means of a large hammer or vibrator. Drilled shafts generally have larger cross sections and are constructed by drilling a cylindrical hole to the required depth, placing steel reinforcement in the excavated shaft, and backfilling with concrete.

The Foundations Unit (Office of Materials and Road Research) will perform all foundation borings and designs.

**5-2.04 DRAINAGE/DEWATERING**

All excavations, whether for embankments or structure foundations, should be maintained in a well-drained condition at all times. This requires removal of ground water and control of surface runoff during preparation of the foundation.

Failure to dewater excavations slows the construction process and can lead to unstable slopes and softened subgrade. In low-permeability silty and clayey materials, dewatering can generally be accomplished through a system of gravity ditches and sumps and pumps. In high-permeability granular soils or bedrock, where large quantities of water flow are required to be cut off, a more elaborate system consisting of dewatering wells may be required. Construction water control is generally the responsibility of the contractor. Consult the Foundations Unit or Geology Unit (Office of Materials and Road Research) to assess the potential impact on nearby structures and waterwells.

Control of surface runoff is also important. Surface runoff should be directed away from excavations. Ponding water will lead to softened subgrades, slowing the construction process and requiring additional earthwork. At the end of the day the embankment surface should be shaped, compacted and sealed (by rolling) to facilitate any surface run off. Stockpiled material should be kept at locations that will not inhibit site drainage. The District Design Engineer should provide temporary drainage facilities.

## 5-2.05 GEOSYNTHETICS: GEOTEXTILES AND GEOGRIDS

Geosynthetics is a broad generic term for a family of synthetic materials, usually various polymers of petroleum, which are frequently used to enhance, replace, or make more cost effective use of, soil and rock materials. Included under geosynthetics are products such as geotextiles, geogrids, geonets, geomembranes, geocomposites, plus several others. Only geotextiles (5-2.05.01) and geogrids (5-2.05.02) will be briefly discussed here, because they are or will be the most frequently used. Geomembranes are impermeable and may be included as part of the overall design of maintenance facilities involving salt storage or brine ponds, or in ponding areas where leakage must be prevented. (Short mention of geosynthetics may be also found within other specific chapters of this manual.)

In addition to the routine uses of geosynthetics, such as for wrapping perforated pipe or under riprap, the need for and use of such materials should be recommended by the District Soils/Materials Engineer. Geosynthetics are generally not recommended by Mn/DOT for applications such as lining trenches for drainage, to prevent transverse reflective cracks in bituminous overlays, or to reduce the required design thickness of granular or bituminous materials in paved roadways. However, the use and acceptance of geosynthetics for both conventional and unconventional designs is constantly changing. The use of geosynthetics should comply with applicable specifications: Mn/DOT 2511.3 for Riprap, 2501.3C for Pipe Culverts, 2502.3C for Subsurface Drains, and all other pertinent special provisions. Depending on the specific requirements, assistance with such designs can be provided by the Geology Unit, Foundations Unit, Pavement Design, or Grading and Base Unit. Four references listed at the end of this chapter will be helpful for additional reading and may be borrowed from the Geology Unit: two FHWA publications, a text book by Koerner and the student text for Grading and Base II, Course Book. Please see one of these references for more specific characteristics of geosynthetic materials and also design procedures for various applications.

### 5-2.05.01 GEOTEXTILES

Geotextiles are permeable geosynthetics, often referred to as fabrics. They typically perform five functions, the most important of which are filtration, separation and reinforcement. Mn/DOT 3733 specifies six types of geotextile and summarizes the use for each type. Types I, II, III, and IV function primarily as filters, i.e., permit the movement of water, but retain soil particles. These four types of geotextile involve the greatest number of individual applications by project (due to uses such as wrapping perforated pipe, wrapping concrete culvert joints or as replacement for granular filter under riprap), but do not constitute the largest volume of use. Type V functions primarily as a separator (prevents two dissimilar materials from mixing) and it may also provide some soil reinforcement. The Type V fabric likely includes the largest volume of geotextile used in Minnesota. Typical uses might include: bottoms of subcuts in soft/wet soils to facilitate equipment movement and promote compaction of backfill material, culvert designs to separate the granular bedding from underlying soft and/or wet soils, and occasionally for separation/reinforcement designs for low fills over shallow swamps.

Type VI geotextile is used for reinforcement. It facilitates construction and provides additional strength to minimize the possibility that traditional or light weight fill materials will "fail" during or after construction. Applications such as "floating" fills over swamps or steepening side slopes are examples of the reinforcement function. Note that in Mn/DOT 3733, Type VI specifications are site specific. Recommendations for use and geotextile properties can/should be provided by the Foundations Unit. The decision whether to dig out or displace swampy soils with granular material vs. "floating" the fill over the swamp by the use of geotextiles (or possibly a geogrid) involves consideration of factors such as: function/type of roadway (tolerance for some unevenness), depth of swamp, environmental concerns with both excavation and disposal of organic material, when the roadway must be open to traffic (settlement period), and availability of and haul distance for granular replacement soil. Geosynthetics will not prevent settlement, but rather will provide more uniform settlement and likely reduce total settlement to some extent.

Geotextiles may be woven, nonwoven, or knit. The nonwoven and knit varieties generally have greater elongation (stretch) under load. Nonwoven fabrics are almost universally supplied for

Mn/DOT Type I thru IV applications. Knit geotextiles should only be used to wrap perforated drain pipes. While both woven and nonwoven materials will meet the requirements for Type V, woven slit-films are most commonly supplied because they are less expensive. Major reinforcement designs (Type VI), almost always require high-strength woven products.

Generally, geotextile recommendations should be referenced to one of the six types specified in Mn/DOT 3733. For various reasons, modified types are often used, and this should be clearly indicated to avoid confusion. Project-specific specifications are usually required for Type VI reinforcement applications. Typical specifications for separation and reinforcement applications are available from the Special Provisions Unit.

## 5-2.05.02 GEOGRIDS

Geogrids are a small but growing subset of geosynthetics and are a network of integrally connected polymer elements formed into a very open, grid-like configuration. They have large apertures (1/2" - 1 1/2", or more). Individual grid elements may be solid or composed of several strands of polymer. These products have relatively low elongation (stretch) under load and are primarily used in reinforcement applications. Grid products are currently being widely used in conjunction with modular block retaining walls. Geogrids and high strength geotextiles often compete for the same market niche. The Foundations Unit, in the Office of Materials and Road Research, can provide assistance in the use of and specifications for geogrids.