June 2015

This design guide is intended for use by Engineers, Technicians, and Soil Conservationists who have a need to plan and/or design Access Roads on private lands. It can also be used by consultants and as an aid in reviewing consultant's work. A methodology is outlined, following Practice Standard 560-Access Roads, to ensure that consideration is given to the various site conditions affecting roads including hydrology, hydraulics, and materials. The current PIA Conservation Practice Standard 560- Access Roads must also be read thoroughly and in its entirety. Due to the diversity of rainfall, soils, and topographies throughout PIA for road sites, some parts and references of this guide may be more applicable on a particular job than others. It is envisioned that steeper roads in high rainfall areas will present the greatest challenges for stability and could benefit from a thorough review of this guide.

Two helpful references (BMP Field Guide-Low Volume Roads Engineering-USDA Forestry Service, and Water/Road Interaction: Introduction to Surface Cross Drains-USDA Forestry Service), are cited frequently in this design guide and have been installed on the PIA website under Topics/Technical Resources/Engineering/Technical Papers at:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/pia/technical/engineering/?cid=stelprdb1187350
These references can be downloaded in pdf and printed for further reference.

A few exhibits are attached for ready reference at the end of the design guide as well as a few standard details that could be inserted into a set of design drawings. Links are presented with specific chart or exhibit numbers and page numbers. There are some webinar training links provided as well at the end of this guide.

Table of Contents

1. Site Visit 2
2. Instrument Survey 2
   2.1 Scenario 1: New road or new alignment 3
   2.2 Scenario 2: Existing Road, no alignment changes 3
3. Hydrology 4
4. Hydraulic Design 4
   4.1 Stream Crossings 5
   4.2 Cross Drains 6
5. Road Design Parameters 7
6. Slope Stability/Side Slopes 7
7. Soils & Surfacing Materials 8
   7.1 Existing Soil or Imported Soil 8

7.2 Select Quarried Material (gravels).....9
7.3 Thickness of Surfacing Materials & Geotextile 9
8. Compaction of Earth and Gravel Roads.....11
9. Operation and Maintenance 13
10. Webinars 13
11. Standard Design Details..... 14
12. Attachments 1-10..... 15-26

Typical technical assistance scenarios commonly encountered:

Scenario 1: New Road Alignment or Routing Required – (full or partial) – due to existing road issues or landuse changes the producer may request, or NRCS may recommend, new alignment or routing due to steepness, unfavorable drainage issues or sensitive area avoidance (wetlands, cultural resources, etc.). Surfacing & drainage issues to be determined after site visit.

Scenario 2: Existing Road With No Alignment Changes - Surfacing & drainage issues to be determined after site visit.

1. Site Visit

A. Visit the site – determine the EJAA Job Class based on surfacing material, maximum grades, and road length. Ensure someone from NRCS with the required authority visits the site during the planning, inventorying, & evaluation steps.
B. Determine suitability of existing alignment/routing, locations of potential water crossings, ponded water, location of gullies (especially the upslope start of the gullies), suitability of surfacing & native soil material, steep sections.
C. Determine if one lane or two lanes are required and turnout areas if needed.
D. Determine need and considerations for cross-drains following the checklist guidance for cross-drains, Water/Road Interaction: Introduction to Surface Cross-Drains (WRI/ISCD), USFS, p.12, figs. 8, 9, 10, 11 (**Attachment 1**) http://www.stream.fs.fed.us/water-road/w-r-pdf/crossdrains.pdf

2. Instrument Survey

A. Some grade information will be needed during the Site Visit (inventory and evaluation) to determine needs and feasibility.
B. A clinometer or accurate hand level could be used for flatter sites, but an instrument survey will be needed for more complex topographies.
C. A second survey, the design survey will be needed to collect detailed site data for an engineering design if the first one did not contain sufficient detail.

D. Survey data collected should be sufficient to produce a proposed centerline profile, and topographic information for cuts and fills at cross-section intervals. (see Section 2.2.a below).
E. The topography and road length will determine the appropriate instrument; a level, a theodolite capable of vertical and horizontal angles, or total station.

2.1 Scenario 1: New road or new alignment.

a. Survey the proposed alignment. For non-GPS survey equipment, use turning points for long roads and close the survey.
b. Route Surveys guidance shown on pages 1-112 thru 1-119 of NEH part 650 Ch. 1 Surveying: GPS survey procedures located on p. 104 at: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=25276.wba
c. An open traverse (end point is not the starting point) may also be used. The survey should contain a closing shot on the temporary benchmark (TBM) to check for accuracy. NRCS accuracy standards are located on p. 1-3 of NEH 650 Ch. 1 Surveying: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=25276.wba
d. As a minimum, a hardcopy field survey book (SCS ENG-28A or hardbound Engineer Field Book 210-191A, or Rite in the Rain, All Weather writing paper) showing a site sketch, party crew, date, features, benchmarks, TPs, centerlines, baselines, etc. is needed for the legal record and to assist further survey work (layout, construction checks) on the site. (link above NEH 650.0105 Field Notes, EFH Ch. 1, p. 1-5 thru 12).
e. Where needed, use horizontal or vertical curves to describe significant alignment changes (p. 113-119).
f. TR-62 Engineering Layout, Notes, Staking, & Calculations, Fig 2-10 p. 2-61 thru 2-63 provides example of a Route Survey of proposed centerlines. Fig.2-12, p. 2-67 and 2-68 provides example of Topographic Survey w/closed traverse method: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=18637.wba

Note: automated total stations and GPS survey grade equipment store data on-board for later downloading. The notekeeping formats contained in the references herein may not be applicable in all cases, however, guidance is provided and applicable for methodology and establishing benchmarks, baselines, turning points, closures, traverses, cross-sections and profiles. Not all essential information can be stored and transferred as digital data such as site sketch, benchmark description, etc.

2.2 Scenario 2: Existing road, no alignment changes.

a. Existing Road – repair and rehabilitate existing road. Profile & Cross-Section guidance at: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=25276.wba Page 1-73 thru 1-78.

b. Survey sufficient distance away from centerline to allow for any roadside ditches (waterways) and outlets, grade stabilizing structures, toes of fill slopes, daylighting of cut slopes, if needed. An access road is commonly not a stand-alone practice.
c. Where needed use horizontal or vertical curves to describe significant alignment changes (EFH Ch. 1.)

3. Hydrology

A. Locate the road and any drainage outlets on a USGS topo quad or a reliable GIS generated topo map.
B. Determine the drainage area and any sub-drainage areas for the entire road length. A sub-drainage area would be needed anywhere runoff crosses the road surface or a cross-drain is planned and would include the areas between any cross-drains (road surface) and runoff from adjacent lands.
C. Determine the soil and cover conditions using photography and maps, Ch. 9 Hydrologic Soil-Cover Complexes, NEH Part 630 Hydrology : http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17758.wba
D. Ground truth the drainage area map (a site visit with a reasonable level of investigation by the responsible technical person) by driving/walking through the drainage areas. Verify the existence of culverts, diversions, other roads, changes in landuse not shown on the topographic maps or aerial photography that could increase or decrease runoff to the road site.
E. Use EFH-2 to compute Q10, Q25 (10 yr. & 25 yr., 24 hr. runoff) for all sub-drainage areas. (ITS Downloadable software).
F. For drainage areas with urban development more than 10% use TR-55 to determine Q10 for each sub-drainage area (ITS downloadable software).
G. For road surface drainage itself (no outside drainage area) between cross drains, use rational formula Q=CiA , for high rainfall areas, select jungle area i=200mm – 400mm use c for final road surfacing, Ch. 5 Hydrology, Low Volume Roads Engineering (LVRE) BMP Field Guide, p.39-41: http://pdf.usaid.gov/pdf_docs/PNADB595.pdf

4. Hydraulic Design

A. Size all drainage structures following NRCS Conservation Practice Standard (CPS). The CPS is the agency minimum and function as agency policy. (see **Attachment 2**).
B. For simplified purposes, the design frequency storm flows (Q) for any cross-drains from the sub-drainage area above it (including the road surface itself) and any outside drainage area from adjacent land onto the road surface or through roadside ditches (waterways) can be considered additive (Q crossdrain = Q road surface area above + Q

adjacent sub-drainage areas). This assumes the tc, time of concentrations, on each hydrograph are the same.

4.1 Stream Crossings

a. Culverts (also used as relief culverts from natural or ditch drainages.)

1.) Commonly used culverts are round pipe (concrete, corrugated metal, HDPE), or concrete boxes. Designs should consider inlet/outlet control issues and the flow depth upstream and downstream of the culvert. The depth of water & velocities can be used to determine channel lining requirements and headwall heights.

2.) Consider alternatives to reduce damages caused by plugging (alternate relief routes, multiple pipes/boxes, increased O&M, trash racks, etc).

3.) Design resources:

a.) Engr. Field Handbook Chapter 3 Hydraulics, p. 3-30 thru 3-37, nomograph method for culvert sizing 3-91 thru 3-94. http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17542.wba (eDirectives/Handbooks/Title 210 Engineering/National Engineering Handbook/Part 650-Engineering Field Handbook/Ch 3 Hydraulics

b.) LVRE BMP Field Guide nomograph method p. 84-86. http://ntl.bts.gov/lib/24000/24600/24650/Chapters/J_Ch8_Culvert_Use_Installation_&_Sizing.pdf or at the NRCS Engineering sub-website: http://pdf.usaid.gov/pdf_docs/PNADB595.pdf

c.) Use Headwalls and wingwalls of concrete or rock riprap (with either geotextile or gravel/sand between rock and native soil) to stabilize inlets and outlets (LVRE BMP, Ch. 8, link above).

d.) Use rock riprap upstream and downstream of culverts to prevent scouring due to excessive turbulence & velocities. Ref. Isbash curve for rock sizing. (**Attachment 3**). A conservative approach is to select the size gradation of loose rock and then grout for grouted rock riprap. Use geotextile under loose rock riprap to prevent the piping of fines and base materials through the large gaps between the rocks. For use of the Isbash curve: Engineering Field Handbook Ch. 16 Streambank and Shoreline Protection, Appendix 16A at: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17553.wba

e.) Hydraulic Formulas 2.2.1 (Engineering Field Tools 3.4.1.2) Inlet or Outlet controls (ITS download)

f.) HY-8 v7.2 – Federal Highway Administration software automates the nomographs, charts, and graphs based on user input and provides analysis and reports. Recommend reading Quick Start documentation and HDS-5 documentation from Help menu first. (ITS download)

g.) HEC-RAS from US Army Corps of Engineers for water surface profile (ITS download)

h.) ASTM C-1433 Precast Reinforced Concrete Monolithic Box Sections for Culverts (HS20 loading): http://compass.astm.org

b. Ford Crossings/Low Water Crossings

1.) Can be used for stream crossings or at natural drainage concentrations.
2.) Commonly used material: concrete or grouted rock.
3.) Make the cross-sectional area of the crossing equal to or greater than the natural channel cross-sectional area.
4.) Sideslopes of the ford may be flatter than the natural sideslopes for drivability.
5.) Can accommodate larger flows than culverts. Allows fish and debris to pass (see 'vented fords', number 8. below)
6.) May not be passable, even dangerous, by vehicle or walking during storm events. Consider guardrail requirements for safety.
7.) Other design requirements in NRCS Conservation Practice Standard 578 Stream Crossings.
8.) Ref: Low Volume Road Engineering BMP Manual, Ch. 9 p. 91-96. http://ntl.bts.gov/lib/24000/24600/24650/Chapters/K_Ch9_Fords_&_Low-Water_Crossings.pdf or http://pdf.usaid.gov/pdf_docs/PNADB595.pdf

Note: all stream crossings inverts (top of slab or rock) should be set at or no greater than 0.5 foot above the natural bottom elevation of the existing channel, so as to reduce the effects to the natural streamflow. Survey data to establish natural stream bottom elevation is needed before design and construction begins.

4.2 Cross Drains

a. Read the Water/Road Interaction: Introduction to Surface Cross Drain paper (WRI/ISCD, SFS) at:
http://ww.fs.fed.us/eng/pubs/html/wr_p/98771806/98771806.htm or
http://www.stream.fs.fed.us/water-road/w-r-pdf/crossdrains.pdf
b. Determine maximum spacing based on USCS soil type of the planned surface aggregate and Road Grade (**Attachment 4**, Ref. Table 4, WRI/ISCD, USFS).
c. Apply any applicable reduction factors in footnote 'a' of Att. 4. If after applying the reduction factors, the resulting distance is less than 20 meters, use 20 meters.
d. Adjust cross drain locations to fit the natural drainage requirements of the terrain. The spacing should not exceed spacing from steps b & c above.
e. Follow Checklist guidance of **Attachment 1** for surface dip geometry, orientation, and erosion control measures.

f. Select design storm frequency [Refer to Section 4. Hydraulic Design, (**Attachment 2**)]. Cross drains function as diversions, use 25 yr. 24 hr storm (ref. 362-Diversions)
g. Compute Q25 (Section 3. Hydrology steps E., F., G. above)
h. Where the cross drain is lined with concrete or grouted rock, use NRCS Conservation Practice Standard 488 - Lined Waterway or Outlet for additional design guidance.
i. With the cross-slope percent selected and Q25, size the cross-drain by selecting shape, dimensions, and materials (Hydraulic Formulas 2.2.1. Engineering Field Tools 3.4.1.2) or equivalent.
j. Design depth is the channel storm flow depth plus 0.3' minimum freeboard.

5. Road Design Parameters (refer to Practice Standard 560)

A. Select Road width:
   1.) All purpose, one way - 14 ft. (includes 2'shoulder each side),
   2.) All purpose two way 20' wide (includes 2' shoulder each side)
   3.) All purpose two way with trailers 24' wide (includes 2' shoulder each side)
B. Select Road features:
   1.) Shoulders of soil, gravel, pavement, or grass.
   2.) Turnouts shall be used when two way traffic share one lane for a limited distance.
   3.) Turnouts are wide sections of the roadway 20'wide min. for at least 30' distance.
C. Select Road Grade:
   1.) Should not exceed 10% except for short lengths.
   2). Max. grade of 18% but only for short lengths and only if necessary for special use roads as defined in the practice standard.
      Steep Sections >10% in high rainfall areas, consider special treatment such as paving and drainage structures in high rainfall areas to prevent excessive road gullying.
      a.) Look for examples of good and problematic roads in similar site conditions (grade, rainfall, soils, surfacing) in the area to determine the need for paving and drainage structures.
      b.) Consider alternatives with producer for alignment changes away from steep sections in high rainfall areas.

6. Slope Stability/Side Slopes – for roads and drainage structures.

A. All cut and fills < 4' high, steepest slope is 2H:1V.
B. If vegetation is required, slopes flatter then 2H:1V may be needed. Rule of thumb: maximum slope maintainable with equipment is 3:1 without specialized equipment.
C. Cut and Fill slopes > 4' high, with slopes steeper than 2H:1V, use only where soil conditions warrant such as rock, cemented soils and only when special stabilization

measures are installed (ex: diversions to cutoff runoff, erosion control geosynthetics or plastics, hydromulches, bioengineering, critical area planting, etc).

D. Avoid areas susceptible to slide conditions or treat to prevent slides.

E. Regardless of design slope and stabilization measures selected: all slopes must be stable. Flatter, well compacted, well drained slopes are typically more stable. Ref. Low Volume Road Engineering BMP, Ch. 11, but follow NRCS guidance (steps A-C above). Look for stable fill or cut slopes in the immediate area. For more complex slope analysis refer to various references in NRCS New Professional Engineers and Geologists (NPEG) Notebook, Geotechnical Engineering Chapter, Slope Stability (contact local NRCS Field or Area Engineer). For general ranges of stable slopes, ref. **Attachment. 5.**

7. Soils & Surfacing Materials

7.1 Existing Soil or Imported Soil

a. Erosion resistant soils should be selected as surfacing materials, especially on steeper grades in high rainfall areas (ref. **Attachment 7**).

b. Determine the USCS classification and soil suitability information of the existing & proposed soils (could be the same material) using Web Soil Survey:
http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

c. Determine Area of Interest, Make a Soils Map, and run reports: use Soil Data Explorer/Soils Reports/Soil Properties & Qualities/Soil Physical Properties/Engineering Properties, and Soil Reports for Construction Materials (Roadfill) and Building Site Development (Roads & Streets). Analyze reports for suitability of soil as a road material, especially in high rainfall areas. More Soils Reports are available. Note Hydrologic groups of the soils under the road and the adjacent areas. Also note the depth to bedrock and determine any excavation impacts to achieving the required design depth. Shallow depths to bedrock may require the new roadbed to be raised higher than the existing one. This may have impacts to surrounding drainage requiring more cross drains or other drainage structures.

d. With the USCS soil type, Sieve Data, and the proposed road slopes enter the following graph to determine more suitability criteria (**Attachment 6,** Grain Size Distribution for Roadway Surfacing, ref Fig 12.4, LVRE BMP, p.120)
http://ntl.bts.gov/lib/24000/24600/24650/Chapters/N_Ch12_Roadway_Materials.pdf

e. Plot the sieve data results (sieve size number & % finer by weight) to determine if the proposed material falls within acceptable band zones. Note that confined base courses (larger gravel sized particles) are recommended in wet, tropical areas,

especially on steeper slopes. If the proposed material does not fall within acceptable suitability zones, then consider surfacing with gravel or another imported soil or provide additional drainage structures if needed (Section 4.2 Cross-Drains). Also consider the surfacing's resistance to erosion (ref. **Attachment 7**)

f. Ground Truthing - Where no soil samples are taken for laboratory gradation or classification, The Soil Survey results can be verified onsite by using the Field Identification and Description of Soils (p. 4-19 thru 4-28, EFH, Ch 4 Elementary Soil Engineering, NEH Part 650) at: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17543.wba and Visual-Manual Procedure for Description and Identification of Soils ASTM D2488-09a, part 10. Descriptive Information for Soils: http://compass.astm.org (Search for ASTM D2488, D2487).
g. Sample hole – as a minimum, a soil profile should be exposed and compared against the Soils Reports. A soil auger or sharpshooter can aide in determining shallow bedrock locations. A test pit(s) may be required at critical points on more geologically complex sites. These might be points where excavation is required or there will be cut slopes.
h. See Section 7.3 Thickness of Surfacing Materials Thickness & Geotextiles

7.2 Select Quarried Material (gravels)

a. Steps VII.A. 1-3 can be completed for the native soil material functioning as foundation material for the gravel surfacing. This can serve as design alternative documentation for selecting offsite materials over native soil material due to native soil material plotting outside of targeted suitability zones.
b. Obtain gradations of commonly processed materials for road surfacing from the quarry supplier and USCS classification from the quarry if available. If not available, samples should be sent to a third party testing lab to prepare.
c. Following Section 7.1.d, with the selected gravel material, plot to determine if material falls within acceptable suitability zones.
d. See Section 7.3 Thickness of Surfacing Materials & Geotextiles.

7.3 Thickness of Surfacing Materials & Geotextile

Note: Surface Treatments defined in CPS 561-Heavy Use Area Protection (HUAP).

a. Aggregate – thickness varies depending on site conditions. Six inches minimum thickness is common for most light traffic or common field roads. Exceed minimums for frequent travel, heavy equipment or unique site conditions.
b. Use of Geotextile with aggregates in one or more of the following conditions:

1.) Low strength native soils needing load bearing strength. NRCS Conservation Practice Standard 313 Waste Storage Facility, Table 2, Presumptive Allowable Bearing Stress Values illustrates the range of strengths based on soil type:
http://efotg.sc.egov.usda.gov/references/public/PB/313_PI_Standard_4-2012.pdf
A dump truck can exert 3000 pounds per square foot (psf) onto road surfacing.
2.) Soft foundation soils –separation needed to avoid contamination and maintain matrix integrity of the aggregate.
3.) Drainage concern – high water tables, high runoff, high rainfall areas.

c. Use Design Note 24 for selecting geotextiles. For road applications, use Class IV from Tables 1 or 2. Non-woven needle punched geotextiles are preferred for their surface friction properties with the material above and below. A Class IV geotextile provides separation and increases bearing strength by distributing wheel loads across a broader area.
http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17538.wba

d. NRCS Material Spec. 592 Geotextile provides more guidance:
http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_016396.pdf

e. Paving
1.) Concrete
a.) Refer to Practice Standard 561-HUAP /Surface Treatment/Concrete which also cites Standard 313-Waste Storage Facility/Slabs on Grade. All slabs designs based on subgrade drag theory per ACI 360 Design of Slabs-on-Ground (vehicular loads), an online paid download from aci.org] at: http://www.concrete.org/store/storeresults.aspx?SortOrder=RELEVANCE&Keyword=aci%2c360R-10 Slab design should contain thickness, reinforcing details, joint spacing, and joint details.
b.) Thickness depends on type and frequency of traffic. For HUAP road applications with light use (reference Section 11. Standard Details-Concrete Pad. For roads with heavier use (frequent travel, heavy equipment), see Step 1.a above for design guidance.
c.) For slabs on steeper grades, concrete anchoring trenches/cutoffs maybe be needed upslope and downslope of discrete runs and at significant changes in grade. If subsurface water and uplift pressures are a concern, consider a perforated pipe drain upslope of cutoff trench. Refer to NRCS Conservation Practice Standard 620 - Underground Outlet and 606 – Subsurface Drain, and National Engineering Handbook (NEH) Part 633, Chapter 26, Gradation Design of Sands and Gravel Filters at:
http://directives.sc.egov.usda.gov/viewerFS.aspx?id=3849

2.) Asphalt

a.) Asphalt-Bituminous Concrete Pavement - refer to NRCS National Practice Standard - 561 Heavy Use Area Protection (external reference: AASHTO Guide for Design of Pavement Structures with 1998 Supplements), paid download after setting up account at: https://bookstore.transportation.org/item_details.aspx?id=1936
For light use areas, the minimum recommended thickness is 4" compacted bituminous concrete over a subgrade of at least 4" of well compacted gravel per std. 561.

b.) Asphalt

1.) Reference: Full Depth Asphalt Pavement, Construction Leaflet No. 11, 1975 at: http://www.asphaltinstitute.org/wp-content/uploads/Thickness_Mix/CL-11%20Ful%20Depth%20Asphalt%20for%20Private%20Driveways.pdf.

2.) Minimum depth of 4" to 6" is recommended depending on subgrade conditions or high volume of heavy vehicles. Potentially thicker pavements may be required over weak subgrade or where high volume heavy traffic is expected.

3.) Other Surfacing types

a.) Soil-Cement - ref. NRCS National Construction Specification 29 and instructions at: http://directives.sc.egov.usda.gov/35947.wba

8. Compaction of Earth & Gravel Roads

A. National Construction Specification 23 Earthfill provides for three classes of compaction (A, B, or C). http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=35601.wba

B. Method A – for soils with less than about 25% gravel, requires a sample to be sent to lab and Proctor curve generated (dry density versus moisture content. Uses either ASTM D698 (Proctor) or ASTM D1557 (modified Proctor). Minimum density specified must be obtained for each layer, usually as a % of the Maximum Density with min. and max. water contents. (Performance spec.). Field density measurements will be needed, typically sand cone, balloon, or nuclear gage to ensure minimum density specified is realized.

1.) An empirical estimate for standard compaction test results is given by:

Max Density (pcf)=130 - 0.8*LL + 0.3*PI

Opt Moist (%) = 6.8 + 0.4*LL – 0.2*PI

2.) A range of Liquid Limit (LL) and Plasticity Index (PI) are given in the Soil Survey for each soil type varying with depth. (see Section 7.1 a & b, Soils & Surfacing Materials).
3.) Iterate the minimum and maximum values of LL and PI into the formulas of Step 1. Above to determine a probable range for estimated maximum density and optimum moisture content. More accurate data can be realized by Atterberg limits testing in a laboratory.
4.) In place field density testing during compaction is necessary to ensure the minimum density specified is reached.

C. Method B – each layer shall be compacted to a mass density not less than the minimum density specified (pcf). (Performance spec.). Relative Density method could be used for gravels and sands.
   1.) Method for determining 50% to 70% relative density (targeted zone for most structures including access road fills is located at: https://view.officeapps.live.com/op/view.aspx?src=http%3A%2F%2Fgeotechnicalinfo.com%2Frelative_density.ppt (ref. Soil Engineering Reference Material, Engineering in Conservation Operations, Volume/Wt. Compaction Review, National Engineering Development Staff, 1993)
   2.) Laboratory testing required (sieve analysis, maximum and minimum index Density tests) as well as field density testing during compaction to ensure the minimum density specified is reached.

D. Method C –each layer shall be compacted by the specified number of passes of type and weight of roller or other equipment or an approved equivalent method. (Method spec.)

   1.) Method C – widely used on access road applications on agricultural landscapes, when involved soils testing may be difficult and when experience has shown that the specification produces acceptable fills. It is best to know the weights of the most commonly available compaction equipment in your area when preparing a method specification.
   2.) Select appropriate equipment, and number of passes for the soil type. **Attachment 8** can be used when 95% to 100% of std. Proctor compaction is desired. For smaller Access Road jobs, smaller equipment may be more suitable than the traditional highway/roadwork equipment. Examples of various types of compaction equipment can be viewed at: http://www.multiquip.com/multiquip/pdfs/Soil_Compaction_Handbook_low_res_

0212_DataId_59525_Version_1.pdf . The weights of commonly available compaction equipment should be determined.

3.) Compact in lifts. Lift height varies depending on type of equipment and soil type per **Attachment 9** (ref. Tbl 4-11, p.4-32 Engineering Field Handbook, Ch 4 Elementary Soil Engineering, Natl. Engineering Handbook Part 650, NRCS) http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17543.wba (ref also Fig 4-14, p. 35-37 Unified classification & properties of soils.)

4.) Moisture Control – the challenge is to ensure the material is not too wet or too dry during placement. Without mandatory onsite quality control testing for in-place densities and moistures using sand cone, nuclear gage, etc. from lab Proctor test results, a simplified onsite hand test could be used frequently to evaluate the moisture content changes throughout the placement period. (ref. **Attachment 10**).

5.) The results of steps 2, 3, and 4 (above) can be combined into a method specification and included in the design.

6.) Onsite inspection needed to confirm the method specification was followed before practice certification.

7.) Note: Compact and scarify the native soil foundation first and install Geotextile when needed before surfacing.

9. Operation and Maintenance

A. O&M Template through eFOTG/Location/Section IV/Current Standards & Specifications/select Access Road 560/560 PI O&M Plan. It is an editable word document at: http://efotg.sc.egov.usda.gov/treemenuFS.aspx

B. Site specific information should be added in the blank box at the bottom.

C. Other O&Ms available for supporting practices including NRCS Conservation Practices 362-Diversion, 468-Lined Waterway or Outlet, 578-Stream Crossing, 410-Grade Stabilization Structure, etc.

D. Emphasis should be placed on frequent inspections and timely maintenance for effective O&M, which will improve the road's lifespan.

10. Webinars

A. Planning and Design of Stream Crossings: http://www.conservationwebinars.net/webinars/planning-and-design-of-stream-crossings/

B. How to Use EFT for Grassed Waterway (412) and Diversion (362) design: http://www.conservationwebinars.net/webinars/eft-wdt/?searchterm=eft

11. Standard Design Details

Standard construction drawing details have been developed for general guidance and require supporting technical documentation prior to use and must be adapted to the specific site. Digital files may be edited and revised where needed for a specific design, however, the designer retains responsibility for the proper application of all standard design details.

Standard design details for Access Roads are available on the PIA Engineering sub-website at the following links below:

Access Road Standard Details:

- Access Road Job Sheet #1 - 6/8/2015 (PDF; 47 KB)
- Access Road Job Sheet #2 - 6/8/2015 (PDF; 76 KB)
- Access Road Job Sheet #3 - 6/8/2015 (PDF; 1.1 MB)
- Access Road Job Sheet: AutoCad Drawing File - 6/8/2015 (DWG; 651 KB)
- Concrete Pads for Access Roads - 6/8/2015 (PDF; 492 KB)
- Concrete Pads for Access Roads: AutoCad Drawing File - 6/8/2015 (DWG; 447 KB)
- Earthen Waterbar - 5/28/2015 (PDF; 61 KB)
- Earthen Waterbar: AutoCad Drawing File - 5/28/2015 (DWG; 498 MB)
- Rock Armoring: Armoring Cross Drain (Heavy Use Roads) - 6/3/2015 (PDF; 60 KB)
- Rock Armoring: Details for Cross Drain - 6/3/2015 (PDF; 51 KB)
- Rock Armoring: AutoCad Drawing File - 6/3/2015 (DWG; 727 KB)
- Rolling Dip - 5/28/2015 (PDF; 60 KB) ;
- Rolling Dip: AutoCad Drawing File - 5/28/2015 (DWG; 494 MB)

Attachment 1 – Checklists for Surface Cross Drains

I. Checklist for Surface Dip Geometry

- Cross drains should be constructed with an outslope grade of 3 to 5 percent or equal to the existing out-slope grade.
- For drivable dips, the minimum freeboard should be 6 inches (150 millimeters) with a roll-out length of at least 19.7 feet (3 meters). If the dip is unarmored, freeboard should be increased to allow for the tendency of the dip to lose its shape due to traffic.
- Drain dips and drivable water bars negotiable by high-clearance vehicles have steeper rollout grades. The recommended minimum depth is 6 inches (150 millimeters) with a rollout distance of at least 3.3 feet (1 m).
- The above values are minimums to be maintained. If maintenance cannot be performed to maintain this minimum geometry, freeboard and roll-out length should be increased so that ruts that cut through the top of the dip do not reduce freeboard below these minimums.
- The above values should be adjusted according to local climate. Freeboard and run-out distance should be increased for surface dips and waterbars where run-off volumes could be higher.

II. Checklist for Surface Cross Drain Locations

- Surface cross drains should be located at intervals close enough to prevent volume concentration that causes surface erosion or unstable slopes.
- Locate cross drains far enough above stream crossings to avoid releasing drainage water directly into live streams. Surface and ditch water should be diverted and dispersed before it enters streams using lead-out ditches, settlement ponds, ditch dams, surface shaping, or other measures.
- Where overtopping of the road could occur, a dip or grade roll should be designed to ensure that the overtopping flow crosses the road at a point that minimizes erosion (erodible-resistant surfacing is often added), and so that flow is not diverted along the road or away from its natural flow path.
- Cross drains should be located above breaks in vertical profile from shallow to steep grades to prevent the shallow grade surface drainage from gaining velocity and erosive power on the steep grade.
- Whenever possible cross drains should be located to release water on convex slopes or other stable areas that will disperse water rather than channeling it.
- Dips should not be used within the confines of curves with a radius of less than 98.4 feet (30 meters) on roads open to traffic because they may create unsafe conditions for vehicle travel.

Attachment 1 (continued) – Checklists for Surface Cross Drains

III. Checklist for Orientation of Surface Cross Drains

- Dip orientation (skewed or perpendicular to the road centerline) depends on the type of traffic expected, length of the dip, and road grade. If dips are shorter and the traffic will include larger trucks with longer frames, then the dips should be oriented perpendicular to the direction of traffic. Dips skewed from perpendicular to centerline more effectively drain steep road grades, are more comfortable for vehicle occupants, and, if long enough, will not cause severe twisting of truck frames.
- Open-topped culverts, and slotted culvert pipes may be oriented from 60 to 90 degrees to the direction of travel.
- Waterbars are typically used in closed-off areas with little traffic, and should be oriented to lead the flow from the surface. One rule of thumb is to add five to the percent road grade and orient the waterbar at that many degrees off perpendicular.

IV. Checklist for Control of Erosion in Surface Cross Drains

- Cross drains should be armored where soils are highly erodible or provide poor traffic support during wet weather use. (USCS groups CH, CL, MH, SC, SM, SW, SP, ML).
- Permanent erosion control measures (armoring, flow spreaders, vegetation) should be used at all cross drain outlets in USCS soil groups CH, CL, MH, SC, SM, SW, SP, ML).

Attachment 2 Practice Standard 560 - Access Road Design Criteria

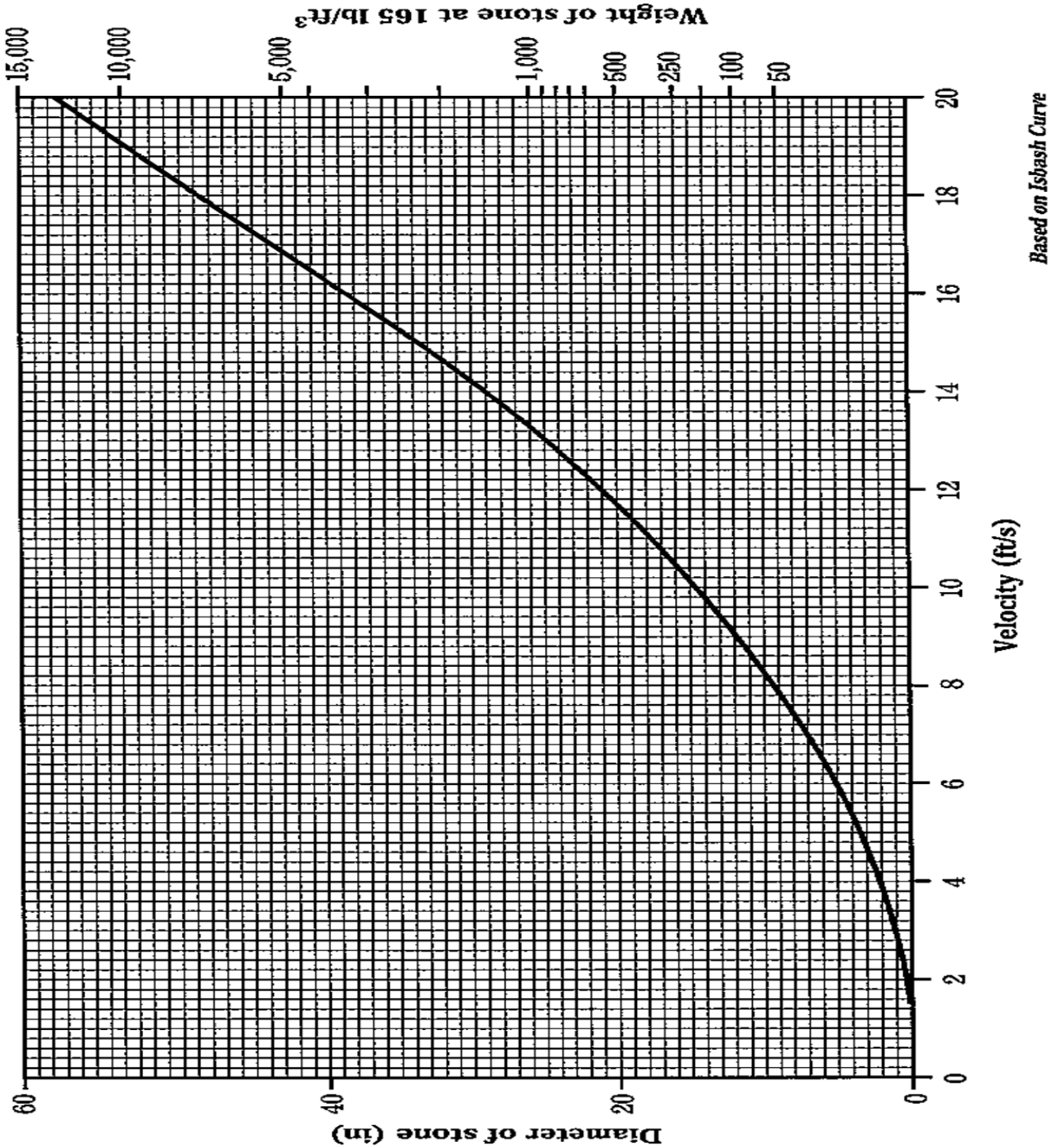
- Drainage – minimum design storm frequencies of culverts & bridges, use Table 1.
- Raise storm frequency if significant risks. Discuss acceptable levels of risk with the producer (ref. CPS 578 Structure for Water Control)

Table 1-Culvert or Bridge

Road Type	**Storm Frequency (Minimum)**
Forest Access Roads, Farm Field Access Roads	2 year - 24 Hour
Farm Driveways, Recreation Facility Access Roads	10 year - 24 Hour
Public Access Roads, Camp grounds, etc.	25 year - 24 Hour

- **Stream Crossings**-use guidance under CPS 578-Stream Crossings. Water surface elevation for 10 yr-24 hr. storm is required. Note additional permitting requirements.
- **Diversions**- where diversions are used in a drainage scheme use CPS 362-Diversion guidance for (25 yr.- 24 hour design storm for road protection)
- **Lined Channels** – use CPS 468 Lined Waterway where lined roadside ditches or channels are used to move water downslope, 10yr.-24 hr. design storm).
- **Cross-Drain** – Dips – cross the road slope, use CPS 362 Diversion for guidance.
- Each drainage structure or cross drain must be designed to safely pass the anticipated design storm for its associated drainage area.

Attachment 3 Isbash Curve for Riprap sizing



Attachment 4: Cross Drain Spacing Guidance

Table 4—Guidelines for maximum distance[a] between contiguous surface cross drains based on USCS soil erodibility groups[b].

Road Grade	Group 1 GW, GP, Aggregate Surfacing	Group 2 GM, GC	Group 3 CH, CL	Group 4 MH, SC, SM	Group 5 & 6 SW, SP, ML
percent	*meters*				
2	120	97	75	52	29
4	103	84	65	45	26
6	88	71	55	39	23
8	74	60	47	33	20
10	61	50	39	28	17
12	50	41	32	23[c]	14[c]
14	42[c]	34[c]	26[c]	19[c]	11[c]

[a]Distance between cross drains should be reduced according to the following (based on Packer and Christensen 1964):

Reduce the distance by:	If the road is located:
5 meters	in the middle one-third of a slope
11 meters	in the bottom one-third of a slope
3 meters	on an east or west exposure
6 meters	on a south slope.

If, after applying the above, the resulting distance is less than 20 meters, set the distance between cross drains at 20 meters and apply aggregate surfacing and erosion protection measures, such as vegetative seeding of road, fills, shoulders, ditches, and embankments.

[b]Adapted from the distance recommendations summarized in Table 3, and soil erodibility hierarchy suggested by Gray and Leiser.

[c]Not recommended for dips because they may require approach grades steeper than 15 percent.

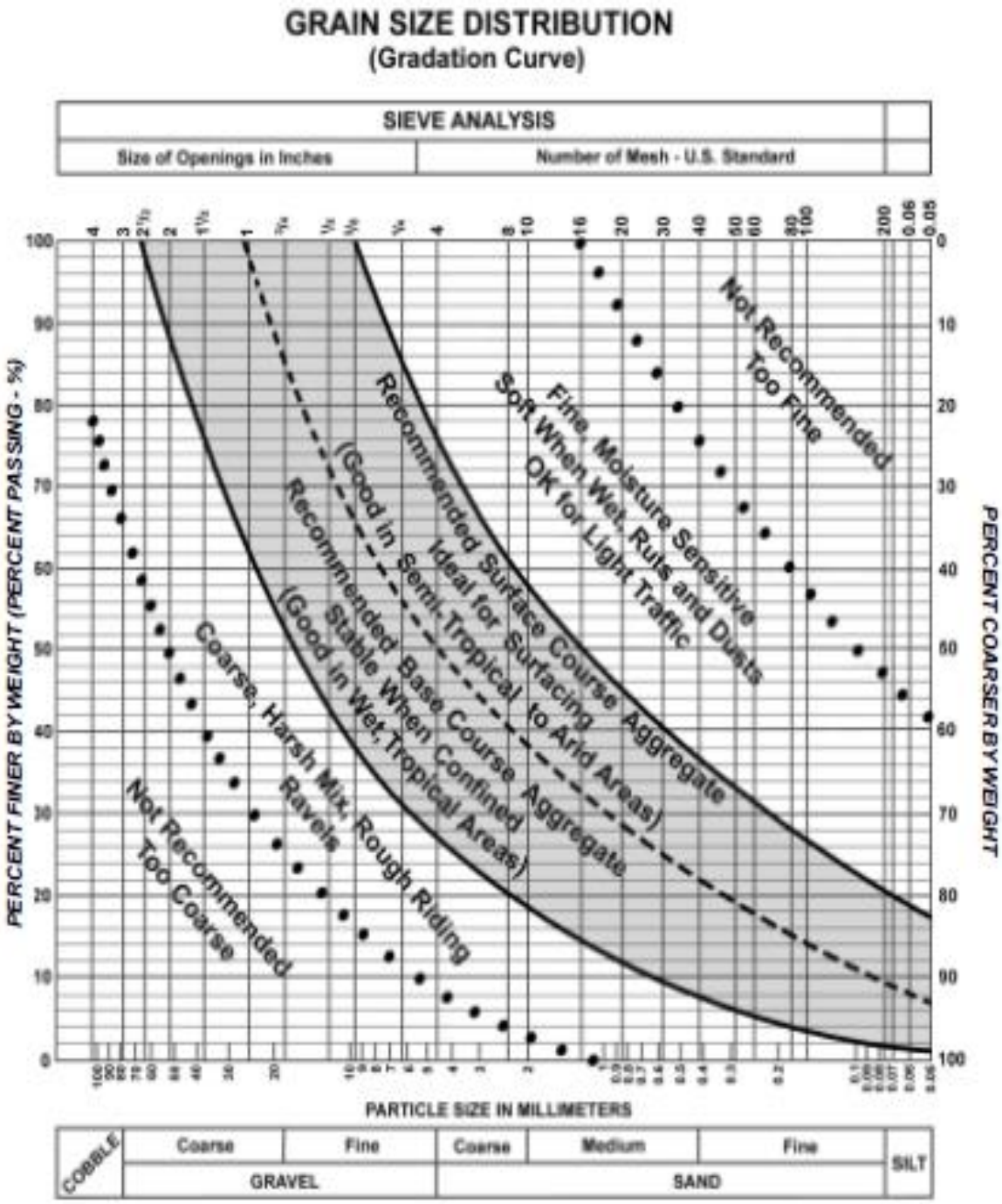
Attachment 5: Stable Slope Recommendations*

Stable slopes for most soils of medium or greater density can
Be estimated as:

Rock	1 to 1-1/2:1
Gravel	1-1/2 to 2:1
Sand	2:1 to 2-1/2 :1
Clay	2-1/2 to 4:1
Silt	3 to 4:1

*From Basic Soils Engineering, NEH Part 650 EFH Ch. 4, NRCS USDA.

Attachment 6: Grain Size Distribution for Road Surfacing



NOTE: Gradation Ranges Shown Are Approximate.

The best roadbed surfacing materials have some plasticity and are well graded. They have gradations parallel to the curves shown above, and are closest to the "Ideal" dashed curve in the middle of the gradation ranges shown.

Attachment 7: Relative Erosion Resistance of Unified Soil Classification System (USCS) Soils

Table 4-12 – Comparative erosion resistance of soils*

Most Resistant

Large Gravel	GW, GP
Clayey Gravel	GC
Highly plastic clay and clayey sand	CH, SC
Clays, silty gravel	CL, GM
Silts, silty sand, organic silts	MH, OH, ML, SM, OL

Least Resistant

*From Basic Soils Engineering, NEH Part 650 EFH Ch. 4, NRCS USDA.

Attachment 8: Compaction Equipment

TABLE 5
Compaction Equipment and Methods

Equipment Type	Applicability	Requirements for Compaction of 95 to 100 Percent Standard Proctor Maximum Density: Compacted Lift Thickness, in.	Passes or Coverages	Dimensions and Weight of Equipment	Possible Variations in Equipment
Sheepsfoot Rollers	For fine-grained soils or dirty coarse-grained soils with more than 20 percent passing No. 200 sieve. Not suitable for clean coarse-grained soils. Particularly appropriate for compaction of impervious zone for earth dam or linings where bonding of lifts is important.	6	4 to 6 passes for fine-grained soil. 6 to 8 passes for coarse-grained soil.	Soil Type — Foot Contact Area sq. ft. — Foot Contact Pressures psi Fine-grained soil PI>30 — 5 to 12 — 250 to 500 Fine-grained soil PI<30 — 7 to 14 — 200 to 400 Coarse-grained soil — 10 to 14 — 150 to 250 Efficient compaction of soils wet of optimum requires less contact pressure than the same soils at lower moisture contents.	For earth dam, highway and airfield work, articulated self propelled rollers are commonly used. For smaller projects, towed 40 to 60 inch drums are used. Foot contact pressure should be regulated so as to avoid shearing the soil on the third or fourth pass.
Rubber Tire Roller	For clean, coarse-grained soils with 4 to 8 percent passing the No. 200 sieve.	10	3 to 5 coverages	Tire inflation pressures of 35 to 130 psi for clean granular material or base course and subgrade compaction. Wheel load 18,000 to 25,000 lbs.	Wide variety of rubber tire compaction equipment is available. For cohesive soils, light-wheel loads, such as provided by wobble-wheel equipment, may be substituted for heavy-wheel load if lift thickness is decreased. For granular soils, large-size tires are desirable to avoid shear and rutting.
Do.....	For fine-grained soils or well graded, dirty coarse-grained soils with more than 8 percent passing the No. 200 sieve.	6 to 8	4 to 6 coverages	Tire inflation pressures in excess of 65 psi, for fine-grained soils of high plasticity. For uniform clean sands or silty fine sands, use large size tires with pressures of 40 to 50 psi.	
Smooth Wheel Rollers	Appropriate for subgrade or base course compaction of well-graded sand-gravel mixtures.	8 to 12	4 coverages	Tandem type rollers for base course or subgrade compaction 10 to 15 ton weight, 300 to 500 lbs per lineal in. of width of rear roller.	3-wheel rollers obtainable in wide range of sizes. 2-wheel tandem rollers are availabe in the range of 1 to 20 ton weight. 3-Axle tandem rollers are generally used in the range of 10 to 20 tons weight. Very heavy rollers are used for proof rolling of subgrade or base course.
Do....	May be used for fine-grained soils other than in earth dams. Not suitable for clean well-graded sands or silty uniform sands.	6 to 8	6 coverages	3-wheel roller for compaction of fine-grained soil; weights from 5 to 6 tons for materials of low plasticity to 10 tons for materials of high plasticity.	

Attachment 8 (con't): Compaction Equipment

TABLE 5 (continued)
Compaction Equipment and Methods

Equipment Type	Applicability	Requirements for Compaction of 95 to 100 Percent Standard Proctor Maximum Density			Possible Variations in Equipment
		Compacted Lift Thickness, in.	Passes or Coverages	Dimensions and Weight of Equipment	
Vibrating Sheetefoot Rollers	For coarse-grained soils sand-gravel mixtures	8 to 12	3 to 5	1 to 20 tons ballasted weight. Dynamic force up to 20 tons.	May have either fixed or variable cyclic frequency.
Vibrating Smooth Drum Rollers	For coarse-grained soils sand-gravel mixtures - rock fills	6 to 12 (soil) to 36 (rock)	3 to 5 4 to 6	- do -	- do -
Vibrating Baseplate Compactors	For coarse-grained soils with less than about 12 percent passing No. 200 sieve. Best suited for materials with 4 to 8 percent passing No.200 sieve, placed thoroughly wet.	8 to 10	3 coverages	Single pads or plates should weigh no less than 200 lbs. May be used in tandem where working space is available. For clean coarse-grained soil, vibration frequency should be no less than 1,600 cycles per minute.	Vibrating pads or plates are available, hand-propelled, single or in gangs, with width of coverage from 1-1/2 to 15 ft. Various types of vibrating-drum equipment should be considered for compaction in large areas.
Crawler Tractor	Best suited for coarse-grained soils with less than 4 to 8 percent passing No. 200 sieve, placed thoroughly wet.	6 to 10	3 to 4 coverages	Vehicle with "Standard" tracks having contact pressure not less than 10 psi.	Tractor weight up to 85 tons.
Power Tamper or Rammer	For difficult access, trench backfill. Suitable for all inorganic soils.	4 to 6 in. for silt or clay, 6 in. for coarse-grained soils.	2 coverages	30-lb minimum weight. Considerable range is tolerable, depending on materials and conditions.	Weights up to 250 lbs., foot diameter 4 to 10 in.

Attachment 9: Maximum Lift Thicknesses

Table 4-11. Maximum lift thickness for compaction equipment

	Maximum loose lift thickness[1]	
Equipment [2]	inches	cm
Hand Compactor (mechanical)	4	10
Track Tractor	6	15
Small Plate Vibrator	8	20
Sheepsfoot roller	9	25
Rubber-tired roller [3]	12	30
Rubber-tired equipment	18	45
Vibratory Roller	24	60

1. Rock size should be limited to 2/3 of the loose lift thickness so that the rock will fit within the compacted lift thickness.

2. For efficient compaction, the equipment must be suitable for the soil type. Clean sands and gravels need vibratory compactors. Small, hand guided plate vibrators are available for confined areas. Track tractors are also effective in compacting clean coarse-grained soils. They should be operated as fast as practical so they will produce vibrations.

3. Plastic soils need sheepsfoot or tamping rollers. Rubber-tired rollers are good for wet plastic soils, low plastic, and non-plastic fine soils.

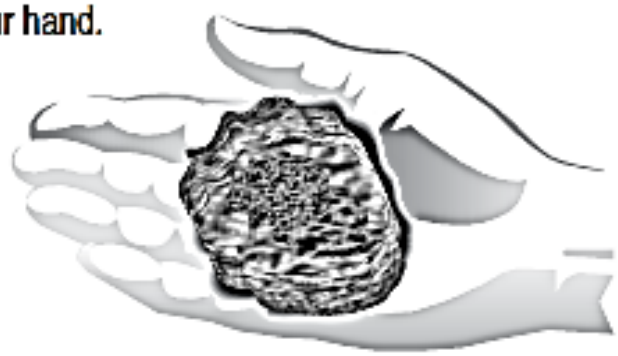
*From Basic Soils Engineering, NEH Part 650 EFH Ch. 4, NRCS USDA.

Attachment 10: Hand Test for Determining Approximate Optimum Moisture Density

HAND TEST

A quick method of determining moisture density is known as the "Hand Test."

Pick up a handful of soil. Squeeze it in your hand. Open your hand.



If the soil is powdery and will not retain the shape made by your hand, it is too dry. If it shatters when dropped, it is too dry.

If the soil is moldable and breaks into only a couple of pieces when dropped, it has the right amount of moisture for proper compaction.

If the soil is plastic in your hand, leaves small traces of moisture on your fingers and stays in one piece when dropped, it has too much moisture for compaction.

Figure 9