10.0 SPECIAL DESIGN ELEMENTS

10.1 HYDRAULICS

- **General**

The ODOT *Hydraulics Manual* is the basis for design of all drainage facilities. The Hydraulics Unit, in the Geo/Hydro Section, should be consulted about drainage issues.

The purpose of a highway drainage system is to prevent the accumulation and retention of water on and by the highway and to prevent adverse impacts to the environment. Drainage facilities must be designed to convey water through, along, or away from the highway and bridges by the most direct means consistent with economy, ease of maintenance, Oregon Drainage Law, Federal Clean Water Act, other applicable environmental regulations, and least disturbance of natural conditions without damaging the highway or adjacent property.

A drainage plan with support calculations is part of the design data that must be prepared on all projects. The Roadway Engineering Section usually prepares the drainage plan. The drainage plan should address inlets, storm drains, small culverts, pipe materials, outlet protection for small pipes, roadside ditches, and cutoff ditches. It is to be independently checked in Roadway Engineering or the Hydraulics Unit before final plans are prepared. If the Hydraulics Unit is needed to design or analyze any special features, either a Hydraulics Report or a Stormwater Report will be prepared. A Stormwater Report may also be needed on large projects that require review by other agencies.

- **Design of Drainage Structures:**

1. Determine the natural points of concentration, discharge and other hydraulic controls.
2. Provide for removal of detrimental amounts of surface water.
3. Determine the area of net new impervious surface added by the project.
4. Provide the most efficient drainage and water quality facilities consistent with cost, maintenance, economy and legal obligations.
5. Determine environmental and biological constraints.
6. Provide cost effective design of bank and embankment protection features.

- **Economic and Legal Aspects That Must Be Considered During Drainage Design:**

1. Cost of construction and right of way.
2. Effects on adjacent property, particularly with respect to State liability.
3. Interference with traffic including road closures or detours.
4. Water in natural channels diverted from its usual course.

5. Water diverted or discharged over land or through a water course that would not normally receive such waters.
6. Peak surface runoff increased and discharged to water bodies that would not normally receive such peak flows.
7. Percolating waters intercepted and diverted for the protection of the highway.
8. The use of infiltration for disposing of water into soils and subsequently groundwater must be registered with the Oregon Department of Environmental Quality and is required to be monitored.
9. Maintaining hydraulic conditions within an adopted floodway according to Federal Emergency Management Agency (FEMA) regulations.

- **Oregon Drainage Law**

Oregon drainage law, which originates from common law or court-made law, has developed without legislative action, and it is embodied in the decisions of the courts. Therefore, there are no Oregon Revised Statues to cite pertaining to Oregon drainage law.

Oregon has adopted the civil law doctrine of drainage. Under this doctrine, adjoining landowners are entitled to have the normal course of natural drainage maintained. The lower owner must accept water that naturally comes to his land from above, but he is entitled not to have the normal drainage changed or substantially increased. The lower landowner may not obstruct the runoff from the upper land if the upper landowner is properly discharging the water.

For a landowner to drain water onto lands of another in the State of Oregon, one of two conditions must be satisfied initially: (1) the lands must contain a natural drainage course; or, (2) the landowner must have acquired the right of drainage supported by consideration (i.e., a purchased drainage easement). In addition, because Oregon has adopted the civil law doctrine of drainage, the following three basic elements must be followed:

1. A landowner may not divert water onto adjoining land that would not otherwise have flowed there. "Divert water" includes but is not necessarily limited to:

   A) water diverted from one drainage area to another; and
   B) water collected and discharged which normally would infiltrate into the ground, pond, and/or evaporate.

2. The upper landowner may not change the place where the water flows onto the lower owner's land. (Most of the diversions not in compliance with this element result from grading and paving work and/or improvements to water collection systems.)

3. The upper landowner may not accumulate a large quantity of water, then release it, greatly accelerating the flow onto the lower owner's land. This does not mean that the upper landowner cannot accelerate the flow of water at all; experience has found the drainage to be improper only when the acceleration and concentration of water were substantially increased.

Subsurface waters which percolate to the surface can be intercepted and diverted for the protection of the highway without regard for the loss of these waters to the adjacent landowners. In those cases where wells and springs are involved, the right of way agent should contact the affected owner(s) to prevent any misunderstanding over damage that could be claimed. Drainage designs should satisfy Oregon drainage law to avoid claims or litigation resulting from improper drainage design. When it is apparent that the drainage design will not satisfy the law, then drainage easements should be obtained from the affected property owners. The legal staff should be consulted in those situations that appear to be unique and could result in litigation.

Where certain drainage patterns have been established over long periods of time (i.e., in excess of at least 10 years), that are not the original natural drainage, there may be legal rights acquired which allow the continuance of the altered drainage pattern. Again, legal staff should be consulted in such situations.

Oregon drainage law is discussed further in the Hydraulics Manual.

- **Cooperative Projects**

Participation in cooperative projects for flood control and/or flood protection mitigation, and/or water quality treatment must be approved by the Technical Services Managing Engineer with the extent of participation being restricted to the amount of benefit accruing to the Oregon Department of Transportation. No commitments should be made prior to approval by the Technical Services Managing Engineer and the amount of participation shall be documented by formal agreement. Actual work performed by ODOT under such agreements shall be limited to highway right of way unless otherwise approved in advance by the Technical Services Managing Engineer. Projects should consider opportunities for regional stormwater management facilities as appropriate in conjunction with city or county projects.

- **Hydraulics Report**

The hydraulics report is produced by the Geo/hydro Section and provides technical information to other units regarding challenging hydraulic features of the project. The types of information that may be in this report include the following:

- Hydraulics design of bridges
- Hydraulics design of large culverts 48 inches in diameter or larger
- Floodplain/Floodway analysis

- Fish passage design
- Scour protection design
- Bank protection design
- Outlet protection design

- **Stormwater Report**

The stormwater report can be produced by Roadway or Geo/Hydro, and these two working groups may have shared responsibility for different sections of the calculations and documentation. The report should provide documentation of the design calculations supporting the final plans and specifications. The types of design information that may be in this report include the following:

- Inlet spacing
- Storm drains
- Culverts, small, less than 48 inches in diameter
- Detention
- Water quality
- Outlet protection
- Roadside ditches
- Cut-off ditches

10.1.1 DESIGN FEATURES

- **Floodways**

The National Flood Insurance Program has established floodways on many rivers and streams in Oregon. A floodway is the regulated portion of the stream channel plus portions of the adjacent floodplain where encroachment is prohibited or limited. The remaining portion of the floodplain that is not included within the floodway boundaries, known as the floodway fringe, is often suitable for encroachment. The regulations require the areas within the regulated floodway to be kept free of encroachment in order that the 100-year flood may be carried without substantial increases in flood stage or elevation. Minimum standards of the Federal Emergency Management Agency (FEMA) limit such increases in flood stage in the floodway to no more than 1 foot, provided hazardous velocities do not result. In some instances, community officials have adopted a floodway that allows less than a 1 foot rise. Highways adjacent to or crossing floodways should be designed to maintain the existing floodway conditions, if practicable. Floodway boundaries can be determined by consulting the appropriate Flood Insurance Study or the Hydraulics Unit. The Hydraulics Unit should be consulted before any work in the floodway or floodplain is considered.

In some cases it may not be practicable to construct a project without modifying the existing floodway boundary. A floodway boundary revision request or other documentation must then be submitted to and approved by FEMA. This process may require up to 12 months to complete.

FEMA approval of requests for floodway revisions are normally obtained by the local jurisdiction; either the City or County. In other cases temporary construction (such as work bridges, cofferdams, etc.) is needed to construct the project within the floodway. The Hydraulics Unit often obtains approval for temporary construction directly from FEMA. The Hydraulics Unit prepares the requests and documents for submittal to the local jurisdiction or FEMA. Additional information on the National Flood Insurance Program and floodways can be found in the *ODOT Hydraulics Manual, Chapter 2.*

- **Bridge**

When bridges over waterways are replaced or modified a detailed study is required. The Hydraulics Unit prepares and/or reviews these studies. Information on Bridge Hydraulics can be found in the *ODOT Hydraulics Manual, Chapter 10.*

- **Scour and Bank Protection**

Scour can occur around bridges, along river bottoms, and along roadway embankments and can lead to catastrophic failure of structures, embankments, and roadbeds. When this scour becomes critical it is necessary to correct the eroded areas and provide protection from future scour. The Hydraulics Unit prepares and/or reviews all proposed solutions for scour mitigation. Information on scour and bank protection can be found in the *ODOT Hydraulics Manual, Chapter 10 and Chapter 15.*

- **Inlet Selection**

The performance of inlets and cross slope has an impact on hydraulic capacity. In a past study, the performance of the CG-3 curb opening inlet was compared to the standard grated inlets. The study ignored the curb opening portion of the CG1 and CG2 inlets in the calculations; this provides additional safety factor in the analysis for these inlets.

G1	-	Single Grate
G2	-	Double Grate
CG1	-	Single Grate plus curb opening
CG2	-	Double Grate plus curb opening
CG3	-	Curb Opening only

The efforts of the study provided the following results:

Gutter Grade	Inlet Recommendations
< 8%	CG-3, CG-2, G2 are all acceptable
< 1%	CG-3 more efficient than CG-1 and G1
> 1%	CG-3 not recommended

In summary the study concluded that the CG-3 curb opening inlets are cost effective when the gutter grade is less than 1%.

Slotted drain inlets are cost effective and efficient inlets, but create challenges for maintenance. The slotted drainpipe should be evaluated in the same manner as other pipes (i.e., minimum cleanout velocity = 3 ft./s). This translates to providing a minimum slope of 0.89% for an 18 inch and 1.5% for a 12 inch diameter corrugated pipe. It is not recommended to place slotted drain inlets in sags unless a tapered slot is provided. Due to the tendency of these inlets to plug, assume 50% clogging and provide twice the calculated required length for flow interception.

Trench drain inlets are long and thin like slotted drains but include small removable grates that provide maintenance access and a sloped bottom so they can be installed in pavement on any slope. Trench drain inlets should not be used in areas with high speed traffic.

- **Storm drains**

Roadway drainage often includes inlets and storm drains to convey runoff collected by the inlets. Each inlet should be checked for efficiency and capacity. Each pipe should be evaluated for structural integrity, capacity and outlet protection. Design of inlets and storm drain pipes included in the Drainage Plan is usually prepared by the Roadway Engineering Section. It is to be independently checked in Roadway Engineering or the Hydraulics Unit before final plans are prepared. Pipes larger than 24 inches should be reviewed by the Hydraulics Unit. Chapter 13 in the *ODOT Hydraulics Manual* explains design policy and procedures. Note that final design calculations and drainage maps for all projects should be prepared and retained in the project file.

- **Culverts**

All culverts should be evaluated for structural integrity, capacity and outlet protection. An existing culvert should not be extended without first conducting a thorough evaluation of the pipe's structural integrity. Pipe rehabilitation or replacement may be required if the culvert has exceeded its service life. Culverts with diameters 48 inches or larger should be designed by the Hydraulics Group and are considered "Large" culverts. "Small" culverts are smaller 48 inches. Refer to Chapter 9 in the *ODOT Hydraulics Manual* for design policy and procedures. A culvert Design Sheet (a sample is available in the Hydraulics Manual) or equivalent computer hydraulic modeling, should be prepared with the design data.

- **Fish Passage**

When a culvert is within the project limits it should be evaluated for fish and wildlife passage by a biologist assigned to the project and/or an Oregon Department of Fish and Wildlife biologist. If fish or wildlife passage is necessary, the Hydraulics Unit should be consulted for the replacement or retrofit evaluation and design, if required. Information on design for fish passage is located in the *ODOT Hydraulics Manual, Chapter 9.*

- **Pipe Materials**

ODOT Notice No. 81-1 requires that soil samples be taken at each proposed pipe installation site where the use of metal pipe would be an option. The purpose is to measure soil and water pH and resistivity.

During the field survey, soil samples will be taken at each site and of backfill soil that may be used. If there is evidence of corrosion in other metal pipes handling the same stream flow, water samples will be required. If the foundation soil changes significantly throughout the length of the pipe, or if the backfill material shows evidence of variability, adequate samples of foundation material and backfill material will be required.

Samples will be sent to the ODOT Engineering Laboratory in Salem or a qualified testing facility for testing. A sample should weigh 9 to 15 pounds, and may be submitted in either a heavy plastic or canvas bag. The sample data sheet must show the station, anticipated pipe size, whether the material is for foundation or backfill, and any appropriate comments about the condition of metal pipes in the vicinity.

See *ODOT Hydraulics Manual* for information about alternate materials policy and design instructions for pipe material selection.

- **Detention**

Detention may be necessary to limit peak runoff if existing drainage facilities used for stormwater conveyance are not sized adequately for estimated peak flows, if the project increases peak flows to a quantity-limited waterway, or in accordance with an approved drainage master plan. All detention facilities must be reviewed or designed by the Hydraulics Unit. Refer to Chapter 12 of the *ODOT Hydraulics Manual* for guidance on project requirements and design guidance.

- **Water Quality Treatment**

Projects that add traffic capacity or significant impervious area must address water quality issues. Projects which provide minor transportation improvements are not intended to be required to provide stormwater treatment facilities. Minor transportation improvements include:

- Projects which do not increase motorized traffic capacity (i.e., guard rails, shoulder improvements, signalization, etc).
- Projects entirely within boundaries of existing impervious surfaces (pavement).
- Projects designed for non-motorized modes (i.e., bicycle lanes, sidewalks, etc.).

Some projects will require specially designed treatment facilities while other projects will only require best management practices (BMPs) be included. The Roadway Designer must provide the projects net new impervious area and any areas collected by new curb (where curb was not present previously) to the Water Quality Specialist in the Environmental Section. This information will be used to help determine what level of water quality mitigation may be required. Various local jurisdictions have special requirements that must also be addressed. All water quality facilities must be reviewed or designed by the Hydraulics Unit. Refer to PDLT Notice 05 (PD-05) and Chapter 14 of the *ODOT Hydraulics Manual* for guidance on project requirements and design guidance.

- **Outlet Protection**

Protection should be provided at each pipe outlet to minimize local scour caused by concentrated flows and high flow velocities. Typical outlet protection utilizes a rip rap pad sized sufficiently to dissipate the energy from the end of the pipe into sheet flow. Environmentally sensitive locations may require larger transition areas and planting. The outlet protection for pipes 48 inches or larger should be reviewed by the Hydraulics Unit.

- **Roadside Ditches**

Roadside ditches should be provided to convey roadway runoff where storm drain systems are not appropriate. Roadside ditches should also be designed to prevent saturation of the roadway base material. This can be accomplished by requiring the water surface elevation in the ditch to not exceed the elevation of the bottom of the base material. A typical roadside ditch should be sized for capacity and stability in addition to water quality treatment.

The peak discharge, longitudinal slope, and ground cover for each ditch affects the ditch capacity. On steep slopes shear stresses on the ditch bottom should be evaluated to assure the ditch does not erode. The discharge contributing to ditches runs off from areas from within the right of way, but this area is often small compared to runoff from outside the right of way. Evaluate each ditch for significant flows from off-site. The standard 6 inch deep ditch should be used on all projects unless the calculated peak flows indicate insufficient capacity or instability. Water quality mitigation requirements may require a 3 foot wide flat bottom ditch be used to provide BMP level treatment.

Shear stresses will be less in ditches not flowing full. The information on stability for cohesive and non-cohesive soils include a range of values because soil properties such as plasticity and gradation vary considerably and can significantly affect how the soils react to shear stresses in the bottom of the ditch. For more information refer to the *ODOT Hydraulics Manual*, Chapter 8.

- **Cut-off Ditches**

Cut-off ditches should be provided above high erodible cuts to convey drainage of surface water away from the face of the cut. They should be set back about 10 feet from the top of cut slope.

- **Exceptions**

  If a proposed hydraulic design can not meet requirements as defined in the ODOT Hydraulics Manual (2004/05) for the following items listed, then a design exception shall be required.

  1.) Design Frequency [Design Flood] (AASHTO 3.2.5 and 7.62; ODOT Chap.3)
  2.) Design Spread (AASHTO 13.9; ODOT Chap 13)
  3.) Allowable Headwater at Upstream Culvert End (AASHTO 9.3.3; ODOT Chap 9)

  Design Frequency [Design Flood]
  The recurrence interval of flood for which the drainage structure is sized; to assure no traffic interruption or significant damage will result. The following issues are of particular concern when evaluating exceptions to the design standard

  <u>General</u>
  - Significant Increase of flood hazard for property

  <u>Cross Drainage</u>
  - Overtop Highway, or
  - Exceed a certain depth on the highway embankment (see allowable headwater)

  <u>Storm Drains</u>
  - Encroach on the street or highway so as to cause a significant traffic hazard, or
  - Limit Traffic, emergency vehicle, or pedestrian movement to an unreasonable extent

  Design Spread
  The width of storm water flow in the gutter measured laterally from the roadway curb.
  - Reflects public expectation for finding water on the pavement surface
  - Is related to design speed and safety concerns with hydroplaning

  Allowable Headwater
  The depth of water that can pond at the upstream end of a culvert during the design flood.

- Stability of roadway embankment. Most roadway embankments are designed and constructed without saturation of embankment materials or lateral forces considered – they are not designed as dams
- Upstream and downstream impacts relating to erosion and flooding

10.2 TEMPORARY EROSION CONTROL

- **General**

The *ODOT Hydraulics Manual, Volume 2* is the basis for design of plans and specifications. The Hydraulics Unit, in the Geo/Hydro section, should be consulted about problems involving temporary erosion control design. An erosion and sediment control plan (ESCP) is part of the data that must be prepared on all projects that disturb soil.

The purpose of erosion control measures is to minimize the disturbance of soil particles, to limit the transport of sediment-laden water from construction sites, and prevent entrainment of sediment into receiving waters. The benefits include minimizing turbidity and its impact to water quality and fish habitat.

The Oregon Department of Environmental Quality, acting under Section 402 of the EPA's Clean Water Act, requires that all construction activity disturbing 5 acres or more, and after December 1, 2002, were revised under Phase II to apply to sites of 1 acre or more, of soil have an erosion control plan developed to comply with the National Pollutant Discharge Elimination System (NPDES) permit. Each region now has an NPDES 1200-CA permit to cover work done within that region; however, complying with the stipulations of the permit will require the cooperative effort of everyone involved. Contact a Region Environmental Coordinator for a copy of the permit.

The Federal Highway Administration is required by Section 1057 of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) to develop erosion and sediment control guidelines for states to follow when constructing highways using federal funds. In order to fulfill this requirement, on July 26, 1994 FHWA adopted the guidelines presented in Volume III of AASHTO Highway Drainage Guidelines.

As part of The Oregon Plan for Salmon and Watersheds, the Oregon Department of Transportation now assures erosion control plans are provided on all projects that disturb soil and use federal funding. Local jurisdictions may also have soil erosion and stormwater quality control requirements, and these should be considered on a location by location basis.

Temporary and permanent erosion control measures need to be considered during the project planning. The project site and vicinity topography and drainage patterns must be researched and used during the development of Erosion and Sediment Control Plans. The ESCPs consist of plans, details, and specifications that are included in the contract documents prepared by Roadway Engineering or Geo/Hydro. The erosion control plans must contain all of the necessary elements to accomplish the goals and meet the limitations of permits. Contract documents include specifications in Sections 00280 and 170.30(c) to address contractors' compliance with this permit.

10.3 PAVEMENT

- **General**

The pavement design for each project will be determined by the Pavement Design Group. Because the depth of surfacing is a major factor in the project design and cost, the pavement design is needed early in the project development process. If the Pavement Design Group is to complete their design work on time, keeping them informed of any changes in the project scope and schedule is very important.

The primary function of the Pavement Design Group is to provide the most practical and cost-effective pavement/base/subgrade design for the conditions and criteria for a specific project. Development of the design is accomplished through a combination of field investigation, data analysis, and application of appropriate design procedures. Pavement design procedures and ODOT Policies are outlined in the ODOT Pavement Design Guide. The surfacing type selection, such as PCC versus AC, will be the responsibility of the Pavement Design Group and will not be left to the competitive bidding process.

- **Project Scope**

Before the pavement design process can be started, the project scope must be established. Once the project scope is established, the Pavement Designer can begin the field investigation. Because of the limited availability of the Pavement Design Field Crew and other factors, scheduling fieldwork several months prior to the date when a complete design is necessary is important. Any changes in the project scope could require additional field work and should be brought to the attention of the Pavement Designer as soon as possible.

Field work for most projects will involve deflection testing of the existing road surface. This work cannot be performed when the existing pavement or subgrade is frozen. For this reason field work for projects in frost susceptible areas needs to be completed during the summer prior to the time a design is required. This may in some instances (particularly for Regions 4 and 5 and projects at the higher elevations in the Cascades) require the scope and project schedule to be finalized eight to nine months in advance of the time a pavement design is required. Typically, if a pavement design for a project in the above areas is needed prior to July of a given year, a work request needs to be provided by August of the previous year.

- **Design Considerations**

Additional information important in the selection of the most appropriate pavement design for a particular project is listed below.

1. The availability of materials
2. Source of embankment materials
3. Traffic staging details*
4. Amount of grade change required or tolerated (curbs, crosslope, R/W, stream or cut encroachment, etc.)*
5. Location and extent of widening
6. Location and extent of alignment changes*
7. Extent of current or future planned projects on the same section of highway
8. Unusual traffic patterns on a project*
9. Areas where soft subgrade may be encountered
10. Age, condition and upgrade plans for utilities under the pavement*
11. Type of drainage facilities in place or to be placed*
12. Actual type of curb present*
13. Change in traffic pattern use on existing pavement*
14. Extent and frequency of chain usage
15. Extent and frequency of snow plow damage
16. Grade constraints at bridges

*Important for urban area projects

- **Urban Pavement Rehabilitation Projects (in town, curbed sections)**

This type of project requires a very detailed review of several of the items listed above before field work should be conducted for development of the pavement design. The items are designated with an asterisk above. Many of these sections have very little curb exposure left or have unacceptable cross-slopes and/or other geometric features. This type of information is very important in determining the options available and the type of fieldwork necessary to develop the design. For more information regarding field work and pavement design for urban projects refer to the ODOT Pavement Design Guide.

- **Pavement Preservation Minimum Design Life**

All pavement designs must meet the minimum design life requirements outlined in the ODOT Pavement Design Guide. A design exception may be requested through the process described in Chapter 13. Typical acceptable reasons for getting a design exception are as follows:

1. A life cycle cost analysis shows that the proposed maintenance/rehabilitation strategy is more cost effective than what would be required to meet the minimum design life.

2. The proposed short term fix keeps the road passable until a project can be put in the STIP to provide a long term solution. A commitment should be made at the time of the agreement of the exception to get the project into the next STIP.

- **Project Scoping and Design Estimates**

The Pavement Design Group is also available to assist in the prospectus development and project scoping process. In most cases the Pavement Design Group can develop a preliminary design estimate that will be fairly close to the requirements of the final design. By using the Pavement Design Groups' expertise in the early stages of a project, the risk of significant cost overruns due to changes in the pavement design may be minimized.

For projects with asphaltic concrete quantities in excess of 400 tons, the designer should include a separate bid item for the liquid asphalt. Any request to not have a separate bid items should obtain the approval of the pavement designer. In addition, the standard liquid asphalt quantity is equal to 5.7% of the mix for ¾ inch HMAC pavements and 6.2% of the mix for ½ inch HMAC pavements. Any deviation to the standard liquid asphalt quantity requires the approval of the pavement designer.

10.4 GEOTECHNICAL DESIGN

- **General**

Two of the many questions faced by the highway designer include:

- What are geotechnical project elements; and
- How should they be dealt with?

Geotechnical project elements include all issues of design and construction involving soil and rock including pavement materials, but not including pavement thickness determination. How to deal with geotechnical project elements is a more complicated question. Almost every highway project uses either earth or rock as a construction material. Almost every project is built upon the earth and relies on it for support. The more experienced designer working with small and uncomplicated projects can probably handle earth and rock issues using a few rules of thumb and by relying on the Standard Specifications. On the other hand, complicated issues or difficult projects for which simple design guidance probably is not enough, should be addressed by a geotechnical professional working with the design team.

The purpose of this section is to make the highway designer aware of the broad range of geotechnical issues that may need to be addressed on any project regardless of size or apparent complexity. Some design guidance is provided for well-defined and simple conditions probably not needing professional geotechnical involvement. A little more comprehensive guidance is provided to aid preliminary layout of cut and fill slopes. Another section discusses the significant problems with sliver fills and talks about how to construct them properly if they cannot be avoided. Finally, a brief overview is given of the way in which geotechnical engineering and geology are used to develop and present the design information likely needed for more complicated projects.

10.4.1 GEOTECHNICAL DESIGN ISSUES

The following is a list of the geotechnical issues common to highway projects of almost any size:

- **Selecting and Designing Stable Slopes for Cuts and Embankments -** This far ranging issue must consider the materials available or required for construction, the space available to make the slopes, erosion from the slope, picking slopes to minimize maintenance, how the slopes will be constructed, surface drainage over the slope, and quality control to insure good performance. The subject also includes designing steeper than usual slopes to accommodate right of way limitations, avoid environmental features, or simply save money. Many options can be used to build steep slopes ranging from specially placed select materials to geosynthetic reinforcement.

- **Avoiding or Dealing with Unstable or Potentially Unstable Slopes -** This deals with the broad subject of building on or around landslides or not creating landslides with earthwork construction. Both cuts and fills may be involved. The subject also includes the possibility of destabilizing an existing fill by making changes to it including widening or slope steepening. Special design is usually necessary to recognize and deal with this issue.

- **Embankments over Soft Foundations -** An embankment on soft ground often settles dramatically and may slide, slump, or sink during construction if not designed properly. It is important to know how much settlement will occur and how long it will take to finish. Often, measures must be taken to accelerate settlement or improve foundation strength. Options include flat slopes, berms, stage construction, surcharging, wick drainage, foundation reinforcement, and lightweight embankment materials.

- **Materials for Construction –** On-site soils must generally be used for economy but they may be poorly suited for embankment construction. Soil type and excess moisture are often problems. Wet soils and strategies for dealing with them must be recognized. Finding suitable sources for borrow can be important. Also under this heading are design strategies for getting embankment built over wet, soft subgrade, or building embankment in wet weather. Other issues may include the presence of boulders or rock in excavation and the proper placement and compaction of soil, soil rock mixtures, and rock fills. Special density testing and compaction requirements will often be required for special cases including embankments with steep slopes, high embankments, or fills in critical locations.

- **Widening Cuts and Fills -** Projects involving widening must be carefully considered to assure that cuts and fills will perform well and can actually be constructed. Sliver cuts and fills can be and often are severe construction problems. There are also issues around the type of fill used in a widening and whether certain material may actually destabilize an existing embankment by causing water to backup in the old fill. Widening can have significant geotechnical issues and is so important that a separate section is devoted to this subject later in this design guide.

- **Earthwork Balance Analysis -** On moderate to large projects, estimating the volume shrinkage or swell of earth and rock material from borrow to embankment can be a major source of error in balancing the earthwork. A careful consideration of the volumes of material along with evaluation of the earth density can be used to refine shrink/swell estimates.

- **Surface and Groundwater Control -** Water control is necessary for stable slopes.

- **Seismic Site Response and Mitigation Design -** Although not commonly addressed yet, consideration will be increasingly given to the seismic stability of embankments and slopes. A key issue is the liquefaction of embankment foundations.

- **Rock Slopes -** In designing new alignments or widening in rock, the issue is the appropriate slope and its configuration to minimize rockfall. Some projects may require improvements in existing rock slopes to minimize the impacts of rockfall. Design guidance is provided later in this document.

- **Pavement Subgrade -** The Pavement Unit deals with this issue to determine if wet soils will make pavement construction difficult.

The above list is not exhaustive as every project is unique.

10.4.2 GEOTECHNICAL DESIGN SERVICES

Except for the simple designs involving low fills and cuts or projects not involving geotechnical issues, geotechnical design will be a part of the overall design process. This section provides a brief discussion of the scope of the work normally required to provide meaningful geotechnical design input.

Most geotechnical work is specific to a site where some type of civil work will be constructed and includes at least three parts. The first part is an investigation of subsurface conditions that always includes characterization of the subsurface. This is usually the most costly of the three parts and the one that takes the longest time. Subsurface characterization usually centers around drilling, excavating or other means to sample and identify the nature and extent of soil and rock materials that will either be used to support facilities or will themselves be used as construction materials. Industry practice, judgement and experience are all considered in defining the scope of the field investigation. Often, significant pressure is exerted to do less field investigation than may be necessary to provide quality information because of the cost and time required. Less than adequate investigation almost always results in construction problems, delays, change orders and claims.

The second part starts with a review of the samples and other field information and then centers around laboratory testing to determine soil properties. Depending on the project and the subsurface, the scope of this part may vary dramatically.

In the last part, the previously obtained information is used to develop design information. The issues that can be addressed in this step have already been summarized in the first section. Normally, design information is presented in a written report that also usually includes documentation of the entire process. Reports present the design information to the roadway designer, project manager, inspectors, contractors and others who may have an interest.

Depending on the size and complexity of a project more than one report may be prepared. Formats also vary from lengthy formal documents to short memos. The important thing about reports to remember is that design information will always be presented in writing. This report signed and sealed by a licensed professional engineer with geotechnical expertise. This practice not only satisfies the law but also allows those who sign and seal roadway plans to incorporate geotechnical design features into their design without having to be geotechnical engineers themselves.

It is important for the roadway designer and others to understand how geotechnical issues may affect their design. They should consult with a geotechnical professional all during the project but particularly in the early stages. Early advice can help identify geotechnical issues and determine if they might influence the first stages of geometric design. For example, a known unstable area can be avoided early rather than having to make significant alignment adjustments later. Or, it may be possible to decide early in a project that steep slopes will be used to solve a space problem. Identifying geotechnical issues can also provide early notification about expensive problems that are going to need to be solved. These problems are often not included in the earliest estimates of the project cost and can cause difficulties when they are discovered late in the development process. Another common problem includes deal making with stakeholders about some feature that has geotechnical implications. Typically these can include heroic efforts not to encroach on an adjoining property for one reason or another. Surprises about the feasibility or cost of these features can be avoided by obtaining geotechnical advice before making the deal.

Finally, it is important to understand that geotechnical design information is specific to the site and to the type of structure or feature being designed and constructed. This means that the overwhelming majority of the geotechnical work scope outlined above can only be accomplished after a preliminary design determines approximately what will be built and where it will be located. It is equally important to understand that significant changes in the nature and, more particularly, the location of a feature may require a repeat of the entire geotechnical process at the new location. Therefore, late design changes may delay a project because significant geotechnical work must be redone.

10.4.3 DESIGN GUIDANCE FOR SIMPLE PROJECTS

A simple project is defined as one with cuts and fills less than 6 to 10 feet high and design slopes that are 1 vertical to 2 horizontal or flatter. Geotechnical input is probably not required for simple projects meeting the following conditions:

1. Embankment foundation is not soft and wet.
2. Ground and surface water does not emerge from cut slopes.
3. Embankment materials are placed in lifts and compacted according to the Standard Specifications.
4. Embankments or cuts are not being made in unstable areas. Unstable areas include slumps, slides, erosion gullies and existing embankment or cut slopes in soil steeper than about 1 to 1.5.

5. There are no wet soil construction issues. East of the Cascades, this is seldom a problem except at higher elevations. On the west side this is usually an issue for fast projects and if winter work is contemplated.
6. Sliver fill issues are properly considered as discussed in the Highway Widening section.

Slopes steeper than 1V:2H or slopes not meeting the simple design conditions should be custom designed with the advice of a geotechnical professional. As a matter of good design practice, all slopes should be as flat as possible. The flatter the slope, the more stable it is, the easier it is to vegetate, the less material erodes from its surface, and the less critical construction and embankment quality are to its stability.

10.4.4 ROCK SLOPE DESIGN

Projects dealing with rockfall concerns or containing cut slopes in rock are becoming more common. Highways traversing Oregon's steep mountainous terrain were typically built many years ago and were not built to today's geometric standards. Many are showing the effects of age. Because of the nature of rock materials and the geologic environments in which they are found, virtually every rock slope design problem is unique. Dealing with these issues requires custom designs and is best accomplished with the involvement of an experienced geotechnical professional.

- **Cut Slopes in Rock**

Except for the most uncommon case where a rock unit contains no fractures, rock along a highway should be considered as an assemblage of rock blocks bounded in three dimensions by breaks in the rock called discontinuities. The orientation and strength of these discontinuities define what cut slope angle will be stable. Put another way, except for very weak rock, the breaks in a rock mass control overall slope stability, not the strength of the intact rock blocks.

The discontinuities in a slope can combine to create mass instabilities in the form of circular and planar failures similar to those found in soil slopes. More commonly though, they lead to localized failures in the form of individual blocks, wedges, or toppling columns. Rock cuts should be designed for the steepest continuous slope that satisfies physical and stability considerations.

Determining the appropriate cut slope angle is a lengthy and detailed process. In general, it includes gathering discontinuity data during statistical mapping where the orientation of joints, fractures, bedding planes, etc. are measured. Joint sets are defined. A rock mass rating is established. The strength along discontinuities is determined for critical joint sets. A kinematic analysis using the joint orientations, the strengths along discontinuities, and their relationship to the proposed highway alignment is performed to determine where failures can occur. In addition, where appropriate, limit equilibrium analysis is performed. From this data a cut slope angle that will preclude failures is determined.

Several issues need to be considered when designing rock cuts. These issues include:

- Cost of construction
- Right of way
- Safety
- Maintenance
- Constructibility

The cost of construction and the impact to adjacent property are issues that must be balanced with stability concerns by the design. Typically, a rock mass will contain more than one set of discontinuities that intersect within the slope in such a way that for each degree of slope flattening, fewer and fewer intersections will be exposed in the cut face that could fail. Logically though, each degree of slope flattening increases the amount of material to be excavated and the cost. Removal of half a mountain to build a stable slope is not practical. If the selected cut slope is unacceptably prone to rockfall, other measures may need to be included to deal with safety. These measures can include a combination of any of the following:

- Rock bolting
- Slope screening
- Shotcreting
- Rockfall barriers
- Enlarging the size of a standard rock fallout area at the base of the slope

Including intermediate slope benches is not recommended because of the difficulty of adequately maintaining them. Often access to benches is not provided, or if provided, a failure along the bench can restrict access or isolate the remaining bench. Over time, benches can accumulate rockfall debris and become a launch feature that increases the risk of rockfall reaching the roadway. Rockfall debris is most easily observed and safely removed from fallout areas located at the roadway grade.

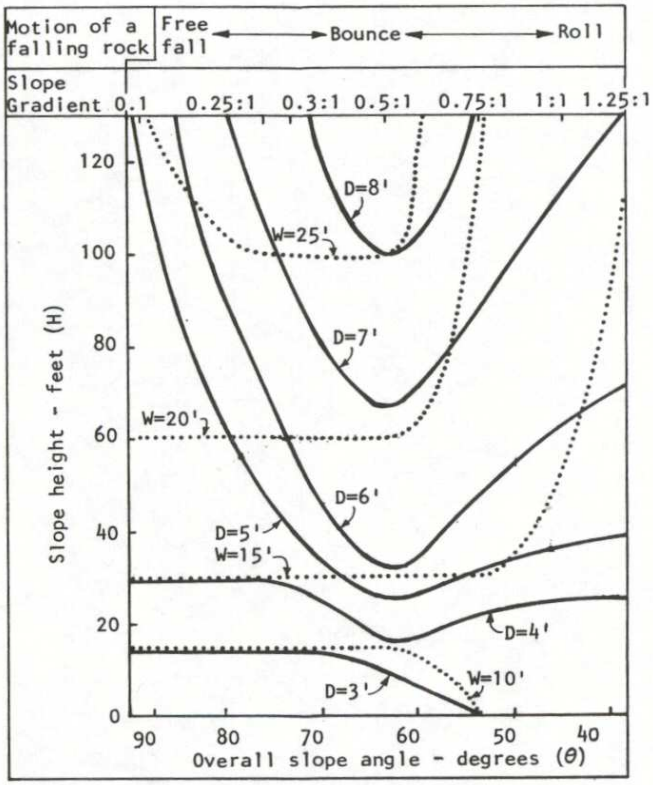
The cost and danger associated with ditch maintenance and rockfall road patrols needs to be considered in the design process. This should be part of the life cycle cost analysis. Slopes that actively produce rockfall are costly and a significant inconvenience to maintenance forces. A discussion of rockfall risk should be included as part of the Geotechnical Report.

Rock cuts designed at a slope angle of 1:1.25 or steeper, should include a rock fallout area at highway grade located between the toe of the slope and the edge of the roadway. Preliminary catch ditch dimensions may be estimated based on rock cut slope inclination and height from the Ritchie Rockfall Catch Ditch Design Chart, Figure 10-1. Final catch ditch dimensions should be determined using the *Rockfall Catchment Area Design Guide* (FHWA Final Report, SPR-3 (032), 2001). ODOT has adopted a goal of 90% rock retention on all new and reconstructed rock slopes. If 90% retention is not achievable because of other factors such as cost, environmental concerns, right-of way impact and future risk, then the design should significantly improve the retention of rockfall to an acceptable percentage. The minimum dimensions beyond a standard ditch will be described in the Geotechnical Report.

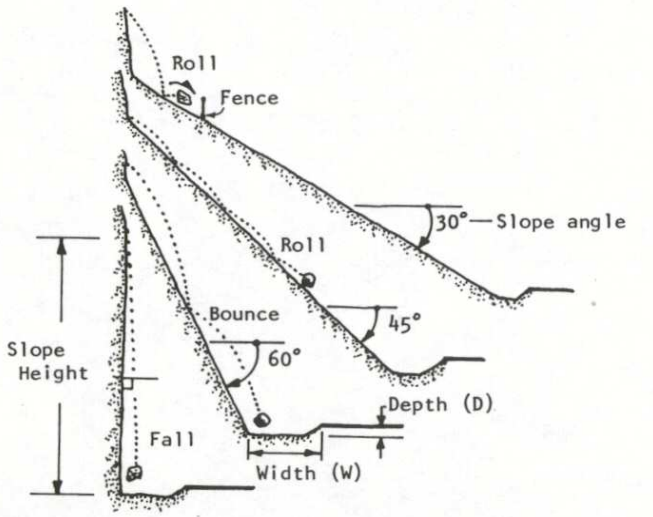
The constructibility of a rock cut slope design is important to consider. If a template design is used, sliver cuts can result. When the top of a proposed cut intersects very steep original ground the cut can be difficult to construct. More often, the width of the cut is too narrow to safely hold drilling and excavation equipment. Depending on the height of the proposed cut, the minimum width required for safe construction is 13 to 20 feet. A thorough review of design cross-sections should be performed to check cut width throughout the cut section. Sliver cuts can lead to cost overruns and major construction claims. The Special Provisions should highlight anticipated difficult access situations. This issue will be addressed in the Geotechnical Report. In some cases, a mandatory prebid meeting may need to take place so contractors know what to expect and especially if specialized equipment or unusual conditions are anticipated.

Rock cuts routinely require blasting to facilitate excavation of the rock. On some large excavation projects and anytime difficult blasting conditions are anticipated, the Geotechnical Report will identify the requirement that the contractor retain a pre-approved blasting consultant. The list of pre-approved blast consultants is available from the Geotechnical Unit. Difficult blasting conditions include nearby highway or private structures or utilities that may be susceptible to vibration or air blast damage. Layered hard and soft geologic materials can also cause problems. Staged blasting may also be needed to keep too much shot rock from blocking adjacent roadways and causing unacceptably long road closures. Specifications resulting in contractor liquidated damages are commonly included in the Special Provisions.

All rock cuts that are 1:0.75 or steeper are constructed using controlled blasting techniques. When this occurs, a per linear foot bid item for controlled blasting must be included. The quantity of controlled blasting is determined by dividing the estimated surface area of the cut by 2.5 feet, the typical spacing for presplit holes. All other production blasting costs for the blasting consultant, air shock and vibration monitoring, etc., are incidental to the general excavation bid.



Ditch design chart.



Rock falls on slopes.

Figure 10-1
Ritchie's Rockfall Catch Ditch Design Chart
Source: "*Rock Slopes: Design, Excavation, and Stabilization,"*
FHWA, 1989

The cost of blasting is outlined in Section 00335 of the Standard Specifications. There is no mention in this specification for how blasting will be paid for on a project that is bid as an embankment job. It is important that this be clarified and covered in the Special Provisions.

- **Rockfall Mitigation Design**

The safe operation of highways in mountainous terrain often requires that measures be taken to control the incident of rockfalls. Most methods for dealing with unstable rock slopes have been around since the 70's and have been used on a wide range of geological conditions. However, it is essential that the method used be appropriate for the defined problems at a particular site.

The most common types of rockfall mitigation measures fall into four broad categories. They are:

- Rock reinforcement
- Rock removal
- Protective measures
- Drainage

- **Rock Reinforcement** - Rock reinforcement includes rock bolts, dowels, cable lashing, retaining walls, shotcrete, and buttresses. Of these, rock bolts and shotcrete are most commonly used. The bolt size, corrosion protection required, bolt location and orientation, bolt tension, special equipment requirements and the bid quantity will be described in the Geotechnical Report. For shotcrete design, the report will include the limits of application, the required thickness, reinforcement and drainage requirements, and the bid quantity.

- **Rock Removal** - Rock removal includes resloping, trimming and scaling. Over time, the outside surface of a rock cut can deteriorate to the point where rockfall reaches an unacceptable level. The excavation must be wide enough to accommodate drilling and earth moving equipment. Sometimes unloading the top of the cut is required. The new slope angle and cut height is determined by stability analysis.

  On a generally smaller scale, trimming is the process of removing overhangs left after a portion of the slope has failed. Trimming is done using blasting methods where closely spaced holes are drilled and loaded along the plane of the desired slope. This is also called blast scaling. It's important to note that not all overhangs need to be removed. Many are stable and pose no threat to the public.

  Scaling is one of the most common procedures performed on rock slopes. It is the operation of removing loose blocks of rock from the surface of the cut. Scalers work from the top of the slope downward so all loose rock above them has been removed. The work is performed from ropes using a steel tipped pry bar. Scaling includes the removal of trees from the slope that can act as levers to dislodge rocks by wind action and/or root wedging.

- **Protective Measures** - Protective measures include catch ditches, barrier systems, catch fences, slope protection mats, and structures such as tunnels and rock sheds. Structures are very expensive and therefore only rarely used. The other four methods are routinely used.

  Catch ditches (fallout areas) serve to restrict rockfall from the roadway and provide both rockfall and snow storage. One method used to determine the necessary depth and width of the fallout area is computer modeling. Certain predictions can be made this way of how many rocks will be retained based on a certain size and shape of ditch. Another method is to estimate the percent of rocks that reach the roadway with the current ditch configuration and comparing it to a new ditch using the design charts in the "*Rockfall Catchment Area Design Guide"*. Both methods should be checked against each other and with other design tools to verify consistency and reasonableness of the design. Barrier systems include berms, free standing walls, GM rails, and woven wire rope systems such as the Brugg fence. The intent of these is to intercept and capture rockfall behind them. They must be periodically cleaned out and therefore maintenance is an issue that must be accounted for in the design. The type of system selected is based on expected rockfall sizes and kinetic energies that must be absorbed by the barrier. Improper analysis can lead to a very early failure of the system.

  Catch fences are a common measure used on slopes where the anticipated rockfall size is less than 2 feet. They are relatively inexpensive and have a long history of good performance. They intercept rockfalls and decelerate them so they remain in the roadside ditch where routine ditch maintenance is performed. They are installed near the base of a slope and consist of gabion mesh draped from a cable suspended 7.5 feet above the ground on 4 inch posts. The slope should be 1:0.75 or flatter for optimal performance.

  Slope protection mats serve a similar purpose as catch fences in that they are used to control the descent of rockfall so the rock will be retained in the roadside ditch. The difference is that the mesh is draped over the entire slope, not just at the base. The mesh is attached to cables that are in turn secured to ground anchors spaced between 10 and 40 feet apart, depending on the type of material the anchor would be installed into. The same 2 foot rule of thumb applies as for catch fences. The mesh can be placed on any slope angle vertical to flat and has been shown to help promote vegetation establishment on slopes as steep as 1:0.75. Both catch fences and slope protection mats can use Poly-vinyl Chloride(PVC) coated mesh that can accommodate any desired color to blend into the environment.

- **Drainage** – Water in a slope is a major contributor to slope instabilities. The lateral force exerted in a tension crack increases by the square of the height of the water in the crack even when the cracks are very thin. Water trapped in a slope can also freeze in the winter. When water freezes in a fracture it expands and can widen the crack. Over time, this process can ice-jack a block from the slope. Keeping the slope drained prevents much of this from occurring. Drains are typically inclined to be self-cleaning and drilled to a depth about one-third the height of the cut and spaced 10 to 30 feet apart.

  The selection of any of the above-described rockfall mitigation methods is based on detailed investigation and analyses and experience. The design considers cost, maintenance,

performance requirements and risk to the public. A description of the design criteria will be included in the Geotechnical Report.

10.4.5 HIGHWAY WIDENING

Widening highways by either adding new fill to existing embankments or cutting further into existing cuts has become one of the prime design issues in an era of preservation and modernization projects. Making highways wider often encroaches on adjoining property-requiring time consuming and sometimes expensive right of way purchase. Encroachment on wet lands or streams can be of equal concern. Roadway designers often find themselves needing to "fit" new shoulders and lanes into the limited space between the existing highway and the existing right of way boundary or some other obstacle. If not carefully considered and designed, the widened portion of the highway can be unstable as well as difficult and expensive to build properly.

- **Design Guidance**

If at all possible, extensions to existing embankments should be wider than 6 to 10 feet measured horizontally and should have finished slopes no steeper than the existing embankment slope. Both of these provisions assure that the new fill is wide enough to facilitate placing it in horizontal layers and compacting it properly using normal sized construction equipment. Placing and compacting fill in horizontal lifts assures that it will be as strong or stronger than the existing embankment. New fill at least 6 feet wide along with a 3 foot bench into the existing slope as shown on the standard benching detail assures that a total of 10 feet of fill surface is available to equipment. This is considered a minimum for full sized machinery and is still a very confined space to work in, all things considered. A total of 12 feet would be optimal. Small self-propelled compaction machinery commonly used in trenches could be used for embankment extension compaction and could probably be used to compact on fill surfaces much less than 6 feet wide.

Consideration also needs to be given to the material that will be used to widen an existing embankment. Stability problems have been observed where fills were widened with materials that were considerably less pervious to water than the existing embankment. Under extreme conditions groundwater saturates the existing embankment and is trapped by the new less pervious fill. The water pushes the new fill off the slope. In this case, it may be necessary to install drain layers between the new and the old fill to prevent such failures.

- **Sliver Fills**

An embankment extension less than 6 feet wide is defined as a sliver fill. A sliver fill can include a slope steeper than the existing embankment slope that toes out on or above the toe of the existing fill. A sliver fill could also have the same slope or a flatter slope than the existing embankment but be less than 6 feet wide over some or all of its height. Sliver fills toeing out on the existing slope are often used to avoid buying right of way when a new wider shoulder is

required and/or to provide room for a flat slope in the base course rock between the back of the guard rail post and the top of the slope. A sliver fill is almost always necessary where the end of a widened embankment feathers into the existing fill. Seldom does the addition of a new lane result in a sliver fill unless the existing embankment is very high.

Sliver fills should be avoided in design. They are difficult and expensive to build and are unstable if not placed and compacted in layers. Consideration should be given to buying the right of way needed to avoid the sliver fill. Considering the cost and difficulty of building a sliver fill properly, the cost of the right of way may not be as serious an issue as it is often portrayed. Standard field density testing frequencies at 1 test per 500 cubic yards of embankment allows sliver fills to be constructed with fewer tests to assure that proper compaction is being achieved. To avoid sliver fills for simple shoulder widening, consider reducing the space between the back of the guardrail and the top of slope. For example, standard design calls for a 1:3 base aggregate slope between the pavement edge and the top of the embankment slope. The base aggregate can actually be sloped as steep as 1 vertical: 1.75 horizontal (with approval) to save space, an effect that increases as the base thickness increases. Guardrail posts can also be moved close to the top of the slope if they are lengthened. This will required the Standards Engineer's approval.

If there is no way to avoid a sliver fill, then design and construction efforts must assure that it gets built and compacted in layers for strength and stability. The following outlines design advice and a few things to watch out for:

- Properly placing and compacting a sliver fill in thin lifts requires benching into the existing embankment as shown in Figure 10-2. Benching this severe can remove all or parts of a travel lane during construction and requires replacing the paving removed from the benching.
- The benching removes and replaces a large amount of material relative to the quantity of the sliver fill. Therefore, the amount of earthwork actually required to build the sliver fill is grossly underestimated by simply referring to the sliver fill quantity (benching is currently an incidental cost). Therefore, consideration should be given to creating a specific pay item for sliver fill benching.
- Be aware that the material removed in benching may be wet and have to be processed prior to compaction or discarded and replaced. It is also a good idea to specify granular soil for sliver filling to ease compaction, provide high strength and provide high permeability.
- The field density testing frequency of the sliver fill also needs to be increased by special provision to about 1 test per 500 cubic yards or 1 test every other lift, whichever produces the most tests.
- Consider writing a special provision requiring small compaction equipment for sliver fill construction. This would allow the benching to be less severe.
- Be sure that the temporary traffic plan considers the effect of severe benching. It will be difficult to support traffic on a lane that will be removed for benching.

- Compare the real cost of sliver filling against the cost of buying right of way. Right of way may be less expensive when all of the costs of properly building a sliver fill are considered.
- Finally, consider the possibility of low retaining walls constructed at the top of the embankment slopes. Using Mechanically Stabilized Earth(MSE) wall technology, these may prove to be less expensive than some other alternatives.

- **Sliver Cuts**

A sliver cut is defined as sloped excavation less than 10 feet wide over some or all of its height. Sliver cuts in soil should be avoided because they are difficult to build. Cuts at least 10 feet wide over the full height of the slope are required to use conventional earth moving machinery and to maximize production. Cuts less than 10 feet wide and about 10 to 25 feet high measured along the slope can be excavated with a large backhoe but at the expense of production. If a sliver cut is used, consider how it will be built and be sure to account for the difficulty in the cost estimate.

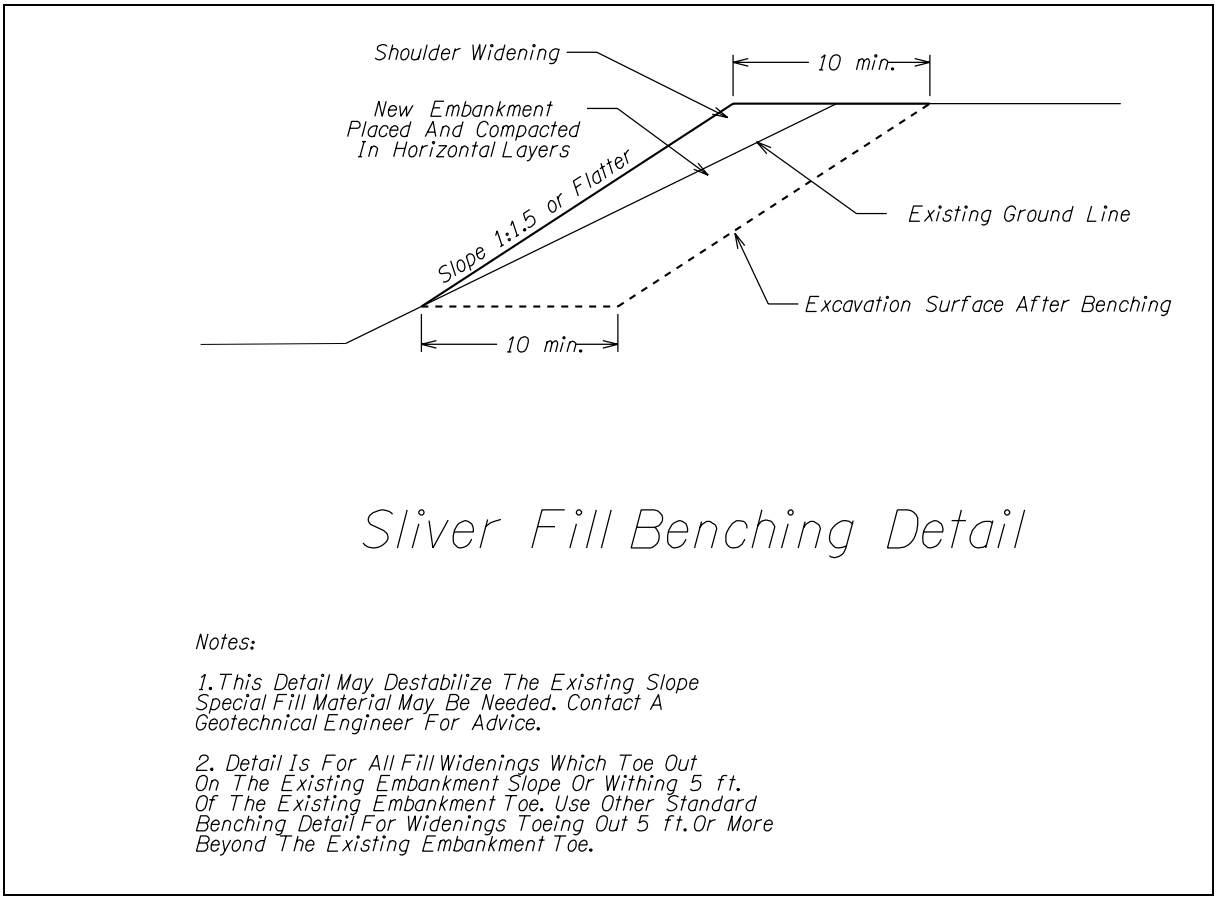


Figure 10-2
Sliver Fill Benching Detail

10.4.6 SELECTING EMBANKMENT SLOPES – DESIGN GUIDANCE

There are only a few rules to consider in selecting embankment slopes for geometric design:

- Always use the flattest possible slope. Flat slopes erode less, are easier to vegetate, and are more stable. Flat slopes are easier to build, require less inspection and need less capable materials for adequate performance. They can also be mowed.
- The maximum design slope is 1 vertical to 2 horizontal under normal conditions. Slopes this steep will probably require geotechnical analysis and design depending on height but they normally can be made to perform adequately with relatively minor cost and effort assuming good foundation conditions.
- Pay attention to surface water runoff. It will probably be necessary to collect surface runoff and route it away from the steepest slopes. Failure to do so causes many slope instabilities.

Slopes steeper than 1 vertical to 2 horizontal can be successfully designed and constructed under special circumstances but should not be considered routine. The more intense design process and attention to many details during construction make steep slopes relatively expensive and difficult to build well.

In recent years the attention to detail during construction has not kept up with the proliferation of slopes steeper than 1:2. Specific steps should be taken to better assure the stability of steep slopes and, at the same time, set them apart from routine embankments with flatter slopes so that they get more attention during construction. These design steps will require any combination of the following features for steep slope design and construction:

1. Materials specified by gradation and Atterberg limits will be used in at least the outer part of the embankment. These will likely be granular soils or stone embankment material. Any borrow specified by gradation will require periodic gradation testing at intervals of 1000 to 2000 cubic yards.
2. Geosynthetic reinforcement will be used either to aid compaction of the outer surface or to actually reinforce the slope or both. As a compaction aid, 6 foot long geotextile strips placed on every other lift will become common.
3. Positive erosion control on the slope surface will be obtained using erosion control matting.
4. Increased compaction testing frequency will be specified. About 1 test per 500 cubic yards or every other lift will be required.
5. Increased fill density requirements (95 percent compaction) will be used to produce consistent high strength.

Even with these restrictions, building a specially designed steep slope will be less expensive than a retaining wall. However, it may not be less expensive than buying a little more right of way and building a flatter slope.

10.4.7 SELECTING CUT SLOPES IN SOIL AND WEAK ROCK – Design Guidance

Cut slopes more than 6 to 10 feet high must be designed by considering the materials in the cut and by paying attention to geologic details like rock jointing, joint orientation, joint strength and groundwater. For preliminary layout, simple rules similar to those for embankment slopes can be used for guidance:

- Always use the flattest possible slope. Flat slopes erode less, are easier to vegetate, and are more stable.
- The maximum design slope is 1 vertical to 2 horizontal under normal conditions. Slopes this steep will likely require geotechnical analysis and design if they are higher than 6 to 10 feet.

In some ways designing cut slopes is more complicated than designing fill slopes. At least there is some control over the material used to build an embankment. The first consideration in cut slope design is the strength of the intact soil or rock. Simply stated, the stronger the material, the steeper the cut. The next and most difficult part is to account for discontinuities in the material that may have more of an influence on behavior than intact strength. In soils, these features may be fissures, cracks, and a layer of prior movement or boundaries between layers of changing material. In rock there is similar concern for joints, fractures, and boundaries between beds. Finally, the influence of groundwater is considered.

Similar to embankments, cut slopes higher than 6 to 10 feet and steeper than 1 to 2 need to be custom designed. Few options exist for making slopes steeper than their material strength would allow. The primary approach involves some type of structural reinforcement centered around grouted dowels, or tensioned soil, or rock anchors. These are expensive solutions compared to flattening.

10.4.8 GEOTEXTILES

Geotextiles are synthetic fabrics that have a wide range of uses in highway construction. The functions served by geotextiles include the following:

- **Separation -** In this function the fabric separates two layers of material from each other. Separation is required to prevent a first material from migrating into and deteriorating the strength of the second material. A common separation application has a fabric between subgrade and base course to keep the subgrade from pumping into the base under traffic loading. A contaminated base is much less strong. Fabric opening size defines how well a separator fabric works. The finer grained the subgrade the smaller the fabric openings must be to be effective. A separation geotextile does not necessarily have to be good at passing water, thus its permittivity may be small.

- **Filtration** - In this application the geotextile is the filter between two soils. A filter is needed where water flows from a soil into a granular drain material. The filter keeps the soil in place while allowing water to pass into the granular drain material. Without a filter all

gravel drains will eventually plug. Filter geotextiles need moderate to high permittivity to pass water. The fabric openings must also be small enough to retain soil but not too small to retard water flow.

- **Strength** - A geotextile can be used to reinforce soils and make them stronger. A common example of this application is a wrapped faced geotextile retaining wall. Less commonly, geotextiles are used to reinforce steep slopes and embankments placed over soft soils. In this application the material does not necessarily have to be highly permeable. In a common misunderstanding, most people associate using a geotextile with reinforcing a paving section. Unless the subgrade is very soft, a geotextile beneath a pavement or a layer of rock mainly serves as separation and not as reinforcement. There are, however, highly specialized high modulus geotextiles that can be used in pavement reinforcement applications. The use of these fabrics does require specific analysis and design.

Commonly a geotextile will serve two or more functions at one time. Geotextile used beneath riprap, for example, serves both as a separator and a filter. While the separation application is obvious, the filter application is subtle. Water surging around the riprap needs to be able to pass freely between the subgrade and the riprap. The filter allows this to happen while keeping the subgrade in place. In some strength applications it is also an advantage that the geotextile both carry and remove water. In removing water it is acting as a filter even though its prime purpose may be reinforcement. In general, select geotextiles based on the functions they must serve.

Geotextiles in highway use come in two varieties, woven and non-woven. Non-woven fabrics consist of a randomly oriented agglomeration of threads bonded together. The term woven fabric is self-explanatory. Non-woven fabrics make the best filters but are also good at separation. Woven fabrics have better strength but do not pass water well and are usually poor filters. They are good separators, however.

In today's marketplace and based upon the way specifications are written, woven fabrics are being used for separation and reinforcement and non-woven fabrics are being used for filtration and separation. Only in reinforcement applications has specific geotextile design been performed. In the areas of filtration and separation, it is possible (though seldom done) to design a geotextile by limiting the size of the fabric openings compared to the surrounding soil. It is also possible to design a geotextile specifically to handle construction stress without damage but this too is seldom done. Anywhere a geotextile is used in a critical application, a geotechnical professional should design it specifically for that application.

It is possible to properly select a geotextile for straightforward applications not involving reinforcement by using Table 02320-1 in the Standard Specifications. In the table a list of material requirements are organized under fabric names.

Filters for wrapping gravel drains or French drains should be either Type I or Type II drainage geotextile. These will be non-woven fabrics with two possible weights. Use the heavier Type II fabric in applications where large angular rock will be in contact with the fabric. The most

important fabric property for this use is the pemittivity. The heavier weight of the fabric is used to limit installation damage.

Subgrade geotextile will generally be used in separation applications between subgrade and base course. This fabric can be woven but the contractor could use a non-woven fabric. Woven fabric is usually supplied because it is inexpensive. If the fabric must also serve as a filter do not allow the woven to be used, or select a drainage geotextile from the table that has the same or higher strength as the subgrade geotextile. A filter is needed if water is expected to move from the subgrade up into a granular drainage layer.

Type I or Type II riprap geotextile is used beneath riprap. The Type II fabric is heavier and should be used beneath large riprap to minimize puncture during installation. Riprap geotextiles are non-woven and therefore will be good filters. Actually, riprap geotextile can also be used for any drainage and separation situation that drainage or subgrade geotextile would be used for.

To summarize, if drainage and filtration is needed, use a non-woven fabric. However, non-woven fabrics used in drainage applications may clog if not specifically designed to filter the soil that they protect. This is the risk taken if specific design is not conducted.

10.5 ENVIRONMENTAL STUDIES

- **Project Classification**

When a project is identified in the Statewide Transportation Improvement Program, (STIP) the responsible Region initiates a Project Prospectus, which includes Part 3, the Environmental Classification Request. The Region recommends the environmental classification, Class 1, 2, or 3, and Environmental Services confirms the recommendation. For federal projects, FHWA must concur on the classification.

Most projects are Class 2 projects, which do not require an Environmental Assessment or Environmental Impact Statement, but many require specific environmental reports, mitigation, permits, and clearances. Class 1 projects, projects that will have a significant impact on the natural or human environment, require a draft and final Environmental Impact Statement (DEIS/FEIS) and the issuance of a Record of Decision (ROD). Class 3 projects, projects with substantial, but not environmentally significant impacts to the natural or human environment, require an Environmental Assessment/Revised Environmental Assessment(EA/REA) and a Finding of No Significant Impact (FONSI).

Issuance of the ROD or FONSI by FHWA allows the project to advance to the final design phase and to undertake right of way acquisition.

- **Environmental Studies**

The full spectrum of environmental impacts is evaluated for Class 1 and 3 projects and documented in a DEIS/FEIS (Class 1) or EA/REA (Class 3). Projects that become Class 2 projects (Categorical Exclusions) are evaluated to determine that there are minimal impacts, if any, and documented in the Part 3 of the Prospectus. Class 2 projects may also be documented in staff reports or documents focused on one environmental subject area. The level of detail required is driven by the nature of the impacts, not necessarily the class of the project.

The purpose of the environmental evaluation is to give information to the project team, the public, and the regulating agencies so that project decisions can be made by decision makers who are informed of all the consequences of the decisions they are making. It is hoped that this will lead to the solution that best balances transportation needs, safety, economics, and protects to the greatest extent feasible, the natural habitat and human environment. Environmental protection normally requires avoidance, minimization, and mitigation, in that order.

- **Specific Impacts**

Project impacts that affect the environment can be either direct or indirect. An example of a direct impact would be the removal of habitat by realigning the roadway prism. Indirect impacts often occur from changes in access. For example, providing an interchange where only an overcrossing existed may induce land use changes which, in turn, impact habitat. These are more difficult to predict with certainty, but are often the more profound impacts. Either type of impact can influence the facility design as the project team attempts to avoid, minimize or mitigate the impacts. Typical of some of the impact areas are:

Noise: Noise barriers may be used to mitigate traffic noise on a project. The preliminary design for these barriers is done by the Geo/Hydro Section. The public involvement process may be used to help determine the type and desirability of a noise barrier.

The final decision as to the type of noise barrier to be constructed will be made during the final design process. Geo/Hydro will do the final design of the structural element of a noise wall. The Roadway Design Section will do the final design of an earth berm.

It is essential to realize that additional right of way may be necessary to construct the footings for a wall. In addition, conflicts can arise between a noise barrier's location and utilities, signing or drainage facilities. Coordination during the final design process involving all of the affected groups will help in avoiding conflicts with wall placement.

Historic: Structures and sites designated as being on or eligible for the National Register of Historic Places require evaluation of avoidance alternatives. These sites must be avoided unless no feasible or prudent alternative exists. This same protection is given to public recreation and wildlife refuge areas. These are all known as 4(f) properties.

Archaeology: National Register sites are to be avoided (designated no work areas) or a recovery process undertaken.

Wetlands: All classes of projects frequently impact wetlands. It is critical to determine if there are alternatives that avoid the impact, and if not, how the impact can be minimized or mitigated, in that order, for all wetland areas. Different alignments, steeper slopes, retaining walls, and other techniques must be used to avoid or reduce impacts, if these techniques are feasible in the impact area.

Water Quality: Seasonal in-stream water periods are designated for most Oregon waterways; stream classification and fisheries activity can also influence the design. Since the recent listing as Endangered of so many of Oregon's fish species, water quality and in-water work have become critical project issues. Designs that can avoid in-water work or disturbance of water quality, including changes to an area's hydrology, are important to consider.

When the ADT is projected to be greater than 30,000, specific water quality mitigation measures are normally required. Water quality mitigation is also required in certain sensitive water body

areas. During construction of projects disturbing ground surfaces, erosion control must be included in the construction plans. Refer to PD-05 for information related to water quality mitigation.

Threatened and Endangered (T&E) Species: Many projects have the potential to impact wildlife in general and T&E plant and animal species more specifically. In this case, design changes to avoid impacts are required. Conservation measures are often required as part of the construction contract to avoid impacts to protected species. Since these vary widely with the various species, it is important to work closely with the biologist when designing the facility and work conditions near endangered and threatened species, particularly near fish bearing streams and wildlife groups.

Air Quality: Transportation plans, programs and projects within Oregon's nine air quality non-attainment areas must conform with the intent of the State Implementation Plan (SIP) for air quality. Major projects in these areas requiring DEIS/FEIS or EA/REA environmental documentation must demonstrate conformity before FHWA can issue a ROD or FONSI. Smaller projects involving signalization, channelization, changes in vertical or horizontal alignment or bus terminals may also require a conformity determination. An air quality specialist should be consulted when questions arise regarding specific conformity requirements in the following areas: Portland Metro, within the METRO Urban Growth Boundary (UGB), Salem-Keizer Area Transportation Study, Eugene-Springfield UGB, Medford-Ashland Air Quality Maintenance Area, Grants Pass UGB, Klamath Falls UGB, La Grande UGB, Lakeview UGB and Oakridge UGB.

Hazardous Materials: All projects need to be reviewed for potential impacts to hazardous material sites. There are many risks that can be created or aggravated even when working completely on ODOT right of way. When excavating or working along ditches the designer must be careful of disturbing contamination or causing lateral transport of that contamination, and the design must manage contaminated material, transport, and surface drainage.

All projects require a Pollution Control Plan. The plan will address the contractor's response in the event of an unforeseen spill, leak, or discovery.

New federal policies stress that the State needs to consider future land uses when deciding the location of facilities. It is not necessary to try to avoid all contamination. The contaminated site could be used for transportation, which could to bring the site into greater productivity.

Other Areas: Project impacts to floodplains, scenic resources, emergency services, neighborhoods, social and cultural interactions, businesses and other environmental subject areas can be of sufficient importance to influence the design. Land use and planning, particularly compatibility with comprehensive plans, Department of Land Conservation and Development goals, and requirements of the Transportation Planning Rule, are critical elements in determining the design of the facility.

Permits: Many of the above areas, such as wetlands, require special permits (see Section 10.9), approvals or agency concurrence.

- **Design Specifications**

A summary of mitigation and conservation measures is included in the REA or FEIS for the specific project. These are incorporated into the plans and specifications for the project. Although there are some standard conservation measures listed in the *"Oregon Standard Specifications For Construction-2002",* project specific items are identified in the REA or FEIS. It can generally be assumed that the standard highway construction practices are acceptable for projects, unless specifically amplified or identified in the Summary of Mitigation in the REA or FEIS.

The Environmental Project Manager for a specific project (author of the REA or REIS) should be consulted on questions regarding the mitigation or conservation measures.

Some Class 2 projects may also require mitigation measures. Designers are usually informed of these needs by memo or similar communications from the Environmental Specialists.

- **Plans, Specifications and Estimate (PS&E)**

Approximately 7 weeks prior to bid letting, the PS&E document is delivered to the Highway Finance Office for final processing. All Environmental work must be completed at this point. The designer should check with the Environmental Services Information Specialist to determine if all clearances and documentation has been completed. The clearances include environmental document completion, noise, air quality, hazardous materials, wetlands, cultural resources, and threatened and endangered species.

10.6 TRANSPORTATION ANALYSIS

- **General**

The Transportation Planning Analysis Unit (for areas outside of Region 1) and Region 1 Traffic Unit, with assistance from region staff, cities, counties, and other state agencies, is responsible for providing highway design traffic, traffic analysis and volume-capacity ratios for modernization and preservation projects.

- **Modernization Projects**

The Transportation Planning Analysis Unit (TPAU) and Region 1 Traffic Unit are responsible for the analysis of modernization projects. TPAU involvement in project development should begin during scoping and continue throughout the process. The transportation analysis for modernization projects includes developing traffic data for the Environmental Assessments (EA) and Environmental Impact Studies (EIS). This information is used by Environmental Services in air quality and noise analysis for the project. The traffic information required is the same for both the EIS and EA and includes the following:

1. Develop the base, intermediate, and future year traffic volumes. The future year should be 20 years beyond the year the project construction is completed. The traffic volume information includes the total number of cars and trucks, by section of roadway, for each of the following categories:
    a) Average Daily Traffic (ADT)
    b) Design Hour Volume (DHV) – this is the future year 30th highest hour traffic volume.
    c) Average hour volume during the peak 8 hours of the day
    d) Peak truck hour volume.
2. Determine the volume/capacity ratio (v/c). At signalized intersections, the v/c ratio can be determined using SIGCAP2, an ODOT signalized intersection analysis software, or by using the Highway Capacity Manual methodology. The Highway Capacity Manual methodology can be used to calculate the v/c for all other facility and traffic control types. Determine if signal warrants are met for intersections that are currently unsignalized. The ODOT preliminary signal warrants should be used to evaluate a future signal installation.
3. Evaluate signal progression for the transportation system in accordance with OAR 734-020. The progression analysis should be evaluated using Synchro or other software approved by the ODOT Traffic Management Group. The progression analysis should also adhere to all requirements the Traffic Management Group has set for progression analysis (minimum bandwidth, cycle length, efficiency, etc.).
4. Determine the 95th percentile storage lengths required for all approaches of each alternative.
5. Determine the speed, by section of roadway, for each alternative and for each category listed in Item Number 1 above. The speeds are determined using a combination of field observation, v/c versus speed relationships, and progression analysis.

6. Write a narrative report summarizing the above transportation analysis.

- **Preservation Projects**

TPAU and Region 1 Traffic Unit will provide all transportation analysis information needed for preservation projects. If there are no increases in capacity then no traffic information is required. If there is a change in capacity (widening shoulders, adding/removing turn lanes, adding signals, etc.) then, at a minimum, the base and future year ADT, DHV and v/c must be determined to ensure consistency with the v/c in Table 10-1.

- **Traffic Studies**

TPAU or Region 1 Traffic Unit will perform traffic impact studies (TIS) at the request of Region Managers, cities, counties and other state agencies. A TIS usually includes the following information for the current and future year (20 years after site construction) for the existing and proposed development (see OAR 734-051 for more details):

1. Existing/proposed land use information
2. Evaluation of other planned/built land uses in the vicinity
3. Existing trip generation from the site (using recent count or Institute of Transportation Engineers(ITE) Trip Generation)
4. Trip generation of proposed site (using ITE Trip Generation) and assignment to the transportation system
5. Current and future DHV, with and without proposed development
6. Safety concerns – horizontal/vertical alignment, access/intersection crash data, etc.
7. Existing roadway geometry in the vicinity (lane configurations, intersection control, and current/proposed access locations)
8. The alternative access and roadway improvements
9. The access category for the adjacent highway, the v/c, storage requirements, and progression information for both the existing and proposed development
10. The results of the traffic data and analysis, along with the impacts of the project and recommended action, will be summarized in report form (see the ODOT Development Review Guidelines for a more detailed description of this process)

- **Design Guidelines**

It is essential to obtain projected traffic volumes, capacity analysis, and v/c ratios from TPAU or the Region 1 Traffic Unit. All major highway improvements shall be designed for the appropriate v/c ratio 20 years after completion. Table 10-1 shows the acceptable v/c ratios for project development/design. If the volume-capacity ratios in Table 10-1 cannot be met, a design exception should be sought. If it is known early in the planning or project development process, that the v/c

standards cannot met, the design exception should be sought at that time instead of later in the project design phase.

The v/c numbers shown in Table 10-1 may be different that the v/c capacity numbers that are shown in the Oregon Highway Plan. The numbers in the Oregon Highway Plan are for planning purposes and should not be used for project design.

Table 10-1
20 Year Design-Mobility Standards (Volume/Capacity [V/C]) Ratio

Highway Category	Land Use Type/Speed Limits					
	Inside Urban Growth Boundary				Outside Urban Growth Boundary	
	STAs	MPO	Non-MPO outside of STAs where non-freeway speed limit <45 mph	Non-MPO where non-freeway speed limit >= 45 mph	Unincorporated Communities	Rural Lands
Interstate Highways and Statewide (NHS) Expressways	N/A	0.75	0.70	0.65	0.60	0.60
Statewide (NHS) Freight Routes	0.85	0.75	0.70	0.70	0.60	0.60
Statewide (NHS) Non-Freight Routes and Regional or District Expressways	0.90	0.80	0.75	0.70	0.60	0.60
Regional Highways	0.95	0.85	0.75	0.75	0.70	0.65
District/Local Interest Roads	0.95	0.85	0.80	0.75	0.75	0.70

Notes:

- Interstates and Expressways shall not be identified as Special Transportation Areas (STAs).
- The peak hour is the 30th highest annual hour. This approximates weekday peak hour traffic in larger urban areas.
- MPO category includes areas within the planning boundaries of the Portland, Eugene/Springfield, Medford and Salem/Keizer Metropolitan Planning Organizations, and any other MPO areas that are designated after the adoption of this plan.

- **Estimating Capacity for Highways**

Since there are many variables that could affect the capacity of a highway, <u>use the following process as a general guideline only.</u> The Transportation Planning Analysis Unit or Region 1 Traffic Unit will provide design level data. The purpose of this process is to give designers an estimation of allowable daily traffic volumes that can be used to see if a prospectus has identified the correct number of lanes for a state highway. The allowable daily traffic volumes are not intended for detailed design purposes. If there is a discrepancy between the prospectus and the results from this analysis, a designer should contact the TPAU for a more detailed evaluation.

- **Capacity Estimation Process Outline:**

1. Determine the "Highway Category" and "Land Use Type/Speed" for the facility that you are working with.
2. Determine the acceptable Volume/Capacity Ratio
3. Determine the average daily capacity
4. Determine the allowable average daily traffic volume (ADT)
5. Compare the allowable ADT to the 20-year future ADT projected for the facility.

Note - this estimation process uses two of the most critical adjustments when determining the capacity of a roadway (signals and truck traffic impacts), there are several other factors that are used by the Transportation Planning Analysis Unit when determining the actual capacity of a facility.

1. **Determine Highway Category and Land Use Area Type***: Refer to Appendix D of the Oregon Highway Plan.*
2. **Determine Highway acceptable Volume/Capacity Ratio:** The maximum allowable volume-capacity ratios for state highways can be found in Table 10-1.
3. **Determine the Average Daily Capacity:** This process will allow you to estimate the average daily capacity for the highway under study/investigation. Note that this is only an estimation of the capacity, the Transportation Planning Analysis Unit should be contacted to determine the capacity of a roadway for design purposes.

<u>Average Daily Capacity = Ideal Daily Capacity x FS x FT</u>

- **Ideal Daily Capacity** – unadjusted capacity of a roadway (Table 10-2).
- **FS** – a factor to account for the presence of signals (Table 10-3).
- **FT** – a factor to account for the presence of truck traffic and the type of terrain (Table 10-4).

Table 10-2
Ideal Daily Capacity

Highway Category	Land Use Type/Speed Limits				
	Inside Urban Growth Boundary			Outside Urban Growth Boundary	
	MPO	Non-MPO outside of STAs where non-freeway speed limit <45 mph	Non-MPO where non-freeway speed limit >= 45 mph	Unincorporated Communities	Rural Lands
Interstate/ Expressways					
4 lane*	74,500	NA	68,000	63,000	63,000
6 lane	117,500	NA	107,500	94,500	99,500
Statewide					
2 Lane Undivided**	31,500	30,000	30,000	26,000	21,000
2 Lane Divided	39,000	37,500	37,500	32,500	26,000
4 Lane Undivided	51,000	48,000	48,000	45,000	42,000
4 Lane Divided	68,000	64,000	64,000	60,000	56,000
6 Lane Divided	102,000	96,000	96,000	90,000	84,000
Regional Highways					
2 Lane Undivided	30,500	29,500	29,500	25,500	20,500
2 Lane Divided	38,000	37,000	37,000	31,500	25,500
4 Lane Undivided	49,500	47,000	47,000	45,000	41,500
4 Lane Divided	66,000	63,000	63,000	59,500	55,500
6 Lane Divided	99,500	94,500	94,500	89,500	83,500
District/Local Interest Roads					
2 Lane Undivided	28,000	28,500	28,500	25,000	20,000
2 Lane Divided	35,000	35,500	35,500	31,000	25,000
4 Lane Undivided	48,500	46,000	46,000	44,500	41,000
4 Lane Divided	64,500	61,500	61,500	59,000	55,000
6 Lane Divided	96,500	92,000	92,000	88,500	82,500

*The number of lanes refers to the total number of through lanes on the facility.
**For the purpose of this computation, a divided roadway has a raised median to prevent mid-block left turns or it allows mid-block left turning vehicles to exit from the through traffic lanes.

If the facility is in an urban area that has signalized intersections, the signalized intersection adjustment factor (FS) needs to be applied to the ideal capacity. FS is the same for all of the land use types/speed limits.

Table 10-3
Signalized Intersection Adjustment Factor (FS)
(applied to ideal daily capacity if there are signalized intersections)

Highway Category	FS
Interstate	NA
Statewide	0.51
Regional	0.46
District	0.45

If the facility has truck traffic, the slower moving trucks will take up more capacity than a passenger vehicle, especially if they are traveling on grades. Table 10-4 shows the adjustment factors (FT) for truck traffic on Level (1-2%), Rolling (3-4%), and Mountainous (5% or greater) terrain that are one-quarter mile or longer.

Table 10-4
FT
(Reduction factor for presence of trucks)

Number of Lanes	Percent Trucks											
	0-5%			6-10%			11-15%			>15%		
	L*	R**	M***	L	R	M	L	R	M	L	R	M
2	.97	.91	.80	.95	.83	.67	.93	.77	.60	.91	.71	.50
4-6	.95	.85	.69	.90	.73	.53	.86	.65	.43	.82	.58	.36

* L - level terrain, which has a grade of 1-2%
** R - rolling Terrain, which has a grade of 3-4%
*** M – mountainous terrain, which has a grade of 5% or more

4. **Determine the Approximate Allowable Average Daily Traffic:** To determine the allowable average daily capacity for a facility, carry out the following computation:

Allowable Average Daily Traffic = Average Daily Capacity x (v/c from table 10-1)

5. **Compare the Approximate Allowable ADT to the 20-year future ADT projected for the facility:** If the forecasted ADT, found on the prospectus, is greater than the calculated allowable ADT, contact the Transportation Planning Analysis Unit for a more detailed analysis.

10.7 TRAFFIC MANAGEMENT

- **General**

The design of a project will include traffic management elements such as the location and function of traffic control devices (signals, signing, pavement marking, etc). The Traffic Management Section (TMS) provides traffic support during all phases of project development and construction. Traffic Management support includes preparing project plans, specifications and estimates for traffic signals, ramp meters, variable message signs, permanent signing, and illumination. In addition, the Traffic Management Section provides statewide policies and guidelines for all traffic control devices, administers ODOT's Project Safety Management System and provides technical assistance for traffic operation improvements on state highways. TMS also manages statewide listings for safety programs and traffic signal approval, manages speed zone designations for all public roads, monitors traffic speeds, provides litigation support, tests electrical equipment, operates traffic signals, and provides maintenance of traffic signal and other control equipment. The designer should be aware of these traffic functions and the support which is available from TMS during the design phase of projects. The designer should provide adequate notification to TMS staff through the assigned traffic designer or designated representative to ensure timely input consistent with the project schedule. In addition to the traffic design aspects of projects, the designer should consider future maintenance access and right of way need for electronic traffic equipment.

For further discussion of the roles and responsibilities of TMS, as well as information regarding the use of traffic control devices, see the ODOT Traffic Manual. This manual contains information regarding policies, procedures, warrants, and design considerations for traffic related items.

- **Authorities of the State Traffic Engineer**

The designer should be aware that State Traffic Engineer approval is required for the installation or modification of traffic signals as well as other traffic control devices and applications. Other examples of applications requiring the approval of the State Traffic Engineer include: provision of multiple turn lanes, emergency vehicle preemption capability, U-turns at signalized intersections, turn prohibitions, flashing beacons, marked crosswalks at uncontrolled intersections or mid-block locations, crosswalk closures, designation of one-way operation, school zones, speed zones, parking prohibitions, restriction of lane use by type of vehicle, variable message signs (and other ITS devices), and the approval of roundabout locations. (See the ODOT Traffic Management Manual for more detail.) Many of these authorities are designated by Oregon Administrative Rule or come through a letter of authority from the Technical Services Manager.

Typically all requests for approval of traffic control changes or applications come from Region Traffic. Region Traffic staff are familiar with the requirements for documentation and investigation of traffic control applications. The Region Traffic Manager or Engineer should concur with all requests before forwarding them to the State Traffic Engineer.

Early participation of traffic representatives in project scoping and identification can identify items requiring approval of the State Traffic Engineer as well as related traffic concerns with safety, operation, and application of traffic control devices.

- **Signals**

When a project involves signals the roadway designer should contact the Signal Design Unit. Information that the signal design will require includes: roadway features such as elevation profiles; guardrail requirements; truck turning radius requirements; pedestrian ramp designs; utility locations (particularly poles and above ground wires); storm drain locations; lane use width; pedestrian ramp locations; proposed curb and corner radii alignments; or other features that will have a bearing on the placement of traffic signal equipment. It is very important that items such as signal cabinets and signal poles not be located near sidewalks where they are obstructions to pedestrians, bicyclists, or vehicles. Overhead utility lines such as power and communications should be reviewed to determine any conflicts with signal poles and signal heads. Typically this field information is in electronic file format.

The signal designer will provide projected layout of signal equipment (poles and controller cabinet) and cost estimates. The signal designer will also provide technical expertise regarding the signal equipment such as signal pole foundation size, ramp metering, lane usage, and signal loop locations. In the case of retrofit projects, the signal designer can provide information on existing signal equipment locations, lane configuration, signal loop replacement, and signal phasing. Crosswalk locations are normally determined through communication between the roadway and signal designers.

One of the most essential items the signal designer can provide the roadway designer is locations where the purchase of right of way or easements is needed. This item is sometimes overlooked but is critical in keeping the right of way purchase process on track. It is essential that the roadway designer notify the signal designer in advance so that proper right of way needs are determined and submitted, enabling the purchase of all right of way needs to occur in one phase of the project.

In some projects, multiple signals are involved and are part of an interconnected traffic signal system. Safe and efficient traffic signal timing along state highways depends on optimal intersection spacing. It is difficult to predetermine where such locations should exist, although one-half mile intersection spacing for Statewide and Regional highways is often desirable. Items that are involved in interconnect systems include highway capacity, lane balance, cycle lengths, vehicle storage and progression speed. When a project involves multiple signals, the roadway designer should contact Traffic Operations to determine the need for a signal interconnect system.

Temporary signals may be needed for traffic staging or in temporary locations during project construction. As with permanent signals, the designer should contact and communicate with the

Signal Design Unit in the early project stages to ensure that adequate time is allowed for temporary signal design.

- **Signs**

The designer should contact the Sign Design Unit when a project involves signing. Typical information that the sign design will require includes a detailed sign inventory with dated photographs and accompanying highway milepost or station. Typically, a roadside inventory or detail map (electronic version) is provided that identifies sign locations. The sign designer should be provided with project limits and the scope of work. Projects that involve sign bridges or cantilevered signs will require communication between the sign designer, roadway designer and bridge designer.

As with traffic signals, right of way or easement needs are critical for sign designs. Accurate right of way or easement acquisitions will lead to proper location of signs. The road designer should contact the Sign Design Unit early on in project development to determine if signing will or should be included in the project. When notified early in the process the sign designer will be able to provide signing plans, special provisions, and right of way needs in an efficient manner.

- **Signal and Sign Supports in Islands**

Designers need to carefully weigh the benefits of constructing islands for the accommodation of sign and signal support. It may be preferred to look at other alternatives such as location of the supports on the other side of the roadway. If installation cannot be avoided and a raised island is considered necessary, consider the following priorities:

1. Clear islands with mountable curb are most desirable.
2. Where pedestrian or other small devices are necessary, they will be on breakaway supports.
3. Where a fixed object cannot be avoided, a brief, written justification should be attached to the preliminary plan review transmittal letter.

Standard barrier curb on islands will be considered inappropriate for use on any arterial or rural facility unless supported in the justification document noted in (3) above.

- **Illumination**

Prior to illumination design for a project, it must first be determined if illumination is warranted for the project. Region Traffic identifies locations for illumination and forwards the information to the Traffic Management Section for determination of policy agreements and statewide consistency before proceeding with project illumination design. If there are agreements between ODOT and local governments, the designer or project leader should forward them to the illumination designer.

When it has been determined that illumination will be part of the project, the roadway designer will need to provide the illumination designer with final roadway alignment, detailed project information relating to illumination needs. Typically 30% roadway plans that include centerline profiles, cross sections, existing roadside features, roadway alignment, and right of way line information will be sufficient for the illumination designer. Communication between roadway designer, the illumination designer, bridge designer, and traffic signal designer is critical in providing proper illumination designs for a project.

- **Striping**

Traffic Management is responsible for the policies and guidelines regarding striping and pavement marking. The striping guidelines provide statewide consistency. The responsibility for completion of the striping plans on state highway designs rests with the Roadway Designer. Striping should conform to the Striping Design Guidelines and the MUTCD.

- **Intelligent Transportation Systems (ITS)**

Intelligent transportation systems goal is to improve safety and reduce congestion on the roadway infrastructure through the use of technology. Some of the ITS applications include ice sensors (road and weather information systems); speed monitoring sites, variable message signs, traffic cameras, communication linking cables, and ramp meters. ITS projects can be stand-alone but it is important for the designer to consider ITS improvements as part of highway modernization/reconstruction project work.

As with other types of traffic management projects, early identification of right of way needs is important. Items such as variable message signs, speed monitoring cabinets, and traffic cameras may require additional right of way or need to be protected by guardrail or barrier. Traffic cameras may require special right of way locations to allow proper orientation and field of view.

- **Crash Analysis**

There are several tools available to the designer to assist with the crash analyses. The Motor Vehicle Traffic Crash Database, compiled and maintained by the Crash Data Unit, is available on ODOT's Transviewer website at http://intranet.odot.state.or.us/otms/transview. It covers state, county, and city road systems. The SPIS (Safety Priority Index System) Crash Summary Database is compiled and maintained by Traffic Management Section. This PC database summary is provided annually with three years of data plus estimates of volumes and information on SPIS sites. Another source of crash data is the Arc View tool, which is part of the STIP-SIP process (see below).

These reports and others allow the designer to summarize data by different characteristics, such as weather conditions, types of crashes and types of vehicles. Preparing collision diagrams to identify patterns is helpful. Familiarization with the volumes, speeds, physical features and geometry also assists in the process. Crash and fatality rates should be compared to the statewide average for similar facilities. After analyzing the specific site or segment the designer can better determine the appropriate actions for correction. Region Traffic personnel routinely perform crash analyses and can help with specific sites or trends. Contact Region Traffic for assistance.

- **Project Safety Management System**

Traffic Management Section, in cooperation with other ODOT sections, has developed and is maintaining ODOT's Project Safety Management System (PSMS). The PSMS consists of four elements:

1. Hazard Elimination Program (HEP)
2. Safety Priority Index System (SPIS)
3. Safety Investment Program (SIP)
4. Road Features Rating System (RFRS) (currently under development)

These elements consist of on-line evaluation tools, databases and funding options. These tools will assist project leaders and designers to evaluate and improve safety on Oregon highways.

1. Hazard Elimination Program (HEP)

   HEP is a federally funded program to carry out safety improvement projects. The objective of HEP is to fund safety projects which address hazardous locations, are typically low cost (less than $500,000), are quick hit, and are generally stand-alone projects. Typically HEP projects are justified based on one of two methods: Benefit/Cost Ratio Analysis or Risk Analysis. The responsibility for program management lies with the Traffic Management Section.

2. Safety Priority Index System (SPIS)

SPIS is a methodology developed by ODOT to identify potential safety problems on state highways. Essentially, SPIS is a tool for comparing and prioritizing crash histories of state highway locations. Each year regional reports of the top ten percent ranked SPIS sites are generated for review by Region Traffic. Region Traffic evaluates these sites for correctable safety problems and possible solutions. If a correctable problem is identified, a cost/benefit analysis may be performed. If viable options are identified, funding may be pursued, often times HEP funding.

3. STIP – Safety Investment Program (STIP-SIP)

STIP-SIP tools have been developed to assist designers in identifying segments of state highways where the largest number of people are being killed or seriously injured in vehicle crashes. The goal of the STIP-SIP is to reduce the fatality rate in Oregon from the 1998 rate of 1.68 to the rate of 1.3 by the year 2010. Tools developed to help reach this goal are as follows:

A. The ArcView mapping tool is a STIP-SIP tool developed to provide project teams a graphical method to display categories of fatal/serious injury segment information, SPIS locations, crash data, and ADT on a state map. Five-mile sections, called SIP segments, of the state highway system are categorized by the number of fatal and severe crashes during a three-year period. The following is the stratification for SIP categories:

- Category 1: 0 fatal or injury A (serious) crashes;
- Category 2: 1 to 2 fatal or injury A crashes;
- Category 3: 3 to 5 fatal or injury A crashes;
- Category 4: 6 to 9 fatal or injury A crashes;
- Category 5: 10 or more fatal or injury A crashes.

When selecting safety projects to be included in the STIP, the SIP category of the section is considered. For roadways without a crash history of fatal and serious injury crashes (Categories 1 and 2), minimal safety upgrades are included in the project. Highways with greater crash frequency (Categories 3, 4 and 5) receive more investment in safety improvements, often in stand-alone safety projects. The goal of the STIP-SIP is to create a balance to meet the competing needs of two important transportation facility elements, safety and pavement preservation, thereby providing the most cost effective means of reducing fatalities and serious injuries on the state highway system. See the Project Safety Management System Users Manual, located on the Traffic Management Section Intranet site, for additional information.

B. The Countermeasure Analysis Tool (CAT) is another STIP-SIP tool developed as an Intranet product. The tool is used for selecting applicable safety countermeasures and comparing benefit/cost ratios to determine the most cost effective elements to improve safety.

- **Road Features Rating System (RFRS)**

RFRS is currently under development and will be designed to apply safety condition ratings to roadside features.

For further information about ODOT's Project Safety Management System or any of the programs refer to the ODOT Traffic Manual.

- **Work Zone Analysis and Constructibility**

With the continuing increase in traffic volumes, the issue of the constructibility of a particular design becomes crucial. Some designs will be difficult to build and still maintain an acceptable traffic flow. The Traffic Operations Unit in the Traffic Management Section provides work zone analysis for all construction projects after the EIS phase. Traffic analyses, including work zone traffic analyses, required prior to the EIS phase, are performed by the Transportation Planning and Analysis Unit (TPAU). Services include but are not limited to the analysis of:

- One-Way/Two-Way Operation
- Detours
- Extended Total Closures
- Limited Total Closures (as per the standard specification)
- Weave Analysis
- Storage Lengths
- Benefit/Cost Analysis
- Liquidated Damages
- Volume Projections
- Projected Seasonal Variations
- Closure Lengths
- Hourly Lane Restrictions
- Queue Projections
- Temporary Signal Timing
- Lane Closure Lengths

As with the other services that the Traffic Management Section provides, adequate lead time for the work zone analysis request is very important. The designer should be aware that one request for services may require a number of different analyses to be made, depending on variations in the Average Daily Traffic (ADT), the type of work required for the project (bridge repair,

inlay/overlay, roadway reconstruction, etc.), and proposed method of construction. On complex projects such as a freeway interchange, a number of requests will normally be required, generally beginning with the initial design and ending only with the project reaching the final design stage.

10.8 BRIDGE

- **General**

It is important to contact the Bridge Section when a project involves some type of structural element, whether it be a retaining wall, culvert, bridge, cantilever sign support, etc. The designer should stay in contact with the bridge designer as a project develops to ensure that the roadway and bridge elements of a project fit together.

- **Bridge Definition**

A bridge is defined as a structure spanning and providing passage over a river, chasm, road, or the like, having a length of 20 feet or more from face to face of abutments or end bents, measured along the roadway centerline.

- **Structure Types**

Structure types include various culverts, slabs, box beams, and various types of deck girders, box girders, arches, and trusses. The selection of structure type is determined by the site, economic, environmental (in-water work windows, etc.) and esthetic considerations. Generally the longer the structure, the higher the cost per square meter.

For small streams, a culvert might be used instead of a bridge. However, for locations with low deck-to-streambed clearances, a culvert may not be proposed because it could not provide enough waterway area. Fish passage issues may also preclude the use of a box culvert unless the bottom of the culvert can be covered with natural streambed material.

Concrete structures may either be pre-cast or cast-in-place. Pre-cast members offer the advantage of off-site fabrication (especially important in remote locations), speed of construction and minimal falsework. However, it may be difficult to accommodate horizontal curves, and change in gradelines or superelevations. Cast-in-place structures can more easily accommodate the geometrics and can usually span longer distances. However, cast-in-place concrete requires falsework, which can create a traffic hazard at grade crossings and potentially cause problems at stream crossings.

- **Structure Lengths**

Roadway Crossings

- Provide the required roadway horizontal clearances plus 1:2 end slopes for all bridges except for county roads or less-traveled highways. Use 1:1.5 end slopes for county

roads and less-traveled highways per the Highway Design Manual. When using end slopes steeper than 1:2 a geotechnical review shall be completed to ensure stability.

Stream Crossings

- Provide the required waterway opening to pass the specified design flood. The Hydraulics Report will provide a required waterway area, the stream bed elevation and the design flood high water elevation. Normally, a minimum bottom-of-beam clearance of 12 inches is provided above the design flood high water elevation.
- Normally, overtopping is not desirable, but may be required to accommodate regulated hydraulic considerations.

- **Structure Clearances**

Vertical Clearances for highway traffic

- All new structures on Interstate Freeways are to be designed with a minimum vertical clearance of 17 feet-6 inches.
- All non-Interstate-Highways are to be designed with a minimum vertical clearance of 17 feet.
- The maximum height for legal loads is 14 feet.
- A minimum vertical clearance of 14 feet-9 inches is required during construction.

Horizontal Clearances for highway traffic

- Normally the bridge roadway width will equal the approach roadway width plus 4 feet for bridge rail shy distance.

Vertical Clearances for railroad traffic

- All new structures are to be designed with a minimum of 23 feet vertical clearance.
- A minimum vertical clearance of 21 feet (UPRR) or 21 feet-6 inches (BNSF) is required during construction.

Horizontal Clearances for railroad traffic

- Normally the bridge opening will allow for a future track (20 foot spacing) on one side with 18 feet horizontal clearance and 25 feet horizontal clearance from the other track to allow for a maintenance access road.
- A minimum horizontal clearance of 12 feet (UPRR) or 15 feet (BNSF) is required during construction.

Horizontal Clearance during construction

- On Interstate Freeways the minimum width of 19 feet between face of rail for one-way/one lane traffic, plus additional clearance to falsework behind rails. Above 8 feet vertical on each side an additional 2 feet horizontal is required.
- On non-Interstate highways the minimum width of 16 feet between face of rail for one-way traffic, plus additional clearance to falsework behind rails.

- Minimum width of 28 feet between face of rail for two-way traffic, plus additional clearance to falsework behind rails.

- **Curbs and Sidewalks**

For a particular crash tested bridge rail, the curb or sidewalk height should be used as shown on the appropriate standards drawing.

- **Deck Drains**

Some form of drainage system is normally needed on or off structures that have curb or concrete parapet rails. The Roadway Plans drainage details should be carefully reviewed. If drains are required, the Hydraulics Unit will do the design and determine the size and spacing. Bridge length, deck grades, cross slope, typical section, and deck surface type will be needed to determine the deck drain layout.

- **Structure Superelevations**

The structure superelevation should match the roadways. Structures are more susceptible to surface icing for excessive superelevation rates (greater than 8%).

- **Traffic Control During Construction**

There are four basic methods of handling traffic for replacing a bridge:

- Close the highway while removing and rebuilding the bridge.
- Use the existing roadway and bridge while constructing a parallel bridge on new alignment.
- Construct a temporary detour bridge around the existing bridge and replace the bridge on the existing alignment.
- Use stage construction with existing or new lanes carrying traffic while other portions of the existing bridge are being removed and rebuilt.

Another traffic handling consideration that should not be overlooked is accommodating pedestrians (including the disabled) and bicycles passing through the work site, especially in urban areas.

- **Bridge Rail End and Barrier Treatments**

- Rural conditions, bridge rail end treatment: Use standard approach guardrail to bridge rail transitions. Apply at all rail ends inside the clear zone.

- Urban conditions, bridge rail end treatment: Normally no approach rail is used when the design speed is 40 mph and below. In these cases, the end of the bridge rail will be protected by a tapered down concrete transition, even if the rail is at the back of a raised sidewalk and is outside the clear zone.

- Ditch rider roads, bridge rail end treatments: When ditch rider roads are closer to the end of the bridge than standard transitions will allow, a crash-tested treatment shall be used. There is a minimum distance from transition to ditch rider road that allows this system to work, so judgement shall be used in those situations.

10.9 PERMITS & DOCUMENTS

10.9.1 PERMIT RESPONSIBILITIES

A number of permits and/or documents may be required from various agencies during the advance of a project from design to construction. The following list of permits and the units responsible for obtaining them is as comprehensive as possible at this time:

Permit	Issuing Agency	Responsible Party
Airport Clearance	Federal Aviation Administration (FAA)	Region Tech Center / Engineering Services / through Aviation Department
Railroad Crossing (New and Alteration)	ODOT	Rail Division
Section 401 of Clean Water Act (Water Quality Certification)	Department of Environmental Quality (DEQ)	Environmental Permits Coordinator
Land Use Plan (Conditional Use; Flood Plain, etc.)	County/City Planning Department	Region Office
Building Permit	County/City	Region (Project Mgr.)
Other Local Permits	Irrigation/Diking Districts, etc.	Region Office
Right of Entry/Use Permits (through USFS/BLM Lands)	U.S. Forest Service/Bureau of Land Management (BLM)	Region Office/ R/W
Material Site	Oregon Department of Geology & Mineral Industries (DOGAMI)	Region Geologist Resources*

*For Commercial and other Contractor Option sites, the permit is obtained by the Contractor, Site Operator, or Landowner.

Coastal Zone Management	Oregon Dept. of Land Conservation & Development (DLCD)	Environmental Permits Coordinator

Water Use (Water Impoundment)	Water Resources Division	Watermaster
Fill/Removal Permit	Oregon Division of State Lands	Environmental Permits Coordinator
Section 10 of Rivers and Harbors Act	U. S. Army Corps of Engineers	Environmental Permits Coordinator
Scenic Waterway Permit	Oregon State Parks & Recreation and/or Bureau of Land Management	Environmental Permits Coordinator
Waterway Permits	U.S. Coast Guard	Environmental Permits Coordinator
Section 404 of Clean-Water Act Permits	U.S. Army Corps of Engineers	Environmental Permits Coordinator
Water Well	Oregon Water Resources Department	Operations (Buiding Manager)
Construction Permit	Property Owner	Right of Way
Environmental Documents		Environmental Services
Wetlands Report	See Note	
Cultural Resources Report	See Note	
DEQ Indirect Source Permit	See Note	
Noise Study Report	See Note	

Note: 1200 C permits are issued to Regions and are effective for 5 years.

The Project Prospectus (Part 2 and Part 3) will, in most cases, identify those permits and documents required for each project, and who is responsible for obtaining them.

Permits for some local agency and off-system projects are to be obtained by the agency or the consulting engineer as stipulated in the Oregon Department of Transportation/Agency agreement for the project.

An Air Quality report is required for all projects that increase capacity in Portland, Salem, Eugene, Medford, Grants Pass, and Klamath Falls, La Grande, Oakridge, Lakeview.

FHWA also requires a Hazardous Materials report or other documentation.

10.9.2 PERMIT TYPES

• Airports

In compliance with Federal Aviation Regulations (PART 77), "Objects Affecting Navigable Airspace," highway projects within 20,000 feet of an airport will be carefully examined by Project Support and/or Roadway Engineering prior to the public hearing stage to determine if there is a possibility of conflict.

When it is determined that a notice is required, the Engineering Services Unit will complete FAA Form 7460-1 and submit it to the Federal Aviation Administrator as prescribed in FAA Reg. 77.17 via the Oregon Department of Aviation at least two months before construction begins. If during the preliminary design phase an obstruction conflict becomes apparent, immediate contact with FAA should be made.

• Diking and Irrigation District

When a proposed highway project is expected to impact an existing development that involved Federal funds in its construction (such as dikes, irrigation projects, revetments, dams, etc.) an investigation shall be made by the Project Manager or a designated representative of the Region Manager, to determine the need for notification, approval or permits of another agency. In most cases, approval will be required from the Federal authority originally involved, as well as the local agency.

The Project Manager should establish communications with these Districts to alert them that some work is proposed that will affect their facility and to ascertain what special considerations are needed in the project plans & specifications.

- **Use Permits and Agreements**

Right of way over government land is acquired through right of entry on Bureau of Land Management property and through an easement from the U.S. Forest Service. Applications for these are made through the Right of Way Section in Salem. The government classification and proposed right of way lines are to be shown on the detail map in the usual manner. The Memorandum of Understanding between the U.S. Forest Service and the Oregon Department of Transportation details the process by which right of way through National Forest land is obtained. The issue of obtaining right of way over government land is a very detailed and time consuming process. There are other

permits and authorizations required from the U.S. Forest Service, Bureau of Land Management, and other Federal Agencies.

- **Department of Geology and Mineral Industries**

A permit is required from DOGAMI for all work in all aggregate sources or borrow sources, whether publicly owned, privately owned and commercially operated, or other private sources (e.g., a farmer). These permits control the development and assure the reclamation of the sites as required by state law (ORS 517.750 - 517.955).

After the need for borrow/aggregate has been determined, the Region Geologist will determine whether ODOT will offer its own prospective source or rely on the contractor to obtain his own material source.

When the source is ODOT owned or controlled (ODOT has a lease with the landowner), the Region Geologist will determine the source and prepare the necessary documentation for the permit. The application and supporting documentation and fee is then submitted directly to DOGAMI.

The Region Geologist will forward a copy of the development plan and reclamation specifications directly to the designer for incorporation into the plans and specifications.

When the contractor provides the source, the contractor will obtain the permit. **The Construction Project Manager has the ultimate responsibility to verify that the material site has a valid DOGAMI permit.**

- **U. S. Coast Guard Permit**

Some of the larger rivers as well as bays and estuaries in Oregon are considered to be navigable. The Coast Guard and the Corps of Engineers operate according to a list of officially designated navigable waters. Commercial navigation may no longer be practical in some of the waterways listed as being navigable and projects over those waters may be exempt from the need for a permit. Since it is easier to define when a permit is not needed that will be the starting point.

For projects involving the construction of bridges or the major reconstruction of bridges over navigable waters a Coast Guard permit may **not be required** if the bridge is over waters:

1. Which are not being used or are not susceptible to use in their natural condition or by reasonable improvement as a means to transport interstate or foreign commerce; and

2. Which are (a) not tidal, or (b) if tidal, used only by recreational boating, fishing, and other small vessels less than 21 feet in length. (Federal Aid Highway Manual, Vol. 6, Chapter 7, Sec. 1, Par. 1)

The Permit Coordinator requests that the Federal Highway Administration makes the determination that a Coast Guard permit is not required under these criteria.

If the waters in question do not meet Criteria 1 and 2 above, a Coast Guard Permit **will be required.**

The application for the permit is made by letter to the 13th Coast Guard District (Seattle). This application should be made one year in advance of the project construction date.

The Coast Guard should be contacted and their comments requested about provisions for navigation when a project involves a navigable waterway, **whether or not a Coast Guard permit is required.** Their stipulations concerning such items as navigation clearances, lighting, etc., will then be included in the project plans and specifications.

• U. S. Corps of Engineers/Division of State Lands Permit

The US Army Corps of Engineers (USACE) regulates discharge of dredged or fill material into waters of the United States, including wetlands, pursuant to Section 404 of the Clean Water Act (33. S.C. 1344). A permit will generally be required when filling into waters of the U.S.

The Oregon Division of State Lands, as the state regulating agency, will generally require that a permit be obtained for fill or removal in the beds or banks of streams or wetlands. A joint permit application form is used for both of these agencies. However, two or more permits may be issued.

The joint permit application is reviewed by State and Federal Resource Agencies (ODFW, DEQ, USFWS, EPA, NMFS, etc.) for compliance with statutes, such as the Endangered Species Act (ESA), and good resource management practices. Their comments and conditions will be incorporated into the permits.

It is extremely helpful during the field survey for the Project Manager to contact the local District Fish Biologist of the Oregon Department of Fish & Wildlife to discuss the project and learn in advance the conditions under which work will be allowed in any streams. The Permits Coordinator obtains the permit. Application is made when the following information is available for the impact site:

(1) Vicinity map which shows the location of the project.
(2) Plan, elevation and typical section drawings which show the existing and proposed structures.
(3) Any environmental documents required for the project such as a Wetland Delineation, Impact Assessment and Mitigation Report.
(4) The Biological Assessment for the project impacts to the threatened and endangered species can be sent when it is completed.

This information should be submitted as early in the design process as possible. This will insure any conditions or stipulations contained in the permits can be incorporated into the project plans and specifications. These conditions may be as minor as time limits for in-stream work or as major as extensive wetland mitigation plans.

Any special conditions or stipulations regarding work in the stream are then included in the final project plans and specifications. (For Corps of Engineers Permit Rules see Code of Federal Regulations (CFR 33, Ch. 11, part 323)

• Construction Permit

The construction permit applies to land service facilities to be built for individuals on their land. It gives the State or its contractor a right to enter upon the property of an individual to perform construction work for the benefit of the owner. This might include road approaches or access roads which cannot be accommodated in their entirety within the highway right of way; irrigation facilities which serve only the individual involved; or any other facility constructed for the sole use and benefit of the owner involved, the later removal of which would not be detrimental to the highway. No time limits are placed on construction permits.

- **Stormwater Report**

The stormwater report can be produced by Roadway or Geo/Hydro, and these two working groups may have shared responsibility for different sections of the calculations and documentation. The report should provide documentation of the design calculations supporting the final plans and specifications. The types of design information that may be in this report include the following:

- Inlet spacing
- Storm drains
- Culverts, small, less than 1200 mm in diameter
- Detention
- Water quality
- Outlet protection
- Roadside ditches
- Cut-off ditches

10.10 ROADSIDE DEVELOPMENT

- **General**

Roadside development is work occurring on a transportation facility right of way that doesn't fall into other categories such as illumination, utilities, or access control. The purpose of roadside development is to help integrate the transportation facility into the surrounding environment, which includes the larger transportation corridor. The purpose may be environmental, cultural, functional, or combination of these. The work may be mitigation (avoidance or minimizing impacts), compensation (replacing functions that are impacted), or enhancement (creating or improving something desirable in the landscape). Also included in this category of work is comment and advice for the modification of the work of other technical specialties that is related to the affect on the natural or cultural landscape of the transportation facility. Roadside development work is most often a part of road projects, but it can be the sole purpose of a contracted project.

Because roadside development usually deals with multiple overlapping large and small systems, it is not easy to precisely describe the term, just as there is no exact definition of the term "landscape." The normal ODOT practice is to have specialists participate in scoping roadside development work on significant projects.

For the reasons cited above, specific roadside development requirements can have a variety of origins. One critical source is the environmental document whose legal purpose is to determine project impacts and state the actions intended to deal with those impacts. Other typical sources of requirements are various kinds of permits, agreements with county or city governments, the operating policies of various authorities such as the U.S. Forest Service, and ODOT's mission concerning the environment or quality of life for residents and visitors to Oregon. Some needs of a project are discovered as the project evolves because they relate to project impacts that come to light or are finalized during later stages of development. Final roadbed slope lines are one example.

It is important to note that the roadside development work done for projects is almost always required, rather than optional. For questions about the sources of requirements that are not referred to in this section, contact the Landscape Architecture Group in the Environmental Services Unit. One primary source of actions on federal participation projects is the National Environmental Protection Act (NEPA).

- **Project Development Phases**

<u>Planning</u> - The ODOT Transportation Development Branch (TDB) usually looks at the "big picture" to develop initiatives like the Corridor Program, and develop policies which integrate local land use policies with statewide transportation systems. Many of these policies condition what actions are to be taken later on in projects and in these cases, TDB or Region planners as well as published

documents of the TDB such as the *Oregon Transportation Plan* or Transportation Corridor Plans can be important resources.

Local government or transportation-related planning also must be considered for a comprehensive project. Some sources of information or requirements include local and regional Transportation System Plans (TSPs), local comprehensive plans, transit plans, and impacts to or from other planned projects in local capital improvement programs. Also included in the planning phase is consideration of other known major factors such as proximity to parks, funding options, access management, or other critical features.

Programming and Scoping - Timely anticipation of the need for roadside development work will help establish a realistic design schedule and budget. Any project may have roadside development, but the rule of thumb is that the greater the disturbance to the natural or built landscape, the greater will be the need for work. Key flags are sensitive environments or populated urban areas where extensive work is being proposed. A brief review of the sources of work in the first section may help in scoping, but specific development of needs with the appropriate specialists may be required. In spite of best efforts, there will be times that the total work is not determined until late in the project design phase.

Design - Field data collection that enables design work to begin is important to the success of roadside development. Data needs vary for the kind of work anticipated and ideally will be determined during project scoping. Data must be requested as the need becomes clear in the design process. Examples of data are a survey of existing trees, analysis of native plant communities, existing and proposed topography, soil types and depths where planting is proposed, existing wetlands or other water features, available potable water supply information, existing noxious weed populations, or similar data. Also falling into the category of field information are government regulations, policies, or initiatives external to ODOT. Examples of these could be master plans for local improvement districts, zoning or development requirements, scenic waterway or byway requirements, and other similar kinds of information that must be known in order for design to be completed. Primary resources to research this kind of information are the Region Permit Specialist, Local Government Coordinator, or Region Environmental Coordinator. Often, agencies with jurisdiction will have to be surveyed for relevant requirements, and project needs are sometimes determined through such forums as meetings with neighborhood groups or other stakeholders.

Roadside development design in ODOT often focuses on the proposed contract document or design products as one way to scope the design process. The following is a list of the most familiar contract document and design products:

- Roadside development conceptual mapping
- Sketches or renderings to illustrate concepts.
- Planting, Irrigation, and Contour Grading Plans
- Various environmental mitigation plans - whether specifically identified by name, such as Wetland Mitigation, or not
- Site Development Plan
- Typical or unique project details
- Cost Estimate with Bid Items

- Specification Special Provisions
- Special advice for project construction
- Post-construction Maintenance Plan

Construction – Design work of any type must be "biddable and buildable," and also anticipate potential construction problems. This is critical for roadside development work because it usually deals with living systems that are subject to natural elements such as weather, and business elements such as supply of plant materials in a timely fashion. A few considerations are waterway high and low periods, planting seasons versus contract periods, problems caused by erodible soils, restrictions on work such as in-stream periods, the ability to water new plants where no irrigation system exists, length of the plant establishment period, and many other such issues. Good communication between the various parties involved in the origination and design of the work is required for successful construction, especially because "adjustment" of all types of project elements as construction progresses is the rule, rather than the exception.

Post-Construction - A critical concept in roadside development is, that in meeting legal and other requirements, ODOT is responsible for establishing permanent functions. Some examples of functions include modifying topography or establishing vegetation for specific purposes such as habitat mitigation, water quality, creation of new wetlands, neighborhood screening, soundwall mitigation, or existing planting replacement. In most cases, the permit requires monitoring after completion. For example, regulatory agencies require ODOT to monitor wetlands for five years to correct problems. Some cities require the replanting of newer street trees that die. Federal funding participation brings with it the need to protect the federal investment. In the post-construction period, roadside maintenance is the most critical element in maintaining the designed function. However, there are other activities that affect roadside functions such as utility work, permit activities like plant collection, or other causes of disturbance.

ODOT regions are responsible for post-construction activities, and the system works best if the maintenance needs of new work are understood as the project is being developed. Transportation facilities such as roads are designed and built according to established needs, and then appropriate maintenance is programmed to keep the facility safe and functioning. In the same way, the best practice in planning for roadside maintenance is a clear understanding of the functions to be maintained and then working to ensure the ongoing maintenance capability.

- **Roadside Development Responsibilities**

The Landscape Architecture Group located in the Environmental Services Section in Salem has roadside development design and contract documents as their primary responsibility. Several other units have major responsibilities including the Environmental Section, Project Design Teams, Region Environmental Specialists, and the Hydraulics and Erosion Control Groups of the Geo/Hydro Section, among others. Private consultant landscape architects and environmental specialists may also have important design roles on projects.

Project teams are now responsible for overseeing projects. Ownership of roadside development work generally follows the same path as other kinds of work; the specialists are responsible for their work but the project team determines how the work is conducted and coordinated on a given project. Whenever there are roadside design contact documents, the individual responsible for the design needs to be identified on the plan sheet, if possible. Landscape Architects, by state law, are required to stamp their work products with an Oregon Landscape Architecture Stamp.

Roadside development offers a focal point to assess the whole project site at any point in development, and assess, mitigate, and compensate for project impacts. Every design specialty can participate in how their project work affects the quality of the roadside well as how roadside environments impact the quality of the project. One example of this is how traffic signing designers now routinely call for painting the backs of signs on certain highways to reduce their visual contrast in scenic areas.

Projects are transferred to maintenance after construction, so they assume the ongoing responsibility. Their participation in project design and construction is critical for long term success. Roadside maintenance is one of the legs to the "three-legged stool" of planning, design/construction, and maintenance. The ability to provide long-term care for constructed designs allows ODOT to be able to continue to practice partnership with regulatory agencies such as FHWA, the Army Corps of Engineers, and many others. The advantage of this regulatory partnering to ODOT's ability to conduct project development cannot be overstated.

- **Roadside Development Tools and References**

Some references for roadside development projects have already been mentioned-the project environmental document, permits, agreements, relevant policies or regulations of various agencies and governments, and project documents such as the Prospectus and Narrative. Some useful internal references are the Right of Way Development and Control part of the *Standard Specifications for Highway Construction*; the Roadside Development section of the *Contract Plans Development Guide*; the proposed Roadside Vegetation Management Guidelines, and the proposed Roadside Development Inspection Manual. External references include *A Guide for Transportation Landscape and Environmental Design* by the American Association of State Highway Transportation Officials (AASHTO) and the *American Standard For Nursery Stock* from the American Association of Nurserymen (AAN).

Another important tool is the terrain modeling capability of ODOT's 'Intergraph InRoads' software. The use of terrain modeling for contour grading design will become a standard on road projects as it applies to landscape, wetland, and riparian restoration or enhancement. This allows accurate cross sections to be developed for testing alternate design concepts and for use during project construction. Project terrain modeling works best when planned for in project scoping and scheduling. Other tools in use and expected to see greater use are photo image editing and three-dimensional rendering of site designs using Microstation CADD.

- **Specific Project Considerations**

Salvaging project topsoil, stockpiling, and re-using on finished slopes should be considered wherever practical.

As we meet the basic design and construction needs of roadways and structures, existing native plant communities must be saved and protected wherever practicable. They can never be re-created exactly as they were before disturbance and attempts to re-create native plantings still meet with mixed success.

Roadside development requirements need to be identified during the location survey to assure that enough right of way is available for compliance. Sufficient right of way should be included to provide smooth finish grade transitions between existing landforms and the facility. Flattening steep slopes, slope rounding at the top and bottom of cuts and fills, and parabolic ditch sections are methods for developing a more compatible transition.

Additional right of way may be appropriate where issues exist such as endangered species preservation, wildlife corridors required to be protected, or transportation corridor visual quality.

High visibility areas and urban roadside areas almost always require some degree of ongoing maintenance. Slopes 1:3 or steeper can not be maintained by normal roadside mowing, so reducing slopes to less than 1:3 can reduce future maintenance efforts where mowing is acceptable. Planted shrubs and trees are an alternative to mowing on steep slopes and they have many other kinds of benefits.

Interchanges, except in special circumstances, require roadside development. The degree of treatment is determined by the amount of landform change, urban/rural nature of the site, local interests and participation, local ordinances, and other such factors.

Sound berm designs should allow sufficient area (10 – 12 feet) between the toe of berm and the Right of Way for maintenance access.

Soundwalls should be set back from the edge of curb a minimum of 1.5 times the height of the wall. This achieves a better visual balance between the vertical mass of the wall and the horizontal plane of the roadway. It also helps address clear zone issues. Soundwall ends should be stepped down or wrapped around corners where streets intersect the highway. Soundwalls are a large vertical element on the land and treatment of their surface is important, as is the issue of graffiti on walls.

Areas that require landscape screening, such as residential areas or undesirable views visible from the highway, need sufficient Right of Way to plant trees while maintaining clear zone requirements.

Utility pole location and street tree placement needs to be coordinated during design. This is often difficult because utility companies may not determine pole locations until very late in the design process.

Any area that is planted in any way must be able to be safely accessed for maintenance.

On federal participation projects, law requires that an amount equal to 1/4 of 1% (.0025) of the roadside development estimated cost must be used to plant native wildflowers. (Erosion control and some other costs are excluded.)

- **Roadside Development Initial Project Checklist**

ODOT Information - Include or check roadside development items in project Prospectus, scoping, environmental documents, schedule, City-State Agreement, key contacts list, special needs such as riparian revegetation, state commitments, Scenic Byways or Scenic Rivers, and other critical policies or programs such as Transportation Corridors or Forest Highways.

External Information - Relevant city and county permit requirements, external review authorities, key contacts list, critical laws and policies of local, state or federal agencies, working partners, initial project objectives, water supplier, et cetera.

Design and Construction – Includes performing or coordinating roadside development scoping and preliminary budget, participation on project resource team, research, preliminary concepts, designs, contract document preparation, plan sheet drafting, consultant oversight, expert plan review, construction observation, and consultation on change orders. A variety of people perform this function.

Roadside Maintenance - Name of maintenance authority (ODOT or other), name of responsible contact, inclusion of maintenance in project review and inspections, maintenance standards, maintenance agreement or contract, maintenance plan for designed areas, approximate resources needed, maintenance ability to meet needs added by project.

10.11 MISCELLANEOUS

10.11.1 FENCING

The design shall include fencing to be placed at the access control line on freeways. In other situations fencing shall be a consideration in the right of way agreement and installed when required by that agreement.

10.11.2 SNOW PROBLEMS

On the Cascade and Siskiyou Mountain passes and east of the Cascades, drifting snow may be a serious problem. The following factors should be considered:

• Investigation

The direction of the prevailing winter winds must be determined before effective measures can be taken to prevent snowdrift problems. Personal observations, interviews with persons familiar with the local winter conditions, including the ODOT maintenance foreman, and reviews of local records may be of value.

• Grade

Highway grades above the surrounding ground are much less subject to drifting because of wind action. A cut section of highway may act as a natural fence, impeding the steady flow of wind, resulting in snow being deposited on the roadway.

• Cross-Section

It may be possible to reduce or eliminate drifting snow problems by streamlining the roadbed. Steep slopes and obstructions to air movement cause snow drifts. Any flattening of the slopes will reduce the areas where snow is deposited on the road. Guardrail is particularly objectionable and wherever feasible should be eliminated by flattening fill slopes. In cut sections the intersection of the cut with natural ground should be back of a 1:6 slope measured from the edge of the shoulder. Widening the cross section through cuts may be desirable to provide for snow storage.

When considering the use of flat slopes for reducing snowdrift problems, the impacts on the safety and aesthetics of the highway should also be considered.

• Control with Snow Fences

Snow fences may be required where control cannot be obtained by other methods. It is necessary that any snow fence be properly located and placed. Snow fences are generally placed parallel to and at a distance of 65 feet to 130 feet from the roadway centerline. Their placement depends on a study of conditions at the site, particularly the direction of prevailing winds. A snow fence, in order to function properly, must have an adequate distance behind it to allow for the piling of snow. The fence itself impedes the wind flow, thereby creating a swirling action behind the fence resulting in the snow being deposited. Ordinarily snow fences should be placed so that the distance from the fence to the top of cut or bottom of fill is 10-15 times the height of the snow fence. If a snow fence is to close to a highway, or a cutbank exists without adequate pileup room, it can be more of a problem than a solution. A minimum of 50 feet pileup room is recommended.

Two or more parallel rows of fences may be required, but these should be placed far enough apart so the resulting drifts do not overlap, generally 50 feet to 100 feet apart. Snow fences should not be placed any closer than 16 feet to right of way fences or natural parallel barriers.

• Control with Landscaping

Trees and shrubs planted at the appropriate location may also provide a permanent and effective type of snowdrift control. The Landscape Unit should be contacted.

Additional information may be obtained from the ODOT *Inspector's Manual* and the ODOT *Maintenance Manual*.

10.12 RAIL

- **General**

As with airports, rail crossings in the vicinity of projects cause the influence areas of the respective modes to overlap. Projects near railroads, light rail, and other rail system crossings need to be reviewed for potential impacts. Rail crossings may be at-grade or grade separated depending on elements such as type of facilities, conflict points, and safety requirements. It is desirable to avoid or reduce at-grade rail crossings. Discussions between the Project Team and Rail Division should be held to determine the need to grade separate the crossing or leave it as an at-grade crossing.

Roadway projects in the vicinity of railroads need to accommodate the type of cargo and goods that are exchanged between rail and other transportation modes such as truck freight. Turning radii, travel lanes, or additional dedicated turn lanes need to be considered in the accommodation of vehicles moving such cargo and goods between roadway freight and rail lines. The existing Transportation System Plans should be reviewed to determine any related rail transportation needs.

- **Design Elements**

If at all possible, the intersection angle between the roadway and railroad should be as close to 90 degrees as possible. Right angle crossings maximize the driver's view of the rail crossing, location of tracks, and view of on-coming trains. A right angle crossing is also preferred for bicyclists and pedestrians. Besides the same visual problems of such a crossing, angled crossings coupled with flange openings create problems for the thin tires of a bicycle. The flange opening width should be kept to a minimum through the entire rail crossing section.

Sight distance is a critical consideration at railroad crossings. Sufficient sight distance must be available to the driver to recognize the crossing, see and perceive the crossing device and the trains themselves, and come to a stop condition if necessary.

Horizontal and vertical alignments are very important at rail crossings. The vertical profile between the roadway and the rail crossing should be as level and consistent as possible for smooth transition between surface types, sight distance and visibility of the crossing, and ability to react to the specific situation. Rail crossings along horizontal curves are not preferred as they impact the visibility of the crossing and cause the driver to focus on the curvature of the roadway instead looking for a train.

Some additional design elements involved with rail crossings include location of driveways, other accesses, and signals located at rail crossings. Vehicular storage queues in the vicinity of rail crossing intersections must be carefully reviewed and measures taken to prevent trapping of vehicles on the rail crossing. Sign locations need to be thought out in order to maintain proper clearance between the roadway and the railroad tracks.

The minimum horizontal and vertical railroad clearance to be provided on crossings shall conform to ODOT regulations shown in Figure 5-12. Additional clearance may be required and should be determined individually for each crossing. Information regarding these clearances shall be obtained from the Railroad/Utility Engineer. The Rail Division should be contacted when rail crossings are involved in a project.

- **Crossing Types**

The crossing type (signals, signals and gates, stop sign) is generally determined on a case by case situation, but typically the crossing will have both crossing gates and signal lights. The designer needs to take into account the lead time needed for interaction with other divisions such as Rail when a crossing is involved. The Rail Division should be contacted to determine the appropriate crossing type and other rail requirements.

Stopping Lanes at Railroad Crossings

Additional stopping lanes at railroad at-grade crossings were formerly added routinely. In some cases stopping lanes are not justified. Section 6.40 of the ODOT Traffic Manual outlines the procedure for determining the need for additional stopping lanes at railroad at-grade crossings. Additional design guidance for railroad grade crossings can be found on ODOT Standard Drawing RD445 for use when stopping lanes have been justified.

- **Curb Exposure**

Curb exposure at railroad crossings is very important. Standard curb (barrier) is to be used. The roadway curb exposure at railroad protective devices shall be a minimum 7 inches for new construction and 6 inches for existing installations and for maintenance after initial installation. In overlay situations, the construction of a new curb should not be ruled out. Each situation should be looked at individually to determine the correct solution.

10.13 AERONAUTICS

- **General**

Transportation modes often link to each other enabling goods and services to be transferred from one mode to another. The influence areas of the individual modes often overlap each other. Airports that are near a project must be reviewed for impacts to the project and the airport.

- **Design Elements**

Projects within the vicinity of an airport must be carefully examined to determine any potential conflict between the two transportation modes. Airport master plans should be reviewed to determine potential impacts to projects. Federal Aviation Regulations – Part 77, "Objects Affecting Navigable Airspace," and Oregon Administrative Rules, Chapter 738, Division 70, are the documents to be complied with involving airport clearance study projects involving structures and other potential obstructions to air navigation. The Preliminary Design Group should be contacted when airport clearance studies are required.

Projects that are near airports should be reviewed for obstructions or elements that may impact the air space. Roadway elements such as bridges, signals, illumination poles, or equipment that is used on these types of roadway projects may have an impact on air space. Even a proposed roadway with only the height of the vehicles as the only vertical impact may penetrate the imaginary flight surfaces. Location of drainage ditches and retention ponds can have an impact on airports by potentially attracting waterfowl to the area. The type of and pattern of illumination located near an airport should be reviewed for lighting conflict between the project and the airport. Glare shields may be needed to prevent signal light glare to the pilot.

Roadway projects in the vicinity of airports need to accommodate the type of cargo and goods that travel through airports. Turning radii, travel lanes, or additional dedicated turn lanes need to be considered in the accommodation of vehicles moving such cargo and goods. Appropriate signing for airports must be addressed in project design. Projects that add lanes should consider adding the lane away from the airport for clearance purposes. Potential for rail, light rail, bicycle and pedestrian, and transit needs should be examined for projects near airports, providing the necessary links between the different transportation modes. The existing Transportation System Plans should be reviewed to determine any related airport transportation needs.

- **Contacts**

The Oregon Department of Aviation should be contacted for assistance when any proposed project is within 20,000 feet of an airport; to assist in determining compliance needs with federal regulations; and to ensure proper coordination between the two divisions.