COUNTY OF HUMBOLDT

DEPARTMENT OF PUBLIC WORKS

ROADWAY DESIGN STANDARDS MANUAL

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FOREWORD

Purpose.

This Manual establishes policies and standards for the Roadway Design function of the Humboldt County Department of Public Works. Also included in the Manual are desirable design practices. These policies, standards and practices are to be used to direct, guide and inform County employees involved in the Roadway Design function.

Scope.

The scope of this Manual is primarily restricted to those Roadway Design functions which are referred to as "secondary" design and "final" design. Of necessity, design engineers must concern themselves with all phases of design, including planning, design, and coordination with construction contractors. Therefore, occasional reference is made to desired practices regarding preliminary engineering, field review, and construction or coordination with other functional organizations within the Department of Public Works and County Government.

The design standards contained herein will apply to all County design projects except where Federal authorities require adherence to higher standards.

Objectives.

Humboldt County plans to design new roads and roadway improvements which will provide adequate and safe community service. County Roadway Design must also promote reasonable roadway construction costs, reduced unit maintenance costs, and reasonable reconstruction costs. These objectives must be accomplished with available revenues.

Design policies and standards are intended to guide and inform those Public Works employees involved in the Roadway Design function and are to be viewed as reasonable goals for improvements. It is the intent of the County to establish a program by which existing roadways will be improved, where necessary, to meet these standards and to develop a plan for realizing this objective. The objective of this Manual, therefore, is to provide the specific policy guidelines, engineering standards, and desired design practices which will facilitate accomplishment of the aforesaid County Roadway Design objectives.

It is also the intent of this Manual to remind Public Works Design employees of certain legal aspects of roadway design. Current "ideas" on drainage law, for example, are included in Section 4. The law itself, of course, must be interpreted by County Counsel.

This Manual, through selection of content and format, is intended not only for the engineers, who will be the most frequent users of it, but also for maintenance personnel, administrators, and other readers who are not technically-oriented. The Table of Contents footnotes those sections of the Manual which may be most pertinent to each individual reader's needs.

Qualification of Intent.

It is not the function of this Manual to establish legal standards for roadway design, nor to restrict sound engineering theory or judgment. Design engineering is an empirical science; therefore, certain design standards by necessity are expressed as ranges of acceptable values. Furthermore, it is not intended that any standard of conduct or duty toward the public shall be created or imposed by the publication of this Manual. This Manual is intended as an operational tool for administering roadway design.

This Manual is not a textbook, nor is it a substitute for engineering knowledge, experience, or judgment. The graphs, tables, and words concerning desired practices are intended as aids in the solution of field and office problems. No attempt is made to detail basic engineering techniques; for these, standard textbooks should be used.

Authority of Manual.

This Manual has been developed under the authority of the Humboldt County Board of Supervisors. It is the intent of the Board that this Manual be interpreted and used to accomplish the objectives outlined earlier in this Foreword. Policies regarding specific design practices are included in later sections of this Manual.

It is the desire of the Board to maintain this Manual through the incorporation of current information; therefore, assistance in the form of ideas and suggestions for revisions or additions will be appreciated. Additions, deletions or revision to the engineering standards and/or design practices contained herein will be accomplished by the Director of Public Works under authority granted to him by the Humboldt County Board of Supervisors. Changes in County policy will be recommended to the Board of Supervisors by the Director of Public Works for approval prior to inclusion into this Manual.

GUY C. KULSTAD, P. E.
Director of Public Works

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SECTION 1 - ADMINISTRATION OF ROADWAY DESIGN

1-100 General.

1-101 Objective and Scope.

The objective of this Section is to present County policy regarding the administration of roadway design, the authority relationships involved, definitions of roadway terms, and information regarding maintenance of the Manual. The intended use of policies, standards and design practices is also explained in this Section.

1-102 Policy.

1-102.1 Administration - It is the policy of Humboldt County that the Director of Public Works, acting in his capacity as County Road Commissioner, will be responsible for the administration of policies and standards contained herein.

1-102.2 Application of Policy and Standards - It is the policy of Humboldt County that the Design policies and standards will be applied to the design of new roads or improvements, as defined in Sections D and E of the State of California City and County Projects Manual, or as designated by the Director of Public Works. An objective is to ultimately improve selected County roads to these standards by assigning improvement priorities to roads which deviate most significantly from these standards.

1-102.3 Maintainability - It is the policy of Humboldt County that roadways will be designed to minimize maintenance costs while providing acceptable levels of service.

1-102.4 Maximum Standards - It is the policy of Humboldt County that the design standards which are stated as singular values be interpreted not only as the minimum standards acceptable, but also as the maximum standards to be considered.

1-200 Design Function. Roadway design basically involves:

(1) Proposing and planning new roads or improvements,

(2) Preliminary feasibility and route studies,

(3) Preliminary design,

(4) Coordination with other functional departments,

(5) Geometric, structural, and drainage system design, and

(6) Coordination with those responsible for implementation of design.

This Manual will primarily deal with (5) above. The County's Roadway Classification System is included (Section 7) to assist those who propose and authorize new roads or improvements. Relative construction cost figures and a maintenance index are also included (Section 3) to assist in evaluating economical feasibility.

1-300 Authority - Legal and Organizational.

1-301 Roadway or Highway Design.

Existing Streets and Highways Codes and their amendments shall govern the design of County roadways or highways. These Codes delineate the laws concerning authority and procedures for all highway design effort as exercised by counties. Certain of these Codes will be quoted and referenced in this Manual for the purpose of promoting general understanding. The related Codes and their revisions are extensive and, therefore, will not be incorporated into this Manual. Interpretation of these Codes should be made by Humboldt County Counsel.

1-302 County Board of Supervisors.

According to Section 940 of the California Streets and Highways Code, the "Board of Supervisors shall have general supervision, management and control of the County highways."

Furthermore, in Section 943, Notes of Decisions, it states: "The Board of Supervisors has jurisdiction to determine whether a new road is necessary or not, and, if necessary, over what route it shall be laid out and constructed; and, in laying out public road, the Board exercises judicial functions. . ."

The Board also establishes design policy contained in this Manual.

1-303 Director of Public Works.

For purposes of this and later discussions, the title "Director of Public Works" is inclusive of those functions assignable or described as assigned to the "County Road Commissioner."

Section 2009 of the Streets and Highways Code states: "The Board of Supervisors shall act as the policy-making body with respect to County highway matters and shall, by appropriate action, establish the general policies to be followed by the Road Commissioner in the administration of his Department. The Road Commissioner shall administer his Department and carry out the general policies of the Board in conformity with the estimates of expenditures fixed in the budget as finally adopted by the Board, or as thereafter revised by appropriate action of the Board. The Commissioner shall employ such assistants and employees as may be necessary, in conformity with the budget and County policies and procedure, with respect to personnel and subject to the approval of the Board of the salary or other compensation to be paid. The Commissioner shall have sole supervision and jurisdiction over personnel and over the assignments of personnel engaged in work on County roads."

Furthermore, Section 1075 states: "The Board may have any work upon County highways done under the supervision and direction of the County Road Commissioner."

As regarding bridges, Section 1332 notes: "The Board of Supervisors may authorize such Road Commissioner to employ such workmen and purchase such materials, equipment, tools, and appliances and cause such work to be done as is necessary to construct or maintain such bridges and to keep them in repair. . ."

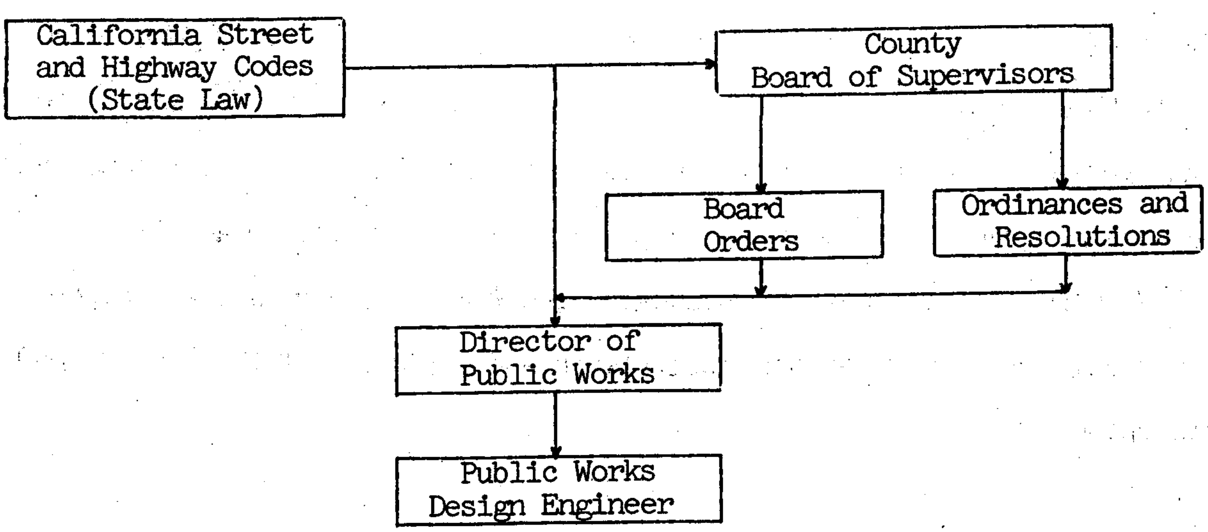
The Director will also authorize the proper application of design standards and will approve all final roadway designs.

1-304 Design Engineering Employees.

As stated on the previous page, "the Commissioner shall have sole supervision and jurisdiction over personnel and over the assignment of personnel engaged in work on County roads." Therefore, all design engineering employees have delegated responsibilities and are accountable to the Road Commissioner.

The design engineer will have the authority to apply accepted engineering practices in carrying out the design function as required by County policy and design standards and as directed by the Director of Public Works.

1-305 Authority Relationships - County Roadway Design.



The Board of Supervisors directs the Director of Public Works through Board Orders. The Director must act in conformance to:

- State Street and Highway Codes,
- Board Orders, and
- County Ordinances and Resolutions.

County Public Works Design Engineers must act in conformance to:

- Directions from the Director of Public Works (including those defined in this Manual), and
- The recognized principles of design engineering.

1-400 Definitions of Policies, Standards and Desired Practices.

1-401 Policies.

Policies are general statements which express a basic rule of conduct regarding a given subject. The intent of a policy is to guide the user toward a desired goal without specifying detailed procedures.

Roadway design policies are made by the Board of Supervisors to express the County's desires and to guide the activities of the Director of Public Works and the design engineers. Changes to, and variations from, County design policy can only be made by the Board unless specific authority for approving such variations is granted by the Board.

1-402 Standards (Roadway Design).

Standards are measures or criteria which specify desired limits of performance. Standards are normally used as a control measure to assure that acceptable goals are accomplished.

Roadway design standards evolve from accepted practice. The number of elements involved in many design engineering problems and the nature of the science is such that standards must often be expressed as ranges of acceptable values rather than as absolute values. These "ranges" provide latitude and allow the engineer to exercise judgment and experience.

Deviations from the standards may be proposed by the design engineer with appropriate justification, but any such changes must be approved by the Director or his designated representative.

The standards will be applied to all County road design projects unless a higher authority requires other standards as a condition for appropriating funds. Federal Aid highway projects require adherence to AASHO standards which are contained in Section 8 of this Manual. Proposed deviations from these standards must be coordinated through the appropriate government agency.

1-403 Desired Engineering Practices.

This Manual contains information regarding engineering "practices" or procedures which, when followed, will promote desired roadway design and construction. These statements of practices are intended to assist the design engineer and are instructional in nature as opposed to being directives. This information will clearly be distinguished from policy and standards.

The design engineer will have the authority to select practices or specifications (materials, type of structures, etc.) which will promote the County's goals.

1-500 Maintenance of the Manual.

It will be the responsibility of the engineer in charge of the design functions to maintain the Manual. The loose-leaf format of the Manual was selected because it facilitates change and expansion. Changes should be dated and distributed to all Manual holders on a regular basis. Approval for changes to policy lies with the Board; changes to standards are authorized by the Director and engineering practice is controlled by the design engineer.

Tables, graphs and other materials, taken from manuals or publications of other government or private agencies, are properly identified to facilitate further reference.

1-600 Nomenclature.

1-601 Official Names.

AASHO	- American Association of State Highway Officials
BPR	- United States Bureau of Public Roads (Agency within Department of Transportation and FHWA)
County	- Humboldt County
CSAC	- County Supervisors Association of California
CEAC	- County Engineers Association of California
Board	- Board of Supervisors, Humboldt County
Director	- Director of Public Works, Humboldt County
Department	- Department of Public Works, Humboldt County
Commissioner	- Road Commissioner (Same as Director for Humboldt County)
FHWA	- Federal Highway Administration
State	- State of California, Divsion of Highways

1-602 Definitions.

Abandonment - The cessation of the public's right in and to the use and enjoyment of a public road, alley, storm drain, etc., by the Board of Supervisors by the authority and procedures set forth in the Streets and Highways Code, State of California.

Abandonment (Summary) - An abandonment which has been effected by order of the Board of Supervisors without the normal required public notice and hearing. This type of an abandonment can be made only when the public right of way to be abandoned has been superseded by relocation and access to the property which, prior to relocation adjoined the right of way, will not be eliminated.

Access Road - A road which provides access or entrance to residences, businesses or other abutting property. It generally provides the least mobility within the County system and is usually the first and last road to be used for a "trip" within the County (see Section 7-301).

Arterial Road - An arterial provides service between major traffic generators such as cities or large towns and normally provides the most direct route to the State system. It usually provides the highest level of service to the County as measured by mobility and traffic volume. An arterial will have some access and traffic control and may be located in, or traverse, urban and rural areas (see Section 7-301).

Auxiliary Lane - That portion of the roadway adjoining the main traveled way for weaving, truck climbing, speed change, or for other purposes supplementary to through traffic movement.

Average Daily Traffic - The average 24-hour volume, being the total number during a stated period divided by the number of days in that period. Unless otherwise stated, the period is one year. The term is commonly abbreviated as ADT.

Average Safe Speed - The average speed which can be maintained by a vehicle over a road assuming the driver heeds warning signs, the basic speed law, sight distance restrictions, speed limits, and other general safety precautions.

Base - A layer of selected, processed, or treated aggregate material of planned thickness and/or quality placed immediately below the pavement and above the subbase or basement soil.

Base Course - The bottom portion of a thick lift asphalt concrete layer upon which a riding surface of the same composition will be applied.

Basement Soil - The material in excavation, embankments, and embankment foundations immediately below the lowest layer of the structural section and extending to the depth that affects structural design.

Berm - A small mound generally made of noncompacted material which is constructed on or near the edge of the shoulder for the primary purpose of directing drainage flow. Berms are sometimes referred to as dikes; however, dikes are usually thought to be constructed of compacted material such as asphalt concrete.

Borrow - Natural soil obtained from sources outside the roadway prism to make up a deficiency in excavation quantities.

Bridges - Structures of a span of more than 20 feet, measured under the copings along the centerline of the road and multiple span structures where the individual spans are in excess of 10 feet, measured from center to center of supports along the centerline of the road.

Channelization - The separation or regulation of conflicting traffic movements into definite paths of travel by the use of pavement markings, raised islands or other suitable means to facilitate the safe and orderly movements of both vehicles and pedestrians.

Collector Road - A road which collects and/or feeds traffic from or to access or arterial roads. A collector can also provide a direct link between two arterials or provide access to an arterial. A Collector also provides service between minor traffic generators (see Section 7-301).

Condemnation - The process by which property is acquired for public purposes through legal proceedings under power of eminent domain.

Control of Access - The condition where the right of owners or occupants of abutting land or other persons to access in connection with a highway is fully or partially controlled by public authority.

Controlled Access Highway - A roadway which has full or partial access control and is designated such by the Director of Public Works. A highway has controlled access when the owners of abutting lands have no right of access to or from their abutting lands or when such owners have only limited or restricted right of access.

County Sign Route - A County road meeting the requirements of CSAC and so designated by their State Traffic Committee, which is traversable year round and leads to points of interest. The State Division of Highways assigns numbers to these routes.

Cul-de-Sac - The turn around area located at the end of a dead-end street or road.

Culverts - A drain, enclosed channel, or conduit for transporting water under, across, or parallel to a roadway system.

Curb - A dike which serves as the front portion of a sidewalk or as the outside edge of a gutter or roadbed.

Design - A roadway design is the level of definition needed to direct the construction of a roadway to the desired standards. A design "package" may include, but need not be restricted to geological reports, survey maps, drawings, materials reports, etc. Design package for an improvement project may contain general engineering instructions along with informal drawings.

Design Speed - A speed determined for design and correlation of the physical features of a highway that influence vehicle operation. It is the safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern.

Design Volume - A volume determined for use in design, representing traffic expected to use the highway. Unless otherwise stated, it is an hourly volume of vehicles traveling in both directions.

Divided Highway - A highway with separated roadbeds for traffic moving in opposite directions.

Easement - A right to use or control the property of another for designated purposes.

Embankment - A raised structure constructed of natural soil from excavation or borrow sources.

Eminent Domain - The power to take private property for public use without the owners' consent upon payment of just compensation.

Encroachment - Occupancy of highway right of way by non-highway structures or objects of any kind or character.

Expressway - A roadway for through traffic with partial control of access, but which may or may not be divided or have grade separations at intersections.

Flexible Pavement - A pavement having sufficiently low bending resistance to maintain intimate contact with the underlying structure yet having the required stability furnished by aggregate interlock, internal friction, and cohesion to support traffic. Asphalt Concrete is a flexible pavement.

Freeway - A freeway is a divided highway for through traffic with full control of access and with grade separations at intersections.

Frontage Street or Road - A local street or road auxiliary to and located on the side of an arterial roadway for service to abutting property and adjacent areas and for control of access.

Geometric Design - Geometric design is the arrangement of the visible elements of a road, such as alignment, grades, sight distances, widths, slopes, etc.

Grade - Inclination with the horizontal of a road usually expressed by stating their vertical rise or fall as a percentage of the horizontal distance.

Grade Separation - A crossing of two highways or a highway and a railroad at different levels.

Highway - A public way for purposes of vehicular and pedestrian travel, including the entire area within the right-of-way. In rural areas, or in urban areas where there is comparatively little access and egress, a way between prominent termini is usually called a highway, roadway or simply a road. A way in an urban area, with or without provision for curbs, sidewalks, and paved gutters, is ordinarily called a street (see Figure 1-602A for "cross section illustration).

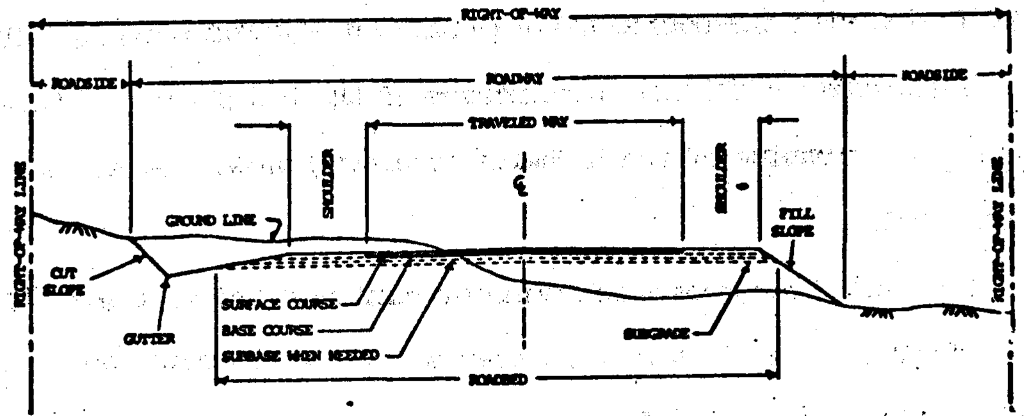
Highway Capacity - The largest number of vehicles that can pass a point on that highway (or roadway) over a given period of time under ideal conditions. Capacity is normally stated in terms of passenger vehicles per hour per lane.

Interchange - A system of interconnecting roadways in conjunction with a grade separation or grade separations providing for the interchange of traffic between two or more roadways on different levels.

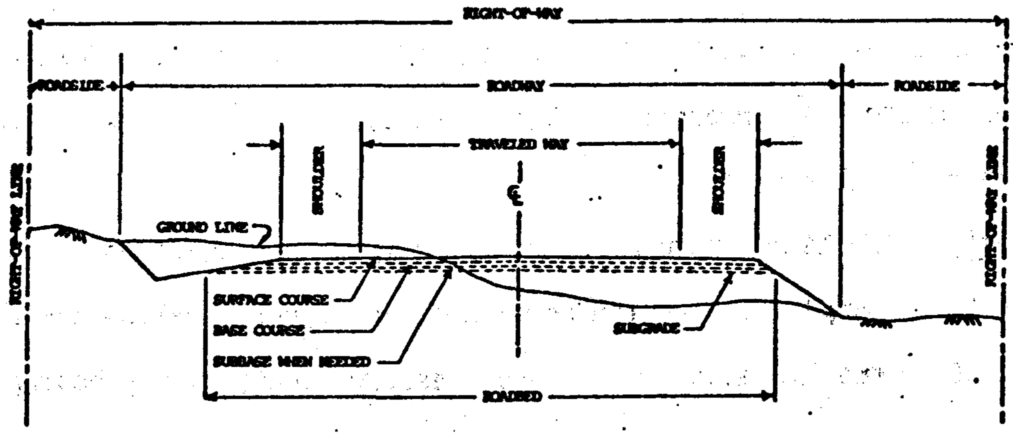
Intersection - The general area where two or more roadways join or cross, within which are included the roadway and roadside facilities for traffic movements in that area.

Inverse Condemnation - The legal process which may be initiated by a property owner to compel the payment of just compensation where his property has been taken or damaged for a public purpose.

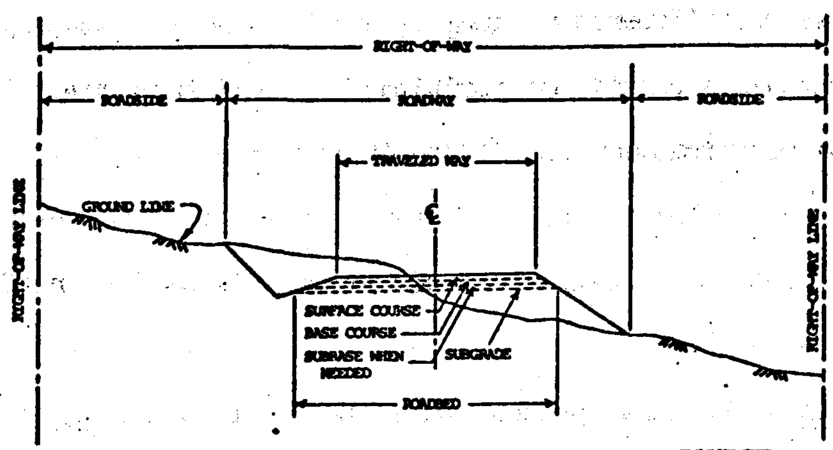
Figure 1-602A



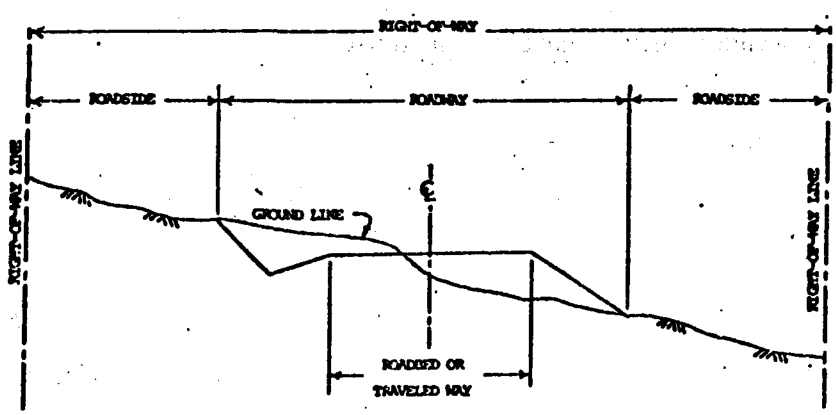
1-LANE OR 2-LANE ROAD WITH PAVED SURFACE COURSE



2-LANE ROAD WITHOUT PAVED SURFACE COURSE



1-LANE ROAD WITHOUT PAVED SURFACE COURSE



1-LANE ROAD WITHOUT PAVEMENT STRUCTURE

Improvement - Any work performed on an existing roadway which is intended to improve the standard or condition of the road to a higher level than the road has been improved to or constructed. Typical improvement projects involve rebasing, adding a surface course, horizontal or vertical realignment, or a major change to a drainage system. Improvement or maintenance projects costing more than $10,000 normally must be contracted by law.

Island - A defined area between traffic lanes for control of vehicle movements or for pedestrian refuge. Within an intersection a median or an outer separation is considered an island.

Level or Flat Terrain - Any combination of gradients, length of grade, or horizontal or vertical alignment that permits trucks to maintain speeds that equal or approach the speeds of passenger cars.

Maintenance - (Legal definition from Streets and Highway Code:) "(a) The preservation and keeping of rights-of-way and each type of roadway, structure, safety convenience or device, planting, illumination equipment and other facility, in the safe and usable condition to which it has been improved or constructed, but does not include reconstruction or other improvements. (b) Operation of special safety conveniences and devices, and illuminating equipment. (c) The special or emergency maintenance or repair necessitated by accidents or by storms, or other weather conditions, slides, settlements or other unusual or unexpected damage to a roadway, structure or facility.

The degree and type of maintenance for each highway, or portion thereof, shall be determined in the discretion of the authorities charged with the maintenance thereof, taking into consideration traffic requirements and monies available therefor."

Median - The portion of a divided highway which physically separates the opposing traffic lanes. Medians are characteristic of divided highways.

Median Lane - A speed change lane within the median to accommodate left-turning vehicles.

Minimum Turning Radius - The radius of the path of the outer front wheel of a vehicle making its sharpest turn.

Mountainous Terrain - Any combination of gradients, length of grade, or horizontal or vertical alignment that will cause trucks to operate at very slow speeds for considerable distances or at frequent intervals.

New Road - Any road which is constructed where another road did not previously exist.

Passenger Car - A self-propelled vehicle generally designed for the transporation of persons, but limited in seating capacity to not more than nine passengers, including taxicabs, limousines, and station wagons. Also included, for capacity purposes, are two-axle, tired pickups, panels and light trucks, which have operating characteristics similar to those of passenger cars, but not motorcycles.

Plan Line - A plan line is the proposed or planned rights of way delineation of a street or highway for future construction or widening. A plan line not initially included in the general plan must be included by amending the existing general plan and by recordation.

Reconstruction - All work performed to rebuild a roadway facility according to the previously existing standard, if applicable, or to a higher standard. All these basic elements of roadway construction must be involved; geometrics, structural section and drainage system.

Relinquishment - A transfer of one jurisdiction's right, title and interest in and to a highway, or portion thereof, to another jurisdiction.

Resurfacing - A surface placed on an existing pavement to restore its riding qualities or increase its strength.

Right-of-Way - That portion of land which is legally owned by the County either through deed or prescriptive rights.

Rigid Pavement - A pavement having sufficiently high bending resistance to distribute loads over a comparatively large area. Portland Cement Concrete is a rigid pavement.

Single Lane Road - A road which allows only one legal-sized vehicle to travel freely at any given point on the roadway.

Two Lane Road - An undivided road having one lane for traffic in each of two opposing directions.

Roadbed - That portion of the roadway located between curb lines or shoulder lines or subgrade hinge points. Divided highways are considered to have two roadbeds. (See Figures 1-602-A)

Roadside - A general term denoting the area adjoining the outer edge of the roadbed. Extensive areas between the roadbeds of a divided highway may also be considered roadside. (See Figure 1-602-A)

Roadside Development - The development by preservation or enhancement of all features within and along the highway right of way exclusive of the roadbed. This includes the contour of the roadside; erosion control, aesthetic and functional plantings; adjacent scenic areas; safety roadside rests; and related developments.

Roadway - That portion of the highway included between the outside lines of the sidewalks, or curbs and gutters, or side ditches including also the appertaining structures, and all slopes, ditches, channels, waterways, and other features necessary for proper drainage and protection. The California Streets and Highways Codes define the roadway as including the right-of-way. (See Figure 1-602-A)

Rolling Terrain - Any combination of gradients, length of grade, or horizontal or vertical alignment that causes trucks to reduce their speeds substantially below that of passenger cars on some sections of the highway, but which does not involve sustained low speeds by trucks for any substantial distance.

Scenic Highway - An officially designated portion of the County Roadway System traversing areas of outstanding scenic beauty which together with the adjacent scenic corridors requires special scenic conservation treatment.

Seal Coat (General) - A bituminous coating with or without aggregate normally applied to the surface of a pavement for the purpose of waterproofing, preserving, or rejuvenating a bituminous surface, or to provide increased skid resistance or resistance to abrasion by traffic. Also used in place of Asphalt Concrete surface when base is adequate to meet traffic demands.

Double Seal Coat - An application of two seal coat layers.

Separate Turning Lane - An auxiliary lane for traffic on one direction which has been physically separated from the traveled way by markings or physical barriers which channel the traffic flow.

Shoulder - The portion of the roadway contiguous with the traveled way designed for lateral support of base and surface courses and/or for emergency use by vehicles. (See Figure 1-602-A)

Sight Distance - Passing - The minimum sight distance on two and three-lane highways that must be available to enable the driver of one vehicle to pass another vehicle safely and comfortably without interfering with the speed of an oncoming vehicle traveling at the design speed, should it come into view after the overtaking maneuver is started.

Sight Distance - Stopping - The distance required by a driver of a vehicle traveling at a given speed to bring his vehicle to a stop after an object on the roadway becomes visible. It includes the distance traveled during the perception and reaction times and the vehicle braking distance.

Speed Limits - The maximum or minimum speed at which a vehicle is permitted to travel under given conditions. It need not be posted and is normally less than the design speed.

Speed Zoning - The establishment of safe and reasonable speed limits for certain special zones or sections of roadways where the general speed limits do not fit the road or traffic conditions.

Stage Construction - The construction of a roadway where the different stages or phases of construction are spread over a number of months or even years as opposed to completing them as one continuous project.

Structural Section - The planned layers of specified materials, normally consisting of subbase, base and pavement placed over the basement soil.

Subgrade - The portion of a roadbed upon which a subbase, base, base course, or pavement is to be placed. (See Figure 1-602-A)

Surface - That portion of the roadway which is contacted by vehicles traveling on the roadway.

Surface Course - The portion of a pavement applied to the top of a thick lift asphalt concrete base course. It may consist of the same composition as the base course. It may also be the top layer of the structural section.

Tack Coat - The initial application of bituminous material to an existing surface to provide bond between the superimposed construction and the existing surface.

Through Street or Through Highway - Every highway or portion thereof on which vehicular traffic is given preferential right of way and at the entrance to which vehicular traffic from intersecting highways is required by law to stop before entering or crossing the same.

Traffic Control Signal - Any device whether manually, electrically, or mechanically operated by which traffic is alternately directed to stop and permitted to proceed.

Traffic Lane - The portion of the traveled way for the movement of a single line of vehicles.

Traffic Markings - All lines, patterns, words, colors, or other devices, except signs, set into the surface of, applied upon, or attached to the pavement or curbing, officially placed for the purpose of regulating, warning, or guiding traffic.

Traffic Sign - A device mounted on a fixed or portable support whereby a specific message is conveyed by means of words or symbols, officially erected for the purpose of regulating, warning, or guiding traffic.

Traveled Way - The portion of the roadway commonly used for the movement of vehicles.

Truck - A vehicle having dual tires on one or more axles, or having more than two axles, designed for the transportation of cargo rather than passengers. Includes tractor-trucks, trailers and semi-trailers when used in combination. Excludes trucks described as passenger cars. Buses are considered as trucks.

SECTION 2 - BASIC DESIGN POLICIES AND GEOMETRIC STANDARDS

2-100 General.

2-101 Objectives and Scope.

The objectives of this Section are to present policies, standards and practices for the design of the physical characteristics of the road pertaining to its use. These characteristics govern the level of service of the road, capacity, speed and contribution to safety.

2-102 Policy.

2-102.1 Basic Design Objectives - It is the policy of Humboldt County that roadway designs will satisfy the following basic criteria.

The roadway will be designed to move traffic efficiently and safely at prescribed service levels, consistent with the actual or expected use of the roadway. This means that the design will be based upon:

(1) Legal requirements,

(2) Sound engineering principles and practices,

(3) Traffic safety considerations,

(4) Economy of Design and Maintenance, and

(5) Allowance for the special nature of Humboldt County roads and traffic problems.

2-102.2 Planning and Development of Programs and Projects - It is the policy of Humboldt County that in the Planning and Development of the County's programs and projects the following questions shall be considered as guidelines for a continuous evaluation process as work progresses:

(1) What will be the environmental impact of this action?

(2) What adverse environmental effects cannot be avoided if this proposal is implemented?

(3) What mitigation measures can be taken to minimize the impact?

(4) What are alternatives to this action, including the possible alternative of no action?

(5) What is the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity?

(6) What are the irreversible environmental changes which will occur if this proposal is implemented?

2-102.3 Scenic Values in Planning and Design - It is the policy of Humboldt County that scenic values be considered when planning and designing roadways. As an agreeable and natural roadside appearance is desirable, the destruction of valuable trees and growth should be avoided if suitable alternative locations are available at reasonable cost.

2-102.4 Design Speed - It is the policy of Humboldt County that design speeds shall be adequate for mobility, yet generally remain consistent with those existing on County roads. It is the desire of the County to provide safe and efficient roads, but not at the expense of solely designing high speed roads.

2-102.5 Detour Roads - It is the policy of Humboldt County that detour roads may be built as needed to satisfy immediate or emergency needs only.

2-200 Design Elements.

2-210 Preliminary Design Information.

The information which a roadway designer needs before he can prepare preliminary design plans for improving a road is:

(1) Present traffic volume expressed as average daily traffic (ADT),

(2) Present truck traffic volume classified by number of axles,

(3) The percent of traffic moving in each direction,

(4) Present and projected roadway type, use, and level of service (See Section 70301), and

(5) Projected traffic volumes for alternative design periods.

For designs involving a totally new roadway, obviously, present statistics are not available. In this case, the best estimate of future volumes is required. It is desirable to conduct an origin and destination analysis prior to assigning traffic values to new roadway design.

2-211 <u>Selection of Roadway Category</u>.

Given the above preliminary design information, the designer's next step for a new road or an improvement would be to select the appropriate roadway category which will best accommodate:

(1) Projected roadway use,

(2) Projected levels of service,

(3) Present roadway features, (if designing a roadway segment improvement),

(4) Future land development plans, and

(5) Other community needs.

Section 7-300 explains, in detail, the procedure for selecting a roadway catetory. The selected category specifies the basic geometric features of the new road or improvement.

2-212 <u>Highway Capacity</u>.

The capacity of the roadway must be determined to assure the designer that the roadway category he has selected will in fact accommodate the traffic volumes anticipated.

As a general rule in rural areas, 900 passenger cars per hour is capacity, and in urban areas, 1500 passenger cars per hour is considered capacity. If the projected average daily traffic is such that roadway capacity will be met or exceeded during the design period, the designer must consider additional lanes and a different roadway category.

The number of commercial vehicles, lane width, and lateral clearance are all factors which affect capacity. If roadway capacity needs to be calculated, the publication "Highway Capacity Manual," dated 1965 and prepared jointly by the U. S. Bureau of Public Roads and the Highway Research Board should be referenced. It contains tables, etc., for calculating capacity.

2-213 Design Speed.

Design speed is a speed selected for design and correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that can be maintained over a specified section of highway when conditions are such that the design features of the highway govern speed. Design speed and posted speed limits are not necessarily the same.

2-213.1 Design Speed Standards - Design speeds as low as 10 miles per hour may be considered for single access roads receiving only private use and design speeds of 65 or 70 may be considered for high volume arterials which function as County "expressways."

The following table expresses allowable ranges of design speeds according to the functional use of the road (see classification system definitions - Section 7-300).

TABLE 2-213.1

DESIGN SPEED RANGES BY ROADWAY FUNCTION

Function	Design Speed (mph)
Private Access	10 - 40
Public Access	20 - 50
Collector	20 - 60
Arterial	30 - 70

2-213.2 Selection of Design Speed - The choice of design speed is controlled principally by the following factors:

(1) Function, use and user of the road,

(2) Character of terrain, land use, and population density,

(3) Traffic (volume and vehicle type),

(4) Roadway type (one, two, or multiple lanes),

(5) Level of access control,

(6) Widths and alignments of lanes and existing bridges, and

(7) Economic and maintenance considerations.

Geometric design features such as vertical and horizontal alignment, sight distances, and superelevation vary directly with design speed. These relationships are based on proven engineering principles. At low design speeds, features such as widths of traveled way and shoulders do not vary directly with design speed. However, traveled way width and clearance to solid objects must increase with higher speeds.

Since roads are to be designed to meet future traffic conditions, it is important that the designer's assumptions regarding future traffic behavior are realistic. The designer should work closely with the County Planning Department and Commission to obtain their estimates regarding growth and future roadway needs.

The designer should not select a design speed which is inconsistent with the basic topography of the area. In curving mountainous terrain, the driver is more apt to understand and "accept" a low design speed than in an area where there is no apparent reason for it.

It is a common design practice to lay out the roadway alignment primarily according to the restrictions which the terrain presents. The design speed which is indicated by this layout is then adopted. This method may be economical and practical in some instances; however, the resulting design speed may not coincide with the desired design speed as determined from consideration of the factors listed earlier in this section.

It should be remembered that the primary objective is to provide roadway service with reasonable mobility and comfort without sacrificing safety for users. For reasons of safety and economy, it may be desirable to design for lower speeds than could readily be accommodated by the terrain. The balance between safety and economy should constantly be considered by the designer.

Early consideration must be given to the costs to provide the type of road indicated by a given design speed. Since design speed is the major controlling factor for roadway design, slight increases in design speed will result in significant cost increases.

2-214 Design Period.

The design period is generally considered to be the design life of the roadway from a capacity standpoint. It is basic to the designer because the design of the structural section is based upon the loading which the road is expected to support during the design period.

2-214.1 Design Period Standards - For County Arterials, design shall be based on estimated traffic requirements 20 years after construction. For all other roads, 15, 10 or 5 year design periods may be used. The Director of Public Works' approval is required for five-year design projects.

2-214.2 Selecting the Design Period - It is difficult to project County traffic needs, therefore, latitude is desired for selecting the design period. Factors to consider when selecting the design period are:

(1) Roadway classification,

(2) Traffic volumes,

(3) Nature of traffic (percent and size on trucks),

(4) Flood history of the road location,

(5) Economics (construction and maintenance costs),

(6) Future development,

(7) Logging cycle, and

(8) Relative geologic stability of location.

The Humboldt County roadway designer must remember that the design period, equivalent wheel load (EWL), and traffic index (TI) concepts are based upon an assumption that roads deteriorate primarily as a result of traffic. This is generally true; however, roads in areas of heavy rainfall and frequent flooding often deteriorate as a result of the natural elements rather than traffic wear.

Also to be remembered, is that the materials used to build or improve County roads often times are not of the highest quality. This means that the constructed road may not actually accommodate the theoretical design year traffic volumes. When selecting a design period, the designer must allow for the factors mentioned on the previous page.

2-215 <u>Design Designation</u>.

The design designation is the expression of the basic design factors which control the roadway design. Following is an example of this expression:

ADT (70)	= 1800		D	=	60%
ADT (90)	= 5200		T	=	8%
DHV	= 600		V	=	50 mph

Roadway Category (5) = Two lane wide traveled way.

The above is explained as follows:

ADT (70) . . . . The average daily traffic, in number of vehicles, for the current year.

ADT (90) . . . . The average daily traffic for the future year used as a target in design.

DHV . . . . The two-way design hourly volume, vehicles.

D . . . . The percentage of the DHV in the direction of heavier flow.

T . . . . The character of the traffic. This is expressed by the truck increment (T) as a percent of the DHV.

V . . . . The design speed in miles per hour.

Roadway Category (5) . . The category or basic type of road to be designed according to the County's roadway classification system.

Within a project, one design designation shall be used except when:

(a) The design hourly traffic warrants a change in the number of lanes, or

(b) A decided change in topography dictates a change in design speed.

2-300 Geometric Design Elements.

2-310 Topographic Elements.

2-311 Sight Distance.

Sight distance is the continuous length of highway ahead visible to the driver. In design, two sight distances are considered: passing sight distance and stopping sight distance (see Section 1-602 for definitions).

Passing sight distance is considered only on two-lane roads. Passing sight distance is not as critical as stopping sight distance for low volume roads since the incidence of passing is relatively infrequent. Also, the high number of curves characteristic of many County roads makes the cost of providing minimum passing sight distance prohibitive in many cases. By providing turnouts, passing may be accomplished with little inconvenience.

2-311.1 Sight Distance Standards - The following table shows the standards for passing and stopping sight distance related to design speed. These are the minimum values to be used in design.

TABLE 2-311.1

SIGHT DISTANCE STANDARDS

Design Speed (miles per hour)	Minimum Sight Distance	
	* Stopping (feet)	** Passing (feet)
10	125	-
20	150	-
30	200	1100
40	275	1500
50	350	1800
60	525	2100
65	600	2300
70	750	2500

* Applicable for all roads - assumed that driver's eyes are 3.75 feet above the pavement and object is 0.5 foot high on the road.

** Assumed that driver's eyes are 3.75 feet above the pavement and object is 4.0 feet high on the road - applicable to two-lane roads.

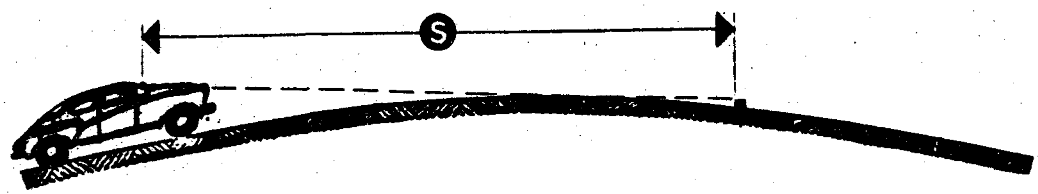
The stopping sight distances in Table 2-311.1 shall be increased by 18 percent on a sustained grade steeper than 3 percent and longer than 1 mile.

2-311.2 Stopping Sight Distance Standards at Grade Crests - Figure 2-311.2 gives the length of vertical curve required to obtain stopping sight distance for a given design speed when the algebraic difference in grades is known.

2-311.3 Stopping Sight Distance Standards at Grade Sags - From the curves in Figure 2-311.3, the length of vertical curve which provides headlight sight distance in grade sags for a given design speed is obtained if the algebraic difference in grade rates is known.

STOPPING SIGHT DISTANCE ON CREST VERTICAL CURVES

Height of eye 3.75 feet
Height of object 0.50 feet



DESIGN SPEED M.P.H.	SIGHT DISTANCE FEET
10	125
20	150
30	200
40	275
50	350
60	525
65	600
70	750

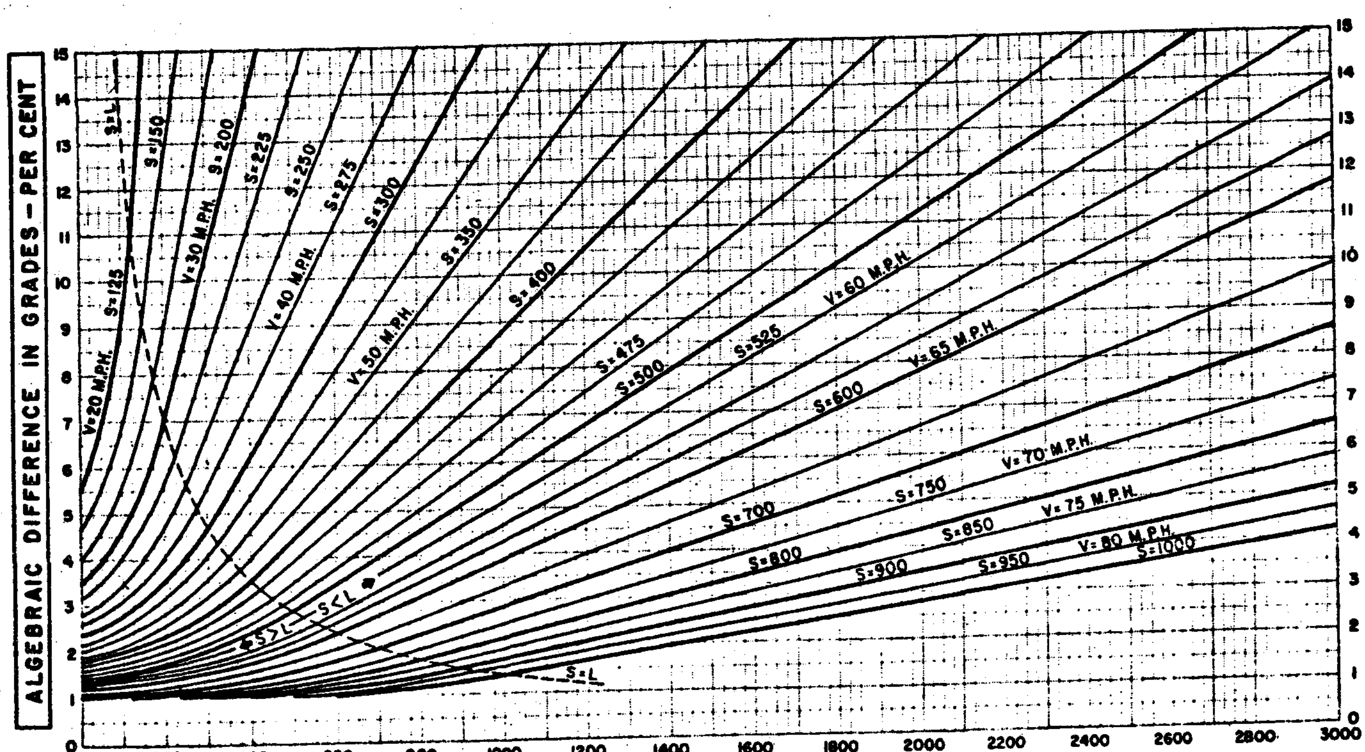
L = Curve length – Ft.
A = Algebraic grade difference – %
S = Sight distance – Ft.
V = Design speed – M.P.H. for "S"

WHEN S > L

$$L = 2S - \frac{1398}{A}$$

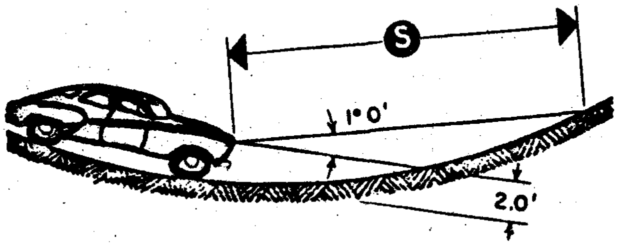
WHEN S < L

$$L = \frac{AS^2}{1398}$$



Note: Taken from California State Design Manual (Figure 7-201.4)

STOPPING SIGHT DISTANCE ON SAG VERTICAL CURVES



L = Curve length - Ft.
A = Algebraic grade difference - %
S = Sight distance - Ft.
V = Design speed - M.P.H. for "S"

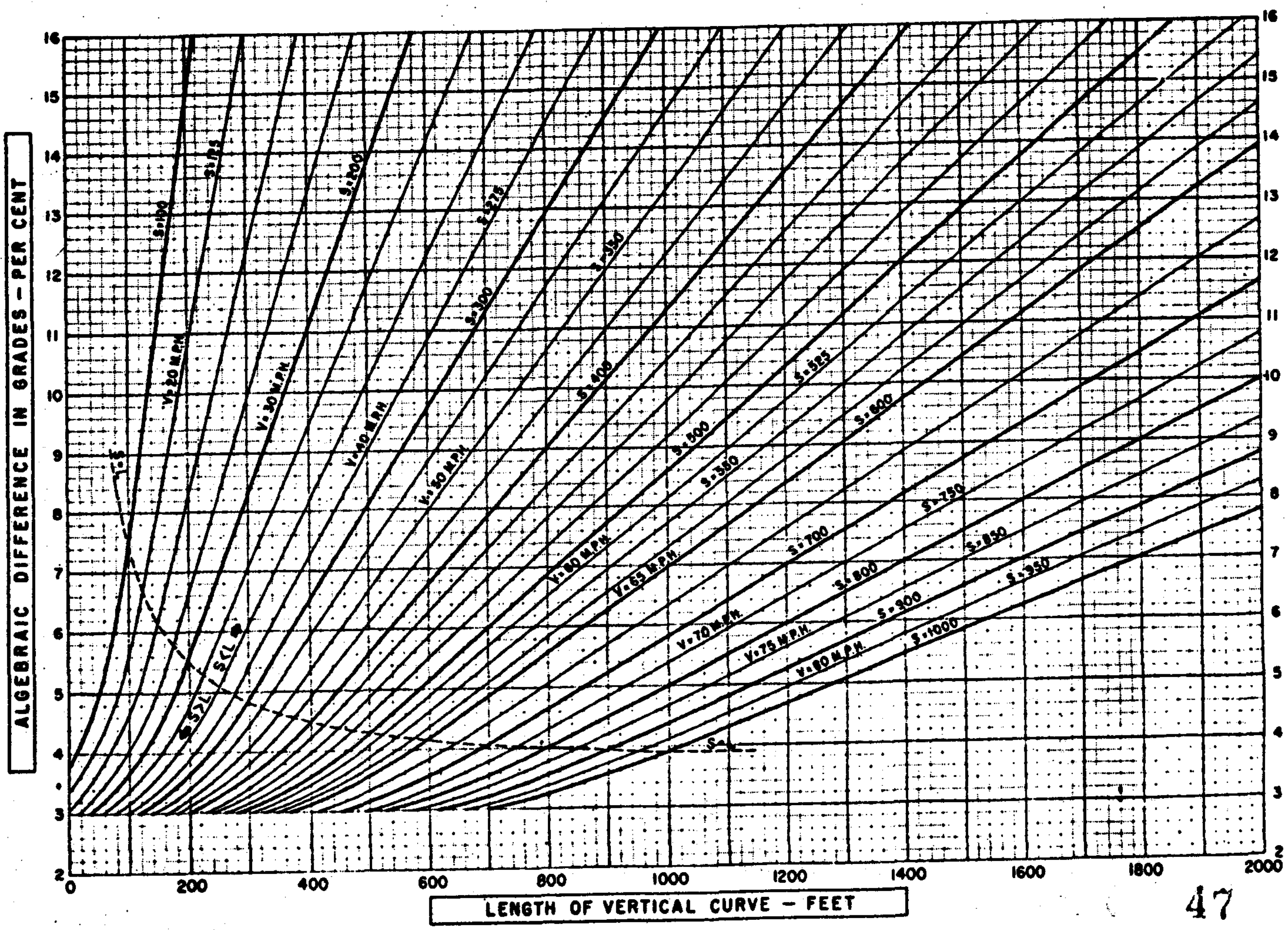
WHEN S > L

$$L = 2S - \frac{400+3.5S}{A}$$

WHEN S < L

$$L = \frac{AS^2}{400+3.5S}$$

DESIGN SPEED M.P.H.	SIGHT DISTANCE FEET
10	125
20	150
30	200
40	275
50	350
60	525
65	600
70	750



Note: Taken from California State Design Manual (Figure 7-201.5)

2-311.4 Stopping Sight Distance Standards on Horizontal Curves - Where an object off the pavement such as a bridge pier, building, cut slope, or natural growth restricts sight distance, the minimum radius of curvature is determined by the stopping sight distance.

Stopping sight distance standards on horizontal curves are obtained from Figure 2-311.4. It is assumed that the driver's eyes are 3.75 feet above the center of the inside lane (inside with respect to curve) and the object is 0.50 foot high. The line of sight is assumed to intercept the view obstruction at the midpoint of the sight line and 2 feet above the center of the inside lane. The clear distance (m) is measured from the center of the inside lane to the obstruction.

The general problem is to determine the clear distance from centerline of inside lane to a retaining wall, bridge pier, abutment, cut slope, or other obstruction for a given design speed. Using radius of curvature and sight distance for the design speed, Figure 2-311.4 gives the clear distance (m) from centerline of inside lane to the obstruction.

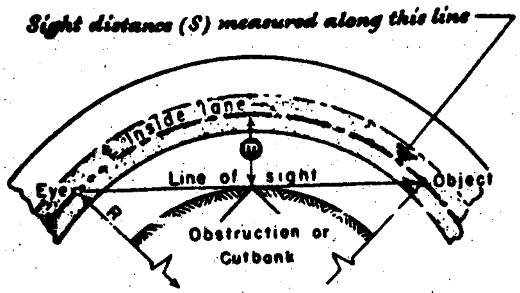
When the design speed and the clear distance to a fixed obstruction are known, this Figure also gives the required minimum radius which satisfies these conditions.

2-311.5 Passing Sight Distance Standards on Crest Vertical Curves - Figure 2-311.5 gives the length of vertical curve required to obtain passing sight distance for a given design speed when the algebraic difference in grades is known.

2-312 Superelevation.

According to the laws of mechanics, a vehicle traveling on a curve exerts an outward force called centrifugal force. Standard superelevation rates are designed to hold the portion of the centrifugal force that must be taken up by

STOPPING SIGHT DISTANCE ON HORIZONTAL CURVES



Height of eye- 3.75 feet . . . Height of object- 0.50 feet

Line of sight is 2.0 feet above ℄ inside lane at point of obstruction

S- SIGHT DISTANCE IN FEET
R- RADIUS OF ℄ INSIDE LANE IN FEET
m- DISTANCE FROM ℄ INSIDE LANE IN FEET
V- DESIGN SPEED FOR S IN M.P.H.

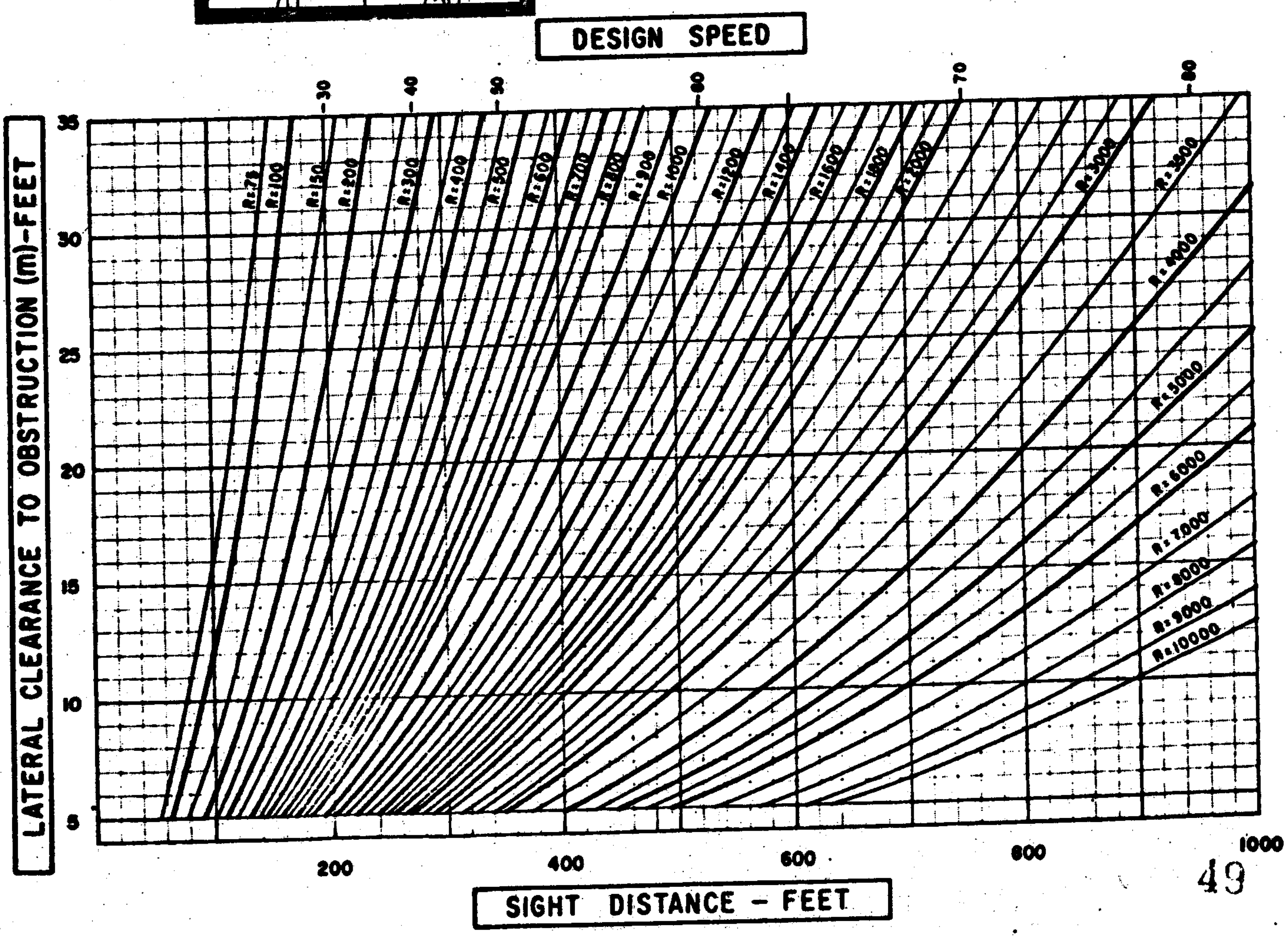
Angle is expressed in degrees

$$M = R\left[\text{VERS}\left(\frac{28.65S}{R}\right)\right]$$

$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R-M}{R}\right)\right]$$

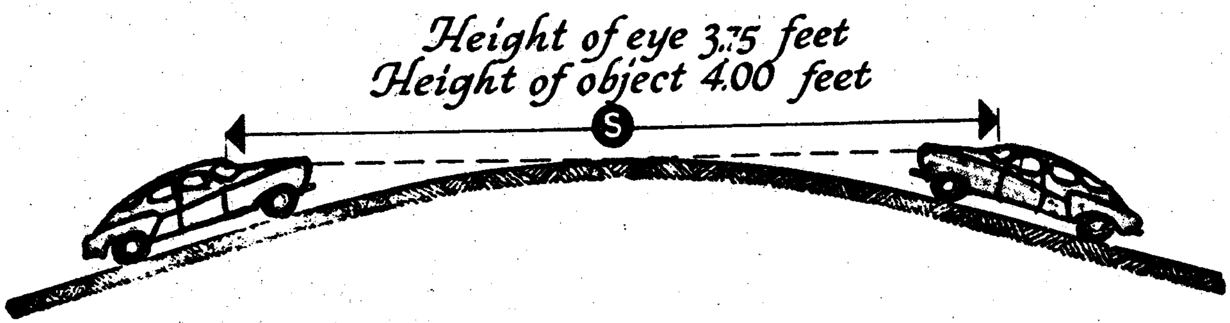
Formula applies only when S is equal to or less than length of curve.

DESIGN SPEED M.P.H.	SIGHT DISTANCE FEET
10	125
20	150
30	200
40	275
50	350
60	525
65	600
70	750



Note: Taken from California State Design Manual (Figure 7-201.6)

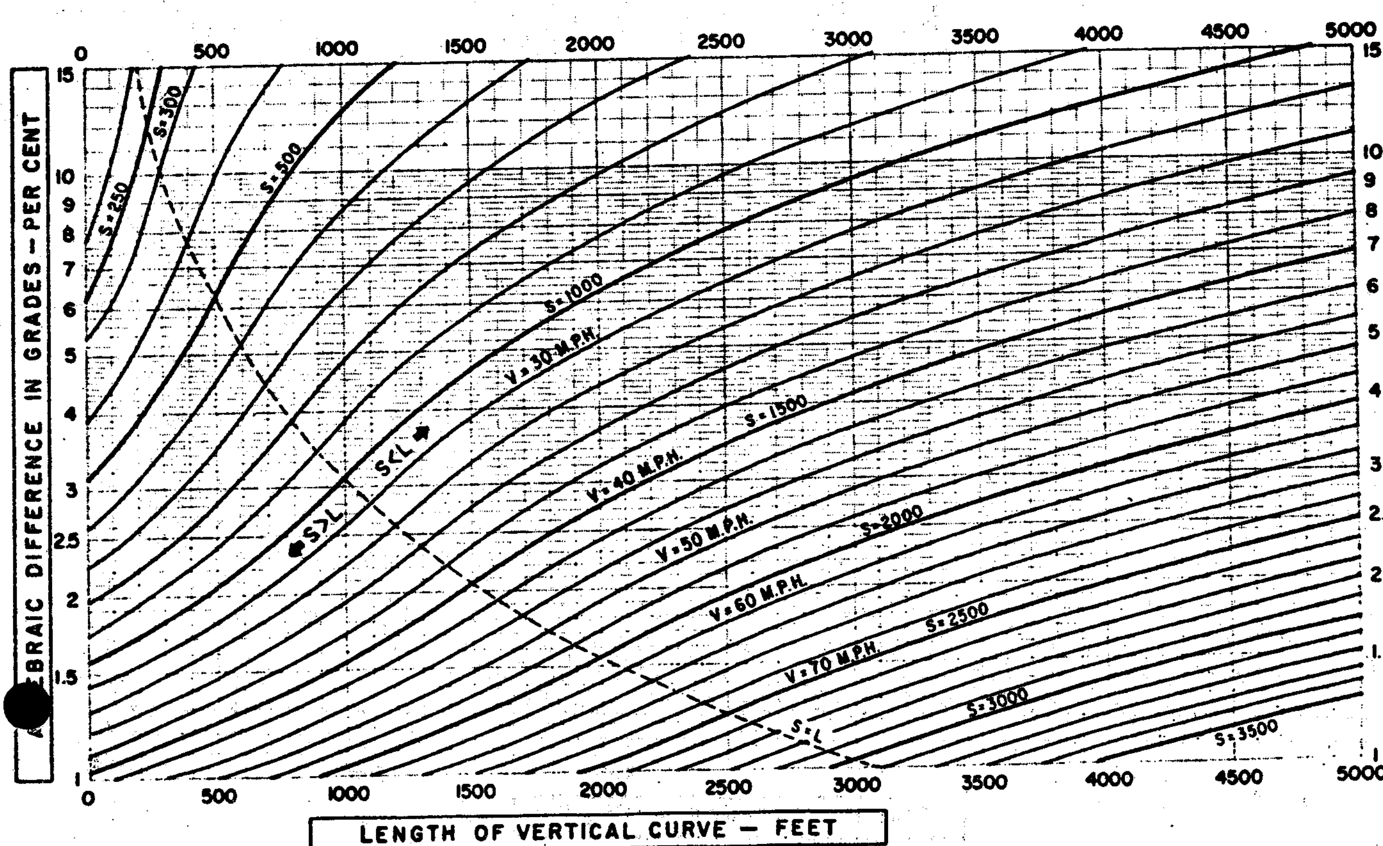
PASSING SIGHT DISTANCE ON CREST VERTICAL CURVES



L = LENGTH OF VERTICAL CURVE IN FEET
A = ALGEBRAIC DIFFERENCE IN GRADE RATE IN %
S = SIGHT DISTANCE IN FEET
V = DESIGN SPEED IN M.P.H. FOR S

WHEN S > L	WHEN S < L
$L = 2S - \frac{3100}{A}$	$L = \frac{AS^2}{3100}$

DESIGN SPEED M.P.H.	SIGHT DISTANCE FEET
30	1100
40	1500
50	1800
60	2100
70	2500



Note: Taken from California State Design Manual (Figure 7-201.2)

tire friction within allowable limits. The limiting safe friction factors related to speed have been found to be as shown in Figure 2-314.1.

2-312.1 Superelevation Standards - For rural high speed roadways, superelevation will not be more than 0.125 foot per foot. The maximum rate for low speed, low volume roads will be 0.06 foot per foot.
Departures from these values may be justified under special conditions such as an increase in superelevation rate on a short radius curve in order to maintain design speed or because of the composition of the surface; i.e., gravel, but in no case shall the rate exceed the maximum of 0.125 foot per foot.

On two-lane roads, it is not advisable to use different superelevation slopes for each half of the roadbed except for design speeds of 30 miles per hour or less when truck traffic is relatively heavy. On grades where trucks cannot maintain the posted speed, it is undesirable to design a maximum superelevation rate.

2-312.2 Relation of Superelevation to Safe Speeds on Curves - Safe speeds for various combinations of curvature and superelevation are obtained directly from Figure 2-314.1.

2-312.3 Snow and Ice Conditions - In some locations, usually above 1500 feet elevation, where snow and ice conditions prevail, it may be necessary to reduce the maximum superelevation to 0.08 foot per foot. Reduction of the standard superelevation rates on curves which require 0.08 foot per foot, or less, is not acceptable. Where snow and ice conditions prevail and on uphill truck lanes, the superelevation will be reduced to maximum 0.08 foot per foot.

2-312.4 Urban Street Conditions - Superelevation should be avoided entirely in urban sections where restricted speed zone or street intersections are controlling factors. In addition, established street grades, curbs, or drainage may prove difficult to alter. Such conditions may warrant, for example, a reduction in the superelevation rate, different rates for each half of the roadbed or both. In warping street areas for drainage, adverse superelevation should be avoided. (See Figure 2-314.1)

2-312.5 Axis of Rotation - For undivided highways, the axis of rotation for superelevation is usually the centerline of the roadbed. However, in special cases where curves are preceded by long relatively level tangents, the plane of superelevation may be rotated about the inside edge of the pavement to improve perception of the curve. In flat country, drainage pockets caused by superelevation may be avoided by changing the axis of rotation from the centerline to the inside edge of the pavement.

The selection of the axis of rotation should always be considered in conjunction with the design of the profile and superelevation transition.

2-312.6 Superelevation Transition - The superelevation transition generally consists of the superelevation run-off (length of roadway needed to accomplish the change in cross slope from a horizontal line to a fully superelevated section or vice versa), the crown run-off, and the remaining 50 feet of the vertical curve as shown in Figure 2-312.6.

A superelevation transition should be designed primarily to satisfy the requirements of safety. Comfort and appearance should also be considered. The length of superelevation transition shall be based upon the combination of the maximum superelevation rate and the design speed of the curve.

2-312.7 Superelevation Transition Standards - Superelevation transition standards are shown on Table 2-312.7.

2-312.8 Superelevation of Compound Curves - Superelevation of compound curves shall follow the procedure as indicated in the State Design Manual.

SUPERELEVATION TRANSITION

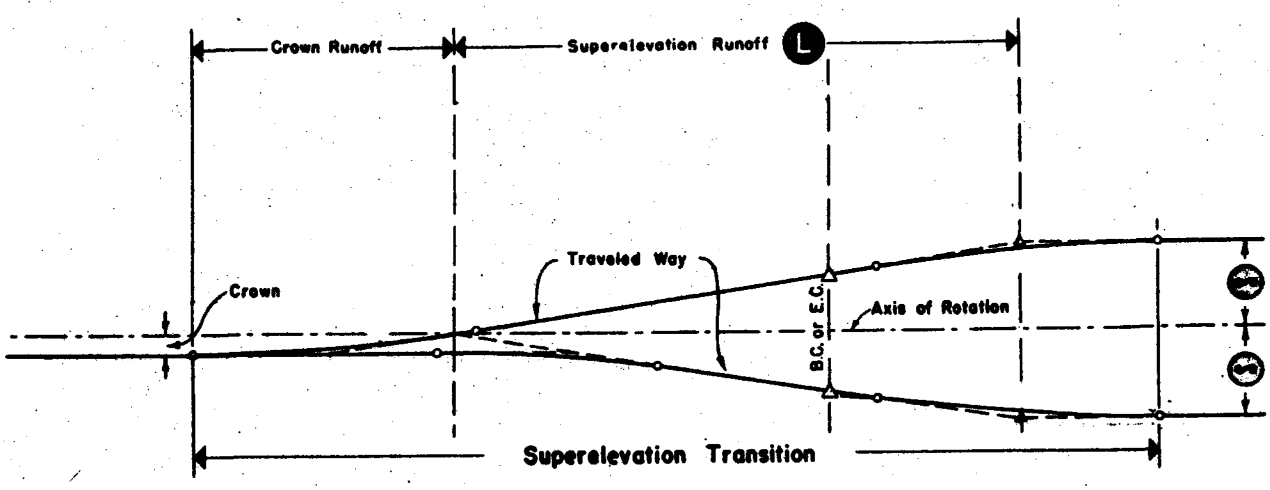


TABLE 2-312.7

MINIMUM LENGTH STANDARDS FOR
SUPERELEVATION RUNOFF FOR TWO-LANE PAVEMENTS

Superelevation Rate "S" Foot/Foot	L - Length of Runoff in Feet Design Speed, MPH of:				
	20	30	40	50	60
.02	50	100	125	150	175
.04	50	100	125	150	175
.06	50	110	125	150	175
.08	50	145	170	190	215
.10	50	180	210	240	270
.12	50	215	250	290	325

2-313 Traveled Way Crown.

The crown or center of a two-lane roadway is designed to be higher than the edges of the roadway in order that water will drain off of the road into the drainage system. On surfaced roads (Asphalt Concrete or Seal Coat) proper crowns may be specified; however, construction practices and technology do not always guarantee adequate crown. The tendency to drive in the center of the road may cause "compacting" of crowns on roads. On unsurfaced roads, maintenance practices such as grading also contribute to the destruction of the crown.

It is difficult to retain a proper crown on an unsurfaced road because in many cases the "surface" material is of poor quality, therefore, proper grading may not be sufficient to hold the crown. Secondly, the tendency is for drivers to drive near the center of the road (especially on low-volume roads) and as a result, a properly constructed crown will be compacted to a point where little or no crown remains.

Because of the quantity of rainfall which the County receives, improper crowns result in improper drainage, which may result in:

- Rapid road deterioration,
- Ponding of water, and
- Slippery surface and hydroplaning.

Where the roadway width is narrow, such as on one-lane roads, a one-way slope is advised rather than a crown. One-way slopes normally should have the low side located on the uphill side of the road.

2-313.1 Cross Slope Standards - Cross slopes will be four percent (4%) on non-surfaced County roads. A two percent (2%) slope will only be acceptable if the surface material is high quality Asphalt Concrete and construction equipment is such that no less than a two percent (2%) slope is consistently achieved.

2-314 Horizontal Alignment.

Horizontal alignment should provide for safe and continuous operation at a uniform design speed for substantial lengths of roadway. The standards which follow apply to curvature on both two-lane and multi-lane highways except when otherwise noted.

The major considerations in horizontal alignment design are: safety, grade profile, type of facility, design speed, topography, construction and maintenance cost. Topography controls both curve radius and design speed to a large extent. The design speed, in turn, controls sight distance, but sight distance must be considered concurrently with topography because it often demands a larger radius than the design speed.

2-314.1 Standards for Curvature Alignment - Following is a Table which gives the minimum radius of curve for specific design speeds. This Table is based upon speed alone; it ignores the sight distance factor.

Horizontal alignment must afford at least the minimum stopping sight distance for the design speed at all points on the highway, as given in Table 2-311.1.

Curve widening shall be considered on low radius curves in order to compensate for off tracking characteristics of trucks and trailers.

TABLE 2-314.1

STANDARDS FOR CURVE RADIUS

Design Speed (Miles Per Hour)	Minimum Radius of Curve (Feet)
20	120
30	300
40	550
50	850
60	1150
70	1800

The safe speed for a particular curve is controlled by the radius and the superelevation. Safe speeds for various combinations of radius and superelevation are given in Figure 2-314.1. In design, this chart is used together with Figure 2-311.4 to provide a safe curve.

2-314.2 Compound Curves - Compound curves should be avoided, however, when required the shorter radius should be at least two-thirds the longer radius when the shorter radius is 1000 feet or less. The total arc length of a compound curve should be not less than 500 feet.

2-314.3 Reversing Curves - Reversing curves without an intervening tangent may be permitted. Severe physical restrictions may dictate the use of curves in opposite directions with a short intervening tangent.

2-314.4 Alignment at Bridges - Curves beginning or ending near a bridge should be so placed that no part of the superelevation transition extends onto the bridge. Compound and/or reversing curves on a bridge are undesirable. If curvature is unavoidable, the bridge should be entirely on a simple curve as flat as physical conditions permit.

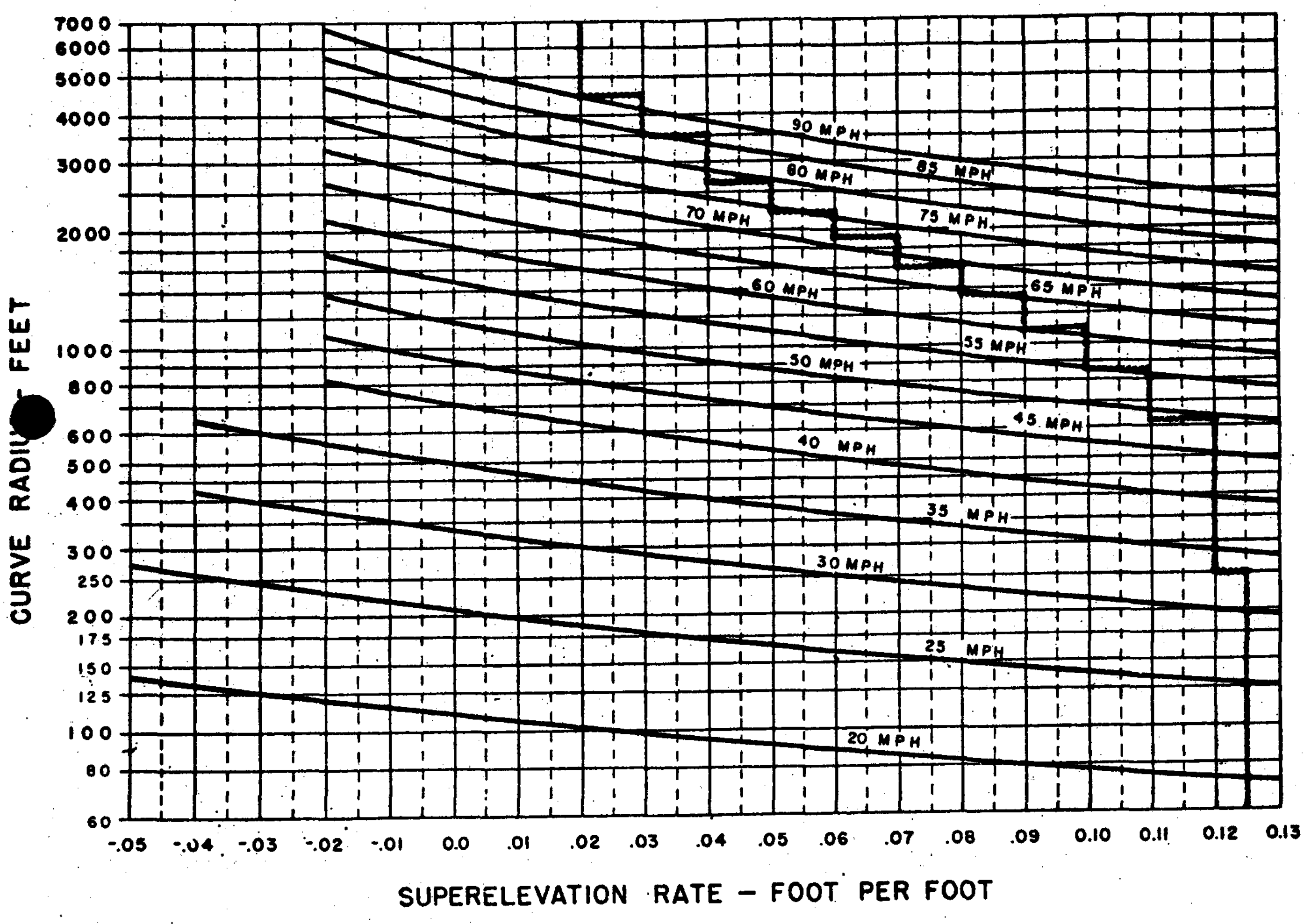
2-315 Gradient (Grade).

The grade line is a reference line by which the elevation of the pavement and other features of the highway are established. It is controlled mainly by topography, by the type of highway, horizontal alignment, safety, sight distance, construction costs, drainage, and maintenance. The performance of heavy vehicles on a grade also must be considered.

All portions of the grade line must meet sight distance requirements for the design speed classification of the road.

2-315.1 Grade Standards - The maximum grade rate will be 12 percent. The minimum will be 0.5 percent in snow country and 0.12 percent at other locations. Except for conventional highways in areas subject to urbanization, a level grade

LIMITING SPEED ON HORIZONTAL CURVES



SPEED	FRICTION FACTOR
20	0.24
30	0.18
40	0.15
50	0.14
60	0.13
70	0.12

S-SUPERELEVATION F-FRICTION FACTOR V-SPEED IN MILES PER HOUR R-RADIUS IN FEET	$S+F = \frac{0.067V^2}{R}$

Note: Taken from California State Design Manual (Figure 7-203.2)

line is permissible in level terrain where fills are shallow enough to call for side slopes of 4:1 or flatter and the dike is omitted.

Table 2-315.1 contains the maximum recommended grades for various types of terrain and differing design speeds.

TABLE 2-315.1

MAXIMUM GRADES

(Percentage)

Type of Terrain	Design Speed (MPH)				
	20	30	40	50	60
Flat	7	7	7	6	5
Rolling	10	9	8	7	6
Mountainous	12	10	10	9	

Note: For highways with ADTs below 250, grades of relatively short lengths may be increased to 150 percent of the value shown.

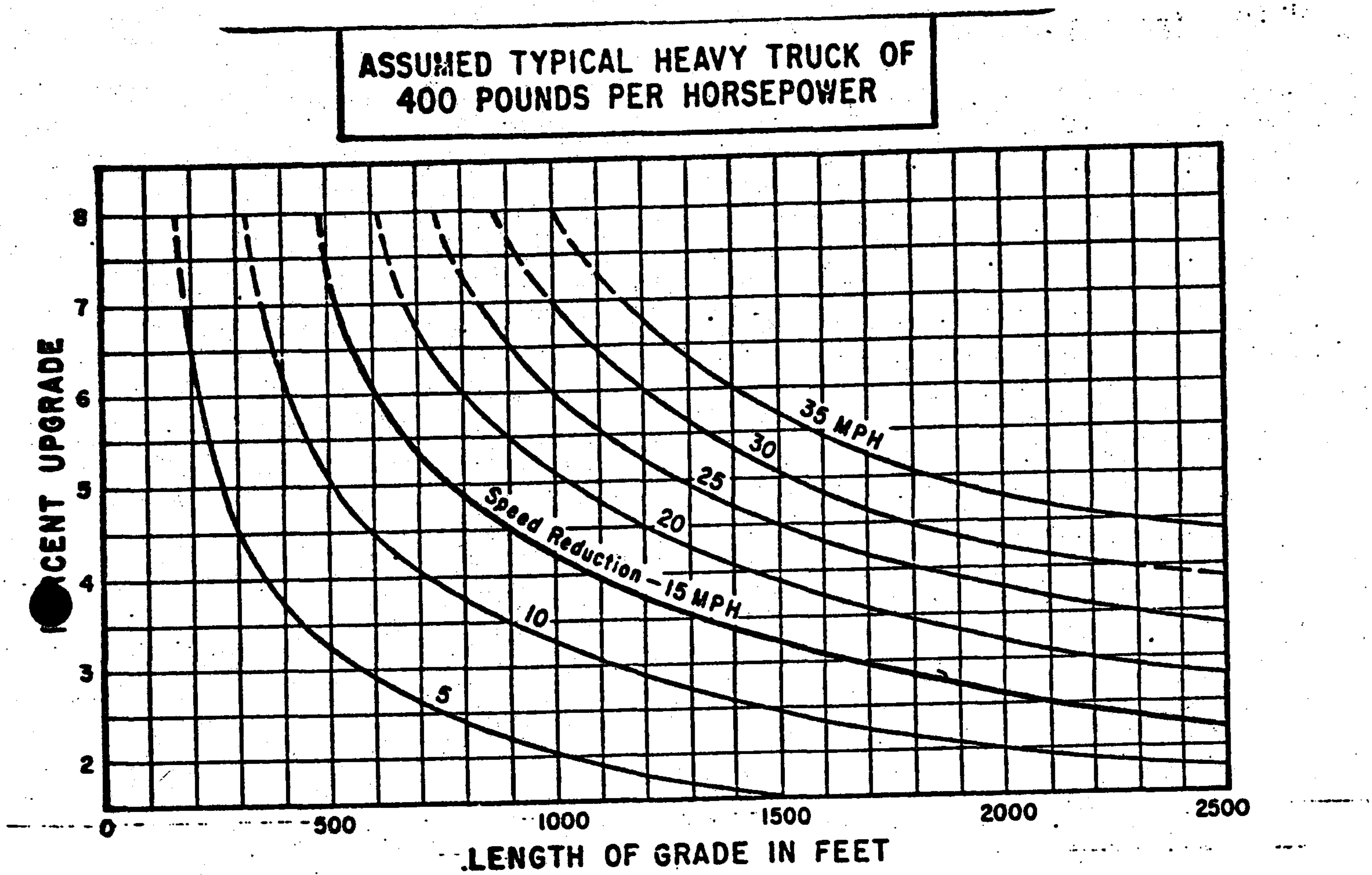
2-315.2 Critical Length of Grades.

Figure 2-315.2 gives the critical length of grade tangent related to percent upgrade and speed reduction. For ordinary design purposes, a 15 mile per hour speed reduction curve will be used.

2-315.3 Grade Line at Structures - (See State Design Manual).

Figure 2-315.2

CRITICAL LENGTHS OF GRADE FOR DESIGN



Note: Taken from California State Design Manual (Figure 7-204.6)

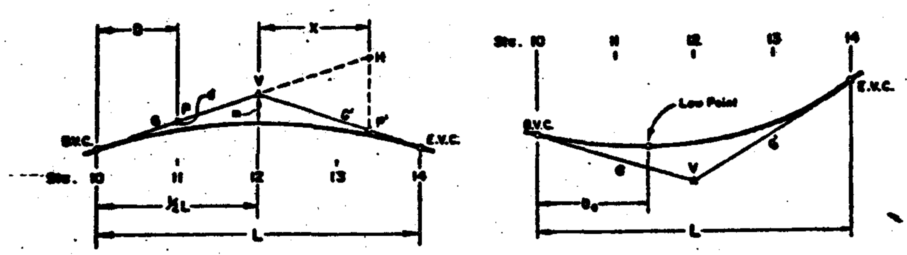
2-316 Vertical Curves.

Properly designed vertical curves should provide adequate sight distance, comfortable driving, good drainage, and pleasing appearance.

2-316.1 Vertical Curve Standards - A parabolic vertical curve is used. Figure 2-316.1 gives all necessary mathematical relations for computing a vertical curve, either at crests or sags. In lieu of the method shown, the rate of change of grade per station may be used in computations.

For design speeds of 40 miles per hour or more, the minimum length of vertical curve normally shall be 400 feet. For 30 miles per hour design speed, it should be 200 feet whenever feasible. As flat vertical curves may develop poor drainage at the level section, this difficulty may be overcome by a slight gutter grade adjustment or by shortening the vertical curve.

FIGURE 2-316.1 - VERTICAL CURVES



IN ANY VERTICAL CURVE | **WHERE**

1. $m = \frac{(G'-G)L}{8}$
2. $m = \frac{1}{2}\left(\frac{\text{Elev. B.V.C.} + \text{Elev. E.V.C.}}{2} - \text{Elev V}\right)$
3. $d = m\left(\frac{D}{L/2}\right)^2 = \frac{4m}{L^2}D^2$
4. $d = \frac{D^2(G'-G)}{2L}$
5. $X = \frac{100(H-P')}{(G-G')}$
6. $S = G-D\left(\frac{G-G'}{L}\right)$
7. $D_0 = \frac{LG}{G-G'}$

L = Length of curve — 100 ft. units or stations.

G and G' = Grade rates — percent.

m = Middle ordinate — ft.

d = Correction from grade line to curve — ft.

D = Distance from B.V.C. or E.V.C. to any point on curve — stations.

S = Slope of the tangent to the curve at any point — percent.

X = Distance, from P' to V — ft.

H = Elevation of grade G produced to station of P'

P and P' = Elevation on respective grades.

D_0 = Distance to low or high point from extremity of curve — stations.

NOTES

A rising grade carries a plus sign while a falling grade carries a minus sign.

Thus in a crest vertical curve as above, G carries a plus sign and G' a minus sign when progressing in the direction of the stationing. When progressing in the opposite direction, G becomes a minus grade and G' a plus grade.

2-320 Geometric Cross Section Elements.

2-321 Roadway Geometrics. There are three basic elements of roadway design cross section geometrics:

(1) Traveled Way,

(2) Shoulder, and

(3) Roadbed.

Traveled way width is the roadway area utilized by moving vehicles if surfaced or, if the road is unsurfaced, it is that area that is maintained expressly for the use of moving vehicles.

Shoulder width is measured from the edge of traveled way to either the inner edge of the gutter or to the ditch, berm or curb. Roadbed width is measured from cut and/or fill hinge point to hinge point. The following diagram illustrates the limits of each cross section dimension as defined above, plus right of way which is discussed in Section 2-322.

2-321.1 <u>Cross Section Standards</u> - Minimum and maximum cross section standards for the various roadway categories shall be as shown on Table 2-321.1.

TABLE 2-321.1

ROADWAY CROSS SECTION STANDARDS

Roadway Category No.	Description	Traveled Way * Width (Feet)	Shoulder Width (Feet)	Roadbed ** Width (Feet)
1	Single Lane - Narrow	10	-0-	12
2	Single Lane-Turnouts	10-12	-0-	12-16
3	Single Lane - Wide	16	-0-	18-20
4	Two Lane - Narrow	18-20	4 @	22-30
5	Two Lane - Wide	24	4 @	32-40
6	Two Lane - Wide (Roadway Parking)	24	8	40-60
7	Multiple Lanes ***	12' Lanes	See State Manual	

@ When required. Shoulders should be provided when a transitional area is required between the surface and the natural ground level as a safe place of refuge for the vehicle operator during a traffic emergency. Also, when lateral support above that provided by the base is required, shoulders may be needed.

* Surface width if paved.

** Roadbed includes, improved shoulder, unimproved shoulder, backup, walkways, slide bench, berm or dike, and ditch or gutter. (hinge point to hinge point)

*** Turning lanes will be 12 feet. For 4 or more lane highways, see State Design Manual.

2-321.2 <u>Constant Cross Section</u> - A constant cross section need not be maintained for the full length of the road or the road segment. However, when varying roadway widths are considered, the effect upon safety must be evaluated. Traffic control devices, warning signs, etc., should be utilized when constant cross sections are not maintained.

2-321.3 Turnouts - Turnouts will be designed to be long enough to accommodate the largest legal vehicle and wide enough to eliminate potentially dangerous conflicts at the roads design speed. The tapered section at both ends of the turnout will be designed to allow safe transition from the traveled way onto the turnout section.

Turnouts should be located on curves where conflicting vehicles have difficulty backing to the nearest widened section and other areas where sight is restricted. The distance between turnouts on low-volume roads (less than 100 ADT) is relatively unimportant provided they are intervisible.

TABLE 2-321.3

TURNOUT STANDARDS

Design Element	Standard
Length	80 Feet (Plus Length for Tapers)
Width	10 Feet
Distance Between	1000 Feet (Maximum)
Desired Location	At Curves
Note: See Section 7, Roadway Category 2 for other standards for turnout roads.	

2-322 Roadside Geometrics.

2-322.1 Right of Way - The procurement of rights of way to such widths as will accommodate the proposed construction, adequate drainage and proper maintenance of a roadway is a most important part of the overall design. Adequate rights-of-way permit the construction of desired slopes resulting in more safety for the motorist and economical maintenance.

2-322.2 Right of Way Width Standard - The California Streets and Highways Codes specify that new roads will not be designed or built with less than a 40-foot right of way. The width of right of way depends on the cross section elements of the roadway, topography, geology, and other physical controls together with economic considerations. Generally, the right of way should extend a minimum of 10 feet beyond the slope catch point in rural areas, or to the back of the walkway in urban areas. In developed areas, it may be more feasible to limit the right of way width to a practical minimum and secure construction easements.

2-322.3 Shoulder Slope Standard.

In a normal crown section, shoulders 6 feet or more in width should slope on a 5 percent grade away from the traveled way. On high speed roadways the slope should be identical to the superelevation rate. Higher or lower slope rates may be considered when shoulders are less than 6 feet wide to accomodate drainage or maintenance requirements.

2-322.4 Dikes Standards.

Dikes are to be used to confine drainage only where it is necessary to protect side slopes susceptible to erosion. Dikes on the high side may be used for protecting the slope in unstable areas.

A high dike is approximately 0.5 foot high and is made of compressed asphalt concrete. On fills, dikes are desired when the side slopes are steeper than 4:1 to control slope erosion.

2-322.5 Side Ditch Standards.

Side ditches are commonly used on the high side of a superelevated curve or where local drainage conditions require their use. For maintenance purposes, the slope from the edge of the shoulder to the bottom of the ditch should not be steeper than 3:1, nor over 1-foot deep at a slope steeper than 6:1.

2-322.6 Side Slope Standards.

Side slopes should be designed for functional effectiveness and ease of maintenance. A desirable minimum for cut slopes is 1:1; however, the geological composition should be considered. Extensive variations from existing slope rates should be allowed only after geological investigation and analysis. Fill slopes should be 1-1/2:1 or flatter. Flatter slopes are desirable in areas of instability, on high speed roadways, and for low fills in flat country where excavation quantities are in excess. Consideration should be given to general maintenance practices; and in snowfall areas to snow removal and snow storage problems.

2-322.7 Slope Bench and Cut Widening Standards.

The necessity for benches, their width and vertical spacing shall be established only after an adequate materials investigation. Benches should be at least 20 feet wide and sloped to form a valley at least 1-foot deep with the low point a minimum of 5 feet from the toe of the upper slope. Outsloping should be considered where benches are needed. They can simplify drainage and maintenance providing erosion does not become the controlling factor. Consideration should be given to utilization of techniques to reduce erosion problems and to encourage rapid vegetation growth on cut slopes (i.e., serrated slopes).

2-330 Clearance Standards.

2-331 Horizontal Clearances to Piers, Abutments and Retaining Walls.

The horizontal clearance to bridge piers, abutments and retaining walls shall be determined upon the basis of engineering judgment with the objective of eliminating fixed objects from near the edge of shoulder wherever economically feasible. A horizontal clearance of 30 feet or more from the edge of the traveled way is desired. Lesser clearances may be used where span length, median width or other controls make the desired clearance unreasonable.

2-332 Horizontal Clearances to Obstructions.

On a road with an ADT of 750 or more, and with a design speed of 50 miles per hour, or greater, a clear roadside area should be provided 10 feet or more outside the shoulder. Where the design speed is less than 50 miles per hour, or ADT is less than 750, a clear roadside area should be provided 10 feet or more from the edge of the through traffic lane. (Applicable to objects such as signs, trees, etc.)

2-333 Vertical Clearances.

The minimum vertical clearance will be 16 feet at all points on the surface of the roadway.

2-334 Clearance Standards From Slope to Right of Way Line.

The minimum clearance from the right of way line to the catch point of a major cut or fill slope will be a minimum of 10 feet for all types of cross sections. There may be exceptions such as more clearance for drainage or less clearance due to building lines.

2-340 Intersections at Grade.

Most roadways intersect at grade. The intersection area is an integral part of each roadway. In varying degrees, four principle factors determine the character of an intersection. These factors are traffic, physical, economic and human.

Traffic factors to be considered include: possible and practical capacities, turning movements, size and operating characteristics of vehicles, control of movements at points of intersection, vehicle speeds, pedestrian movements, transit operations and accident experience.

Physical factors which control intersection design and the application of channelization are topography, improvements and physical requirements for highway and channelization features.

Economic factors, which are important and often controlling, include the cost of the improvement and the economic effect on abutting businesses where channelization restricts or prohibits certain vehicular movements within the intersectional area.

Human factors such as driving habits, ability of drivers to make decisions, effect of surprise, decision and reaction times, and natural paths of movement must be considered.

2-341 Corner Sight Distance Standards - The minimum corner sight distance at intersections will be 100 feet for every 10 miles of design speed (30 miles per hour design speed = 300 feet sight distance). The alignment design should be adjusted so as to avoid an angle of intersection of less than 45 degrees in rural areas and 60 degrees in urban areas.

2-342 Intersection Design Procedures - Intersection design procedures, channelization design standards and typical intersection designs are located in Section 7-400 of the State Design Manual. Channelization and intersection design shall be coordinated with the Traffic Section.

2-350 Traffic Interchanges.

A traffic interchange is a combination of ramps, grade ramps and grade separations at the junction of two or more roadways for the purpose of reducing or eliminating traffic conflicts. Safety and traffic capacity are increased by the provision of a traffic interchange. Crossing conflicts are eliminated by grade separations. Turning conflicts are either eliminated or minimized, depending upon the type of interchange design.

The selection of an interchange type and its design are influenced by many factors including the following: the speed, volume, traffic movement and composition of traffic to be served, the number of intersecting legs, the standards and arrangement of the local street system including traffic control devices, topography, right of way controls, local planning, proximity of adjacent interchanges, community impact consideration and cost.

Interchange types are characterized by the basic shapes of ramps, namely: diamond, loop, directional, or variations of these types. Many interchange designs are combinations of these basic types. They are classified as (a) local street interchanges and (b) freeway-to-freeway interchanges (or expressway-to-expressway).

Where traffic interchanges are considered, channelization or turn pockets should be also considered as perhaps more practical or economical solutions.

2-351 Design Standards and Procedures - Procedures for the determination of interchange type, interchange design standards, typical illustrative designs and detailed design procedures can be found in Section 7-500 of the State Design Manual.

2-360 Maintenance Considerations.

Throughout the Manual, occasional direct and indirect references are made to roadway maintenance considerations. In order to assist the designer in his efforts to design a road or roadway improvement which will be efficiently and economically maintainable, conditions are listed on Table 2-360 which will remind him of maintenance problems that can result from improper design and/or construction practices. These conditions should be reviewed periodically throughout the design project as a means of promoting awareness of the importance of roadway maintenance.

TABLE 2-360

ROADWAY CONDITIONS WHICH CAN RESULT FROM UNDESIRABLE DESIGN OR CONSTRUCTION PRACTICES

Conditions
Drainage structures too large or too small.
Right of way too narrow.
Inadequate shoulder width (surfaced roads).
Improper surface type for traffic volume and base thickness.
Inadequate materials (quality).
Crossdrain too flat.
Berms improperly located.
Utilities improperly installed.
Inadequate structural section (depth)
Design speed too high for surface type.
Deep cut, not benched.
Inadequate head room (drainage structures).
Curves too sharp.
Improper type of drop inlet (DI).
Inadequate crown.
Traveled way too narrow for equipment.
Improper placement of drop inlet (DI).
Cut slopes too steep.
Gutters too flat.
No downdrains (where necessary).
Outlet channels inadequate.
Superelevation rate too steep or too flat.
Gutters too narrow and too steep.
Cut slopes too flat.
Downdrain too short.
Crossdrains placed too shallow.
Crossdrains placed too deep.
Crossdrain too steep.
Grade too flat (poor drainage).
Grade too steep (materials loss).
Roadway elevation too low (drainage problem).
Frequent grade changes (many rolling hills or vertical curves).
Traveled way too wide.
Berms made of improper material.
Roadway elevation too high.
Improper placement of curves.
Right of way too wide.
Improper location or connection to County roads.
Inadequate entrance to drop inlet or culvert.

SECTION 3 - STRUCTURAL DESIGN

3-100 General.

Structural design of the roadbed is concerned with the determination of the optimum combination of pavement and/or underlying layers for each unique set of road conditions or requirements. The optimum design is the combination that is estimated to give the most economical service consistant with traffic requirements (actual or projected). "Most economical service" is defined as the lowest cost per mile per year for initial construction and maintenance of a road which provides the desired service.

The goal in structural design is the selection of the most suitable available materials and combining them in such a manner that the most benefit will be derived from the inherent qualities of each material. In establishing the depth of each layer, the objective is to provide a minimum thickness of overlying material that will reduce the unit stress on the next lower layer commensurate with the load carrying capacity of the material within that layer.

All roads, unless posted with load limits, shall be designed to carry legal loads. The posting of certain County roads to lower than legal loads may be considered. In conjunction with the permit system, lighter sections could be used on residential streets if trucks are prohibited.

The maximum design period for structural sections shall be 20 years. The designing of structural sections for less than 20 years is desirable in many instances. For example, structures to support temporary logging activities, roads in high flood risk areas, and lightly traveled roadways may be designed for less than 20 years. The minimum design period shall be five years.

The design of the roadbed structural section is not an exact science. The many variables to be correlated make it impossible to reduce the total problem to exact mathematics. Present practice, some of which is discussed herein, stems from empirical relationships developed from test track and other pavement experiments as well as the observation of pavements under actual service. Continual research is under way on this subject, and present design methods may be subject to periodic modification. Extensive use of the County's laboratory testing facilities is encouraged to take advantage of recent technological advances.

Humboldt County, along with other counties in the northwestern United States, has a particularly acute problem with regard to structural design in that satisfactory native materials for optimum roadway construction are in short supply. The acute drainage problem in the County also contributes to the structural design problem. High volumes of water rushing over or under low quality building materials at high velocities results in frequent washouts and major damage. Since the cost of importing high quality aggregates is high, extra care must be taken by the designer (with help from the laboratory) to specify the best combination of imported or local materials or material treatment processes to satisfy structural needs and provide maximum economy of construction and maintenance.

3-101 <u>Objective and Scope</u>.

The objective of this Section is to present policies, technical data and practices for the design of the structural section of the roadway. In structural design, it is impractical to restrict engineering alternatives with too many inflexible standards. Therefore, information contained herein is to be interpreted more as "guideline" in nature. Basic concepts, factors involved in structural design, types of structural sections and notes on desirable practices are all included in this Section.

3-102 Policy.

3-102.1 Design Life - It is the policy of Humboldt County to consider the advantages of design life (20, 15, 10, or 5 years), taking into consideration the variables of geology, functional classification criteria and maintenance requirements and capabilities.

3-102.2 Materials - It is the policy of Humboldt County that all designs for new roads or improvements to existing roads will specify materials requirements (quality and quantity) based upon a materials report from the County laboratory. Any planned deviations from these material specifications must be approved by the Director of Public Works.

3-102.3 Surface Types - It is the policy of Humboldt County that County Arterials (County Classification System) will be designed to have an Asphalt Concrete (A.C.) surface. For all other classification of roads, the surface type will depend upon traffic volumes, topography, economic and other considerations. Seal Coat applications will be applied only to structural sections designed to support the designed volumes and composition.

3-110 General Surface Types.

Bituminous mix pavements, penetration treated earth or untreated gravel and unsurfaced graded sections are the three types of traveled way surface used by the County. Portland Cement concrete will not be used primarily because of a lack of adequate soil stability and its high initial cost.

3-111 Selecting Type of Surface.

The selection of the appropriate surface type when designing a new roadway or an improvement should be based upon consideration of the following factors:

(1) Type, quality and quantity of basement, and subbase materials,

(2) Existing surface (if an improvement),

(3) Roadway classification (County System),

(4) Traffic volumes,

(5) Cost of construction and maintenance,

(6) Type of traffic (automobiles versus heavy trucks), and

(7) Geological conditions.

Table 3-111A shows construction costs for various widths and thicknesses of asphalt concrete and double seal coat surfaces. Table 3-111B is a cost index which expresses the relative costs as measured against a surface 0.15 foot thick and 24 feet wide. Table 3-111C expresses the relative average annual costs (in the form of index values) to build and maintain various widths of road with different types of surfacing. Relative surface maintenance costs for different surface types and widths are also expressed as index values as part of Table 3-111C.

Decisions regarding which type of surface to provide should be supported by an analysis of the relative costs involved, using the above-referenced Tables and other relevant cost data. The basic assumptions made while developing these costs, must be clearly understood before they are applied. These assumptions are included as Figure 3-111D.

The cost tables will be revised periodically to reflect current costs.

HUMBOLDT COUNTY

Construction Cost Comparisons/mile
Asphalt

Width (ft.)	Asphalt Concrete* Thickness (ft.) 0.1	0.15	0.3	0.5	1.0	Double Seal Coat
10	$ 6,100	$ 9,300	$14,600	$ 24,300	$ 48,500	$ 7,800
12	7,300	11,100	17,600	29,200	58,200	9,300
14	8,600	12,900	21,000	34,100	68,100	11,400
16	9,800	14,800	23,500	38,900	77,800	12,900
18	11,100	13,300	26,400	43,800	87,500	14,250
20	12,300	14,700	29,300	48,600	97,200	15,700
22	13,500	16,200	32,200	53,500	106,900	17,150
24	14,800	17,700	35,200	58,400	116,600	19,300
28	13,900	20,700	41,000	68,200	136,000	22,100
30	14,800	22,200	43,900	73,000	145,700	23,550
32	15,900	23,700	46,900	78,000	155,400	25,700
40	19,800	30,000	58,500	97,400	194,200	31,350
42	20,800	30,900	61,600	102,300	204,100	33,500

*Includes Prime Coat Costs

(1970-71)

Comparative
Cost Index

Asphalt (1.0=24 ft. x 0.15 ft.)

Width (ft.)	Thickness (ft.) 0.1	0.15	0.3	0.5	1.0	Double Seal Coat-No Prime
10	0.3	0.5	0.85	1.4	2.7	0.4
12	0.4	0.6	1.0	1.65	2.75	0.5
14	0.5	0.75	1.2	1.9	3.85	0.6
16	0.55	0.85	1.35	2.2	4.4	0.7
18	0.6	0.8	1.5	2.5	4.9	0.75
20	0.7	0.85	1.65	2.75	5.5	0.8
22	0.8	0.9	1.8	3.0	6.0	0.9
24	0.85	1.0	2.0	3.3	6.6	1.0
28	0.8	1.2	2.3	3.85	7.7	1.15
30	0.85	1.3	2.5	4.1	8.2	1.2
32	0.9	1.35	2.65	4.4	8.75	1.4
40	1.1	1.7	3.3	5.5	9.85	1.6
42	1.2	1.75	3.5	5.8	11.5	1.8

Numbers rounded to 0.05

(1970-71)

Table 3-111B

COUNTY OF HUMBOLDT

DEPARTMENT OF PUBLIC WORKS

ERVICE LIFE AND SURFACE MAINTENANCE COST COMPARATIVE INDEXES

Table 3-111C

SERVICE LIFE INDEX

Initial Construction and Annual Maintenance Costs for Expected Life of Road

Traveled Way Width (feet) / Roadbed Width	Surface Type	INDEX VALUES: Base Road 24/32 ft. Asphalt Concrete	INDEX VALUES: Base Road 10/12 ft. Gravel
10/12	Gravel**	0.44	1.00
12/14	Gravel	0.50	1.14
14/16	Gravel	0.54	1.23
16/18	Gravel	0.65	1.48
16/18	Seal Coat	0.97	2.20
16/20	Gravel	0.71	1.61
16/20	Seal Coat	1.03	2.34
18/22	Gravel	0.76	1.73
18/22	Seal Coat	1.13	2.57
18/22	A.C.	0.75	1.70
18/26	Seal Coat	1.28	2.91
18/26	A.C.	0.82	1.86
20/24	Seal Coat	1.25	2.84
20/24	A.C.	0.80	1.82
20/28	Seal Coat	1.39	3.16
20/28	A.C.	0.88	2.00
22/26	Seal Coat	1.36	3.09
22/26	A.C.	0.86	1.95
22/30	Seal Coat	1.50	3.41
22/30	A.C.	0.94	2.14
24/32	Seal Coat	1.61	3.66
24/32	A.C.	1.00	2.27

** Gravel and native earth costs are averaged together.

SURFACE MAINTENANCE COST INDEX*

SURFACE MAINTENANCE OF DIFFERENT SURFACE TYPES AND ROADBED WIDTHS

Surface Width (feet)	100 or Fewer Vehicles Per Day Index Values — Surface Type: Gravel	Seal Coat	Asphalt Concrete	Surface Width (feet)	400 Vehicles Per Day Index Values — Surface Type: Seal Coat	Asphalt Concrete
14	0.88	1.14	0.67	14	3.50	2.00
16	1.17	1.10	0.62	16	3.05	1.67
18	1.17	1.00	0.57	18	2.52	1.31
20	1.17	0.88	0.52	20	2.05	1.00
22	1.17	0.74	0.43	22	1.48	0.62
24	1.31	0.83	0.48	24	1.57	0.69
26	1.31	0.88	0.52	26	1.62	0.74
28	1.31	0.88	0.52	28	1.62	0.74
				30	1.67	0.79
				32	1.71	0.79

* Base for Surface Maintenance Index is 18-foot seal coat road having a traffic volume of 100 vehicles per day or fewer. Costs are average annual costs.

HOW TO USE THE SERVICE LIFE AND SURFACE MAINTENANCE COST INDEXES

1. Service Life Index - The purpose of this index is to relate the appropriate costs to construct and maintain various widths and types of roads over the expected life of the road. For example, if you wish to compare the long term costs of a road with a 24-foot roadbed and a 20-foot wide asphalt concrete surface with a road having a 26-foot roadbed with a 22-foot seal coat surface, you may use either of two indexes. The first index has a base number (1.00) corresponding to the highest surface type (asphalt concrete) and the widest road depicted in the index (32-foot roadbed - 24-foot surface). The second index has a base (1.00) which corresponds to the lowest type of surface (gravel or native earth) and the narrowest road used for the index (12-foot roadbed - 10-foot surface).

   Using the high type road as a base, Road 1 in our example (24-foot roadbed - 20-foot A.C. surface) has an index value of 0.80. Road 2 (26-foot roadbed - 22-foot seal coat surface) has an index value of 1.50. Depending upon how you wish to express this relationship, you may use either number as a base for relating the costs of the two roads (i.e., Road 1 is 53 percent of Road 2, or Road 2 is 188 percent of the cost of Road 1, etc.) or you may relate both to the index base road. This relationship may be expressed as follows:

   Road 1 will cost approximately 80 percent of the cost of the index base road (32-foot roadbed - 24-foot A.C. surface) over the expected life of the road and Road 2 will cost approximately 150 percent of the index base road. The same type of relationships may be expressed using the low road type base. Using this index you can not relate maintenance or construction costs independently.

2. <u>Surface Maintenance Cost Index</u> - The purpose of this index is to relate the approximate <u>costs to maintain the surface</u> of various road surface types and roadbed widths. For example, if you wish to compare surface maintenance costs for a seal coat road 20 feet wide versus an asphalt concrete road 20 feet wide, having traffic volumes of about 400 vehicles per day, you would locate the index values from the appropriate index (one shows costs for 100 or fewer vehicles per day and the other for 400 vehicles per day). In this case, the seal coat index value for 400 vehicles per day is 2.05 and the value for asphalt concrete is 1.00. This means that the approximate average surface maintenance costs for the seal coat road are 205 percent (or about double) of the costs for the asphalt concrete road.

Keep in mind that these values reflect surface maintenance costs only and not total maintenance costs.

BASIC ASSUMPTIONS AND SOURCES OF DATA FOR SERVICE LIFE AND SURFACE MAINTENANCE COST COMPARATIVE INDEXES

1. Construction costs are from Humboldt County's recent contract experience (1970).
2. The maintenance cost base for the Service Life Index was developed from the 1969-70 Humboldt County Maintenance Budget. Costs include routine maintenance, heavy rainfall and snow removal projects and seal coat projects (most of which involved resealing existing surfaces). The cost relationships between different surface types and roadbed widths were based upon San Mateo County experience as taken from Highway Research Board Publication 63, "Economics of Design Standards for Low-Volume Rural Roads."
3. Surface maintenance costs for Surface Maintenance Index were derived from Humboldt County cost experience and local practices (i.e., method of grading, number of blade passes per mile, grading speed, etc.).
4. Relative maintenance costs for different roadbed widths and surface types (for Surface Maintenance Index) were based upon San Mateo County experience as taken from Highway Research Board Publication 63, "Economics of Design Standards for Low-Volume Rural Roads." The cost base itself was taken from Humboldt County experience (see 3 above).
5. Adjustments were made to the construction costs of double seal coat and gravel roads to compensate for the structural strength of asphalt concrete.
6. Expected road life assumptions for Service Life Index were:

   Gravel Roads - 10 years (assuming gravel is added periodically).

   Double Seal Coat Roads - 15 years (includes 4 surface applications; the initial coat plus a coat every 4 years).

Asphalt Concrete Roads - 15 years (assuming an initial surface application plus routine maintenance including blanket patching as required).

7. Surface Maintenance Costs include:

- Grading and adding gravel for gravel roads, and
- Pothole patching and edge patching for seal coat and asphalt concrete roads.

ASSUMPTIONS UNDERLYING THE DEVELOPMENT OF COST COMPARISONS AND THEIR INTENDED USE

(See Tables 3-111A & B)

The cost data presented here has been developed for the purpose of displaying the relative construction costs of alternative roadway designs. They are not intended for use in evaluating any particular roadway project. These relative costs should not be used for project estimating. Our intention was to concern ourselves with added or "incremental" costs as opposed to total costs.

We have basically viewed costs as being those which are normally associated with major reconstruction such as "storm damage" projects as opposed to minor improvements such as widening the road by 2 feet for a relatively short distance; therefore, any incremental cost assumptions are not expressed as "decreasing cost rates with increasing roadway widths" but rather as "general volume price breaks." Our assumed rates depend upon the degree of effort and material involved. For example, for excavation costs, rather than stating different quantity rates for roadways above a given width or depth, we have expressed different rates for heavy, moderate and light excavation. Heavy excavation would be the equivalent to a 15-foot deep cut; moderate a 10-foot cut and light constitutes a 3-foot cut or less.

This approach, we believe, is more consistent with present estimating practice and seems more realistic in terms of relating to actual projects. Our "constructed" cost models were compared to actual projects which had similar circumstances to ensure the reasonableness of our fabricated costs or cost indexes.

The underlying assumption in our logic is that the most costly improvements will be prompted by a pressing need (such as a washout) and the action taken will be to reconstruct a section of road to a given standard.

We are not convinced that adding roadway width beyond some arbitrary dimension necessarily decreases unit costs. Total project volumes appear to us to be more relevant when considering volume economies than do roadway widths. The basis for our cost data and the assumptions and simplifications which we have made are listed as follows:

1. Costs are based primarily upon estimates of contractors who have recently completed projects for Humboldt County. They are compilations of bid results.

2. Costs are expressed on a "per mile" base.

3. Costs are approximate and do not include engineering and County overhead.

4. User costs are not considered; only construction costs.

5. No attempt was made to calculate annual costs or present or future values of costs. Salvage costs were not considered.

6. Detailed cost rates and the cost factors included in these rates are presented as Exhibit 1.

HUMBOLDT COUNTY

(1970-71)

Construction Cost Rates

Cost Element	Unit of Measure	Cost per Unit ($)	Cost Factors Included -
Clearing & Grubbing	Acre-Heavy*	$2,000.	Labor, Equipment and Contractor's Overhead.
	Medium*	1,000.	
	Light*	500.	
Excavation (presumes a thorough cut)	Cu.Yd-Heavy (15' deep cut)	$ 1.00	Labor, Equipment, and Contractor's Overhead.
	Moderate (10' deep cut)	1.25	
	Light (3' deep cut)	2.00	
Drainage**-Pipe (Installed) (Assumes 2 ft. structure backfill)	Lineal Foot-12"	$ 10.00	Labor, Equipment, Material (In Place - No major structures)
	18"	14.00	
	24"	20.00	
	30"	26.00	
	36"	35.00	
	42"	40.00	
	48"	47.00	
-Drop Inlet	Each Unit	500.00	
Native Material (5 mile haul)	Cu. Yd.	$ 1.70 (County Rate)	Labor, Equipment, Material, Overhead. (Source to site in-place)
Classified Aggregate	(I) Cu. Yd.(subbase)	$ 7.18	Labor, Equipment, Material (Source to site, in-place)
	(II) Cu. Yd.(base)	8.83	

* Subjective measures

** Drainage costs were not "constructed". They were based on composites of representative projects. No major structures were included.

Cost Element	Unit of Measure	Cost per Unit ($)	Cost Factors Included
Surfacing - Double Seal (Includes primer at 2 cents per sq. yd)	Sq. Yd.	$ 1.37	Labor, Equipment, Material, Contractors Overhead (In place)
Asphalt Concrete	1000 ton or less	$ 15.00	Labor, Equipment, Material, Contractors Overhead (In place)
	Over 1000 ton	12.00	

3-200 Asphalt Concrete Pavement Design.

3-201 Design Factors. The major factors to be considered in developing an asphalt concrete structural cross section are as follows:

3-201.1 Structural Quality of the Basement Soil - This quality is measured by means of the stabilometer and expansion pressure tests and is expressed as the resistance value R. (Reference Test Method No. Calif. 301.)

3-201.2 Traffic - The magnitude and number of all wheel loads estimated for a predetermined period are converted to an equivalent number of 5,000-pound wheel loads or EWL for short. This makes it possible to compute their destructive equivalent which is expressed as a numerical value called Traffic Index or TI. For conversion from EWL to TI, see Table 3-203C. For a more comprehensive discussion, see Section 7-600 of the California Design Manual.

3-201.3 Slab Value of Pavement and Supporting Layers - The required thickness of a given layer or layers of roadbed structure varies with the respective slab or tensile strength. This tensile quality is expressed in terms of a gravel equivalent value.

3-201.4 Economic Factors - A satisfactory structural section may be accomplished with various combinations of materials. In selecting the most appropriate design, economy both in initial cost and future maintenance is a prime consideration. Relative costs of native earth and classified aggregates for various roadbed widths and thicknesses are presented in Tables 3-200A through 3-200D. Tables A and B are expressed in 1970 dollar costs and C and D are cost indexes.

TABLE 3-200A

HUMBOLDT COUNTY

(1970-71)

Construction Cost Comparisons/mile
Native Material (Sub-Base or Base Materials) - 1970

Width (ft.)	Thickness (ft.) 0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
12	$ 810	$1,260	$1,710	$2,060	$2,600	$3,050	$ 3,500	$ 4,040	$ 4,490
14	990	1,440	1,980	2,420	2,960	3,500	4,040	4,580	5,120
16	1,080	1,620	2,240	2,780	3,410	3,950	4,580	5,210	5,830
18	1,260	1,800	2,510	3,140	3,770	4,490	5,120	5,830	6,460
20	1,350	2,060	2,780	3,500	4,130	4,940	5,650	6,460	7,180
22	1,530	2,240	2,960	3,770	4,580	5,390	6,190	7,000	7,810
24	1,620	2,420	3,230	4,130	4,940	5,830	6,730	7,630	8,440
28	1,890	2,870	3,770	4,760	5,740	6,730	7,810	8,800	9,780
32	2,150	3,230	4,310	5,480	6,550	7,720	8,800	9,960	11,130
40	2,690	3,950	5,300	6,640	7,990	9,330	10,680	11,940	13,280
42	2,780	4,220	5,570	7,000	8,350	9,780	11,130	12,570	14,000

TABLE 3-200B

HUMBOLDT COUNTY

(1970-71)

Construction Cost Comparisons/mile

Classified Aggregate (Class I Sub-base & Class II Base) - 1970

Width (ft.)	Aggreg. Class	Thickness (Ft.) 0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
12	I	$ 5,300	$ 7,200	$ 8,700	$11,000	$12,900	$14,800	$17,100	$18,950
	II	6,550	8,850	10,700	13,500	15,850	18,200	21,000	23,300
14	I	6,050	8,350	10,250	12,500	14,800	17,100	19,350	21,600
	II	7,450	10,250	12,600	15,400	18,200	21,000	23,800	26,600
16	I	6,800	9,500	11,750	14,400	16,700	19,350	22,000	24,650
	II	8,400	11,650	14,450	17,700	20,500	23,800	27,050	30,300
18	I	7,600	10,600	13,250	15,950	18,950	21,600	24,650	27,300
	II	9,300	13,050	16,300	19,600	23,300	26,600	31,300	33,550
20	I	8,700	11,750	14,800	17,450	20,850	23,900	27,300	30,350
	II	10,700	14,450	18,200	21,450	25,650	29,350	33,500	37,300
22	I	9,500	12,500	15,950	19,350	22,750	26,150	29,550	33,000
	II	11,650	15,400	19,600	23,800	27,950	32,150	36,350	40,550
24	I	10,250	13,650	17,450	20,850	24,650	28,450	32,200	35,650
	II	12,600	16,800	21,450	25,650	30,300	34,950	39,650	43,800
28	I	12,150	15,950	20,100	24,250	28,450	33,000	37,150	41,300
	II	14,900	19,600	24,700	29,850	34,950	40,550	45,700	50,800
32	I	13,650	18,200	23,150	27,650	32,600	37,150	42,100	47,000
	II	16,800	22,400	28,450	34,050	40,100	45,700	51,750	57,800

TABLE 3-20 (Continued)

(1970-71)

Classified Aggregate (Class I Sub-base & Class II Base) Cont'd.

Width (ft.)	Aggreg. Class	Thickness (ft.) 0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
40	I	$16,700	$22,350	$28,050	$33,750	$39,450	$45,100	$50,400	$56,100
	II	20,500	27,500	34,500	41,250	48,500	55,500	62,000	69,000
42	I	17,800	23,500	29,550	35,250	41,300	47,000	53,050	59,150
	II	21,900	28,900	36,350	43,350	50,800	57,800	65,250	72,750

TABLE 00C

Comparative
Cost Index

<u>Native Material 1.0=(24 ft. x 0.5 ft.)</u>

Width (Ft.)	Thickness (ft.) 0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
12	0.20	0.30	0.40	0.50	0.65	0.75	0.85	1.00	1.10
14	0.25	0.35	0.50	0.60	0.70	0.85	1.00	1.10	1.25
16	0.25	0.40	0.55	0.65	0.85	0.95	1.10	1.25	1.40
18	0.30	0.45	0.60	0.75	0.90	1.10	1.25	1.40	1.55
20	0.35	0.50	0.65	0.85	1.00	1.20	1.35	1.55	1.75
22	0.35	0.55	0.70	0.90	1.10	1.30	1.50	1.70	1.90
24	0.40	0.60	0.80	1.00	1.20	1.40	1.65	1.85	2.05
28	0.45	0.70	0.90	1.15	1.40	1.65	1.90	2.15	2.35
32	0.50	0.80	1.05	1.35	1.60	1.85	2.15	2.40	2.70
40	0.65	0.95	1.30	1.60	1.95	2.25	2.60	2.90	3.20
42	0.70	1.00	1.35	1.70	2.05	2.35	2.70	3.05	3.40

Numbers rounded to 0.05

TABLE 3-200D

Comparative
Cost Index

Classified Aggregates (I and II) (1.0=24 ft. x 0.5 ft.)

Width (ft.)	Thickness (ft.) 0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
12	0.30	0.40	0.50	0.65	0.75	0.85	1.00	1.10
14	0.35	0.50	0.60	0.70	0.85	1.00	1.10	1.25
16	0.40	0.55	0.70	0.85	0.95	1.10	1.25	1.40
18	0.45	0.60	0.75	0.90	1.10	1.25	1.40	1.55
20	0.50	0.65	0.85	1.00	1.20	1.35	1.55	1.75
22	0.55	0.70	0.90	1.10	1.30	1.50	1.70	1.90
24	0.60	0.80	1.0	1.20	1.40	1.65	1.85	2.05
28	0.70	0.90	1.15	1.40	1.60	1,90	2.15	2.40
32	0.80	1.05	1.30	1.60	1.90	2.15	2.40	2.70
40	0.95	1.30	1.60	1.90	2.25	2.60	2.90	3.25
42	1.00	1.35	1.70	2.00	2.40	2.70	3.05	3.40

Numbers rounded to 0.05

3-202 Evaluation of Soils and Base Materials.

The resistance value R is a coefficient representing the shearing resistance to plastic deformation of a saturated soil at a given density. The R value is measured by the stabilometer test. Almost all compacted soils have a tendency to expand when subjected to water. As they expand, and take on water, soils lose density and load-supporting ability, which is indicated in laboratory tests by a lowering of R value. See Section 7-602 of California Design Manual for further discussions.

3-203 Evaluation of Traffic.

Traffic data required for design include traffic counts which represent the present and estimated future average daily two-way truck traffic volumes. Trucks are classified according to the number of axles, and buses are considered to be trucks. Expansion factors should be determined for each axle classification from the most appropriate available traffic count data.

The purpose of obtaining this information is to make a representative estimate of the equivalent 5,000-pound wheel loads (EWL) in one direction of travel to be expected during the 20-year period following construction or a specified period other than 20 years.

Table 3-203A gives constants used in obtaining the annual number of equivalent 5,000-pound wheel load repetitions in one direction of travel. For other highways or special conditions of loading, the constants may be adjusted if axle load information is known.

TABLE 3-203A

EWL CONSTANTS FOR DUAL-TIRED COMMERCIAL VEHICLES

Type of Vehicle	Annual Design EWL Per Vehicle Per Day City Streets and County Roads
2-axle truck	200
3-axle truck	690
4-axle truck	1070
5-axle truck	1700
6-axle truck	1050

The constants have been computed for use with normal two-way traffic counts to give EWL figures for one-way travel. When using directional counts, the constants must be multiplied by two.

The Table below is an example of the application of the above constants in estimating the EWL. The 20-year EWL is obtained by multiplying the average annual design EWL by 20, so for the example: 20 x 831,950 = 16,639,000 EWL.

(1) Vehicle Type	(2) Present Average Daily Trucks In Both Directions	(3) Expansion Factor to 10 Years After Construction	(4) Expanded Average Daily Trucks (Col. 2 x Col. 3)	(5) EWL Constants	(6) Average Annual EWL (Col. 4 x Col. 5)
2-axle trucks	20	1.70	35	200	7,000
3-axle trucks	100	2.70	270	690	186,300
4-axle trucks	30	1.55	45	1070	48,150
5-axle trucks	230	1.45	335	1700	569,500
6-axle trucks	20	1.00	20	1050	21,000
Total Average Annual Design EWL					831,950

The distribution of dual-tired commercial vehicles over the traveled way of multi-lane roads in one directon of travel varies from lane to lane. For two-lane and four-lane highways, 100 percent of the calculated EWL is used to determine the traffic index (TI) for all lanes. In the above example, a TI of 9.5 is obtained from Table 3-203C using 100 percent of the calculated EWL of 16.6 million, always reading to the nearest 0.5.

TABLE 3-203C

CONVERSION OF EWL TO TRAFFIC INDEX

EWL	*TI	EWL	*TI
104		15,000,000	
	2.5		9.5
562		23,400,000	
	3.0		10.0
2,290		35,600,000	
	3.5		10.5
7,620		53,100,000	
	4.0		11.0
21,800		77,900,000	
	4.5		11.5
55,600		112,000,000	
	5.0		12.0
129,000		159,000,000	
	5.5		12.5
277,000		223,000,000	
	6.0		13.0
558,000		308,000,000	
	6.5		13.5
1,060,000		420,000,000	
	7.0		14.0
1,940,000		568,000,000	
	7.5		14.5
3,400,000		759,000,000	
	8.0		15.0
5,750,000		1,000,000,000	
	8.5		15.5
9,420,000		1,320,000,000	
	9.0		
15,000,000			

* Traffic Index = $6.7 \left(\frac{EWL}{10^6}\right)^{0.119}$

3-204 Evaluation of Slab Value of Pavement, Bases and Subbases.

The design of asphalt concrete structural sections by the method described in this Manual results in a theoretical total thickness expressed in terms of gravel equivalent. This thickness or depth of cover is dependent on the quality of the basement soil (R value) and the estimated traffic in terms of TI.

The depth of cover over any basement material must satisfy two conditions. First, it must be of sufficient depth to protect the material against displacement due to the traffic loads. Second, it must be of sufficient weight to prevent further expansion of the material with resulting loss in stability.

The theoretical thickness of the individual layers as determined by the design method must be converted to actual thickness by means of gravel equivalent factors which are given in Table 3-310.

3-205 Evaluation of Economic Factors in Achieving "Theoretical Thickness."

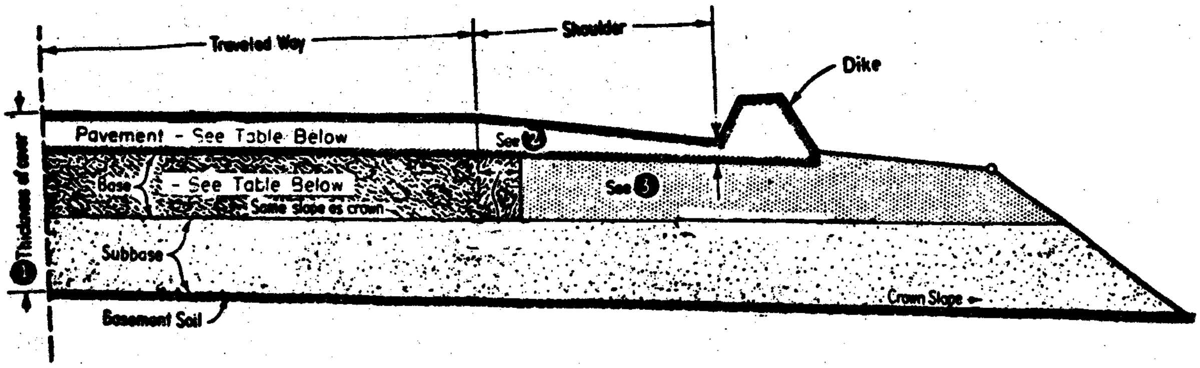
Various combinations of materials can usually be determined which will satisfy the thickness requirements, but one or more may be eliminated on the basis of past experience or availability of materials. The final choice should normally be based on the most economical section considering estimates of initial cost combined with future maintenance. The County cost indexes which relate the costs of various types of structural materials for different thicknesses will be used to develop cost comparisons.

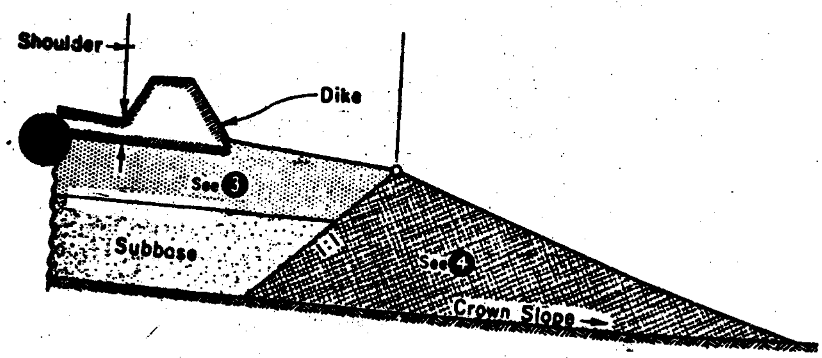
3-300 Structural Elements of Flexible Pavement.

3-310 Typical Designs.

Figure 3-310 shows typical arrangements of the elements of flexible pavement designs. Table 3-310 gives depths of asphalt concrete pavement and base layers for various base materials related to traffic index. This Table is to be used as a guide and is not to be construed as placing limitations on design or eliminating alternate designs from consideration.

STRUCTURAL ELEMENTS OF FLEXIBLE PAVEMENTS





1 THICKNESS OF COVER

Use design formula for thickness of total cover.

2 SHOULDER DESIGN

Except for all-paved 2-lane roads and median shoulders on 4-lane and 6-lane divided highways, shoulder design is based on 1% of EWL but not less than a TI of 5.0

Median shoulders on 4-lane and 6-lane divided highways shall be paved 5'-wide with a uniform thickness of 0.20'

3 SHOULDER BASE

Use base material or high quality subbase.

4 FLAT FILL SLOPE DESIGN

Use embankment material in this area when slopes are flatter than 4:1 and subsurface drainage problems are not anticipated.

Table 3-310

Typical Depths of Pavement and Base Related to TI

Type of base material	Pavement or base layer	Depth of layer (feet)									
		TI 5.0	TI 6.0	TI 7.0	TI 8.0	TI 9.0	TI 10.0	TI 11.0	TI 12.0	TI 13.0	TI 14.0
Class A CTB	Pavement	...	...	...	0.25	0.30	0.35	0.40	0.45	0.50	0.55
	Base	...	...	...	0.60	0.65	0.70	0.80	0.85	0.90	0.95
Class B CTB	Pavement	...	0.25	0.30	0.35	0.40	...	...	...	...	...
	Base	...	0.45	0.55	0.65	0.70	...	...	...	...	...
Class 1 AB (80 R Value)	Pavement	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.65	*
	Base	0.40	0.50	0.60	0.65	0.75	0.85	0.95	1.05	1.10	*
Class 2 AB (78 R Value)	Pavement	0.20	0.25	0.30	0.35	0.40	0.50	0.55	0.60	*	*
	Base	0.40	0.50	0.60	0.65	0.75	0.80	0.90	1.00	*	*

NOTES: The above table was made as a guide with the thicknesses based on the TI in each column and the assumption made that subbase with an R Value of 50 would be used. Extra thickness was added for a safety factor as stated in 7-604.4.

Asphalt concrete base course 0.25 foot thick would normally be specified where the total thickness of asphalt concrete exceeds 0.40 foot.

* Designs in these categories require special justification.

CTB is cement treated base. AB is aggregate base.

Note: Taken from the California State Design Manual (Figure and Table 7-603.1)

3-320 Surface Types.

3-321 Asphalt Concrete Pavement.

Asphalt concrete pavement, in depths commensurate with the anticipated TI and quality of base, may be used for either heavy duty or light duty pavements.

3-321.1 Thickness - Asphalt concrete pavement ordinarily ranges in thickness from 0.15 to 0.65 foot, the depth to be determined by the design method described in this Manual. As a safeguard against slippage, not less than 0.25 foot ordinarily should be placed over Class A cement treated bases. Increased stability and economy frequently results from using an asphalt concrete base course when the required pavement thickness exceeds 0.40 foot.

In some situations, it may be most economical to specify the total planned thickness of asphalt concrete and make the substitution of an asphalt concrete base course optional.

3-322 Road-Mixed Asphalt Surfacing.

Road-mixed asphalt surfacing is used when facilities to manufacture asphalt concrete pavement are not economically available. It is usually placed in depths from 0.15 to 0.35 foot to add structural strength for roadway improvements. Liquid asphalts are used to develop this type of surfacing.

3-323 Bituminous Seals.

Bituminous seals include types such as chip seal, fog seal and slurry seal. Their primary uses are to provide a skid-resistant texture to pavements, provide a wearing surface, recondition a dry or weathered surface, prevent moisture and air from entering the pavement, and fill shrinkage cracks in the existing pavement. They also may be employed on stage construction projects as a temporary expedient.

3-324 Penetration Treatment.

Penetration treatment consists of the application of light liquid asphalt to roadbed material. It will be used by the County principally as a prime coat and shall be applied only on high quality base material. Dust palliatives may be developed through a penetration treatment; however, they are not to be used freely since their application tends to deteriorate the base material rather than protect it.

3-325 Graded Native.

Native earth or gravel surfaces are common in areas with low traffic volumes. Crushed or natural river or bank rock may be used for gravel surfacing. Surface will be maintained by periodic blading.

3-330 Bases and Subbases.

3-331 Untreated Bases.

Untreated aggregate bases may be used under asphalt concrete pavements when specification quality material can be produced economically. They may be used under both light and heavy-duty pavements.

3-332 Cement Treated Bases.

Cement treated bases frequently provide economy in reducing thickness of surfacing and total cover due to their high slab strength and stability. Class A or B cement treated base may be either road-mixed or plant-mixed. The plant-mixed type generally provides better quality and should be specified for use on arterials and major collectors when surfaced with asphalt concrete. Cement treated bases normally have a minimum thickness of 0.50 foot.

3-333 Stabilized Bases.

Asphalt or lime stabilized bases may be used where satisfactory untreated aggregate base material is not available and where the cost of other types of treatment is prohibitive. Substantiation for using such bases must be developed from preliminary tests of available materials.

3-334 Subbases.

A layer or layers of subbase shall be used where the basement soil will not support a structural section consisting of pavement and base alone, or where it is more economical to reduce the base thickness requirement by the introduction of a lower priced subbase layer.

Where cohesionless sand is used as subbase material under a cement treated base, it is necessary to provide a working table layer of aggregate base or cement treated base aggregate. This working table normally will be from 0.30 to 0.45 foot thick to provide for the proper support of the cement treated base.

3-400 Design Procedures for Flexible Pavements.

3-401 General.

As was discussed earlier in Section 3-204, the thickness of cover over any material (i.e. base, subbase, selected material, or basement soil) must satisfy two conditions: First, it must be of sufficient weight to prevent expansion of the material beyond the assumed moisture content and density on which the design is based. Second, it must be of sufficient thickness to protect the material against displacement due to the traffic loads.

In the first case, where expansive materials are encountered, the design procedure becomes involved with determination of various R values for the expansive material which will vary with moisture content and assumed structural sections. For a description of the method, see Test Method No. Calif. 301.

The second case is the more usual case, in which R values of base and subbases are to be specified, and the minimum R value of the basement soil can be determined because under the weight of any structural section based on traffic load, the basement soil will not be expansive. In this case, it is not necessary to assume a structural section to perform the laboratory calculations for R value. Therefore, various designs can be readily determined and the most economical section chosen.

3-402 Basic Data.

The basic data required for a flexible pavement design consists of R values from the Materials Report, the number of lanes from the Project Report, and the lane TI.

3-403 Design Example.

The design procedure is illustrated by an example with basic data assumed as follows:

Minimum R value of basement soil = 10

Two lane construction

Lane TI = 8.0

(1) Determine the total gravel equivalent required by the formula: GE = 0.0032 (TI) (100-R). In this case, the gravel equivalent would be 2.30 feet and this result can be checked on the structural design chart, Figure 3-403A. Intersect the sloping traffic index line for 8.0 with the vertical line representing the R value of 10 and read the gravel equivalent of 2.30 feet from the horizontal line.

(2) Select a base type for the first alternate design. Assume a Class 2 aggregate base which has a specified R value of 78.

(3) Determine the gravel equivalent required for the asphalt concrete surfacing using the formula in (1) above and the 78 R value of the base. The value of 0.56 foot is obtained by the formula and can be checked on the chart, Figure 3-403A, in the same manner as described above for total gravel equivalent.

From Table 3-403A under the column headed TI 7.5 and 8.0, can be found the gravel equivalent factor of 2.01. Dividing 0.56 by 2.01 gives an actual thickness of 0.28 foot which should be rounded up to 0.30 foot. In this same column, the next higher value of gravel equivalent for asphalt concrete is 0.60 and the actual thickness of 0.30 can be read horizontally to the left in the "Actual Thickness of Layer" column.

(4) Select a class of subbase for this design. In actual practice, the materials report would probably designate the most economical class of subbase available for the project. For the example, assume a Class 2 subbase which has a specified minimum R value of 50.

(5) Again using the aforesaid formula, the gravel equivalent of the combined surfacing and base would be 1.28 feet over subbase with an R value of 50. Subtracting the gravel equivalent for the 0.30 foot of asphalt concrete, which is 0.60 from the 1.28, gives a gravel equivalent of 0.68 foot for the base. From the "Aggregate Base" column of Table 3-403A, the next higher value listed is 0.72 and this value corresponds to an actual thickness of 0.65 foot which should be used.

(For Class A cement treated base, there is no specified R value. To determine an alternate design using this base, it is necessary to choose an appropriate thickness for the asphalt concrete such as those shown in the Table at the bottom of Figure 3-310. The gravel equivalent of the selected thickness of asphalt concrete is determined, and the thickness of cement treated base designed. Class B cement treated base is expected to have an R value of 80 and so it can be designed as an aggregate base except that the proper column in Table 3-403A must be used to convert to actual thickness.)

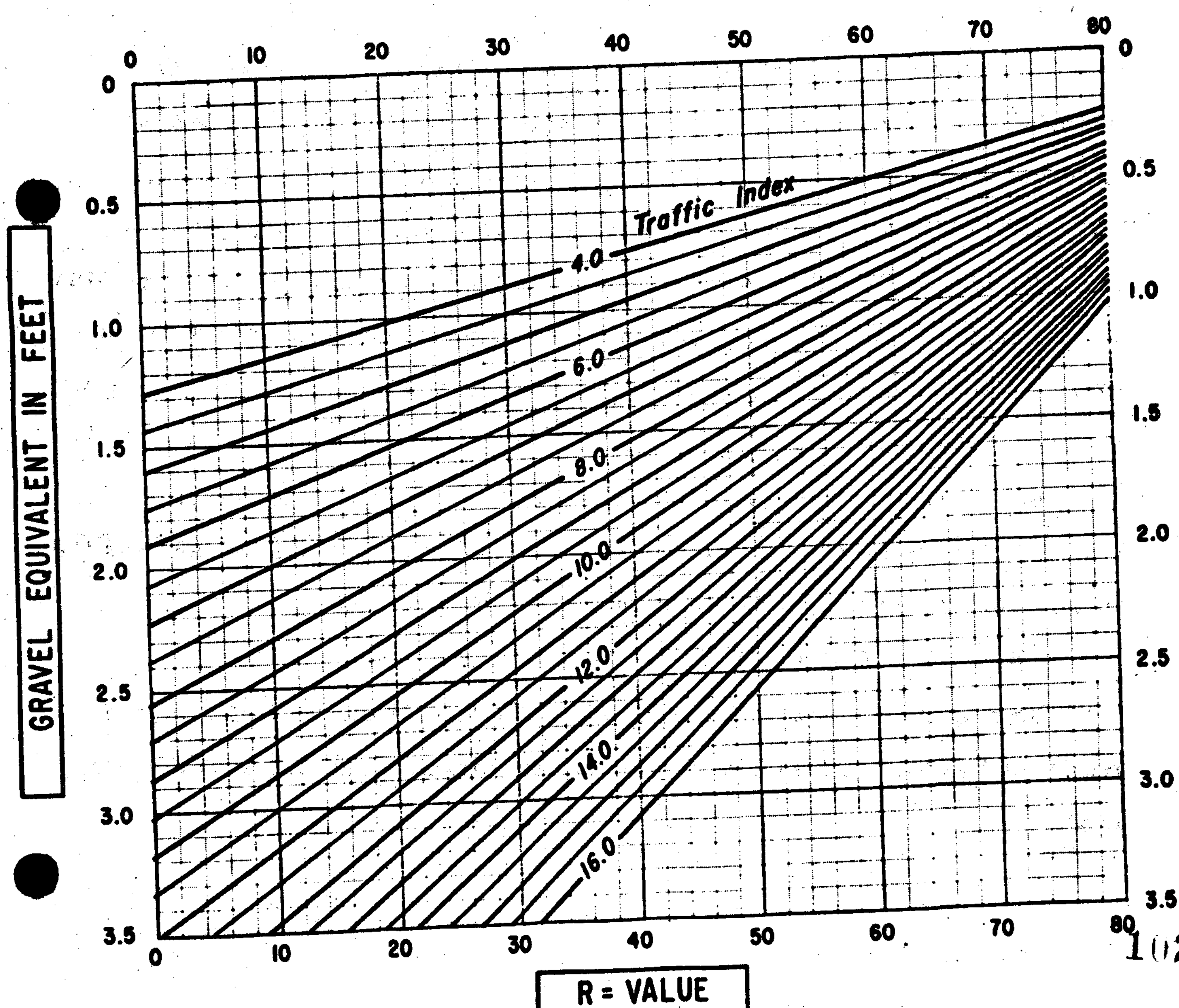
(6) To design the thickness of subbase for the example, the gravel equivalents of the asphalt concrete and Class 2 aggregate base are subtracted from the total required gravel equivalent determined in Step (1).

$2.30 - 0.60 - 0.72 = 0.98$ feet.

Since aggregate subbase has a gravel equivalent factor (G_1) of 1.0, the result of the above subtraction is the actual thickness and 1.00 foot would be used.

STRUCTURAL DESIGN CHART FOR FLEXIBLE PAVEMENTS

EQUATION	
GE= 0.0032 (TI) (100-R)	GE = Gravel Equivalent
	TI = Traffic Index
	R = Resistance Value



Note: Taken from California State Design Manual (Figure 7-604.3)

TABLE 3-403A

GRAVEL EQUIVALENTS OF STRUCTURAL LAYERS IN FEET

Actual thickness of layer - feet	ASPHALT CONCRETE										BTB and LTB	Cement-treated Base		Aggregate base	Aggregate subbase
	Traffic Index (TI)											Class			
	5 and below	5.5 6.0	6.5 7.0	7.5 8.0	8.5 9.0	9.5 10.0	10.5 11.0	11.5 12.0	12.5 13.0	13.5 14.0		A	B		
	Gravel Equivalent Factor (G_f)										G_f	G_f		G_f	G_f
	2.50	2.32	2.14	2.01	1.89	1.79	1.71	1.64	1.57	1.52	1.2	1.7	1.2	1.1	1.0
0.10	0.25	0.23	0.21	0.20	0.19	0.18	0.17	0.16	0.16	0.15	0.12	-----	-----	-----	-----
0.15	0.38	0.35	0.33	0.30	0.28	0.27	0.26	0.25	0.24	0.23	0.18	-----	-----	-----	-----
0.20	0.50	0.46	0.43	0.40	0.38	0.36	0.34	0.33	0.31	0.30	0.24	-----	-----	-----	-----
0.25	0.63	0.58	0.54	0.50	0.47	0.45	0.43	0.41	0.39	0.38	0.30	-----	-----	-----	-----
0.30	0.75	0.70	0.64	0.60	0.57	0.54	0.51	0.49	0.47	0.46	0.36	-----	-----	-----	-----
0.35	0.88	0.81	0.75	0.70	0.66	0.63	0.60	0.57	0.55	0.53	0.42	-----	-----	0.39	0.35
0.40	1.00	0.93	0.86	0.80	0.76	0.72	0.68	0.66	0.63	0.61	0.48	-----	-----	0.44	0.40
0.45	-----	1.04	0.96	0.90	0.85	0.81	0.77	0.74	0.71	0.68	0.54	0.77	0.54	0.50	0.45
0.50	-----	1.16	1.07	1.01	0.95	0.90	0.86	0.82	0.79	0.76	0.60	0.85	0.60	0.55	0.50
0.55	-----	-----	1.18	1.11	1.04	0.98	0.94	0.90	0.86	0.84	0.66	0.94	0.66	0.61	0.55
0.60	-----	-----	-----	1.21	1.13	1.07	1.03	0.98	0.94	0.91	0.72	1.02	0.72	0.66	0.60
0.65	-----	-----	-----	1.31	1.23	1.16	1.11	1.07	1.02	0.99	0.78	1.11	0.78	0.72	0.65
0.70	-----	-----	-----	-----	1.32	1.25	1.20	1.15	1.10	1.06	0.84	1.19	0.84	0.77	0.70
0.75	-----	-----	-----	-----	-----	1.34	1.28	1.23	1.18	1.14	0.90	1.28	0.90	0.83	0.75
0.80	-----	-----	-----	-----	-----	1.43	1.37	1.31	1.26	1.22	0.96	1.36	0.96	0.88	0.80
0.85	-----	-----	-----	-----	-----	1.52	1.45	1.39	1.33	1.29	1.02	1.45	1.02	0.94	0.85
0.90	-----	-----	-----	-----	-----	-----	1.54	1.48	1.41	1.37	1.08	1.53	1.08	0.99	0.90
0.95	-----	-----	-----	-----	-----	-----	-----	1.56	1.49	1.44	1.14	1.62	1.14	1.05	0.95
1.00	-----	-----	-----	-----	-----	-----	-----	1.64	1.57	1.52	1.20	1.70	1.20	1.10	1.00
1.05	-----	-----	-----	-----	-----	-----	-----	-----	1.65	1.60	1.26	1.79	1.26	1.16	1.05

NOTES: BTB is bituminous treated base.
LTB is lime treated base.
For the design of road-mixed asphalt surfacing, use 0.8 of the gravel equivalent factors (G_f) shown above for asphalt concrete.

From California State Design Manual, Table 7-604.3

The completed design is 0.30 foot of asphalt concrete over 0.65 foot of Class 2 aggregate base over 1.00 foot of Class 2 subbase.

An alternate design for the assumed basic data could be as follows:

Actual Thickness (In Feet)	Material in Layer	Gravel Equivalent (In Feet)
0.25	Asphalt Concrete	0.50
0.45	Class "A" Cement Treated Base	0.77
1.05	Class 2 Subbase	1.05
1.75		2.32

The above designs, based on the formula, do not provide an adequate factor of safety. It is necessary to add thickness to the theoretical designs to provide this safety factor and it is accomplished by providing an increase in required gravel equivalent for either the surface or the base material. In designs using Class "A" cement treated base, the increased thickness should be applied to the base layer. In untreated aggregate base and Class "B" cement treated base designs, the factor of safety should be provided by increased thickness of the asphalt surfacing. The increased thickness of surfacing or base will result in a decrease in the thickness of subbase because the safety factor is not applied to the over-all gravel equivalent requirement. The gravel equivalent increases to be added for safety are as follows:

Base Type	Gravel Equivalent Increase (Feet)	Layer Applied To
* Class "A" Cement Treated Base	0.24	Cement Treated Base
Class "B" Cement Treated Base	0.18	Asphalt Concrete
Aggregate Base	0.16	Asphalt Concrete

* When no high subgrade is allowed, the gravel equivalent increase is 0.10 foot for Class "A" cement treated base.

For light traffic and/or moderate speeds, the safety factor should be omitted.

The alternate designs on the previous page, corrected by the safety factors and thickness selected to the nearest 0.05 foot, would be as follows:

Actual Thickness (In Feet)	Material in Layer	Gravel Equivalent (In Feet)
0.35	Asphalt Concrete	0.70
0.65	Class 2 Aggregate Base	0.72
0.90	Class 2 Subbase	0.90
1.90		2.32
0.25	Asphalt Concrete	0.50
0.60	Class "A" Cement Treated Base	1.02
0.80	Class 2 Subbase	0.80
1.65		2.32

Costs of these and other possible designs would be estimated and compared so that the best possible choice could be made considering economics and suitability to the project area.

Where the basement soil has an R value of 40 or more, the subbase layer may be omitted. In cases where the subbase layer would be thin, consideration should be given to increasing the depth of base and omitting the subbase.

A structural section consisting of asphalt concrete placed directly on the basement soil without base or subbase is permissible if it can be shown that it would be cheaper than alternative designs. These full depth asphalt concrete sections also may be justified on widening projects on the basis of safety or less interference with traffic during construction.

For high volume and heavy load projects, a safety factor of 0.12 foot gravel equivalent should be added in full depth designs.

Typical designs based on the formula plus added thickness for a safety factor are shown in the Table at the bottom of Figure 3-310. For other types or classes of bases, or subbases with an R value other than 50, the designs should be determined by the formula as in the example.

Figure 3-403B is a TI calculation form used by the County. R values and gravel equivalent values are also placed on this form which becomes part of the design documentation.

TRAFFIC INDEX CALCULATION FORM

PROJECT ______________________________

Vehicle Type	Present Average Daily Trucks in Both Directions	Expansion Factor to 10 Years After Construction	Expanded Average Daily Trucks	E W L Constants State	E W L Constants County	Average Annual E W L
2 - Axle Trucks		1.70		280	200	
3 - Axle Trucks		2.70		930	690	
4 - Axle Trucks		1.55		1320	1070	
5 - Axle Trucks		1.45		3190	1700	
6 - Axle Trucks		1.00		1950	1050	
Total Average Annual Design E W L -						

10 Year Design 10 x ____________ =

20 Year Design 20 x ____________ =

TRAFFIC INDEX ____________

RESISTANCE VALUE ____________

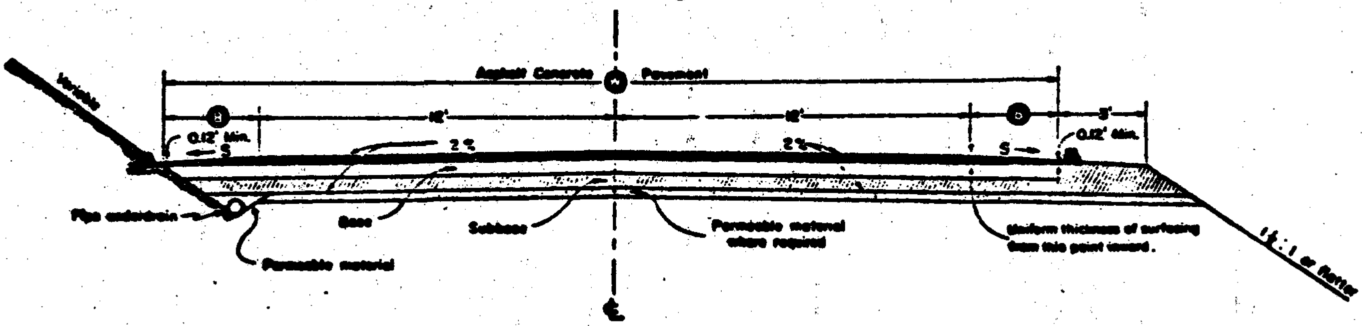
GRAVEL EQUIVALENT ____________

REMARKS:

3-404 Typical Structural Section.

Figure 3-404 shows a typical structural design for an all-paved Category 5 road. The triangular underdrain is to be used where there is the likelihood of surface waters percolating under the pavement. Where subsurface waters are encountered, the standard underdrain shown on the State standard construction plans should be used.

FIGURE 3-404



Note: Some dimensions may vary.

SECTION 4 - DRAINAGE

4-100 General.

Drainage is often the single most important factor to consider in designing roadways or roadway improvements in Humboldt County. Much of the deterioration of roads is attributable to the high volumes of water which pass through the County, creating both surface and subsurface drainage conditions which must be contended with by design and maintenance personnel alike.

Drainage design seeks to prevent the accumulation and retention of water on, within, or along the roadway and provide for the passage of stream flow under the roadway by:

(1) Anticipating the amount and frequency of storm runoff;

(2) Determining natural points of concentration and discharge and other hydraulic controls;

(3) Removing detrimental amounts of subsurface water; and

(4) Providing the most efficient disposal facilities consistent with cost, the importance of the road, maintenance economy, and legal obligations.

Furthermore, storm drains and culverts are designed to provide for the continuous and smooth flow of drainage channels and streams such that velocity and energy line remain close to that of the natural stream or channel, thus preventing excessive silting or scour of both the culvert and the inlet and outlet. Pipe entrances should provide for a smooth transition flow. Water flow should never be turned rapidly at sharp angles and provision should be made at all changes in direction of flow for superelevation of surface, scour, head loss, silting action and possible overflow. Protection should be provided for entrance head, debris passage and possible blockage, entrance scour, or damage in pipe, chemical action on pipes, outlet erosion or back water, and downstream channel.

4-101 Objectives and Scope.

The objective of this Section is to present policy and general guidelines for designing drainage systems. Some desired engineering practices and specific standards are included; however, most of the detailed procedures, culvert specifications, etc., which are needed for design are to be found in reference documents listed in Section 4-107.

Also included in this Section are rules of drainage law, design discharge guides and storm drain design practices.

4-102 Policy.

4-102.1. Coordination with General Plan - It is the policy of Humboldt County that all roadway design project drainage plans must be compatible with requirements of the County's long-range drainage program and the adopted Master Drainage Plans for the various areas of Humboldt County.

4-102.2. Scope of Drainage - It is the policy of Humboldt County that improvements in the drainage of areas outside the right of way shall only be considered if economic benefit would accrue to the County. Furthermore, agreements regarding property owners' or developers' responsibilities to pay for the drainage items or systems must be established by agreements authorized by the Board of Supervisors.

4-102.3 Erosion and Water Pollution - It is the policy of Humboldt County that erosion or water pollution pertaining to or resulting from the construction of highways or roadways is to be held to a practical minimum and shall be temporary in nature.

4-102.4 Drainage Law - It is the policy of Humboldt County that the recognized rules of drainage law be fully applied in the design of drainage systems.

4-103 Design Responsibility and Authority.

California law unequivocally grants authority to highway agencies to acquire, design, construct, and maintain drainage facilities as incident to the authority for the highway itself.

The design engineer is responsible for the hydraulic adequacy of all drainage structures and for structural adequacy. He will also review major repair or replacement projects.

Drainage duties of the designer include:

- Preparation of the drainage plan for each improvement or the review of such a plan when prepared by others;
- Study of important culvert sites and other drainage problems including cooperative projects, starting in the planning phases if feasible and through all stages of design;
- Accumulation and analysis of hydrologic and hydraulic data for existing and proposed drainage structures, also the location and interpretation of high water marks;
- Design of all culverts or the review of culvert designs made by others;
- Review of drainage changes proposed during construction;
- Making of investigations and recommendations on drainage problems arising from the maintenance of existing County highways;
- Coordination of design activities to insure conformance with established drainage and flood protection policies;
- Representing the County at meetings with other interested parties concerning drainage or flood protection problems; and
- Inspection of existing drainage structures during storms.

4-104 Rules of Drainage Law.

There are four basic and reliable rules of drainage law which should be continually reviewed by the designer.

(1) An upper owner has a right to have surface water flow off his land and a lower owner cannot obstruct the flow.

(2) An upper owner may not divert surface waters on his land to the land of a lower owner by artificial means nor may he accelerate the flow by means of ditches or increase the drainage of his own land to the injury of the lower owner.

(3) One may not obstruct or divert the flow of a natural watercourse.

(4) One has a right to protect himself against flood waters.

4-105 Factors to Consider In Drainage Design.

The number of factors which must be considered when designing a drainage system are numerous. Drainage system needs may be met with various combinations of drainage structures and open channel designs.

Figure 4-105 is a "check list" of drainage system design considerations which the design engineer should use as a guide. It will serve to remind him of the factors which may be applicable for any given drainage design project.

4-106 Economics of Drainage Design.

Economic analyses of drainage designs, where required, should consider the following factors:

(1) The cost of construction and right of way;

(2) Useful life and cost of replacement or extension;

(3) Effects of the improvement on property, particularly as to County liability; and

(4) Repair, cleanup, traffic control and other pertinent maintenance charges.

CHECK LIST OF DRAINAGE SYSTEM DESIGN FACTORS

CULVERTS (General)

Economics
Runoff Estimates
Criteria for Balanced Culvert Design
Use of Available Head
Entrance Design
Bed Load and Debris
Outlet Design
Culvert Type and Cross Section
Provisions Against Culvert Deterioration
Federal Requirements
Alignment and Slope
Diameter and Length for Pipes
Multiple Pipes
Bedding and Backfill Considerations
Minimum Thickness of Cover
Headwalls and Other End Treatments
Strength Requirements for Metal Culverts
Strength Requirements for Reinforced Concrete Pipe
Box and Arch Culverts
Maintenance
Downstream Property Consideration
Silt and Debris Deposit of Scour
Drainage Laws

ROADWAY DRAINAGE

Surface Waters Originating within Right of Way
Ground Water
Design Storm Frequency
Runoff
Limits of Flooding

ROADWAY DRAINAGE (Cont.)

Ditches
- Grade
- Slope Ditches
- Side Ditches

Overside Drains
Maintenance

STORM DRAINS

Cooperative Projects
Utilities Clearance
Hydraulic Design
- Discharge
- Conduit Design
- Backwater at Outlet
- Storage
- Floating Trash
- Anchorage
- Drainage of Benches
- Type of Pipe
- Design Service Life

Location and Alignment
Pipe Diameter
Depth of Cover
Gutter Design
- Capacity
- Type
- Longitudinal Slope
- Cross Slope
- Curbed Intersections
- Valley Gutters

Inlet Types
- Curb Opening
- Grate Inlets
- Combination Inlets
- Wall Opening Inlets

Grate Types
Location and Spacing of Inlets - Factors
- Runoff Amount
- Grade Profile
- Location and Geometrics of Interchanges and Intersections
- Width of Flow Limits

STORM DRAINS (Continued)

- Inlet Capacity
- Volume and Movements of Vehicles and Pedestrs.

Hydraulic Design Factors Governing Capacity
- Size of Intake Opening
- The Velocity and Depth of Flow and Gutter Cross Slope Upstream from Intake
- Amount of Depression in Intake Opening Below Flow Line of Waterway

Effect of Grade Profile
Cross Slope for Curbed Gutters
Local Depressions
Trash
Design Water Surface within Inlet
Inlet Floor
Provision for Subsurface Flow
Manholes and Junction Structures
- Location
- Spacing
- Access Shaft
- Arrangement of Laterals

Maintenance

OPEN CHANNELS

Quantity of Discharge
- Discharge of Natural Stream

Uniform Flow
Design Controls - Flow
- Critical Flows
- Subcritical Flows
- Supercritical Flows

Economy
Design Storm Frequency
Bank Protection Requirement
Bottom Width Considerations

OPEN CHANNELS (Continued)

Side Slope Design
Channel Alignment & Grade
Coefficient of Roughness
Channel (Section) Changes
Permissible Velocities for Unlined Channels
Channel Linings
- Type
- Thickness

Maintenance

CURBS AND GUTTERS

Reasons for Usage
- Proper Drainage
- Channelization
- Replace Existing

Types for Particular Use
Position of Curbs
Dimensions
Superelevation

SUBSURFACE DRAINAGE

Basic Knowledge
- Geology
- Soil Mechanics
- Past Experience

Subsurface Discharge
Field Investigations
- Studies
- Borings
- Inspection
- Measurements
- Past History

Types of Underdrains
- Pipes (Single and Multiple)
- Bored Horizontal Drains
- Stabilization Trenches
- Permeable Blanket
- Vertical Wells

Design Requirements
- Subsurface Investigation
- Size and Length
- Separation of Drainage
- Cleanouts
- Grade Requirements

SUBSURFACE DRAINAGE (Continued)

- Depth and Position of Underdrains
- Outlets (Away from Problem Area if Possible)

Service Life Requirements
Type of Installation and Conduit
- Open Joint Underdrains
- Perforated Pipe and Special Type Underdrains (Metal and Non-metalic)

Anticipated Subgrade and Trench Problems
Drainage Disposal by Pumping
Maintenance

ROADSIDE DEVELOPMENT/EROSION CONTROL

Functional Planting
Contour Grading
Side Slopes in Urban Areas
Soil Sterilization
Planting Standards
Sight Distance and Safety Requirements
Erosion Control
- Slope Cultivations and Seeding
- Hydro-Seeding (Nozzle-Planting)
- Dikes and Ditch Linings
- Slope Paving
- Outlet Dissipators
- Soil Cement and Other Shoulder and Ditch Treatments
- Slide Benches
- Interceptor Ditches
- Overside Drains and Spillways
- Textured Slopes

Maintenance

Figure 4-105

4-107 References.

The following list of publications should be referred to for specific drainage design problems. Drainage theory, practice and standards may be found within these reference documents:

Reference	Publisher
(1) Aluminum Culvert	Kaiser Aluminum
(2) Bank and Shore Protection (In California Highway Practice)	California Division of Highways
(3) California Culvert Practice	California Division of Highways
(4) California Highway Design Manual	California Division of Highways
(5) Capacity Charts for the Hydraulic Design of Highway Culverts (Hydraulic Engineering Circular No. 10)	Bureau of Public Roads (Federal Highway Administration)
(6) Concrete Culverts and Conduits	Portland Cement Association
(7) Culvert Design Aids: An Application of U. S. Bureau of Public Roads Culvert Capacity Charts	Portland Cement Association
(8) Debris Control Structures	Bureau of Public Roads
(9) Design Charts for Open-Channel Flow	Bureau of Public Roads
(10) Design of Roadside Drainage Channels	Bureau of Public Roads
(11) Friction Factors for Large Conduits Flowing Full	Bureau of Reclamation
(12) Handbook of Hydraulics	(Kings & Brader) McGraw Hill
(13) Handbook of Drainage and Construction Products	Armco Drainage and Metal Products
(14) Hydraulic Design of Stilling Basins and Energy Dissipators	Bureau of Reclamation
(15) Hydraulic Energy Dissipators	McGraw Hill Book Company
(16) Hydraulics of Bridge Waterways	Bureau of Public Roads
(17) Street and Highway Drainage Volumes I and II	The Institute of Transportation and Traffic Engineering University of California

4-200 Runoff Estimates.

4-201 General.

The runoff estimate, or design discharge, depends upon many variables. Some of the more important are: duration and intensity of rainfall; storm frequency; the size, imperviousness, slope and shape of the drainage area; probable changes in land use. Judgement and care are essential in making runoff estimates. Such estimates may vary considerably because present methods of estimating are inexact and the watersheds encountered in roadway practice usually are small basins, less than 20 square miles in area, for which reliable data frequently are lacking.

4-202 Chart Solutions.

Figure 4-202A gives a graphical solution of the rational method for culverts. This figure includes a map of the State which shows the average rainfall intensity to be expected for given regions during a 60-minute period once in 100 years.

Whenever possible, more localized County maps should be used. Information may also be available from the U. S. Forest Service, the Weather Bureau and the District Office of the State Division of Highways. Many local areas do not have the intensities indicated by Figure 4-202A.

This nomograph does not apply to urban areas; it applies only to natural conditions and is useful where reliable rain-intensity and runoff data are unavailable. In large watersheds, this nomograph should be used with caution. It is not a substitute for careful analysis based on the latest hydrologic data which must be continually accumulated.

The above-mentioned figure applies to a pear-shaped drainage basin. If the basin is of different shape, the time of concentration changes; then the correct runoff is obtained by entering the chart with a computed time of concentration. Figure 4-202B is a form used to calculate drainage design requirements for basins under 10 square miles. Various runoff factors applicable to the County are given on this figure.

4-203 Time of Concentration.

For storm drains, the time of concentration consists of the inlet time and the time of flow in the drain; for culverts, the time of concentration and the inlet time are the same. In a storm drain problem, Figure 4-202A considers the inlet time, but not the time of concentration.

4-204 Field Inspections.

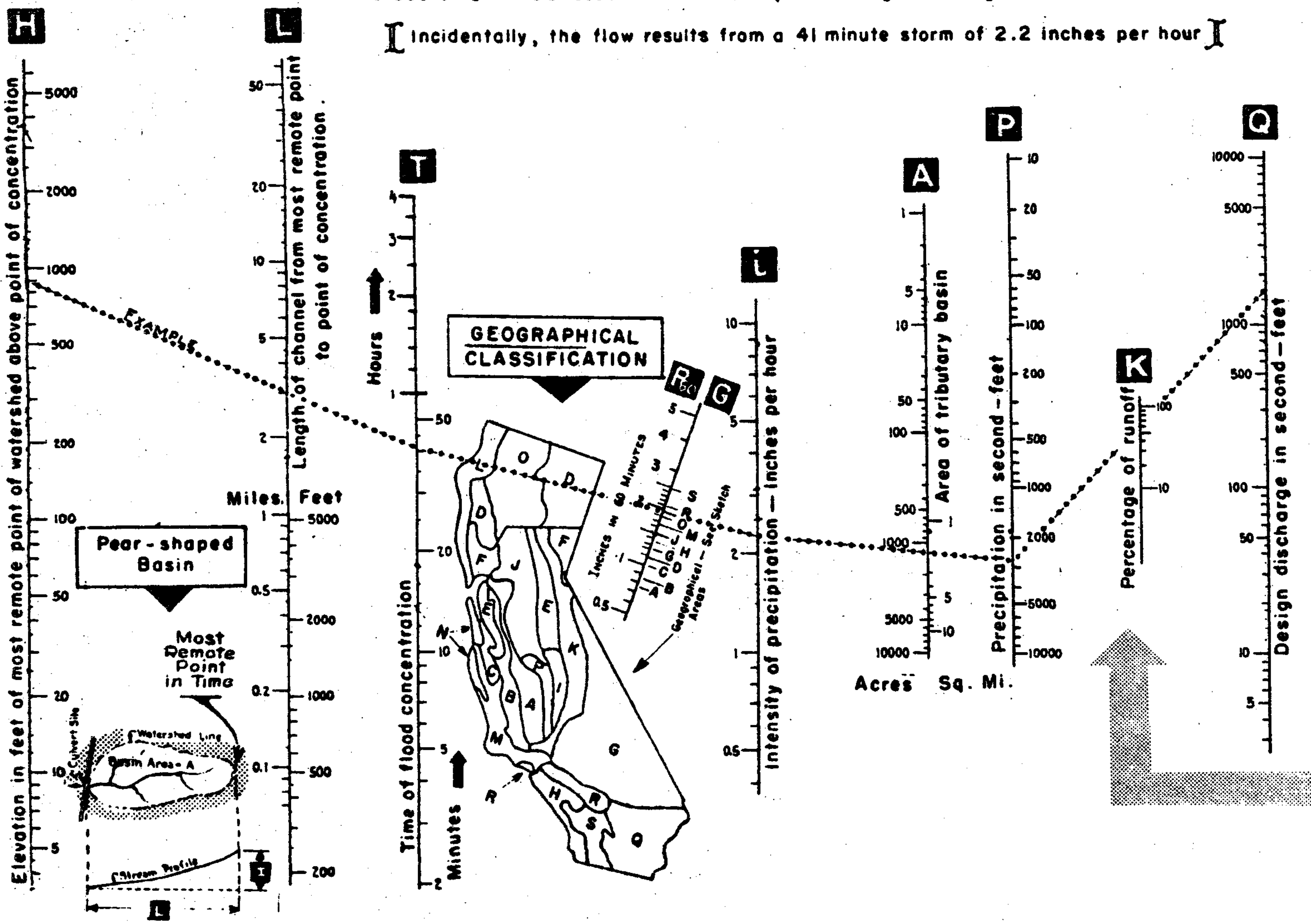
There is no substitute for a field review. Although aerial photographs and topographic maps are good media for the study of a drainage area, field inspections are necessary to verify design assumptions. A field reconnaissance should be made before installing new culverts. When existing culverts are to be replaced with a size different than existing, a field review should be conducted to review location and size.

Example:

A culvert site in the Imperial Valley is 3 miles downstream and 900 ft. lower than the most remote point on the watershed. The tributary basin has an area of 2.0 square miles and average ratio of runoff to precipitation is estimated at 60 percent.

The line through H = 900 ft., L = 3 mi., G = Q, A = 2 sq. mi. and K = 60 intersects Q = 1700 second-feet the required design discharge.

[Incidentally, the flow results from a 41 minute storm of 2.2 inches per hour]



K VALUES

These factors should be modified for infiltration and anticipated changes in character of terrain.

90 - 95	Impervious Surfaces
80 - 90	Steep Barrens
60 - 80	Rolling Barrens
50 - 70	Flat Barrens
40 - 65	Rolling Meadow
35 - 60	Deciduous Timberland
25 - 50	Conifer Timberland
15 - 40	Orchard
15 - 40	Upland Farms
10 - 30	Valley Farmland

COUNTY OF HUMBOLDT
Department of Public Works

Project ____________
W.O. # ____________ Sht ___ of ___
Calc ___ Date ___ Chkd ___ Date ___
Station ____________

ainage Design for Small Basins
Under 10 Square Miles

Area: ____________ A = ____ Acres or ____ Sq. Miles

Length of Basin: ____________ L = ____ Feet or ____ Miles

Highest point in Basin: Elevation a = ____ Feet

Lowest point in Basin: Elevation b = ____ Feet

Elevation above point of concentration ____________ a-b = H = ____ Feet

Percent of runoff: ____________ K = ____
(See Below)

	% of Total Area	Soil Type	RUNOFF FACTORS Less than 2%	2% to 10%	Greater than 10%	Runoff Factor X % of Total Area
NSE VEGETATION ods & Brush, ns oods, etc.		* SL * C	10 15	20 25	30 35	
DERATE VEGETATION wns, Brush, chards, etc.		* SL * C	15 25	30 40	40 50	
GHT VEGETATION sture land, rms		* SL * C	30 40	45 55	60 70	
PERVIOUS vements, Walks, of Tops, Rocky opes, etc.		* I	90	90	95	

TOTAL = 100% K = ____________ Total

SL Sandy Loam; C = Clay; I = Impervious

lve for Q by use of the chart (Design Discharge for Small Basins) using the values found for H, L, A, and K.

= cfs.

4-300 Culvert Design.

4-301 Criteria for Balanced Design.

The culvert facility shall be designed to discharge:

- A 10-year intensity storm without static head at entrance; and
- A 100-year intensity storm utilizing the available head at entrance.

The second condition above may not be required for certain projects, but it should be calculated if any possibility of property damage could result. The first condition should be met in all cases except temporary installations.

The available head may be limited by the fill height or the effects of ponding on upstream property. Additional explanation of these principles and detailed procedures for their application are given in the various references listed in Section 4-107.

4-302 Use of Available Head.

It is not always economical or practical to utilize all the available head. This applies, in particular, to situations where debris and detritus must pass through the culvert and where a headwater pool cannot be tolerated, or where the natural gradient is steep and high outlet velocities are objectionable.

(1) Debris and Detritus. There are two solutions to this problem:

(a) Retain solids upstream from the entrance, or

(b) Pass them through the culvert.

If drift and detritus are retained upstream, a riser or chimney with a debris cage may be added as a vertical extension to the culvert, thus increasing the head; however, this head should not be allowed to develop excessive velocities or cause pressures which might induce leakage in the culvert. If drift and detritus are passed through the culvert, the available head must be used to maintain or accelerate the velocity of the flow approaching the culvert instead of creating a pond at entrance, thereby inviting a blocked culvert.

(2) Steep Gradients. Full use of the available head may develop excessive velocity resulting in abrasion of the culvert itself or in downstream scour. A larger culvert operating with less velocity frequently is more economical than an energy dissipator.

4-303 Chart Solutions to Culvert Capacities.

Detailed analyses for small culverts (less than 15 square feet in cross section) seldom should be necessary; charts usually will suffice. Chart solutions for large culverts should be checked by other methods.

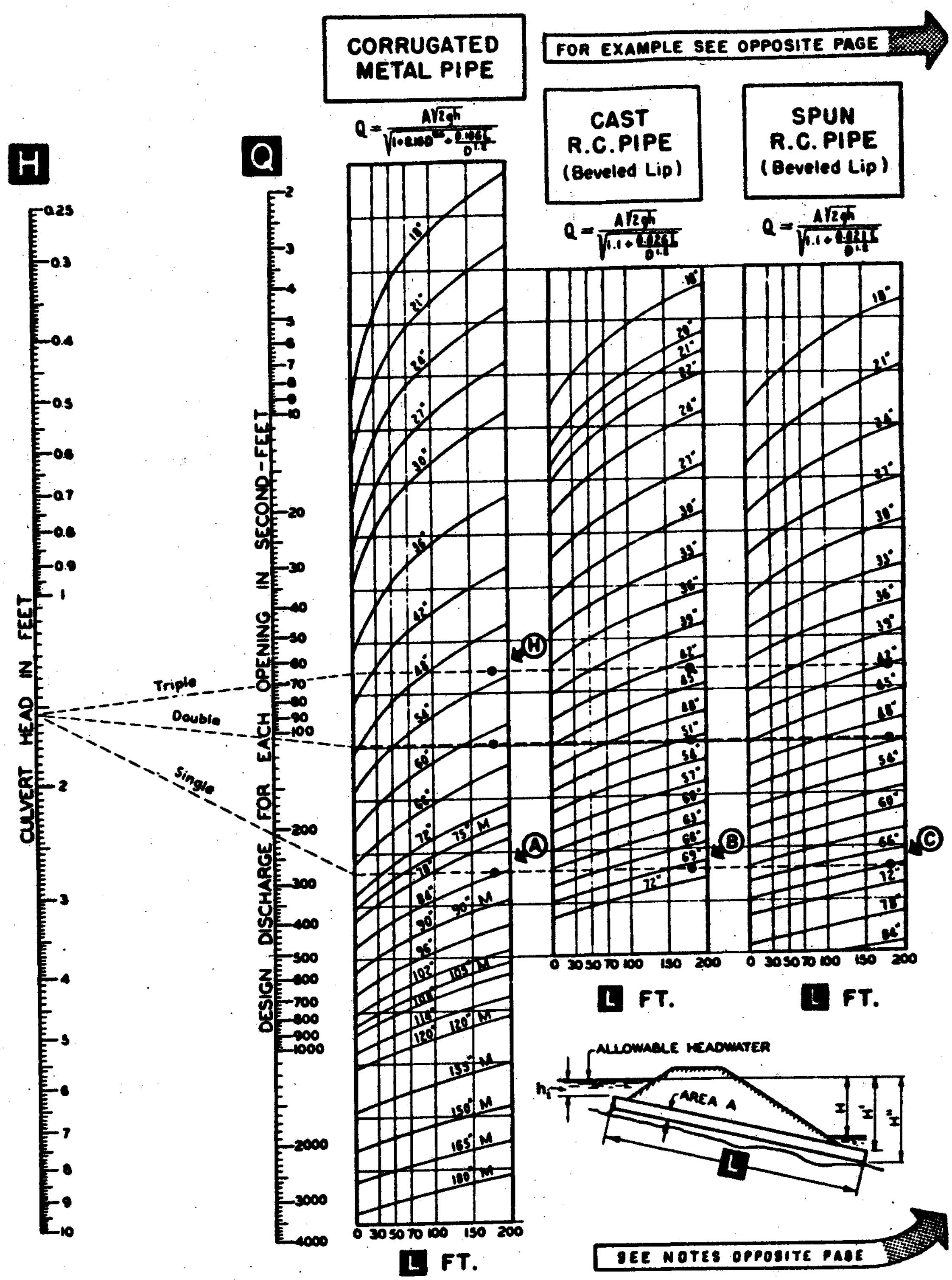
Except for submergence, the charts described below disregard conditions at inlet and outlet, as well as in the approach channel.

(1) Figures 4-303A-B give the capacity of different sizes and types of culverts under various heads.

(2) Figure 4-303C shows the relationship between capacity at the neutral slope (or the slope which will just carry a 100-year flood with a full waterway) and various sizes and types of culverts. This chart may be used for a first approximation.

(3) Figure 4-303D gives the minimum culvert entrance for a 10-year flood directly for circular pipes and indirectly for other shapes by using an equivalent rectangular cross section. Capacity in this case depends on the size of opening and shape of entrance.

See references listed in Section 4-107 for other chart solutions.



DESIGN OF PIPE CULVERTS
(FLOWING FULL)

Note: Taken from California State Design Manual Figure 7-821.3A)

SEE DIAGRAM OPPOSITE PAGE

NOTES

For free outlet, use H' for H; H' may be approximated as H" less an assumed vertical diameter.

The head at entrance (h_i) must exceed velocity head plus entrance loss.

Compute $V = \frac{Q}{A}$; increase section if necessary, until

h_i (C.M.P.) $> 0.022\ V^2$

h_i others $> 0.017\ V^2$

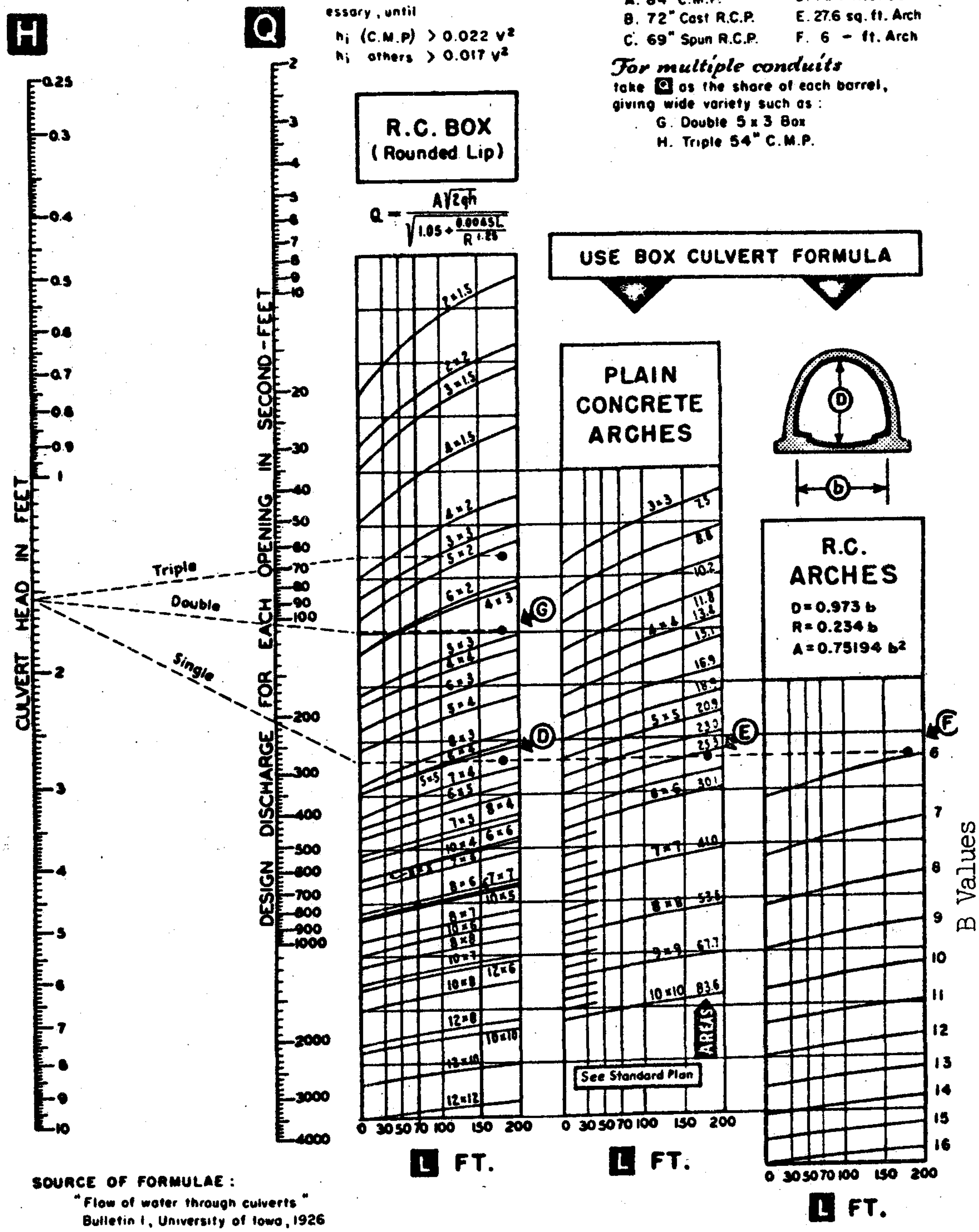
EXAMPLE

To compile alternative sections to carry 210 second-feet for 180 feet, assuming outlet submerged to a stage 1.55 feet below allowable headwater.

For a single conduit
the lowest line is drawn from H = 1.55 through Q = 210 to the fold line. From this intersection, a horizontal intersects L = 180 in each of the six fields, giving alternatives:

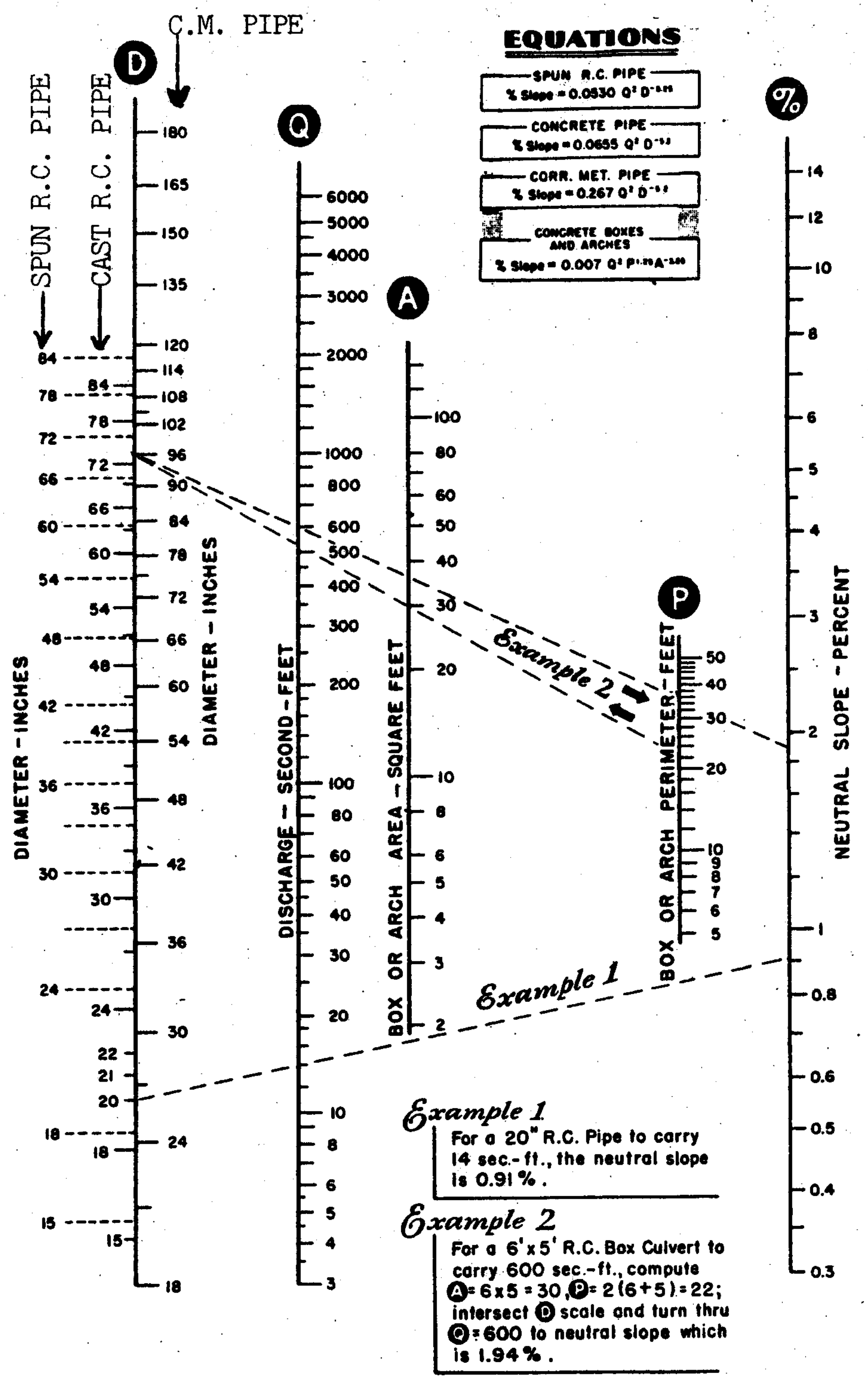
A. 84" C.M.P. D. 7x4 R.C. Box
B. 72" Cast R.C.P. E. 27.6 sq. ft. Arch
C. 69" Spun R.C.P. F. 6 - ft. Arch

For multiple conduits
take Q as the share of each barrel, giving wide variety such as:
G. Double 5 x 3 Box
H. Triple 54" C.M.P.



SOURCE OF FORMULAE:
"Flow of water through culverts"
Bulletin I, University of Iowa, 1926

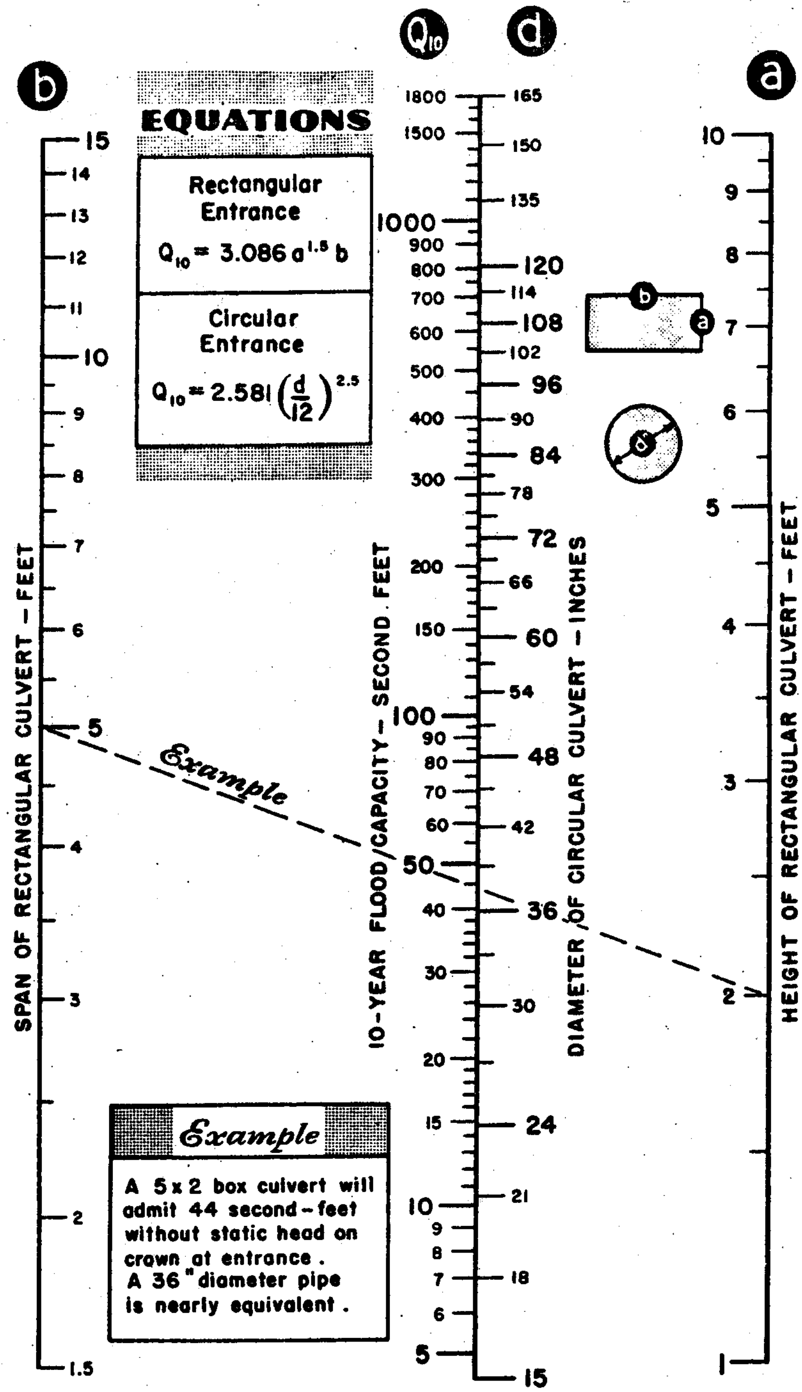
DESIGN OF CONCRETE BOXES AND ARCHES (FLOWING FULL)



NEUTRAL SLOPE OF CULVERT FOR 100-YEAR FLOOD

WITH HEAD AT ENTRANCE

Note: Taken from California State Design Manual Figure 7-821.3C



MINIMUM CULVERT ENTRANCE FOR 10-YEAR FLOOD

WATER LEVEL AT CROWN OF CULVERT

Note: Taken from California State Design Manual Figure 7-821.3D

4-304 Entrance Design.

The design of culvert entrances must consider hydraulics, debris and detritus, the effects on traffic, property, economics aesthetics, and maintenance.

(1) Hydraulic Considerations. The types of flow generally encountered in culvert design are: (a) flow with entrance control, the condition that is most common, which occurs with a free outlet; and (b) flow with outlet control which occurs, for example, with a submerged outlet. Under entrance control, the key factor governing the capacity of a culvert is the size of the entrance opening and friction loss in the barrel does not govern. Devices such as a rounded or beveled lip or an expanded entrance increase capacity. On this basis, capacity is affected by the velocity head and the entrance loss. It follows that the size and shape of entrance will control the level of ponding at entrance, help maintain the velocity of approach, and in special cases, such as a long culvert, lower costs by permitting a smaller size to be used.

The design charts in Figures 4-303A-B account for entrance losses for various heads based on the entrance types stated therein. For entrances not covered by these charts, different methods or other charts may be used. Entrance loss coefficients for all types of entrance are available in BPR hydraulic engineering circulars.

(2) Entrance Improvements. Except for transitions, the entrances discussed below are the types most frequently used and can be provided at reasonable cost.

(a) Rounded Lip Entrance,

(b) Expanded Entrances,

(c) Transitions, and

(d) Entrance Risers.

4-305 Outlet Design.

Improved culvert outlets are designed to restore natural flow conditions downstream. Outlets should be carefully scrutinized for conditions which produce scour. Where progressive erosion is to be expected, corrective measures such as bank protection, wingwalls, or transitions may be considered. When dealing with erosive velocities at outlet, the effects on downstream property should also be evaluated.

4-306 Choice of Type and Cross Section.

The choice of culvert type and cross section is based on the following factors:

(1) Physical and Structural Factors. Of the many physical and structural considerations, some of the most important are:

(a) Durability,

(b) Headroom,

(c) Earth loads,

(d) Bedding conditions,

(e) Culvert rigidity,

(f) Impact.

(2) Hydraulic Factors. Hydraulic considerations involve:

(a) Design discharge,

(b) Shape, slope and cross sectional area of channel,

(c) Velocity of approach,

(d) Total available head,

(e) Bedload,

(f) Inlet and outlet conditions,

(g) Slope of culvert,

(h) Smoothness of conduit, and

(i) Length of culvert.

A comparison of alternative culverts of dissimilar type, but of equivalent hydraulic capacity may be obtained by consulting the various references listed in Section 4-107.

(3) Maintenance and Construction Factors. These include:

(a) Local experience,

(b) Accessibility of site,

(c) Construction conditions.

(4) Economy. Comparative costs should be weighed on a long-term basis considering the factors given under Index No. 4-105. Economic comparisons should consider the overall cost of installation including inlet and outlet treatment and maintenance costs.

(5) Selection of Type.

(a) Selection of a Specific Type - In the cases listed below, the selection of the appropriate culvert type shall be supported by a complete analysis based on the foregoing factors. All pertinent documentation shall be placed on file.

(b) Use of Alternative Types - The plans and specifications should provide for alternatives on the basis of optional selection by the contractor. The required types of pipe are reinforced concrete, asbestos cement, and corrugated metal (steel). Any of these materials may be used if they meet minimum criteria for the required service life.

(c) Service Life and Special Requirements - The service life of metal culverts shall be determined from the pH and resistivity tests covered in Test Method No. Calif. 643 and from guides contained in the references listed in Section 4-107.

4-307 Provisions Against Culvert Deterioration.

All types of culverts are subject to deterioration from corrosion or abrasion.

(1) Metal Culverts. The following measures are commonly used to prolong service life:

(a) All metal culverts shall be galvanized.

(b) Asphalt Dipping - Asphalt dipping combined with galvanizing may merit consideration in these situations:

- Where water is stagnant or where dense vegetation or leaves are likely to produce organic acids;
- Where lack of fall or an obstruction would result in deposition, continuous wetness or both;
- In locations of continuous flow;
- In well drained and normally dry alkali soils.

Under the following conditions asphalt dipping of galvanized pipe usually does not give sufficient protection:

- Where excessive velocities are combined with abrasives in the flow;
- Where the culvert is subject to salt air or salt water;
- In highly mineralized soils, peat soils, also in alkaline soils that are poorly drained and frequently moist;
- Where barnyard runoff exists in the flow.

These conditions warrant consideration of other types of culvert pipe, extra metal thickness or other means of protection.

(c) Invert Paving - Invert paving is frequently used for culverts exposed to excessive wear from abrasives in the flow or where used as a stockpass.

(d) Extra Metal Thickness - Additional metal thickness will increase service life. However, where corrosion combined with abrasion is to be expected, other types of culverts generally will be more economical than metal pipes of heavier gage.

(e) Planking - Placing of inverted channel iron to decrease erosion due to abrasive elements will be considered as an acceptable method to reduce maintenance.

(2) Portland Cement Concrete Culverts. The following measures increase the durability of concrete culverts:

(a) Extra Thickness - Extra invert thickness may serve where erosion is likely to be so severe as to appreciably shorten the service life of a concrete culvert.

(b) Density - High density concrete pipe such as achieved by spinning or other processes should be considered under exposure to salt air or salt water.

4-308 Federal Requirements.

Corrugated metal culverts of the types listed below will meet FHWA requirements for use on federal-aid projects provided that the specifications conform to approved AASHO standards.

(1) Factory-riveted corrugated metal pipe involving diameters from 8 inches to 84 inches, inclusive. (While such pipe is available in sizes greater than 84 inches in diameter, approval is to be considered only on an individual project basis.)

(2) Field-assembled corrugated structural plate pipe involving diameters from 60 inches to 180 inches, inclusive; structural plate pipe-arches involving spans from 60 inches to 192 inches, inclusive; and structural plate arches involving spans from 4 feet to 30 feet, inclusive.

(3) Factory-riveted corrugated metal pipe-arches involving spans from 18 inches to 72 inches, for which there are no approved AASHO standards, will be acceptable for use under fills not exceeding 15 feet when specifications therefor are approved by the FHWA.

FHWA approval will be based on conditions applicable to the locations involved, including the relative economy of alternative types of installations.

4-310 Physical Standards for Culverts.

4-311 Alignment and Slope.

From the standpoint of hydraulic efficiency, durability and maintenance, abrupt changes in direction or slope are undesirable. Angle points are permissible in the absence of abrasives in the flow, otherwise curves should be used.

Curvature in pipe culverts is obtained by a series of small angle points. For further details on curvature, manufacturer's literature should be consulted.

For the downspout type of installation consideration must be given to anchorage.

4-312 Diameter and Length for Pipe Culverts.

The suggested minimum diameter for cross drains under the roadway is 18 inches. For pipe runs exceeding 100 feet, an intermediate inlet or cleanout should be considered or a 24-inch diameter used. For 24-inch diameter pipe runs exceeding 300 feet, intermediate inlets or cleanouts are required.

The length of pipe culvert to be installed shall be determined as follows:

(1) Establish a theoretical length based on slope-stake requirements, making allowance for headwalls.

(2) Adjust the theoretical length for height of fill by applying these rules:

(a) For fills 12 feet high or less, no adjustment is required.

(b) For fills higher than 12 feet, add 1 foot of length at each end for each 10-foot increment of fill height or portion thereof, neglecting the first 12 feet;

(c) In the case of high fills with benches, the additional length is based on the height of the lowermost bench.

(3) Use the nearest combination of commercial lengths which equals or exceeds the length obtained in (2) on the preceding page.

Multiple Pipes - In general, the spacing of pipes in a multiple installation, measured between outside surfaces, shall be one-half the nominal diameter with a maximum of 2-1/2 feet and a minimum of 1 foot.

4-313 Bedding and Backfill Considerations.

The height of overfill a culvert will safely sustain depends upon foundation conditions, methods of installation, and its structural strength and rigidity.

(1) Foundation conditions at the culvert site have considerable bearing on the stresses imposed on the culvert:

(a) A slightly yielding foundation under both the culvert and the adjoining fill is the condition generally encountered.

(b) Appreciable uniform settlement under both the culvert and the adjoining fill will not overstress the culvert.

(c) A relatively unyielding culvert foundation coupled with settlement in the adjacent fill can produce great overstress in the culvert, regardless of type.

(d) An unyielding foundation under both the culvert and the adjacent fill can produce high stresses in the culvert, particularly a rigid pipe with flat bedding. Such stresses are counteracted by subexcavation and backfill together with shaped bedding.

(e) Foundation investigations may reveal a combination of the foregoing conditions. In such cases, as well as for sites where the height of cover exceeds 100 feet, a special design may be required. A more detailed foundation investigation is required for a special design.

(2) Various acceptable methods of installation are presented in the reference documents listed in Section 4-107. For any predictable settlement, provisions for camber shall be made.

(3) Height of cover limitations for circular and pipe-arch culverts are found in Tables 4-313A-D.

TABLE 4-313A

Maximum Height of Cover for Circular Steel Pipe With 2-2/3" X 1/2" Corrugations

Diameter inches	Maximum height of cover (feet)				
	5/16" Rivets		3/8" Rivets		
	16 gage	14 gage	12 gage	10 gage	8 gage
	SINGLE RIVETED				
12	63	83			
15	50	66			
18	42	55	84		
21	36	47	72		
24	32	42	61	75	
30	25	33	49	60	74
36	21	28	41	50	62
	DOUBLE RIVETED				
42	40	43	72	76	80
48	35	38	63	67	70
54		34	56	59	63
60			50	53	56
66			46	49	51
72				45	47
78				43	44
84				40	40

NOTES

[1] Seams may be riveted, welded or helical.
[2] Pipes with helical seams are limited to diameters of 48" or less.
[3] For values below the heavy broken line, if the site investigation establishes abrasive flow conditions when the flow velocity with a full culvert at entrance exceeds 5 fps, heavier gage metal shall be provided.

TABLE 4-313B

Maximum Height of Cover for Circular Steel Pipe With 3" X 1" Corrugations

Diameter inches	Maximum height of cover (feet)				
	Double 3/8" rivets		Double 7/16" rivets		
	16 gage	14 gage	12 gage	10 gage	8 gage
36	43	57	88	(101)	(107)
42	37	49	76	87	92
48	32	43	66	76	80
54	29	38	59	68	71
60	26	34	53	61	64
66	23	31	48	56	58
72	22	29	44	51	53
78		26	41	47	49
84		25	38	43	46
90		23	35	41	43
96			33	38	40
102			31	36	38
108			29	34	36
114			28	32	34
120			26	30	32

NOTES

[1] Seams may be riveted, welded or joined with 3/4" bolts and the number of bolts shall equal the number of rivets. Only one type of seam is permitted in one installation.
[2] For values below the heavy broken line, if the site investigation establishes abrasive conditions when the flow velocity with a full culvert at entrance exceeds 5 fps, heavier gage metal shall be provided.
[3] Fill heights exceeding 100 feet shall be considered a special design (see values in parentheses).

Note: Taken from California State Design Manual Tables 7-822.7A and 7-822.7B

TABLE 4-313C

MAXIMUM HEIGHT OF COVER
FOR STEEL PIPE-ARCHES
WITH 2-2/3" X 1/2" CORRUGATION

Span - Rise (inches)	Minimum Corner Radius (inches)	Maximum Height of Cover (ft.)		
		5/16" Rivets	3/8" Rivets	
		14 ga	12 ga	10 ga
	SINGLE RIVETED			
21 x 15	3	9	9	--
24 x 18	3	8	8	--
28 x 20	3	6	6	6
35 x 24	3	5	5	5
42 x 29	3½	5	5	5
	DOUBLE RIVETED			
49 x 33	4	5	5	5
57 x 38	5	5	5	5
64 x 43	6	6	6	6
71 x 47	7	--	6	6
76 x 52	8	--	6	6
83 x 57	9	--	--	7

1. Seams may be riveted or welded. Helical lock seam limited to 57" x 38" maximum size.

2. Cover limited by corner soil pressure of 1-1/2 tons per square foot.

3. Heavier gage metal shall be provided for arches left of heavy broken line when flow velocity with full culvert at entrance exceeds 5 fps.

4. Bituminous lining not available in 21" x 15" and 24" x 18" sizes.

TABLE 4-313D

MAXIMUM HEIGHT OF COVER
FOR STRUCTURAL STEEL
PLATE CIRCULAR PIPE WITH
6" x 2" CORRUGATIONS

Diameter inches	Maximum height of cover (feet)							
	4-bolt seams							6-bolt seams
	12 gage	10 gage	8 gage	7 gage	5 gage	3 gage	1 gage	1 gage
60	42	62	80	93				
66	39	57	73	85				
72	35	52	67	78	94			
78	33	48	62	72	87			
84	30	45	57	67	80	95		
90	28	42	54	62	75	88	96	
96	27	39	50	58	70	83	90	
102	25	37	47	55	66	78	85	
108	24	35	45	51	63	74	80	
114	22	33	42	49	50	70	76	98
120	21	31	40	47	56	66	72	92
126	20	30	38	45	54	63	69	88
132	19	28	37	43	51	60	66	84
138	18	27	35	41	49	58	63	80
144	18	26	34	39	47	55	60	77
150	17	25	32	38	45	53	58	74
156	16	24	31	36	44	51	56	71
162	16	23	30	35	42	49	54	68
168	15	22	29	34	40	47	52	66
174	15	22	28	32	39	46	50	64
180	14	21	27	31	38	44	48	62
186	14	20	26	30	36	43	47	60
192		20	25	29	35	42	45	58
198		19	25	29	34	40	44	56
204		19	24	28	33	39	43	54
210		18	23	27	32	38	42	53
216		18	23	26	31	37	40	51
222			22	26	31	36	39	50
228			21	25	30	35	38	49
234			21	24	29	34	37	47
240				24	28	33	36	46
246				23	28	33	35	45
252				22	27	32	34	44

NOTES

For values left of the heavy broken line, if the site investigation establishes abrasive conditions when the flow velocity with a full culvert at entrance exceeds 5 fps, heavier gage invert plates shall be provided.

4-314 Minimum Thickness of Cover.

Table 4-314 gives the minimum thickness of cover required for design purposes over culverts and pipe-arches. For construction convenience, the minimum cover for all types of culverts is 6 inches greater than the thickness of the structural materials in the pavement cross section.

Class "C" Concrete backfill may be used for culverts where it is necessary to have less than 18 inches of cover below the top of a flexible pavement. A minimum of one foot of concrete backfill should be used at the sides of the culvert.

4-315 Culvert Joints.

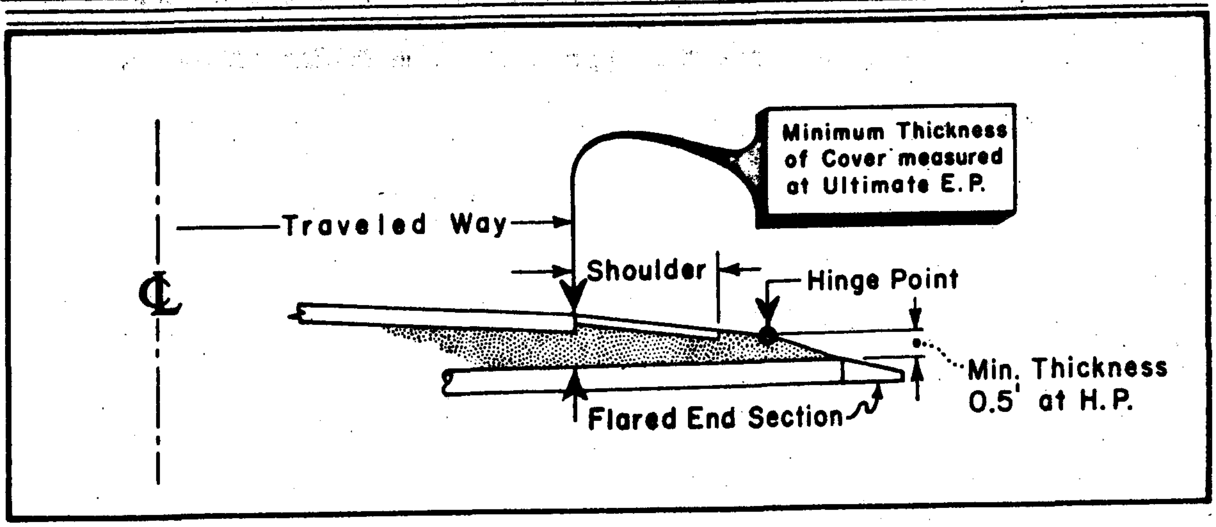
4-315.1 Metal Culverts - Metal culverts 24 inches in diameter, or less, normally require 12-inch hand couplers. Those larger than 24 inches should utilize 24-inch hand couplers.

4-315.2 Reinforced Concrete - Reinforced concrete pipes are normally bonded together by the use of grouting; however, rubberized gaskets or other methods may be utilized with the approval of the Design Engineer.

TABLE 4-314

MINIMUM THICKNESS OF COVER FOR CULVERTS

SURFACE TYPE	MINIMUM THICKNESS OF COVER		
	Corrugated metal pipes and pipe-arches	Structural plate pipes and pipe-arches	Reinforced concrete pipes
Flexible Pavements or Unpaved	$\frac{\text{Diameter or span}}{5}$ 2 ft. minimum	$\frac{\text{Diameter or span}}{8}$ 2 ft. minimum	2 ft. minimum
Rigid Pavements	$\frac{\text{Diameter or span}}{5}$ 1.2 ft. minimum	$\frac{\text{Diameter or span}}{8}$ 1.2 ft. minimum	1 ft. minimum



4-316 Headwalls and Other End Treatments.

(1) General Requirements - The need for culvert headwalls or other structures, at either entrance or outlet, should be based on the physical, hydraulic, and aesthetic conditions particular to the site.

(2) Flared End Sections and Headwalls -

(a) At Entrance - Flared end sections or headwalls are desired for these reasons:

- For hydraulic efficiency,
- To prevent a flow outside the culvert barrel in pervious backfill materials,
- Acting as a counterweight, a headwall prevents flotation of large culverts at entrance where ponding and plugging of the opening by drift are anticipated,
- To prevent erosion of steep embankment slopes due to a frequently recurring headwater pool.

For hydraulic reasons, flared end sections and headwalls are not required under the following conditions:

- For intermittent, low velocity flows where head conservation is not important.
- Where the design discharge isinsufficient to fill the opening of a minimum size pipe.

(b) At Outlet - It is undesirable from a hydraulic viewpoint and usually unnecessary to place headwalls at outlets to culverts less than 48 inches in diameter. Headwalls or other protection are essential regardless of culvert size where a degrading channel is apt to undermine the culvert or erode the embankment.

Whenever erosive conditions are encountered at outlet, standard headwalls or wing-walls should be used with caution. Before any end treatment is considered, the effects of such a discharge on both the outlet structure and downstream property must be evaluated. Where the culvert is exposed to view, either a headwall or a flared end section should be provided.

(c) Flared End Sections - As they provide effective entrance, prefabricated flared end sections should be used in lieu of headwalls. Flared end sections also lend themselves well to situations calling for fill widening.

(d) Straight Headwalls - They may be used where right of way restrictions dictate.

(e) Winged Headwalls - Except in special cases, headwalls with wings are not recommended for use with small culverts as flared end sections are more effective and less expensive.

(f) L-Headwalls - This type has one wing normal to the culvert centerline. It is used in well-defined channels with low to moderate velocity where an abrupt change in direction is required at the culvert entrance. L-Headwalls may be used where warranted in locations well removed from the shoulder.

(3) Mitered Ends. Mitered ends conforming to the fill slope have no place at entrance as they are less efficient than either flared end sections or headwalls. Mitered ends may be used at outlet where the culvert is exposed to view. As they are structurally unstable, they are not recommended for pipes over 48 inches in diameter. Because the mitered section must be removed, mitered outlets also are not recommended where extension of the culvert is anticipated.

(4) Projecting Ends - The projecting end is permissible in mountainous terrain or where it is not exposed to view. Like the mitered end, the projecting entrance inhibits culvert efficiency when the entrance is submerged. In some situations, the outlet end may project beyond the fill, thus providing security against erosion at less expense than bank protection work.

4-317 Strength Requirements for Metal Culverts and Reinforced Concrete Pipe.

Strength requirements for corrugated steel pipes fabricated under the three acceptable methods contained in the "Standard Specifications," and for reinforced concrete pipe are given in various tables contained in reference documents (Section 4-107). To properly use these tables and graphs, the designer should be aware of the premises on which the tables are based as well as their limitations.

4-318 Box and Arch Culverts.

Reinforced concrete cast-in-place box culverts, arch culverts and structural plate arch culverts with a cast-in-place footing and invert are particularly susceptible to unfavorable foundation conditions. The footing pressures under these box and arch culverts vary from approximately 1.5 tons per square foot to 7.5 tons per square foot with zero to 70 feet of overfill. For these reasons, the design engineer shall make a foundation investigation of sufficient scope to determine the supporting power of the foundation material, the potential settlement and unequal foundation support.

4-400 Roadway Drainage Requirements.

For purposes of this manual, roadway drainage covers the collection and removal of waters from the roadway. It includes such items as:

(1) Surface waters originating within the right of way, namely the roadbed, median and contributing slopes;

(2) Surface waters originating outside the right of way and not confined to channels; and

(3) Ground water.

In the design of roadway drainage facilities, the aim is to keep the traveled way free from flooding except for infrequent heavy rainstorms. The frequency and tolerance of flooding shall depend on the importance of the roadway, coupled with the risks and costs involved.

4-401 Standards for Roadway Drainage.

(1) General Requirements:

(a) The design storm frequency and allowable extent of flooding shall be as given in Table 4-401.

(b) In runoff computations by the rational method, a minimum of 10 minutes is recommended for both the time of concentration and the inlet time.

(c) In general, drainage across the traveled way should not flow over more than 4 lanes.

(2) Stage Construction. In stage construction, all permanent drainage installations shall be designed to provide for the ultimate roadway improvement. This applies mainly to storm drain systems.

TABLE 4-401

STANDARDS FOR ROADWAY DRAINAGE

Roadway Feature	* Limits of Flooding	Design Flood Frequency - By Type of Roadway		
		Arterials	Collectors	Access Road
Normal Traveled Way	(a) Flush shoulder design lowest edge of traveled way. (b) Rolled gutter design lowest S-foot width of traveled way, but water shall not overtop shoulder on low side of superelevation.	25	10	10
Traveled Way at Depressed Sections	Lowest S-foot width of traveled way regardless of type of shoulder.	100	25	10

* Based on 10-minute time of concentration.

4-402 Ditches.

(1) Grade - The flattest grade recommended for design is 0.25 percent for earth ditches. Under "ideal" conditions, 0.12 percent may be used for paved ditches.

(2) Slope Ditches - Slope ditches or surface ditches should be provided where it is necessary to intercept drainage from natural slopes inclined toward the roadway. When the ditch grade exceeds a 4:1 slope, a downdrain is often advisable. Slope ditches may not be necessary where side slopes in favorable soils are flatter than 2:1 or where positive erosion control measures are to be instituted during construction.

(3) Side Ditches - These are triangular gutters adjoining the shoulder. For conditions governing their use, see Section 2-322.5.

(4) Chart Solutions - The nomograph in Figure 4-503A applies to all triangular channels.

4-403 Overside Drains.

The purpose of overside drains, sometimes called slope drains, is to protect side slopes against erosion. They convey drainage down the slope which is collected from the roadbed, the tops of cuts or from benches in cut or fill slopes. They may be pipes, flumes or paved spillways as shown on the standard plans.

(1) Spacing and Location - The spacing and location of overside drains depends on the conformation of the ground, the roadway profile, the quantity of flow and the limitations on flooding stated in Table 4-401. Diversion from one watershed to another should be avoided. If diversion becomes necessary, the drainage should be carried to a point of discharge into a natural watercourse or a storm drain.

(2) Type and Use Requirements - Following are details of the various types of overside drains:

(a) Pipe Downdrains - Metal pipes are adaptable to any slope. They should be used where side slopes are 4:1 or steeper. The minimum pipe diameter shall be 8 inches, but large flows or long pipe installations may dictate a larger diameter.

(b) Flume Downdrains - These are rectangular corrugated metal flumes with a tapered entrance. They are best adapted to slopes that are 2:1 or flatter but if used on 1-1/2:1 slopes, lengths over 60 feet are not recommended. Abrupt changes in alignment or grade should be avoided.

(c) Paved Spillways - Permanent paved spillways normally are used on side slopes flatter than 4:1 but they shall be not longer than 24 feet. Spillways also may be used on slopes as steep as 2:1 but their length shall not exceed 14 feet.

(3) Entrance Standards. Authorized entrance tapers for pipe and flume downdrains are detailed on standard plans. An acceptable alternative to the pipe entrance taper is a flared end section. Entrance tapers and flared end sections should be depressed at least 0.5 foot.

The local depressions called "paved gutter flares" may be used at overside drains.

(4) Outlet Treatment. Where excessive erosion is anticipated at an overside drain outlet, a simple energy dissipator should be employed.

(5) Anchorage. Overside drains should be anchored.

(6) Drainage of Benches. Drainage from benches in cut or fill slopes should be removed at intervals ranging from 500 to 800 feet.

(7) Selection of Type. Pipe and flume downdrains shall consist of corrugated steel. For design purposes, materials must satisfy the conditions stated on the following page:

(a) Design Service Life - The design service life of downdrains shall be 50 years when buried more than three feet within the embankment on projects where the design service life of culverts is 50 years. Under all other conditions, such as on the surface of a fill slope, it shall be at least 25 years.

(b) Special Requirements - The design service life of metal downdrains shall be determined from pH and resistivity tests covered in Test Method No. Calif. 643 and other tables contained in references listed in Section 4-107.

4-500 Storm Drains.

4-501 Storm Drain Systems.

Road Commissioner approval is required in advance when an extensive storm drain system is proposed. Storm drain systems for roadways often involve critical disposal problems, particularly where drainage of the surrounding area is inadequate. A cooperative project effected with local interests may provide the best solution to the problem.

4-501.1 Notes on Hydraulic Design.

(1) Design Discharge. Any recognized method of computing the quantity of runoff may be employed. The designer is reminded that using the maximum time of concentration to determine design rainfall intensity does not necessarily give the maximum runoff possible for a given drainage area. Various shorter storm durations should be investigated as the resultant higher intensities over partial drainage areas may produce larger flows.

Where the watercourse is a combination of flow overland and in pipes, the time of concentration is the sum of the inlet time plus the time of flow in the pipe.

Owing to sheet flow over the traveled way and shoulders as well as flow over the ground a minimum inlet time and time of concentration of 10 minutes is recommended for roadway areas.

(2) Hydraulic Design of Conduits. Closed conduits should be designed for the full condition. They may be allowed to operate under pressure, provided the hydraulic gradient is 0.75 foot or more below the intake lip of any inlet which may be affected. In no event should the energy gradient rise above the lip of the intake.

In a shallow system with a flat invert slope, allowance should be made for energy losses at bends, junctions and transitions.

(3) Backwater at Outlet. To determine the lowest outlet elevation for drainage systems which discharge into leveed channels or bodies of water effected by tides, consideration must be given to the probabilities of back water.

When necessary, backflow protection should be provided in the form of flood gates.

(4) Storage. In developing the most economical installation, the designer should not overlook economies obtainable by the ponding effect of storage in gutters, medians and interchange areas. Inlet spacing largely controls surface storage in gutters and medians; inlet capacity governs in sump areas.

(5) Floating Trash. Except at pumping installations, every effort should be made to carry all feasible floating trash through the storm drain system. Curb-opening inlets and drop inlets are well suited for this purpose. In selecting grated inlets for urban sections, the designer should consider the potential use of the street by children and narrow-wheeled bicycles.

4-502 Standards for Storm Drain Pipes.

(1) Location and Alignment. Longitudinal storm drains for the disposal of roadway drainage should not be placed under the traveled way or shoulders. Whenever a location under the roadbed is necessary, manholes should be located outside the shoulder. In urban sections manholes may be located within the roadway section. Where bends are required, the alignment should be on a circular curve. Angle points in the alignment should not exceed 10 degrees; otherwise, a manhole should be used.

(2) Pipe Diameter. The minimum pipe diameter shall be as given in Table 4-502, except that pipes located wholly or partly under the roadbed shall be at least 18 inches in diameter.

The minimum diameter for use with pipe drop inlets (Types GCP, OCP, GMP and OMP) shall be 18 inches.

TABLE 4-502

Minimum Pipe Diameters for Storm Drains

Type of Drain	Minimum Diameter (Inches)
Trunk Drain	18
Trunk Lateral	15 *
Inlet Lateral	15 *

* 18" minimum if wholly or partly under the roadbed.

(3) Strength. Strength requirements for both metal and concrete pipes can be found in the appropriate references listed in Section 4-107.

(4) Selection of Type. In general, the considerations which govern the selection of culvert type apply to storm drain conduits. One exception is the roughness factor which generally assumes greater importance in a storm drain.

(5) Depth of Cover. For applicable standards for minimum thickness of cover, see Section 4-314. For maximum heights of overfill, see the reference documents listed in Section 4-107.

4-503 Gutter Design.

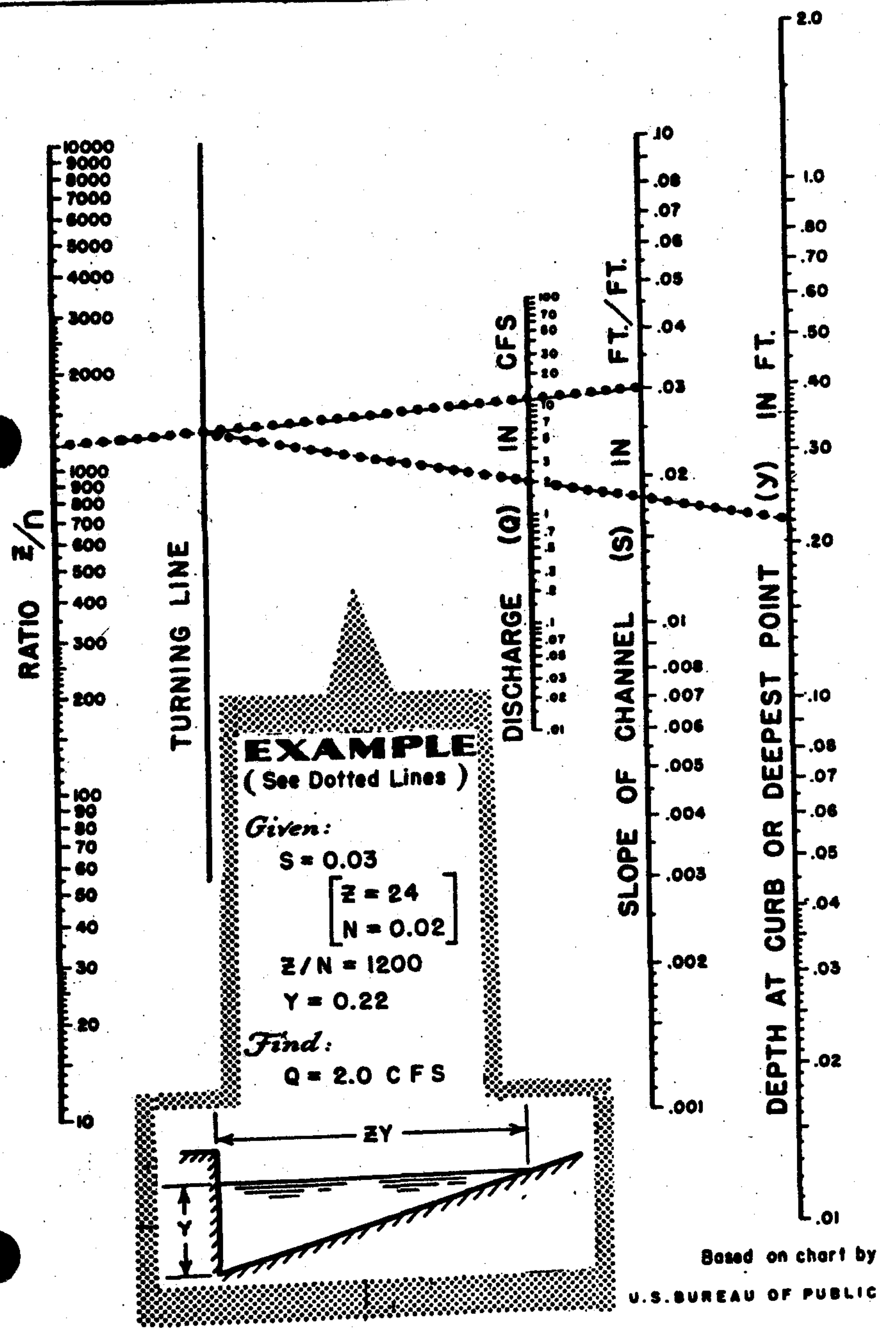
(1) Capacity. Gutters shall be designed to keep flooding within the limits given in Table 4-401. Easy solutions of gutter flow problems are obtained by using Figure 4-503A which applies to triangular channels and other shapes illustrated on the chart.

(2) Gutter Types. The shape and dimensions of approved curb and gutter cross sections commonly used are shown in various reference documents (Section 4-107).

(3) Longitudinal Slope. Longitudinal gutter grades should not be flatter than 0.12 percent.

NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

EQUATION	N IS ROUGHNESS COEFFICIENT
$= 0.56 \frac{Z}{N} S^{1/2} Y^{8/3}$	Z IS RECIPROCAL OF CROSS SLOPE



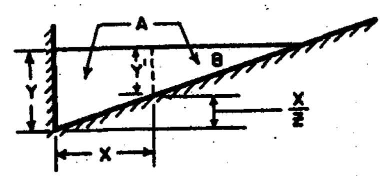
Based on chart by
U.S. BUREAU OF PUBLIC ROADS

INSTRUCTIONS

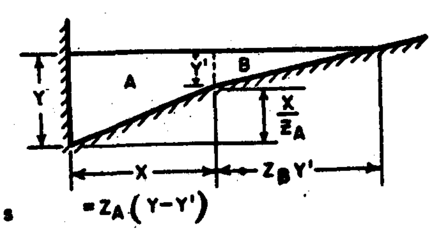
1. Connect Z/N ratio with slope (S) and connect discharge (Q) with depth (Y). These two lines must intersect at TURNING LINE for complete solution.

2. For shallow v-shaped channel as shown use Nomograph with $Z = \frac{T}{Y}$

3. To determine discharge Q_X in portion of channel having width X : determine depth Y for total discharge in entire section A. Then use Nomograph to determine Q_B in section B for depth $Y' = Y - \left(\frac{X}{Z}\right)$



4. To determine approx. discharge in composite section :- Follow instruction 3 to obtain discharge in section A at assumed depth Y ; obtain Q_B for slope ratio Z_B and depth Y', then $Q_T = Q_A + Q_B$



(4) Cross Slopes. On 2-foot curbed gutters to the right of traffic, the normal cross fall shall be 2 inches. On gutters wider than 2 feet, the cross slope shall not exceed 7 percent. Flatter cross slopes should be avoided because they cut down gutter capacity and severely reduce inlet efficiency.

(5) Curbed Intersections. If pedestrian traffic is a ruling factor, intersection drainage presents the following alternatives to be weighed as to effectiveness and economy:

(a) Intercept the whole flow at or near the beginning of the curb return.

(b) Intercept a part of the water and allow the overflow to cross the intersection. The width of flow should be controlled so that pedestrian traffic is not unduly hampered.

(c) If it is small, pass the entire flow through the intersection in a valley gutter—see subparagraph (6) below.

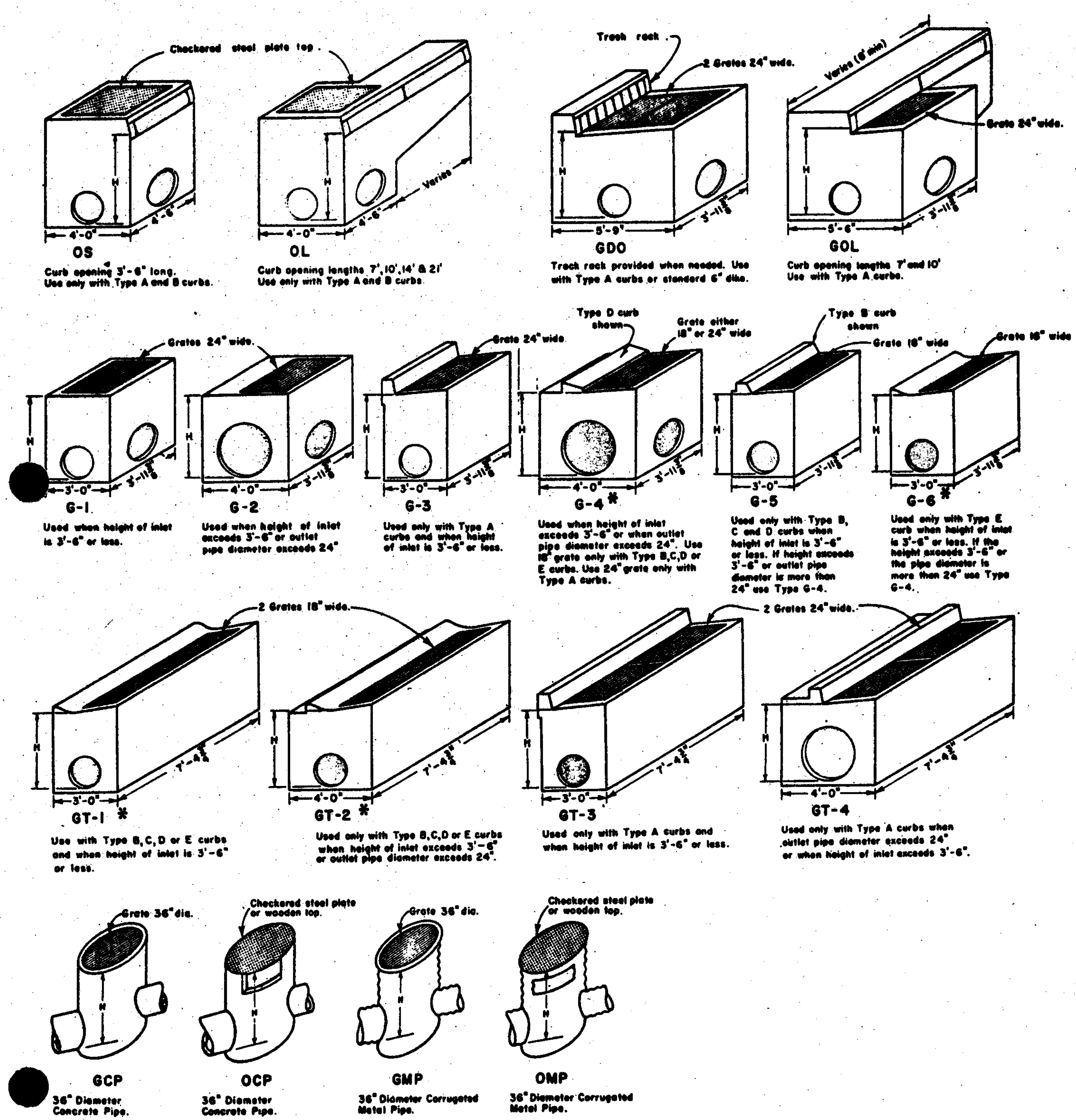
(6) Valley Gutters. Valley gutters across the traveled way should be avoided. In general, the total width of gutter should not exceed 8 feet and cross slopes shall not exceed 3 percent. Two percent is suggested where more than nominal speeds are involved.

4-504 Inlet Types.

The basic features of standard storm drain inlets are shown in Figure 4-504. The variety of standard designs found in the recommended reference documents is considered sufficient to meet any drainage situation; hence, the use of nonstandard inlets should be a rare exception.

From an operating standpoint, there are four main groups of inlets; these are:

STORM DRAIN INLET TYPES



* Not commonly used in Humboldt County. Approval of Director required prior to use.

(a) Curb opening inlets (Type O) which have an opening paralleling the direction of flow;

(b) Grate inlets (Types G, GT, GCP and GMP); these provide a grate opening in the gutter or waterway;

(c) Combination inlets (Types GDO and GOL) which have both a curb and a grate opening; and

(d) Wall opening inlets, in which the intake opening is normal to the flow (Types OCP and OMP).

(e) Slotted drains (not pictured) may be considered. Maintenance factors should be considered extensively before selecting slotted drains.

The choice of type depends in general on site conditions, hydraulics and costs. Although the hydraulic capacity of any type is closely tied to the size and type of intake opening, the capacity is greatly increased by depressing the opening below the normal flowline of the waterway.

4-505 Types and Uses of Grates.

Following are the dimensions and uses of standard grates:

Type 18- 9 - Clear opening--18" x 35-3/8".

Clear bar spacing--1-3/8" (9 bars).

Uses--within the roadbed on highways where bicycles and pedestrians are excluded.

Type 24-18 - Clear opening--24" x 35-3/8".

Clear bar spacing 3/4" (18 bars).

Uses--within the roadbed, normally under urban conditions where bicycles and pedestrians are permitted.

Type 24-12 - Clear opening--24" x 35-3/8".

Clear bar spacing--1-3/8" (12 bars).

Uses--within the roadbed on highways where bicycles and pedestrians are excluded.

Type 24-9 - Clear opening--24" x 35-3/8".

Clear bar spacing--2" (9 bars).

Uses--outside the roadbed. Will not support normal highway wheel loads. This is the best grate for passing leaves.

Type 36-R - Round grate--34-1/2" inside diameter.

Clear bar spacing--2".

Uses--outside the roadbed with concrete or metal pipe drop inlet. Will not support normal highway wheel loads.

Diamond pattern grates may be used where bicycles are expected.

4-506 Location and Spacing of Inlets.

(1) Governing Factors. The location and spacing of inlets depend mainly on these factors:

(a) The amount of runoff,

(b) The grade profile,

(c) The location and geometrics of grade intersections,

(d) Width of flow limitations,

(e) The inlet capacity, and

(f) Volume and movements of vehicles and pedestrians.

(2) Location. There are no ready rules by which the location of inlets can be fixed; the most effective and economical installation should be the aim.

(3) Spacing. Arbitrary spacing of inlets should be avoided. The distance between inlets should be determined by a rational analysis of the factors controlling the design. In a valley median, the designer should consider soil permeability and susceptibility to erosion in the spacing of inlets. To economize on disposal facilities, inlets are often located at culverts or near storm drain conduits.

(4) Inlets in Series. When conditions dictate the need for a series of inlets, the recommended minimum spacing should be approximately 20 feet, using the nearest combination of commercial pipe lengths. Allowance should be made for length added by pipe joints and the bevel at the pipe entrance.

4-507 Hydraulic Design of Inlets.

(1) Factors Governing Inlet Capacity. Inlet capacity is a variable which depends on:

(a) The size of the intake opening;

(b) The velocity and depth of flow and the gutter cross slope just upstream from the intake; and

(c) The amount of depression of the intake opening below the flow line of the waterway.

(2) Curb-Opening Inlets. See reference documents listed in Section 4-107.

(3) Grate Inlets. The charts contained in the recommended references (Section 4-107) give capacities for inlets with a single rectangular grate on the basis of complete interception.

4-508 Local Depressions

(1) Purpose. A local depression is a paved hollow in the waterway shaped to concentrate and direct the flow into the intake opening and thus develop the full capacity of the inlet. In a gutter bordered by a curb, it is called a gutter depression.

(2) General Notes on Design. With certain exceptions, a local depression shall be provided at every inlet even though the waterway is unpaved. Where the size of intake opening is in question, a depression of maximum depth should be considered before deciding on a larger opening. For traffic reasons, the gutter depression shall be omitted in these cases: (a) driveways, and (b) median curb and gutter installations. It shall be permissible to omit gutter depressions at sump inlets where the width of flow does not exceed prescribed limits.

(3) Local Depressions Outside the Roadbed. Local depressions outside the roadbed generally consist of a paved apron or transition of a shape which serves the purpose.

(4) Gutter Depression. The gutter depression is designed for use in a curb and gutter installation. It is carefully proportioned in length, width, depth and shape. To best preserve the design shape, construction normally should be of concrete. Further requirements for gutter depressions are:

(a) Length - See references (Section 4-107),

(b) Width - Normally 4 feet, but for wide flows or a series of closely spaced inlets, 6 feet is authorized, and

(c) Depth - Where traffic considerations govern, the depth commonly used is 0.10 foot. Use the maximum of 0.25 foot wherever feasible at locations where the resulting curb height would not be objectionable.

4-509 Manholes and Junction Structures.

(1) Manholes - General Notes. A manhole is an underground structure which provides access to a continuous underground conduit. It consists of a chamber at the bottom large enough for a man to work in and a shaft which provides access directly from the surface.

There are no fixed rules for the location and spacing of manholes. In the final analysis, the designer must seek a reasonable compromise between cost and ease of maintenance.

(2) Junction Structures. A junction structure is an underground chamber used to join two or more conduits, but does not provide direct access from the surface. It is designed to prevent turbulence in the flow by providing a smooth transition. Where required by spacing criteria, a manhole should be used.

4-600 Open Channels.

4-601 General.

Two channel problems most often face the engineer in highway drainage practice; they are:

(a) To find the discharge of a natural stream, and

(b) To produce a safe, economical channel design.

Both depend on a basic knowledge of the factors which govern channel flow. In a discharge problem, the key factor is the roughness coefficient (n), while in a design problem, the water surface profile and the velocity are the most important considerations.

(1) Uniform Flow. Uniform flow occurs when the flow is steady and the mean velocity is constant; it is only possible in a channel of constant cross section. Under this condition, the water surface is parallel to the bottom of the channel and can be computed by friction formulae such as the Manning and Kutter developments of the Chezy Formula.

(2) Nonuniform Flow. Nonuniform flow occurs when the mean velocity for a given flow varies from one section to another and is the condition most often encountered in highway practice. It may be divided into two general classifications: (a) gradually varied flow where frictional resistance is the principal factor, and (b) rapidly varied flow in which either acceleration or deceleration is the prime consideration.

In gradually varied flow, the stream adjusts itself to the size of the cross section which the slope of the hydraulic gradient requires. In such cases, it is possible to approximate the water surface profile using a friction formula such as Manning's. To obtain reasonably reliable results, the stream must be divided into short reaches in which flow conditions are nearly alike, and velocities should not change more than 10 to 20 percent. In the reaches selected for computation purposes, the water surface profile must not diverge too much from the average channel grade line for even moderate divergencies can introduce gross errors.

Rapidly varied flow occurs in the vicinity of transition sections such as drops, dissipators, or sudden changes in channel cross section. Friction formulae should not be used under such conditions.

(3) Economy in Design. Construction, right of way and maintenance costs must be considered in designing an open channel. The size and shape as well as the choice between a lined and an unlined channel are based on economic comparisons which take into account the foregoing factors. On channel grades producing erosive velocities, it may be more economical to construct an unlined channel with drops rather than a lined channel on a straight grade. The location of a channel in the outer separation, rather than the outer side of a frontage road, may result in economies in right of way and culvert costs.

(4) Chart Solutions. A nomograph for the solution of the Manning Formula is shown in Figure 4-601.

4-602 Design Storm Frequency.

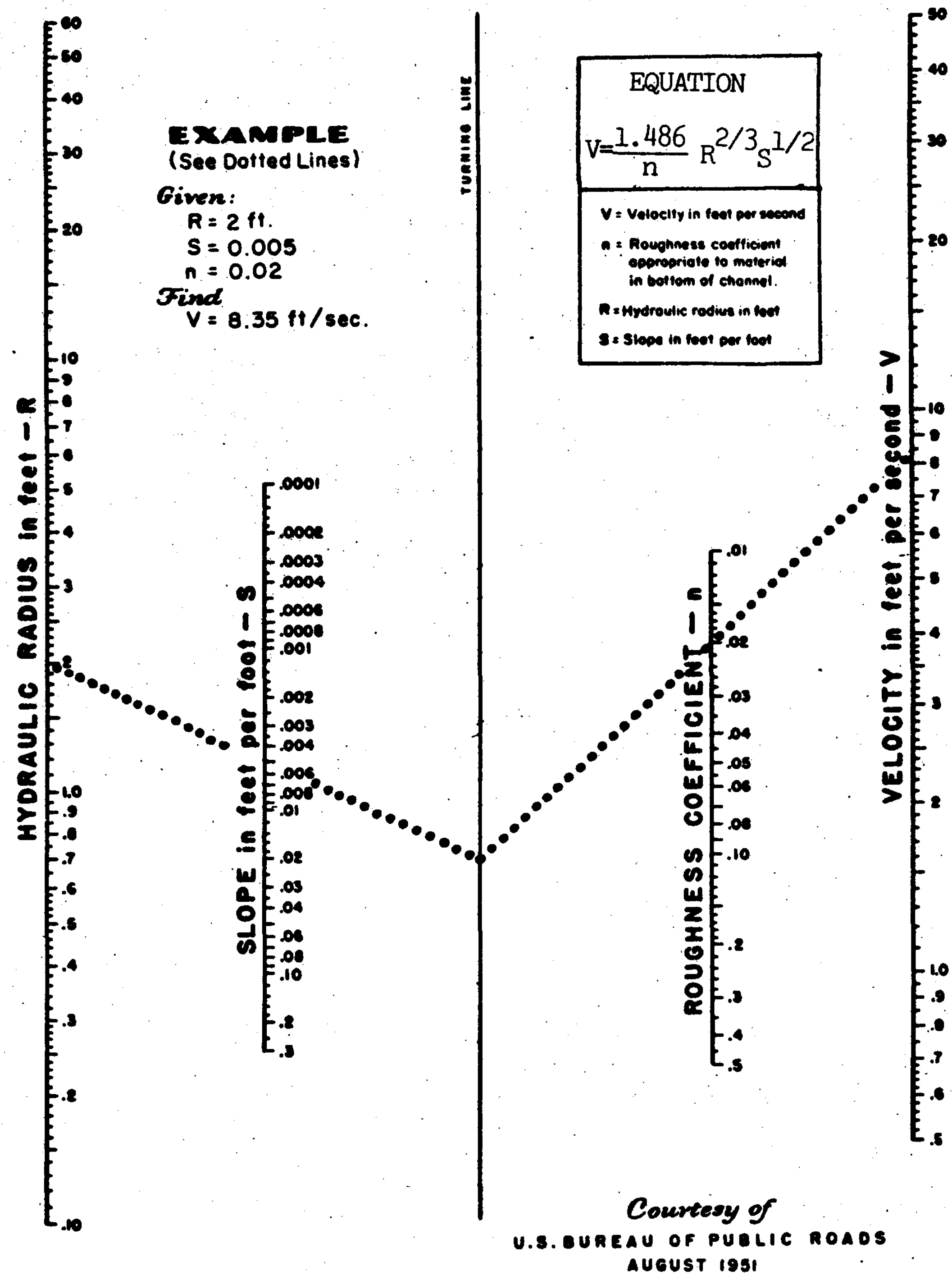
The design storm frequency should be based on the requirements stated in Section 4-400 and Table 4-401.

4-603 Design Controls for Types of Flow.

To obtain the most efficient and economical design requires an understanding of the three types of flow, as explained in the ensuing discussion.

(1) Critical Flows. Under this condition the sum of the kinetic energy and the potential energy of the flowing water is a minimum and the discharge is a maximum for a given total head. Regardless of cross section shape, critical flow exists at the depth for which the velocity head is half the hydraulic mean

NOMOGRAPH FOR SOLUTION OF MANNING EQUATION



depth. Critical flow is an unstable condition met in passing from subcritical to supercritical flow and vice versa. It should be avoided in design.

(2) Subcritical Flows. Subcritical flows are tranquil or streaming where the velocity is less than the critical velocity. They occur when the velocity head is less than half the hydraulic mean depth. Under these conditions, restrictions in the channel can cause the water surface to rise upstream. This phenomenon should be considered in channel design as backwater may be the control for depth.

(3) Supercritical Flows. Supercritical flows are rapid flows where the velocity is higher than the critical velocity. They occur when the velocity head exceeds half the hydraulic mean depth. They may be turbulent and at very high velocities may become shooting flows. Supercritical velocities are accompanied by channel erosion, wave action, and, under certain conditions, a hydraulic jump. In the higher velocity ranges, the superelevation of the water surface at the sharper bends may cause the flow to overtop the bank. Violent wave action also may take place with the same result. Under a supercritical flow, the effect of changes in channel conditions cannot be transmitted upstream.

4-604 Size and Shape Considerations.

All channels should be designed on the basis of maximum utilization of earth-moving equipment consistent with economy in construction and maintenance. Trapezoidal channels are usually the most economical. Wide channels less than one foot deep, however, are inefficient and, generally, are not recommended. Channels of moderate capacity should have a 2-foot bottom. When sediments are transported at low stages of flow, the velocity may be increased further by using a V-shaped channel.

In determining the steepness of side slopes for unlined ditches, consideration must be given to the erosive potential of the soil, and the amount and velocity of the design flow. Under average conditions, slopes ranging from 1-1/2:1 to 2:1 are satisfactory. To facilitate maintenance, side slopes for ditches within interchange areas should not be steeper than 4:1.

Channels with an overflow cross section should be treated as separate deep and shallow channels in computing the flow.

4-605 Channel Alignment and Grade.

(1) Alignment. Except where the alignment is sinuous and curvature sharp, head losses at bends may be neglected when velocities are low. In the higher subcritical velocity ranges, bends cause head losses which should be considered in design. In channels with very high velocities, sharp bends should be avoided.

(2) Grade. The flattest desirable longitudinal slope or grade is 0.12 percent for lined channels and 0.25 percent for unlined channels.

4-606 Coefficient of Roughness.

The determination of Manning's roughness, coefficient (n) calls for judgment and a careful appraisal of channel conditions in the field.

Suggested values of (n) for use in design, which are based on Horton's coefficients, are given in Table 4-606, for each type of conduit or channel. These are regarded as average values. They take into account deterioration of the flow carrying surface, as well as distortion of the grade line due to unequal settlement, construction joints together with other common irregularities. The tabular values should be modified to satisfy abnormal conditions.

TABLE 4-606

SUGGESTED AVERAGE VALUES FOR MANNING'S ROUGHNESS COEFFICIENT (N)
(Based on Materials and Workmanship Required in the Standard Specifications)

Type of Conduit or Channel	Roughness Coefficient (n)
Steel pipe, ungalvanized	0.015
Cast iron pipe	0.015
Metal pipe (2-2/3" x 1/2" corrugations):	
Not lined	0.024
[1]Smooth asphalt quarter lining	0.021
[1]Smooth asphalt half lining	0.018
Smooth asphalt full lining	0.013
Metal pipe (3" x 1" corrugations)	0.027
Metal pipe (6" x 2" corrugations)	0.032
Concrete pipe	0.012
[2]Clay sewer pipe	0.013
Asbestos cement pipe	0.011
Drain tile (terra cotta)	0.015
Unlined Channels:	
Clay loam	0.023
Sand	0.020
Gravel	0.030
Rock	0.040
Lined Channels:	
Concrete (poured)	0.014
Air blown mortar, troweled	0.012
Air blown mortar, untroweled	0.016
Air blown mortar, purposely roughened	0.025
Bituminous (plant-mixed)	0.018
Sacked concrete	0.025
Pavement and Gutters:	
Concrete	0.015
Bituminous (plant-mixed)	0.016
Depressed Medians (10:1 slopes):	
Earth (without growth)	0.040
Earth (with growth)	0.050
Gravel	0.055

[1]For pipe flowing full.

[2]Use (n) value conforming to local practice and materials in remodeling sewers not owned by the County.

4-607 Channel Changes.

From a design standpoint, a channel change is any realignment or other change in the hydraulic characteristics of a channel.

(1) Reasons for Channel Changes. Following are the main reasons for channel changes:

(a) Permit better highway alignment,

(b) Economize by eliminating culverts or bridges where a stream recrosses the highway,

(c) Improve flow conditions in channels at bridges and culverts,

(d) Protect the highway against flood damage, and

(e) Right of way considerations.

(2) Cooperative Projects. In cases where joint benefits result from planned drainage improvements, a cooperative project may be undertaken.

(3) Channel Changes in Larger Streams. Careful study of the stream characteristics is required to achieve an effective design. This study should include an examination of the water surface profile and the velocities upstream and downstream, as well as in the channel change itself. Since channel changes generally decrease (n) temporarily and cause increases in hydraulic radius and slope, any of the following effects may take place depending on conditions.

(a) Improvement of the channel may result in damage by scour,

(b) Where the channel change terminates, sedimentation or meandering may be induced.

(c) A channel change perched above the bottom of the old flood stage stream bed may cause the stream to return to its old bed during a subsequent flood and damage the highway. This condition generally occurs in arid and semi-arid regions.

(d) A flatter downstream gradient may progress upstream undercutting the banks of the channel change or undermining the highway fill.

4-608 Permissible Velocities for Unlined Channels.

Recommended permissible velocities according to soil type are given in Table 4-608. Of the two sets of velocities given, the "sustained flow" values should be used for intermittent flows of long duration.

TABLE 4-608

RECOMMENDED PERMISSIBLE VELOCITIES FOR UNLINED CHANNELS

Type of Material in Excavation Section	Permissible Velocity (Feet per Second)	
	Intermittent Flow	Sustained Flow
Fine Sand (Noncolloidal)	2.5	2.5
Sandy Loam (Noncolloidal)	2.5	2.5
Silt Loam (Noncolloidal)	3.0	3.0
Fine Loam	3.5	3.5
Volcanic Ash	4.0	3.5
Fine Gravel	5.0	4.0
Stiff Clay (Colloidal)	6.0	4.5
Graded Material (Noncolloidal)		
Loam to Gravel	6.5	5.0
Silt to Gravel	7.0	5.5
Gravel	7.5	6.0
Coarse Gravel	8.0	6.5
Gravel to Cobbles (Under 6 Inches)	9.0	7.0
Gravel and Cobbles (Over 8 Inches)	10.0	8.0

4-609 Channel Linings.

(1) Purpose and Type. The main purposes of channel linings are:

(a) To prevent erosion damage,

(b) Increase velocity to prevent excessive sedimentation, and

(c) Increase capacity.

Two types of linings are commonly used: asphaltic pavement and portland cement concrete. Asphaltic pavement cannot withstand hydrostatic pressure and is not recommended for steep side slopes. Portland cement concrete may be used for permanent construction under all conditions of service. Seal coats are not recommended for a permanent installation.

(2) Standards for Thickness of Lining. Table 4-609 gives approximate channel lining thicknesses for both asphaltic pavement and portland cement concrete. The given side thicknesses normally apply to slopes flatter than the angle of repose of the soil and thus do not allow for earth pressure. In favorable soils and in the absence of hydrostatic pressure, side linings are often placed on a 1:1 slope. Under unusually favorable conditions, the slope may be as steep as 3/4:1. In situations where neither hydrostatic pressure nor wear are factors, the floor thickness should be the same as the sides. Under unfavorable conditions, where it is necessary to use a slope equal to or steeper than the angle of repose of the soil, the side lining either may be thickened or designed as a sloping retaining wall.

(3) Notes on Design.

(a) Inflow from the Sides - Where the channel intercepts a surface flow from the sides, the following measures are essential:

- Carry the lining to an elevation slightly below ground level;
- To prevent undermining, place a cutoff lip or wall at the top of the lining; and
- When pipes discharge into the channel, cut them flush with the channel lining.

(b) Drainage - Whenever hydrostatic pressure is anticipated, both weep holes and a drainage system behind the side lining are required.

(4) Slope Paving. The object of this type of channel paving is bank protection, usually on one side of the channel. To guard against undercutting the ends, the slope paving must be turned into the bank a sufficient depth to provide good anchorage, and the bottom of the footing must be below the scour line.

TABLE 4-609

STANDARDS FOR CHANNEL LININGS

Mean Velocity Feet Per Second	Thickness of Lining (Inches)		Minimum Reinforcement
	Sides	Bottom	
ASPHALTIC PAVEMENT			
Less Than 8 8-10	2 3	2-3 3-4	None None
PORTLAND CEMENT CONCRETE (Poured or Pneumatically Applied)			
Less Than 10 10 to 16 16 or More	2-3 1/2 4-5 6 or More	2-4 4-6 7 or More	6" x 6" 10 Ga. Wire Mesh #3 Bars at 15" centers both ways #3 Bars at 12" centers both ways

4-700 Subsurface Drainage.

4-701 General.

The aim of subsurface drainage is the removal of detrimental amounts of ground water to provide a stable roadbed and side slopes.

The solution of subsurface drainage problems often calls for a knowledge of geology and the application of soil mechanics. On major problems, laboratory assistance should be requested.

The basis for design is the Materials Report. This Report includes the findings on subsurface conditions and the recommendations for design.

There are many variables and uncertainties as to the actual subsurface conditions. In general, the more obvious subsurface drainage problems can be anticipated in design; the less obvious are frequently uncovered during construction. Extensive exploration may be required to obtain the design variables with reasonable accuracy. For these reasons, many designs are based on local experience and empirical rules which have given satisfactory results. For this reason maintenance personnel familiar with the area in question should be consulted.

4-702 Subsurface Discharge.

Ground water, as distinguished from capillary water, is free water occurring in a zone of saturation below the ground surface. The rate at which ground water can be removed, or the subsurface discharge, depends on the effective hydraulic head and on the permeability, depth, slope, thickness and extent of the water-bearing formation (the aquifer). The discharge can be obtained by analytical methods. Such methods, however, are usually cumbersome and unsatisfactory; field explorations will yield better results.

4-703 Notes on Exploration.

Field investigations may include: (a) soils and geological studies, (b) borings, pits or trenches to find the elevation, depth and extent of the acquifer, (c) inspection of cut slopes in the immediate vicinity, and (d) measurements of the quantity of discharge, when feasible.

Preliminary investigations must be as thorough as possible, recognizing that further information is sometimes uncovered during construction. Where an existing road is part of the new construction, the presence and origin of ground water is often known or easily detected. Explorations, therefore, are likely to be lesser in scope and cost than explorations for a project on new alignment. In slope stability questions, and other problems of equal importance, an extensive knowledge of subsurface conditions is required. The designer should ask for the assistance of the laboratory in such cases.

In general, explorations should be made during the rainy season or after the melting of snow in regions where a snow cover is common. An exception would be where seepage from irrigation sources occurs.

Ground water difficulties frequently stem from perched water. Pumped water supply wells often give unreliable indications of the water table and such data should be used with caution.

4-704 Types of Underdrains.

Three types of underdrains are used: standard pipe underdrains, bored horizontal drains, and stabilization trenches. French drains have been found to be unreliable and are not authorized.

(1) Pipe Underdrains. The standard pipe underdrains consist of a perforated pipe at the bottom of a narrow trench backfilled with filter material.

(a) Single Installations - This underdrain is commonly used in these cases:

- Along the toe of a cut slope to intercept seepage when slope stability is not in question.
- Along the toe of a fill on the side from which ground water originates.
- Across the roadway at the downhill end of a cut.

(b) Multiple Installations - The same underdrain may be used in a herringbone or other effective pattern in situations like the following:

- Within the structural cross section when a filter blanket is required.
- In stabilization trenches in fill foundation areas. (See Subparagraph (3) below.)

The standard plans for the standard pipe underdrain show two cross sections: one with the filter material carried to the subgrade level and one with a topping of earth over the filter material. The first alternative shall be used under a paved area and the second under an unpaved area.

(2) Bored Horizontal Drains. These are installed in cut slopes and under fills to guard against slides.

(3) Stabilization Trenches. These are placed in swales, ravines and under side-hill fills to stabilize waterlogged fill foundation areas that are well defined.

Recommendations as to depth and width of trench are contained in the Materials Report. Trenches should be wide enough to permit the use of earth-moving equipment. The side slopes commonly used are 1:1.

4-705 Design Requirements for Underdrains.

(1) Size and Length Requirements. The minimum inside pipe diameter for a standard pipe underdrain shall be 8 inches for all lengths. As a general rule, this size is adequate as a collector or lateral in most soils.

(2) Separation of Drainage. Surface drainage shall not be permitted to discharge into an underdrain. The discharge from an underdrain into a storm drain or a culvert, however, is permissible if the outfall for the underdrain is not under pressure.

(3) Cleanouts. Cleanouts may consist of a vertical riser with a light cast iron cover brought to ground level. The diameter of the riser shall be at least the diameter of the conduit. Intermediate inspection of wells is controlled by length, slope and soil conditions.

(4) Grade Requirements. In general, the grade should not be flatter than 0.5 percent. If this slope is unobtainable, grades of 0.20 percent for laterals and 0.25 percent for mains will be acceptable.

(5) Depth and Spacing of Underdrains. The depth of the underdrain depends on the permeability of the soil, the elevation of the water table, and the amount of drawdown needed to ensure stability. Whenever practicable, an underdrain pipe should be set in the impervious zone below the aquifer. Table 4-705 gives suggested depths and spacing of underdrains according to soil type. It is only a guide and should not be considered a substitute for field observations or local experience.

(6) Outlets. Outlets should be provided at intervals of not more than 1,000 feet.

TABLE 4-705

SUGGESTED DEPTH AND SPACING OF UNDERDRAINS FOR VARIOUS SOIL TYPES

Soil Classes	Soil Composition			Drain Spacing - (Feet)			
	Percent Sand	Percent Silt	Percent Clay	3 Ft. Deep	4 Ft. Deep	5 Ft. Deep	6 Ft. Deep
Clean Sand	80-100	0-20	0-20	110-150	150-200		
Sandy Loam	50-80	0-50	0-20	50-100	100-150		
Loam	30-50	30-50	0-20	30-60	40-80	50-100	60-120
Clay Loam	20-50	20-50	20-30	20-40	25-50	30-60	40-80
Sandy Clay	50-70	0-20	30-50	15-30	20-40	25-50	30-60
Silty Clay	0-20	50-70	30-50	10-25	15-30	20-40	25-50
Clay	0-50	0-50	30-100	15(max.)	20(max.)	25(max.)	40(max.)

Note - Depth is measured to invert of pipe.

4-706 Types of Conduits.

The aim of any underdrain installation is long-term effectiveness. This aim is associated with filtering ability, durability, strength of conduit and cost, mainly in that order. In choosing between pipes of different type, the key considerations are filtering ability and durability. Pipe cost assumes secondary importance because it is a minor part of the underdrain investment.

Because open-joint pipes tend to admit excessive solids, pipes with perforated walls and closed joints are recommended. They may be made of metal, concrete, clay, asbestos-cement or bituminous fiber. In the presence of aggresive soils or waters, asbestos-cement and bituminous fiber pipes merit preference.

4-707 Service Life Requirements.

The aim of any underdrain installation is long-term effectiveness. This aim is associated with filtering ability, durability, strength of conduit and cost. From the standpoint of service life, however, the key considerations are filtering ability and durability.

The design service life of underdrain installations shall be as follows:

(a) Underdrains within the roadbed shall have the same design service life as cross drains.

(b) 25 years for underdrains outside the roadbed.

(c) 50 years for stabilization trenches where the cover exceeds 10 feet.

The anticipated service life of pipe metal shall be determined from pH and resistivity tests covered in Test Method No. Calif. 643. Pipe service life may be increased by a bituminous coating.

The guide values contained in the tables mentioned above may be modified where field observation of existing installations dictates the use of other values.

4-708 Type of Installation and Conduit.

Following are the types of underdrain installations relative to conduit characteristics and anticipated service life.

(1) Open-joint Underdrains. Clay, concrete and porous concrete drain tile may be laid with open joints. These drains are effective in collecting subsurface water in areas of coarse grained soil where the admission of excessive solids through the joints will be controlled. This type of construction is appropriate for installations with a 25-year design service life. These pipes are not suitable for use in shallow installations as they would be subject to damage by construction traffic.

(2) Perforated Pipe Underdrains.

(a) Nonmetallic Pipes - Perforated pipes of bituminous fiber and clay may be used in soils of low resistivity and in the presence of highly aggressive soil or water. Perforated asbestos cement pipe may also be used. These pipes are satisfactory in longitudinal drains where settlement is not anticipated. Careful consideration is required before using them in deep stabilization trenches where settlement is anticipated or in shallow installations subject to damage by construction traffic, such as underdrains within the structural section. With these limitations, this group is appropriate for installations with a 50-year service life.

(b) Metal Pipes - Perforated pipes of corrugated metal (either of steel or aluminum) are satisfactory for use in the structural situations mentioned in subparagraph (a) above. However, their use is contingent upon providing the necessary protection against corrosion and abrasion where this is dictated by requirements of the location and limitations of the pipe material.

Perforated metal pipe underdrains may be used to the maximum height of cover required for culverts of similar diameter.

Steel pipes are appropriate for installations with a 50-year design service life and aluminum pipes for installations with a 25-year design service life.

4-709 Selection of Type.

In cases where more than one material meets the foregoing structural, corrosive, abrasive and design service life expectancy requirements, alternatives may be specified on the basis of optional selection by the contractor. The selection of a single type of underdrain may be appropriate due to other related factors. This selection shall be supported by complete analysis of all related factors and documentation shall be placed on file in the district.

4-800 Roadside Development and Erosion Control.

4-801 Functional Planting. The primary goals of functional planting are:

- Erosion control,
- Traffic safety,
- Reduction of fire hazard, and
- Screening adjacent property from traffic sight and/or sound.

The aesthetic effect derived is important, but of secondary benefit.

4-802 Factors Considered In Planting Projects. The following factors regarding planting should be considered:

(1) In determining the category of planting to be used for a given project, both aesthetics and functional needs are considered.

(2) In no case will the County promote landscaping projects for the purpose of control of advertising displays.

(3) A roadway in County territory may be landscaped without an ordinance, the Outdoor Advertising Act being effective on completion of the project.

4-803 Roadside Treatment.

The most pleasing ultimate aesthetic roadside effects can best be developed with easy flowing contours. Contour grading is important in roadside preparation, erosion control and in the maintenance of planting.

The right of way line should be the control for the side slopes. This applies to irregular as well as uniform right of way widths. The toe of slope shall be at least 5 feet from the right of way line when side slopes are flatter than 4:1, otherwise this distance shall be 10 feet. The cost of stabilizing, planting and perpetual maintenance of steeper slopes may sometimes exceed the cost of the additional grading and right of way required to provide a flatter slope.

4-804 Sight Distance and Safety Requirements.

As sight distance and safety are of primary importance, these considerations must not be subordinated to aesthetics.

4-805 Erosion Control.

A general discussion of erosion control is given in the booklet, "Erosion Control on California State Highways" by H. D. Bowers, published by California Division of Highways.

SECTION 5 - BRIDGES AND STRUCTURES

5-100 General.

Humboldt County has 166 bridges in its roadway system (1970 inventory). Many of these structures are old and it is anticipated that new bridge reconstruction and bridge improvement projects will continue to be a significant function for the County Department of Public Works.

The County faces two basic problems in their bridge maintenance function. First, while the traffic volumes on many County roads are low, the nature of much of the traffic (loaded logging trucks) is such that structural integrity is critical. In other words, while many bridges are not used often; when they are used, it is often to their capacity.

Secondly, the geology and drainage conditions of the County are such that the beds and banks of streams and rivers are less than stable. Therefore, much planning and extreme care are necessary to protect the major investments which each new bridge represents.

Because of the critical nature of funding such bridges, it becomes all important that construction costs are held to a minimum. This can only be accomplished by designing the bridge to accommodate minimum County needs. Little can be done to reduce costs of providing for structural integrity and geological stability; however, cost reductions may be realized in the design of roadway width.

For low volume roads, the incidence of traffic conflict (how often vehicles meet in opposing directions) is such that two-lane bridge widths are seldom required. The "existing traveled way width" is often a poor criterion for designing bridge roadway width.

When designing bridges, traffic safety should of course be considered. On two-lane County roads which are surfaced and provide relatively high mobility, it could be hazardous to introduce a single-lane bridge to the motorist. However, on two-lane unsurfaced roads or two-lane narrow surfaced roads which have low traffic volumes and which provide for relatively low mobility with adequate sight distance, a single-lane bridge would be adequate under many circumstances. The cost of the additional lane could not be offset by adding a small and infrequent convenience factor for a small number of County roadway users.

5-101 Objectives and Scope.

The objective of this Section is to present policy, standards, and practices for the design of bridges and structures. The standards are restricted to basic geometrics; the balance of standard specifications are to be found in the State Bridge Manual.

5-102 Policy.

5-102.1 Basic Bridge Roadway Width - It is the policy of Humboldt County that bridge roadway width shall accommodate multiples of full lane widths.

5-102.2 Bridge Construction Standards - It is the policy of Humboldt County that California State Division of Highway bridge construction specifications and standards be followed when designing County bridges and structures.

5-200 Bridge Standards.

5-201 Number of Lanes. When determining the required number of bridge lanes, the following factors should be considered:

(1) Existing traveled way and shoulder width (roadway),

(2) Existing bridge roadbed width (if applicable),

(3) Existing and projected traffic volumes (incidence of conflict),

(4) Type of vehicles (present and projected usage),

(5) Pedestrian usage,

(6) Legal vehicle requirements (federal, state, county),

(7) County Land Use or Zoning Plans,

(8) Existing design speed and posted speed of tangents leading to the bridge,

(9) Roadway surface type,

(10) Nature of bridge needs (permanent vs temporary),

(11) Maintenance requirements,

(12) Costs (construct and maintain), and

(13) Community needs.

The Table below relates the desired number of bridge lanes for each standard Roadway Category.

TABLE 5-201

NUMBER OF BRIDGE LANES

FOR ROADWAY CATEGORIES

Roadway Category	Number of Bridge Lanes	Approximate ADT Range
1-Single Lane (Narrow)	1	0-25
2-Single Lane (Turnouts)	1	25-250
3-Single Lane (Wide)	1	100-400
4-Two Lanes (Narrow)	1 or 2	250-1000
5-Two Lanes (Wide)	2	1000-10000
6-Two Lanes (Roadway Parking)	2	1000-10000
7-Multiple (3 or more)	Same as Traffic Lanes	5000 & above

The selection of the number of bridge lanes should not be based entirely upon traffic volume. All factors listed in Section 5-201 should be considered.

5-202 Width of Roadway (Roadbed).

The width of the roadway for single-lane bridge will be twelve (12) feet. The width of the roadway for a two-lane bridge will be twenty-four (24) feet. For short bridges where the savings of providing narrow width would be minimal, full approach roadway width may be considered as the width for the bridge roadway. Additional width for curbs, sidewalks and other needs should be added if warranted by local conditions to the above stated widths. For multiple lane (more than two lanes) bridges, see the State Design Manual for standards.

5-203 Bridge Length.

The definition of a bridge (Section 1) specifies that it is a structure with a span of more than twenty (20) feet.

The required length of a bridge should be calculated to provide for probable erosion of stream or river bed banks and when such erosion is anticipated, the structural integrity of the bridge should be insured by the placement of support structures (piers and abutments) well onto or into stable material. The services of an experienced geologist engineer should be utilized extensively.

5-204 Vertical Clearance.

The vertical clearance for bridges shall be that which is specified by State law, currently this is sixteen (16) feet. If surface treatments are anticipated for the bridge, extra clearance should be planned initially.

5-205 Cross Slope.

The crown is normally centered on the bridge except for single-lane one-way bridges where a straight cross slope in one direction or a level section shall be used. The cross slope shall be 2% or superelevated as required for horizontal alignment geometrics.

5-206 Structure Design.

See State Bridge Design Manuals, Volumes I, II, and III for detailed standards and specifications.

5-300 Retaining Walls.

(1) Cantilever Walls. In general the cantilever type wall should be the normal selection for all locations where the height of wall varies up to thirty-six (36) feet. All other types should be considered to be special cases.

(2) Counterfort Walls. These walls should be used where a minimum deflection of the wall is desirable. Because of the difference in deflections between cantilever and counterfort walls, it is not good practice to mix types without making some provision for masking the differential deflections by an offset in the wall line at the junction of the two types.

(3) Gravity Walls. While the economical maximum height is approximately six (6) feet, it is permissible to use gravity walls in conjunction with the cantilever type if the height is below six (6) feet and a considerable length of wall is involved.

(4) Crib Walls. Crib walls compensate for differential settlement along the axis of the wall whereas the three walls mentioned above would show signs of local failure. Following are the approved types:

(a) Metal Type - The metal crib wall is often used where the cost of concrete is high, as in mountainous areas. This wall is light in weight, easily installed and quickly placed and is therefore ideal for emergency repairs.

(b) Concrete Type - This type is used in coastal areas where salt air would limit the life of other types. Concrete crib walls are also well suited to scenic areas.

(c) Timber Type - This type of wall has rustic aesthetic value in a rural environment. The probable service life of a timber type crib wall is substantially less than other types and is nonsalvable. However, the lower first cost makes it ideal for temporary uses, as on detours and stage construction.

(5) Concrete Block Walls. This type may be used either for economy, aesthetics or both, where the wall height does not exceed six (6) feet. Where traffic is adjacent to the top of the wall, guard rails should be set back at least three (3) feet from the top front face of the wall.

(6) Special Walls. Standards are by necessity compromises and ordinarily some decrease in cost can be realized by individual design; for the normal case, however, the cost of special designs would exceed the savings. In a long run of wall of standard design, such as a wall between roadways on a sidehill, a special design could result in considerable savings.

SECTION 6 - OTHER STANDARDS AND POLICIES

6-100 General.

6-101 Objectives and Scope.

It is the objective of this Section to present policies, standards, and basic guidelines for designing roadway appertenances such as access openings, curbs, gutters and pedestrian facilities, among others.

6-102 Policy.

6-102.1 Access Openings - It is the policy of Humboldt County that access openings to County roads shall be approved by the Department of Public Works.

6-102.2 Driveways - It is the policy of Humboldt County that all construction to connect driveways to County roads within the maintained system shall be authorized by a valid permit (see Humboldt County Encroachment Permit Ordinance). The construction, repair and maintenance of all driveways shall be the responsibility of the property owner, developer or tenant of the abutting property. This responsibility shall include the entire area of driveway from the edge of the existing pavement or traveled way to the property line and shall include all culverts or other structures necessary for proper drainage control.

6-102.3 Curbs, Gutters and Sidewalks - It is the policy of Humboldt County that the Department of Public Works shall perform all survey work for curbs, gutters and sidewalks.

6-102.4 Roadside Facilities - It is the policy of Humboldt County that roadside facilities such as pedestrian walkways, sidewalks and equestrian or bicycle trails will be provided only where it can be demonstrated to the Board of Supervisors that they are needed or desirable and that these facilities will be designed with safety and economy as the primary control factors.

6-200 Standards and Desired Practices.

6-210 Access Openings - General.

Control of access is achieved by acquiring rights of access to the highway from abutting property owners and by permitting ingress and egress only at locations determined by the County. Roadways with access control require fencing or barriers--natural or installed! The term "access opening" applies to openings through the right of way line which serve abutting land ownerships whose remaining access rights have been acquired by the County. The number of access openings on roadways with access control shall be minimized.

In case of a large highway frontage under one ownership, the cost of limiting access to one opening may be prohibitive, or the property may be divided by a natural barrier such as a stream or ridge, making it necessary to provide an additional opening. In the later case, it may be preferable to connect the physically separated portions with a low cost structure or road, rather than permit two openings.

The designer should work closely with the right of way agent to determine the number, location, and category as to land use of all proposed access openings on the project giving consideration to each individual parcel.

Recessed openings are desired at all points where private access is permitted and shall be provided whenever they can be obtained without requiring alterations to existing, adjacent improvements.

A joint access opening serving two parcels of land is desirable. When points of private access are to be provided with surfacing of sufficient width and structural strength to serve the anticipated traffic, such surfacing shall extend from the edge of the traveled way to the right of way line.

Access openings may be delineated by curbs and the actual opening in the fence may exceed the opening between curbs. This type of design may be used at all access openings whether recessed or not.

6-210.1 Access Openings - Standards - The maximum width of opening, based on land use, shall be determined from Table 6-210.1.

TABLE 6-210.1

MAXIMUM WIDTH OF ACCESS OPENING

Land Use	Single Opening Width (Feet)	Joint Opening Width (Feet)	Frontage Road Multiple Use Width (Feet)
Residential	15	20	40
Agriculture.	20	30	40
Commercial	30	30	60

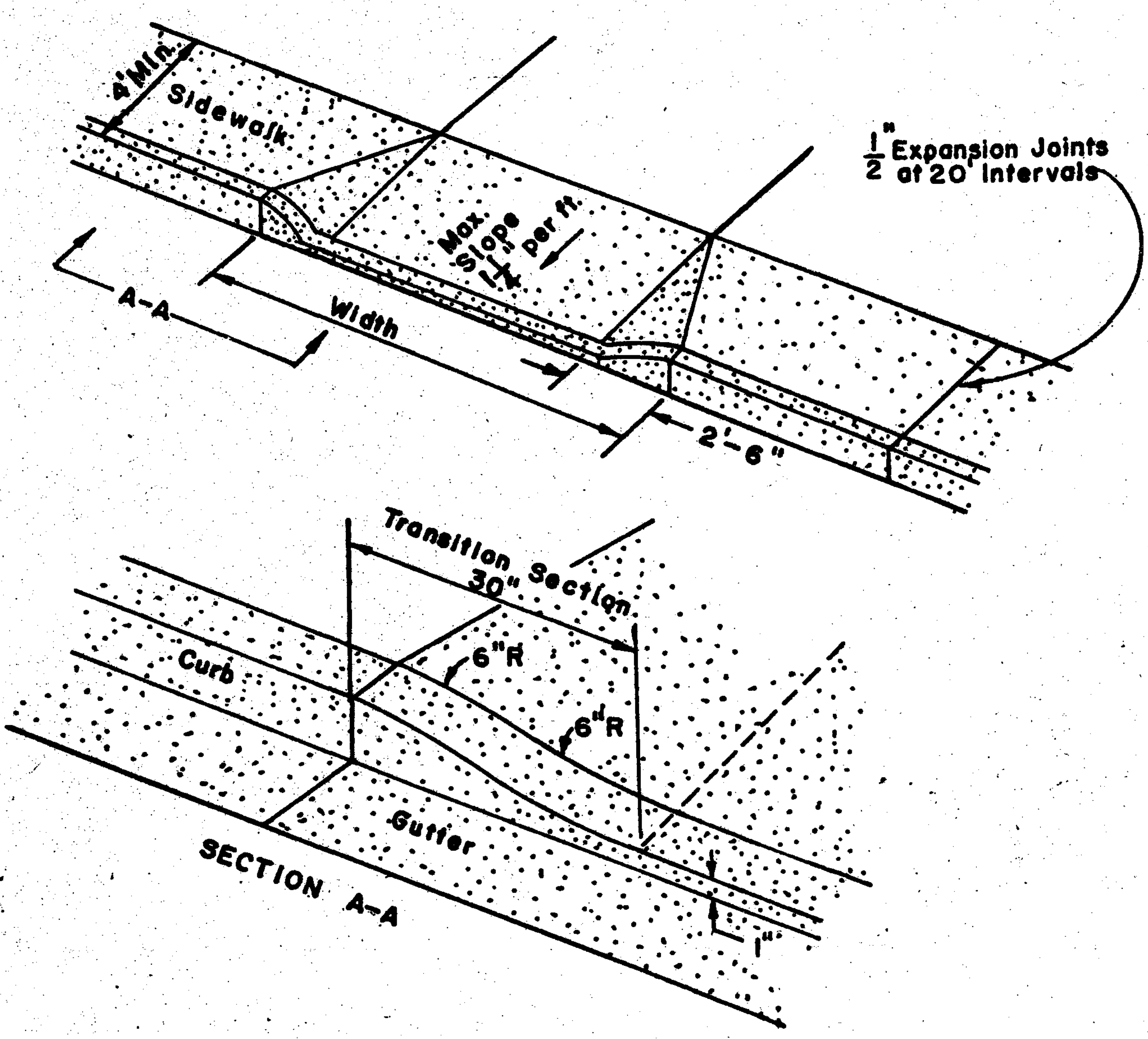
6-220 Residential and Commercial Driveways.

6-220.1 General - The Director of Public Works may require as a condition for issuing an encroachment permit for a driveway that the applicant improve the structural section of the shoulder area between the existing pavement and the curb line. He may also be required to construct a concrete curb and gutter on the curb line and provide a walkway area for the entire length of the property abutting the County road. The structural section shall be determined by the Director of Public Works.

6-220.2 Standards - Refer to Humboldt County Encroachment Ordinance covering driveways for standards regarding construction and location. Also, see Figure 6-220.2 which is a drawing of driveway standards.

COUNTY OF HUMBOLDT

P. C. CONCRETE DRIVEWAY DETAILS



6-230 Curb, Gutter, and Sidewalk Standards.

6-230.1 General - The Department of Public Works shall survey and set the required grade stakes for constructing curbs, gutters or sidewalks. Where construction operations encroach upon the traveled way, adequate provisions will be required for proper traffic control, convenience, and safety of the public. The builder shall also provide access to all properties adjacent to the County road at all times.

6-230.2 Standards - General - The subgrade shall be constructed to grade cross section as directed by the Director of Public Works. Properly constructed forms on the front of the curb shall not be removed in less than one hour or more than six hours after the concrete has been placed.

Expansion joints, one-quarter inch wide, shall be constructed at all returns and at intervals of twenty (20) feet. Expansion joints shall be filled with pre-moulded joint filler conforming to the specifications of ASTM Designation D1751.

The lines and grades of all curb and gutter installations shall be provided by, or approved by, the Director of Public Works. All work shall be performed by the property owner and shall conform to County specifications.

6-230.3 Sidewalk Standards - Official sidewalk width will be those widths determined by the Department of Public Works, being a minimum of four (4) inches thick with a cross slope of one-quarter (1/4) inch per foot toward the curb grade. In residential driveways, the sidewalk shall be at least six (6) inches thick and in commercial driveways, eight (8) inches thick.

The surface of the sidewalks shall be scored into rectangles of not less than sixteen (16) or more than thirty (30) square feet. No concrete sidewalks shall be constructed unless concrete curbs are in place, or are constructed at the same time. Figure 6-230 shows a typical section drawing of a sidewalk.

6-230.4 Curb and Gutter Standards - Figure 6-230 shows typical sections of six (6) and eight (8) inch curbs with gutters. The desired standard dimensions are shown on this Figure.

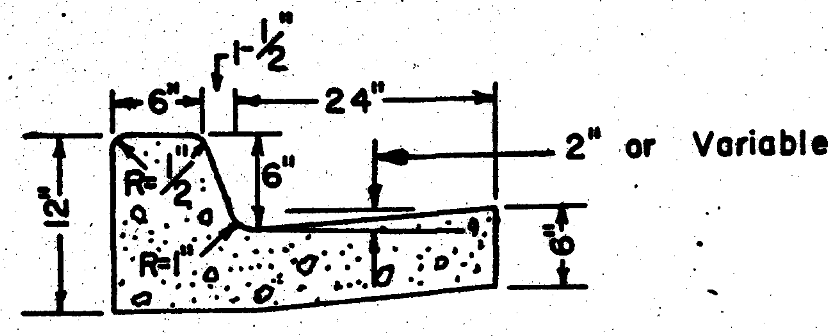
6-300 Intersections and Road Approaches.

Figure 6-300 details a typical desired public road intersection showing desired dimensions of access opening, including radius, width, and sight distance guides.

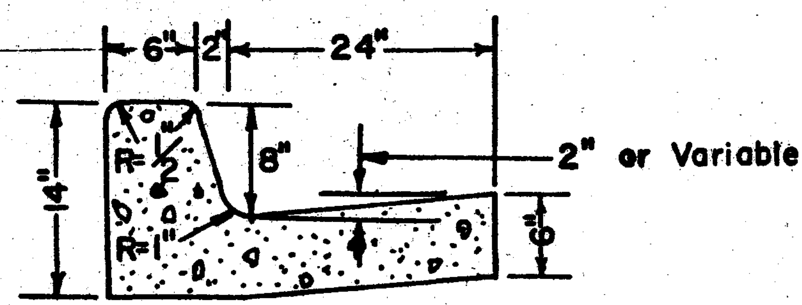
6-400 Pavement Transitions.

Design standards of the various features of the transition between roadbeds of different width should be consistent with the design standards of the superior facility. The transition should be made on a tangent section whenever possible and should avoid locations with horizontal and vertical sight distance restrictions. Whenever feasible, the entire transition should be visible to the driver of a vehicle approaching the narrower section. The design should be such that intersections at grade within the transition area are avoided.

COUNTY OF HUMBOLDT
TYPICAL SECTIONS

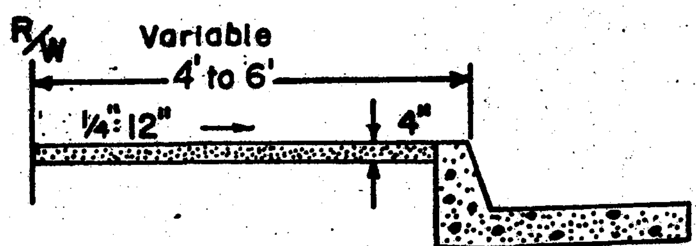


6" Curb and Gutter

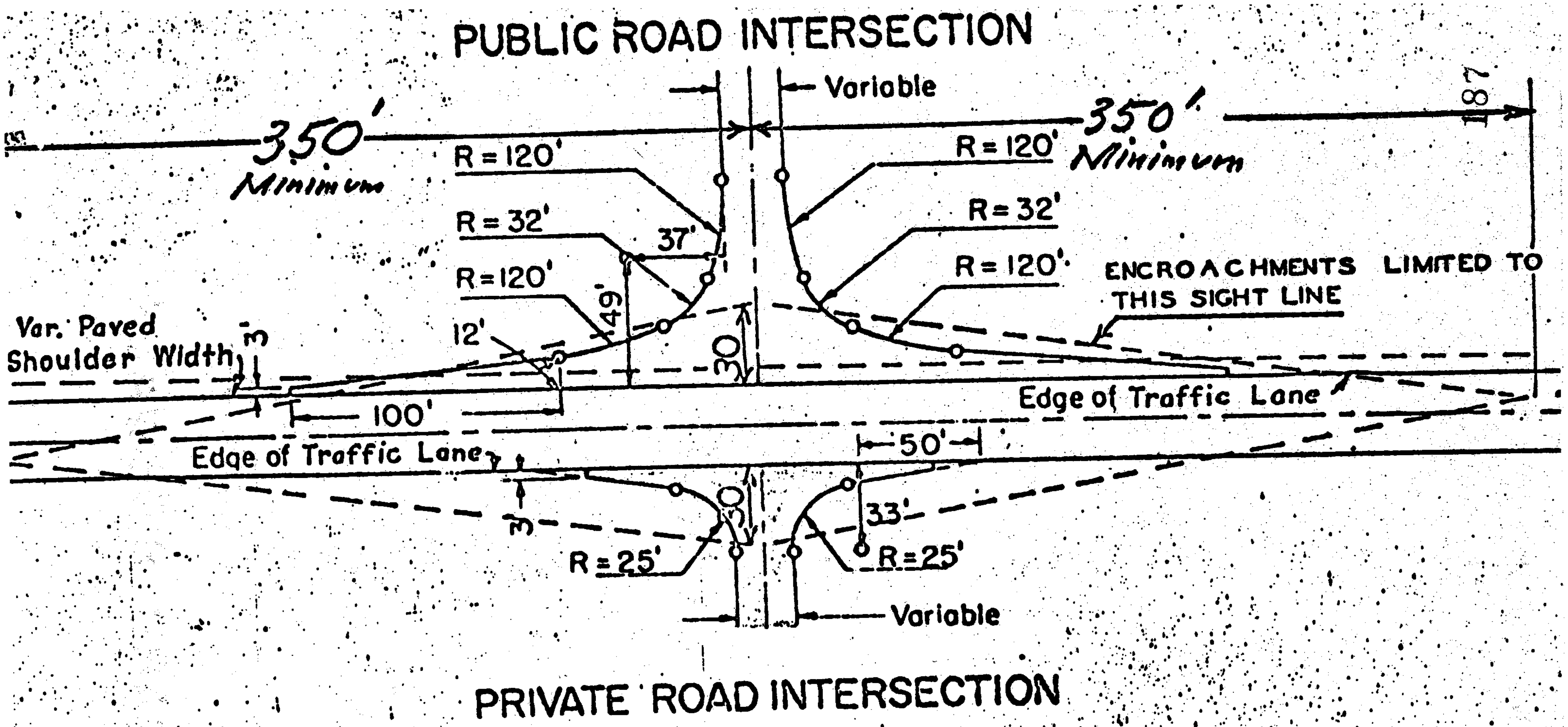


8" Curb and Gutter

STANDARD CURBS



STANDARD SIDEWALK



ROAD APPROACH DETAILS

Figure 6-300

6-500 Pedestrian Facilities.

6-501 Sidewalks. The County may assume financial responsibility for the construction of sidewalks under the conditions described below.

(1) Replacement in Kind - Where existing sidewalks are to be disturbed by roadway construction, the replacement shall apply only to the frontages involved and no other sidewalk construction, such as closing existing gaps in sidewalks, shall be authorized except as part of the right of way agreement.

(2) Conventional Highways - The roadway cross section generally furnishes roadside areas and, if the number of pedestrians is sufficient to interfere with traffic, the city or property owner, whose roadside development induced the pedestrian traffic, may construct and maintain sidewalks on County right of way under a permit.

(3) Interchange Areas - Sidewalks may be constructed where necessary to connect an existing system of sidewalks to provide passage for pedestrians across the roadway right of way or where such system is imminent as evidenced by subdivision activities in the immediate area of the cross road.

(4) Separated Cross Streets - Sidewalks may be constructed on separated cross streets where reconstruction of the cross street is made necessary by the roadway project and where the warrants of Item (3) above apply.

(5) Foot Paths - The construction of foot paths differs from the usual sidewalk installation only in standard and cost, but not in principle. At intersections where the adjacent area is developed and a significant volume of pedestrian traffic is anticipated, an all-weather foot path may be provided across a traffic island.

6-600 Equestrian or Bicycle Facilities.

The County may acquire adequate right of way near roadways in some rural locations to provide for equestrian trails or facilities for riding bicycles. Where such facilities are planned, adequate safety measures must be taken to protect rider and animal and to prevent hinderance to motorists passing by.

The standards regarding width, materials, etc., will be determined by the design engineer and approved by the Director of Public Works.

6-700 Material Specification and Site Selection.

6-701 General.

Due to the lack of large quantities of high quality road building materials, the design of structural sections must include written specification of quantity and quality of materials. The importance of material is such that County roadway designers should be familiar with investigation and testing procedures, and with procedures for selecting material sites and disposal sites.

Factual information obtained from such investigations shall be made readily available to prospective bidders and contractors. The responsibility for interpreting such information shall rest with the contractor and not with the County.

No material sites or disposal sites, except mandatory sites, will be designated in the special provisions. The general policy is to avoid specifying mandatory sources. Data in support of such sources must show certain and substantial savings to the County. Mandatory sources will be specified on Federal-aid Projects, only under exceptional circumstances, and prior approval of the BPR will be required. Supporting data in such cases should be submitted as early as possible, as it must go to the Washington office of the BPR for decision. This policy and requirement also applies to disposal sites.

6-701.1 Materials Report - The materials report shall include complete information on all local sources investigated and shall discuss the quality, cost and availability of materials from commercial plants. The fact that materials sites are not designated in the special provisions does not reduce the importance of thorough exploration and testing. Any discussion of the quality, suitability or quantity of material in local materials sites necessary for design purposes should be included in the materials report and not noted on the test reports. For any potential materials source explored or tested, all boring and test data must be furnished, including those tests which indicate unsuitable or inferior material.

6-702 Materials Information Furnished to Prospective Bidders.

It is the intent that all test data for preliminary tests of local sources which might be considered for use on a specific project will be furnished to prospective bidders on that project. The following information should be included:

(1) A cover page showing key information, an index and agreements,

(2) A vicinity map,

(3) A map of each material site,

(4) A tabulation of test data,

(5) Copies of options or agreements, and

(6) Soil survey sheets.

Maps, test reports and other data included in the "Materials Information" shall be factual, but may include comments, conclusions or opinions as to the quality, quantity, suitability, depth or area of the material in any local materials site if these opinions are clearly indicated as such.

SECTION 7 - DESIGN STANDARDS FOR ROADWAY CATEGORIES

7-100 General.

7-101 Objectives and Scope.

The objective of this Section is to present basic and geometric design standards which correspond to each County Classification System Roadway Category. The Classification System itself is explained in this Section and also included is a reference guide which identifies maximum and/or minimum standard values for all geometric roadway elements. The specific section of the Manual which discusses each design element is noted on the reference guide.

7-102 Policy.

7-102.1 Integrating the County Classification System into the Roadway Design Process - It is the policy of Humboldt County that design of new roads or improvements to existing roads will be based upon pre-determined Roadway Classification, Use, and Level of Service factors. Furthermore, each new roadway design will reference the appropriate category classifications.

7-102.2 Communicating with the Public Using the Classification System - It is the policy of Humboldt County that during discussions, hearings, etc., involving the public, references to the specific roads will include their County Classification designation as well as Use, Level of Service and Type, or Category to promote better understanding.

7-200 Design Standard Elements.

Figure 7-200 is a basic reference guide which contains, for each design element, the range of standard values (variations are primarily a function of traffic volume or design speed). The basic factors which control these values are noted and the Manual section number where further detailed information may be located is also indicated.

DESIGN STANDARDS - REFERENCE GUIDE

Category	Element	Standard Values Maximum	Standard Values Minimum	Basic Control Factors	Reference Section (S) Figure (F), or Table (T)
sic	Design Speed	70 mph	10 mph	Traffic Volume and Terrain	(S) 2-213 (T) 2-213.1
	Design Period	20 years	5 years	Type of Road, Geology and Drainage	(S) 2-214
pographic	Sight Distance Stopping		125 ft. - 10 mph 750 ft. - 70 mph	Design Speed	(S) 2-311 (T) 2-311.1 (F) 2-311.2 (F) 2-311.3 (F) 2-311.4
	Passing		1100 ft. - 30 mph 2500 ft. - 70 mph	Design Speed	(T) 2-311.1 (F) 2-311.5
	Intersections		200 ft. - 20 mph 700 ft. - 70 mph	Design Speed	(S) 2-341
	Superelevation Rate	0.125 ft./ft.		Design Speed, Horizontal Alignment	(S) 2-312 (S) 2-312.1
	Runoff (Transition)	325 ft.	50 ft.	Superelevation Rate, Design Speed	(S) 2-312.6 (T) 2-312.7
	Cross Slope	4%	2%	Surface Type	(S) 2-313
	Horizontal Alignment		120 ft. - 20 mph 1800 ft. - 70 mph	Design Speed, Radius, Superelevation	(S) 2-314 (T) 2-314.1 (F) 2-314..
	Gradient (Grade)	12% - 20 mph	0.12%	Design Speed, Terrain	(S) 2-315 (T) 2-315.1 (F) 2-315.2
	Vertical Curves (Minimum Length)		200 ft.	Design Speed Grade Differential	(S) 2-316 (F) 2-316.1
oss [illegible]tion Geom[illegible]ics	Traveled Way	24 ft. (2 lanes)	10 ft.	Design Speed, Traffic Volume, Parking, Safety, Roadway Category	(S) 2-321 (T) 2-321.1
	Shoulders	8 ft. prkg.	4 ft.		(T) 2-321.1
	Roadbed		12 ft.	Roadway Category	(T) 2-321.1
	Turnouts	1000 ft. btwn.	80 ft. lgth. 10 ft. wide	Volume, Terrain	(S) 2-321.3 (T) 2-321.3
adside Geometrics	Right of Way	Minimum 10 ft. beyond slope stakes - rural areas to back of walkway - urban areas. New Roads - 40 ft. minimum.		Land Use, Terrain, Geology	(S) 2-322.2
	Standard Slopes Shoulders		5%	Terrain, Geology	(S) 2-323
	Side Ditches	3:1 slope	Not over 1-ft deep at 6:1 slope.		(S) 2-325
	Side Slope Cut		1:1	Terrain, Geology	(S) 2-326
	Fill		1-1/2:1 or flatter	Terrain, Geology	(S) 2-326
	Benches		20 ft. wide 1-ft. deep valley.		(S) 2-327
	Clearance Horizontal to Piers, Retaining Walls		30 ft.	Span Length, median width	(S) 2-331
	Horizontal to Obstructions		10 ft.	Traffic Volume, Design Speed	(S) 2-332
	Vertical		16 ft.		(S) 2-333
	Slope to R/W		10 ft.	Drainage	(S) 2-334
ntersections, nterchanges	See State Design				

7-300 Roadway Classification System.

The County Roadway Classification System is an integral part of all roadway design projects. This system will provide the basis for relating County roadway user needs to realistic standards for the design of new and improved roadways. Figure 7-300 is a map of a selected section of the County maintained system. Each road is depicted using symbols representing the three basic functional classification categories: Arterial, Collector, and Access Road.

Due to the existence of a State classification system for County roads, care must be taken to distinguish between the two systems whenever they are referenced. For administrative dealings with the State, their classification will be referenced. The inventory of County roads (data processing print-out) provided by the State designates all roads within the County as:

FAS,

Arterial,

Collector,

Minor - Rural,

Minor - Urban,

Select Rural,

Select Urban, or

State Highways.

COUNTY CLASSIFICATION OF ROADS IN A SELECTED AREA

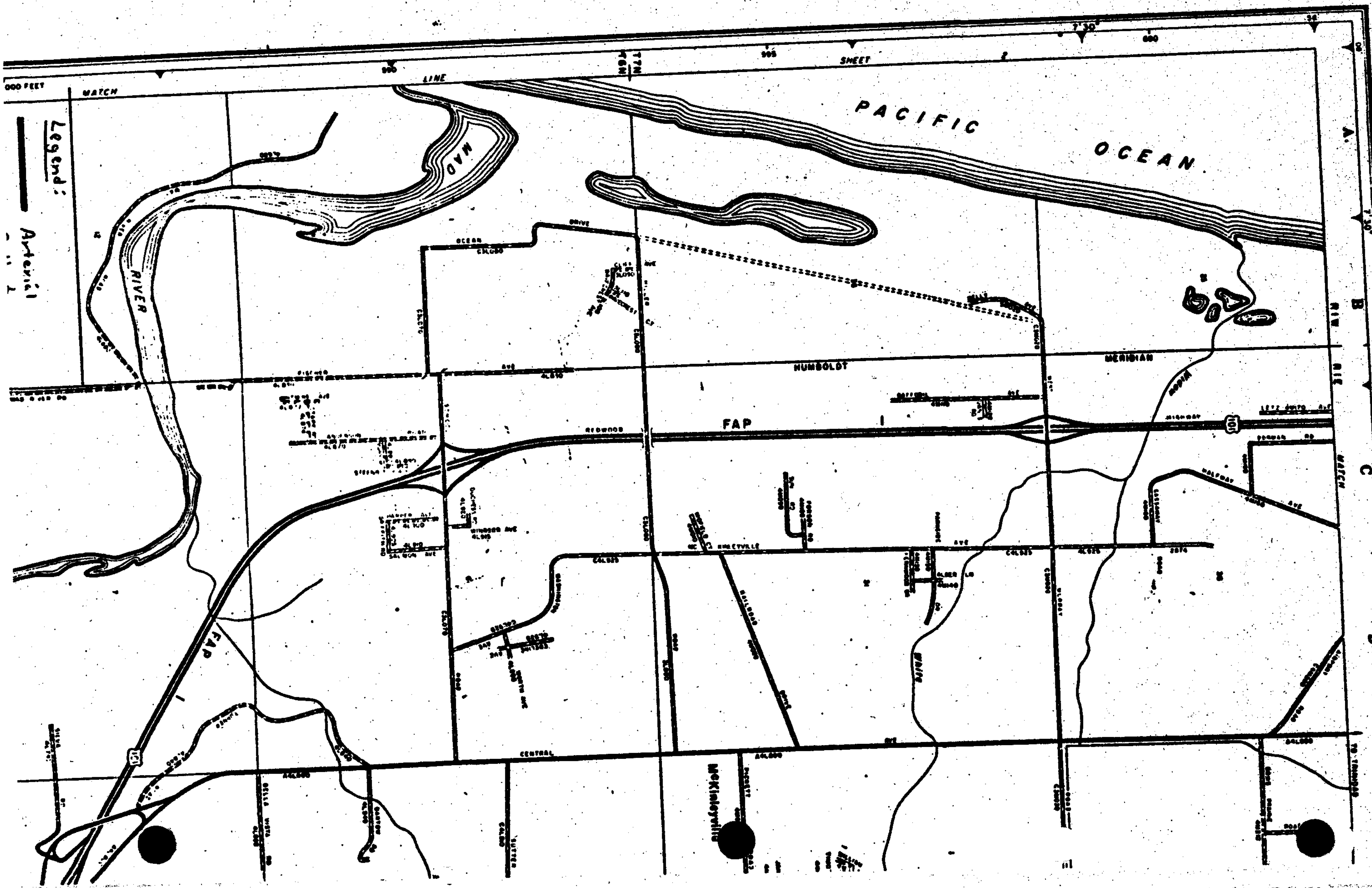


Figure 7-300

Besides the designated classification, the State inventory of County roads contains road identification data, road length, right of way, and termini for each road. The County inventory contains the above listed information, the County's classification and other pertinent data.

Current roadway design practice basically specifies design standards for roadways according to the design hour volume (DHV) of traffic which is expected of the road. Humboldt County design standards will be specified according to the "Use" and "Level of Service," which the road will provide as measured by many factors; volume being one but not necessarily the most important factor. These factors consider the:

- Basic function the road serves,
- Primary user of the road,
- Relative number of residences or facilities served,
- Roadway location (urban vs rural)
- Use of the land abutting the road,
- Mobility (average safe speed),
- Volume of traffic (ADT),
- Number of lanes required, and
- Relative width of the required traveled way.

The consideration of these factors in combination will result in the design of roadways which are appropriate for County needs and desires.

The reader should be familiar with the following description of the classification system concepts and mechanics as well as the geometric design standards before he can fully understand Figures 7-302A - 7-302E, Standards for Roadway Categories 1 through 5.

7-301 System Description.

The following report describes the concepts and procedures for applying the Roadway Classification System.

COUNTY OF HUMBOLDT

DEPARTMENT OF PUBLIC WORKS

ROADWAY CLASSIFICATION SYSTEM

April, 1971

7-301.1 Introduction.

The purpose of this Section is to present the basic concepts regarding the Roadway Classification System and to define the terms which are used to describe the system.

Classification Concept - The Roadway Classification System is to provide a method for describing County roadways in terms of their usage, the service they provide, and their basic physical or geometric features.

A basic concept underlying the proposed system is that roadway categories additional to those usually applied (traffic volume and geometrics), should form the basis for describing and classifying roads. The descriptive categories which make up the classification system are:

- Use Categories
- Level of Service Categories, and
- Roadway Categories

The application of these descriptive categories to a roadway or road segment will allow definition of the following roadway characteristics:

- The basic function it serves within the County network (functional classification-elements of use),
- The primary user of the road (a limited number of residents seeking access to their property or the beneral public),
- The relative number of residences or facilities served by the road,
- The roadway location in terms of urban versus rural surroundings,
- The use of the land where the road is located expressed in planning terms such as commercial, industrial, residential, etc.,
- The mobility that the road provides for traffic as measured by average safe speed,
- The volume of traffic carried by the road as measured by average daily traffic (ADT),

- The number of lanes of moving traffic which the road can accommodate, and
- The relative width of the traveled way which implies the basic roadway width.

To accommodate a data processing system for recording inventory data, a coding system has been developed for each element and category within the system.

Basic Definitions - The terms defined in the following paragraphs are fundamental to the classification system. They should provide the reader with a basic understanding which will later be supplemented with more detailed explanations.

Use Category - A designation or description of how a roadway is utilized which considers four elements: 1) the function which the road performs, as defined by the functional classification system, 2) the primary type of user (private vs public), 3) the number of residences or facilities served, if an access road by functional definition, and 4) the roadway location and land use as later defined. Ten distinct categories of use have been developed based upon the most common combinations of qualifiers within the above four elements. The Use Category is a primary element of the proposed roadway inventory system.

Functional Roadway Classification - A designation or description of streets or roads according to the character of service that they provide or are intended to provide. Functional classification defines the nature of the network traffic channelization process by defining the part that any particular road or street should play in serving the flow of traffic through the County network. Functional Classification is one of four elements used to determine Use Category.

Private Use (of a Roadway) - This describes the type of use normally associated with a road which provides access to a limited number of residences, farms, ranches, or small facilities. A road with private use is normally not used by the general public since it does not lead to areas of public interest. This term qualifies the "primary user" element which is used for determining the Use Category.

Public Use (of a Roadway) - This describes the type of use normally associated with roads on which the general public travels. Public use is distinguished from private use to determine "primary user" which is an element for determining the Use Category.

Roadway Location - A designation of where the road is situated with respect to urban or rural surroundings. Land having 20 acre or larger parcels is considered rural and that having less is urban. County zoning maps are to be referenced as the authority for making the designation. Location in conjunction with land use is one element used to determine Use Category.

Land Use - A designation of how the land abutting the road is being used based upon County planning concepts and definitions. Terms used to describe land use are Residential, Commercial, Industrial, Recreational, Farm/Ranch and Forest. Land use in conjunction with roadway location is one element used to determine Use Category.

Level of Service Category - A designation or description of the service or utility value that a road has as measured by the mobility it provides and the traffic volume which it accommodates. Ten distinct categories or "levels" of service have been developed based upon the most common combinations of mobility and volume criterion.

Mobility - The speed, measured in miles per hour, at which a vehicle can move safely along the roadway during low traffic densities. This is the average speed that can be maintained over a highway, or section, when the design features of the highway are the primary constraint. The design and roadway features which govern this speed are grade, curvature, stopping sight distance, surface condition, and traveled way width. Mobility, along with volume are elements of the level of service category.

Volume - Traffic volume is expressed as average daily traffic (ADT). It is normally the 24 hour volume, or the total number of vehicles during a stated period divided by the number of days in that period. Low volume rural roads are considered to be roads having less than 400 ADT. Volume, along with mobility, are elements of the Level of Service Category.

Roadway Category - A designation or description of a roadway or roadway segment which references the number of traffic lanes and the relative width of the traveled way.

Lane - A portion of the width of a roadway which will safely accommodate a legal-sized vehicle.

Single Lane Road - A road which allows only one legal-sized vehicle to travel freely at any given point on the roadway.

Two Lane Road - A road which allows two legal-sized vehicles to pass at any given point on that road. These vehicles may be opposing traffic or they may be proceeding in the same direction.

Multiple Lane Road - A road providing three or more lanes of traffic. One lane may be for turning only.

Roadway - The total road including curbs, gutters, ditches, slopes, channels, and other features necessary for proper drainage and construction. Right of way is not considered part of the roadway.

Traveled Way - The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Narrow Traveled Way - A traveled way which meets minimal requirements for movement of traffic relative to the mobility and volume requirements of the road. Maneuverability is restricted.

Wide Traveled Way - A traveled way which meets or exceeds the minimum requirements for free movement of traffic relative to the mobility and volume requirements of the road. Maneuverability is not restricted for the free operation of the vehicle.

Traffic Generator - Any location, by its nature or properties, which creates or attracts traffic due to the roadway users' desire or need to travel to or from this location. Cities, towns, state highways, business centers, cultural centers and recreation centers are examples of traffic generators.

Major Traffic Generators - Within the County system, a traffic generator which creates major traffic volumes such as state highways, cities, large towns, large mills and major recreation centers. These are normally the most common trip start points or destinations within the County.

Minor* Traffic Generators - Generators which create lesser traffic volumes (relative to major generators) such as small towns, schools, minor recreation centers, small business or shopping centers, small industrial or commercial centers.

* When actual studies are conducted to classify roads, it may be desirable to develop numeric values to distinguish between major and minor traffic generators.

7-301.2 Determining Use Categories.

The purpose of this section is to present the concept of "Roadway Use," to define the categories of "Use," and to briefly explain how to determine the appropriate "Use Category" for any County road or road segment.

Concept - The establishment of a "Use Category" for defining parts of the County roadway system will assure consideration of the "purpose" for constructing or maintaining a roadway. The importance of a roadway is determined not only by the volume of traffic which uses that road but also by the critical nature of its existence. This category will form the basis for determining roadway priorities. Coupled with other data (Level of Service) the priorities associated with each category will ultimately allow the roadway designer and the maintenance engineer a consistent basis upon which to plan the County's roadway requirements.

Element Descriptions.

Functional Classification - This classification is commonly used by engineers and transportation system developers to broadly define the functional relationship between a given road and the total network. The three terms which are used in describing County roadway functions are:

- Arterial
- Collector
- Access Roads

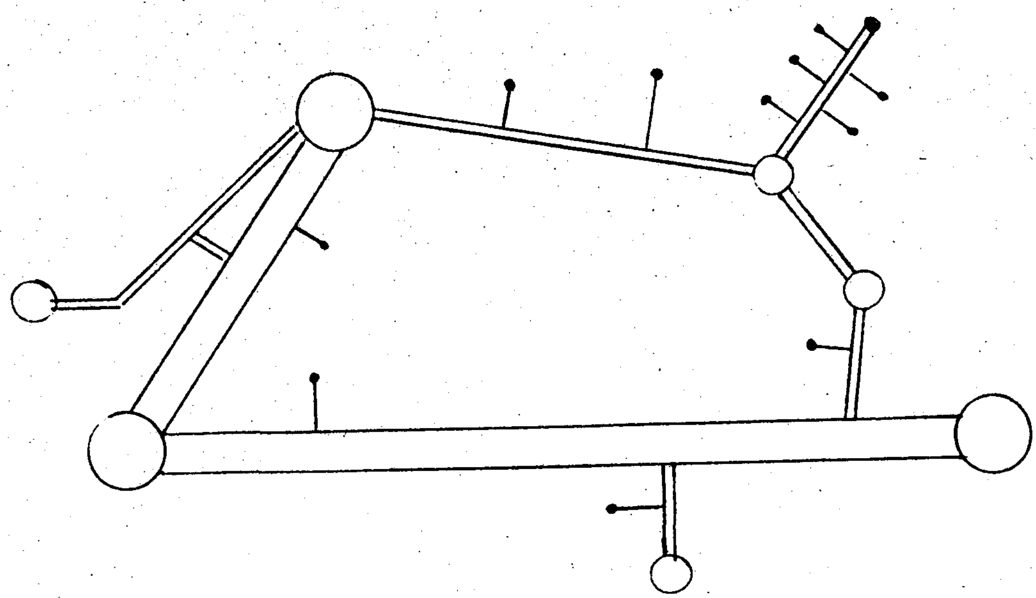
The following definitions are general and summarize the criteria used for establishing each functional roadway classification. Figure 7-301A presents a more explicit definition of each of the three classifications.

Arterial Road - An arterial provides service between major traffic generators such as cities or large towns and normally provides the most direct route to the State system. It usually provides the highest level of service to the County as measured by mobility and traffic volume. An arterial will have some access and traffic control and may be located in either an urban or a rural area.

Collector Road - A road which collects and/or feeds traffic from or to access or arterial roads. A collector can also provide a direct link between two arterials or provide access to an arterial. A collector also provides service between minor traffic generators.

Access Road - A road which provides access or entrance to residences, businesses or other abutting property. It generally provides the lease mobility within the County system and is usually the first and last road to be used for a "trip" within the County.

An illustration of the basic relationships between the different classes of roads is presented on the following page.



Legend

Major traffic generators (cities, large towns, large industrial sites, state highways, major recreation areas)

Minor traffic generators (small towns, minor recreational areas, subdivisions, shopping centers, schools, etc.)

Residences or small facilities (generally of private and not public interest)

Arterial

Collector

Access Road

FUNCTIONAL CLASSIFICATION CRITERIA

FUNCTIONAL CLASSIFICATION	(1) RELATIONSHIP TO SYSTEM	(2) RELATIONSHIP TO TRAFFIC GENERATORS	(3) TRAFFIC MOBILITY	(4) TRAFFIC VOLUMES	(5) NATURE OF ACCESS AND TRAFFIC CONTROL	(6) GENERAL NATURE OF TRIP
ARTERIAL	Provides highest degree of Thru-fare in system. Principal road in the system. Of greatest value to the county.	Normally connects major traffic generators such as towns, State highways, parks & major business areas.	Highest mobility in system. Minimum interference, travel time and highest level of travel comfort in system.	Generally the highest in the system. Range is considerable.	Generally has highest level of control within the system. Varies with roadway volume.	Longest trip in system. To get outside of system. To get to major traffic generators.
COLLECTOR	Collects traffic from access roads & other collectors and feeds it into arterials or to other collectors.	Connects minor and major traffic generators	Provides mobility for relatively short "local" trips. Provides access to arterials for longer trips.	Generally less than arterials however, may be greater in some cases.	Limited control where volume dictates a need.	To get onto arterials or for direct route to local terminal points
ACCESS ROAD	Provides entrance and exit to and from system. Access from trip terminals to collectors or arterials.	Provides direct access to generators. Does not connect generators.	Lowest level within the system. Mobility may be high for roads leading to traffic generators.	Low. May be high when leading to a traffic generator.	Generally none.	To get onto or off of collectors and arterials.

The six criteria are arranged according to their relative significance. Criteria (1) should be weighted most heavily while criteria (6) should have the least influence.

Short, high volume stub routes may not necessarily qualify as arterials. Collectors usually have several access roads abutting them. Rural access roads normally dead end.

The procedure for establishing functional classification is as follows:

- Obtain basic background information concerning the entire roadway network or system. (Note: A map has been developed which shows many of the roads in the County, locations of traffic generators, such as cities, towns, mills, recreation areas; ADT's are noted in key locations as well as populations; land use designations are also shown.) Other maps and County records may be necessary to relate function and to quantify classification criteria.

There are two basic approaches to the classification procedure. The Bureau of Public Roads' procedures call for the ranking of traffic generators in order of population or traffic volume as a first step. They then identify all roads which directly connect these generators as being arterials (or whatever other primary designation which they might use). They then suggest that the mileage represented by these roads be accumulated to the point where a given percentage of the total system mileage is reached. At this point, the balance of roads which connect traffic generators and otherwise serve a collection function are designated as collectors.

Another approach would be to start at the other end of the spectrum, so to speak, and identify all roads which qualify as access roads and then work up through collectors and arterials. One advantage to this approach, is that it seems to overcome the difficulty in distinguishing Arterials from Collectors. This seems more difficult than separating Access roads from Collectors. Therefore, by starting with Access roads and working up, a large percentage of roads would fall into their proper classification with a minimum of dispute. Also, it seems desirable to keep the "trip" concept in mind when classifying. In other words, when visualizing a typical trip within the County, the originating point would usually be a residence or a facility. The first road used would, therefore, be an Access road. The next raod to be used for moderate or long trips would probably be a Collector. For longer trips, the Arterial would then be sought in most cases.

Either of the two above outlined approaches may be used successfully. Once the roads are classified for function, reclassification will only be required if major reconstruction or a significant change in traffic patterns occurs.

In any case, the person or persons responsible for classifying should relate each road to the six criteria on Figure 7-301A. Generally, these criteria are arranged from the most significant, "Relationship to System," to the lesser important criteria on the right side of the table.

It is important to classify each road according to its present function, not its future or desired function. The classifier should endeavor to erase State or Federal classification terminology from his mind when looking at the County network. FAS roads need not necessarily be classified as arterials under the County system.

Primary User (Private vs Public) - The Functional Classification generally defines the character of service that a road provides, however, the exact nature of usage of any given road within each classification is not the same as that of any other road within the same classification. Therefore, more specific definitions of roadway usage are needed to better understand what types of roadways are required to accommodate various kinds of usage.

The identification of "who" uses the road is considered an important use criteria insofar as roadway design and maintenance are concerned. Roads used primarily for access to residences by single families need not be of the same nature as roads which provide access to public parks. Maintenance standards and priority systems for improvements, etc., should also be influenced by the type of user.

The Primary User element of the Use Category may be qualified as either Private or Public. Private use refers to use by a relatively small number of County residents where the road primarily serves as an access to residences. Public use refers to use by the general public where the road normally provides more than access to residences or to a single commercial location.

Number of Residences or Facilities Served (Access Roads) - To establish roadway priorities, additional definition is required for "access" roads. This definition is based on the number of residences or facilities served by the road. The terms to be used in this category are as follows:

- One
- Two - five
- Over five

Roadway Location - Land Use - A combination of two criteria are required for this element. The first is Roadway Location described either as Urban or Rural (Rural land has parcels that are 20 acres or larger). The second is Land Use defined as either Residential, Commercial, Industrial, Recreational, Farm/Ranch, or Forest.

These distinctions are important for the following reasons. First, the planning requirements for design or maintenance of urban roadways is usually quite different than those necessary for rural roads. Maintenance practices such as dumping earth over the side of a rural road are not to be planned for in urban areas. Consideration of roadside parking and storm drain systems is important in urban areas whereas it normally is not in rural areas.

Land use also influences roadway design and maintenance considerations. Roads with heavy industrial or commercial traffic must certainly have different structural maintenance requirements than roads terminating at private residences. County land use maps as provided by the County Planning Department will be the basic reference used in making category determinations within this element.

Category Definitions - Figure 7-301B combines all of the "Usage" definitions just discussed and relates them in a tabular format. These combinations allow establishment of the most probable groupings of these elements and definition of "Use Categories" for Humboldt County roads. The procedure for classifying any County road is as follows:

- Determine Functional Classification.
- Determine primary user. All collectors and arterials are considered to have public users. Access roads leading to parks or business locations are to be considered as having public users. All other access roads would have private users if the road primarily serves residences.
- Determine the number of residences or facilities served. This may not be determinable through County records. Persons familiar with the roads may need to be consulted.
- Determine from maps showing land use (County zoning or general plan maps) the combination of roadway location and land use.
- After making the above determinations, using Figure 7-301B, find the Use Category which is most appropriate.

Figure 7-301B

CRITERIA FOR DEVELOPING USE CATEGORY

DE	USE CATEGORY	FUNCTIONAL CLASSIFICATION	PRIMARY USER	NUMBER OF RESIDENCES OR FACILITIES	ROADWAY LOCATION - LAND USE
0	Single Access - Private	Access Road	Private	One	Rural - Residential Urban - Residential
1	Access Private (2 thru 5)	Access Road	Private	2 - 5	Rural - Residential Urban - Residential
2	Single Access - Public	Access Road	Public	One	Urban or Rural - Commercial, Industrial, Recreational, or Forest
3	Multiple Access - Private	Access Road	Private	Over 5	Urban or Rural - Residential
4	Multiple Access - Public	Access Road	Public	Over 1	Urban or Rural - Commercial, Industrial, Recreational, or Forest
5	Collector - Connector	Collector	Public	N/A	Urban or Rural - Commercial, Industrial, Recreational, Residential, or Forest
6	Collector - Rural	Collector	Public	N/A	Rural - Commercial, Industrial, Recreational, Residential, or Forest
7	Collector - Urban	Collector	Public	N/A	Urban - Commercial, Industrial, Recreational, Residential, or Forest
8	Arterial - Rural	Arterial	Public	N/A	Rural - Commercial, Industrial, Recreational, Residential, or Forest
9	Arterial - Urban	Arterial	Public	N/A	Urban - Commercial, Industrial, Recreational, Residential, or Forest

N/A - Not Applicable as a distinguishing criterion for this element.

7-301.3 Determining Level of Service Categories.

The purpose of this section is to present the concept of "Level of Service," to define the service level categories and to briefly explain how to determine level of service for any County road or road segment.

Concept - The development of definitions of roadway service will help to answer the basic question of "how much" use a road receives. This category, in conjunction with the previously described Use Category, should provide the design engineer with the criteria he needs to conceive a preliminary roadway design and to establish priorities for roadway improvement and maintenance.

Element Descriptions - The level of service category is composed of two elements, traffic volume and mobility. Volume is measured by average daily traffic (ADT) and mobility is described in terms of average safe speed as defined in the introductory section of this report. The various incremental measures of mobility and volume are listed on Figure 7-301C.

Category Definitions - Level of service categories are listed on Figure 7-301D. Each level is based upon a combination of mobility and volume criteria. The twenty most common combinations of criteria are organized basically according to mobility. Levels 1 through 4 relate to very low mobility, 5 through 9 with low mobility, 10 through 15 with moderate mobility and 16 through 20 with high levels of mobility. The determination of levels (maximum values for each service level category) was based upon the engineering concept that the basic geometric design features of a roadway (number of lanes and width of traveled way) must change to accommodate different levels of mobility and volume. The selection of maximum ADT's for each level was based upon what our research indicated were commonly used volume breaks. (100, 250, 400, 1,000, etc.)

The procedure for determining the appropriate existing level of service is as follows:

- Determine the average safe speed (mobility) by either traveling the road and estimating the speed, conduct speed checks and determine the 85th percentile, or by consulting several County employees who are familiar with the road and who are qualified to estimate the average safe speed. The estimator should consider all of the factors outlined in the definition of average safe speed presented earlier in this report.
- Volume may be determined either from existing County records, or for roads where ADT is not calculated, estimates may be made by those most knowledgeable of the roads in question.
- After the average safe speed and the ADT have been determined, locate on Figure 7-301D the Level of Service number in the left column which corresponds to the appropriate combination of mobility and volume criteria.

The procedure for determining the projected level of service is as follows:

- Project the average safe speed as you would estimate the design speed. Project the volume as you would determine the design period ADT, probably through the application of a growth factor to the present ADT.
- Then select the appropriate service level from Figure 7-301D based upon your combined projections of mobility and volume.

MOBILITY AND VOLUME CRITERIA

MOBILITY

	AVERAGE SAFE SPEED
Very Low	0 - 20
Low	25 - 35
Moderate	40 - 50
High	Above 50

VOLUME

General Range		ADT
Low	Nominal	0 - 25
	Very Low	25 - 100
	Low	100 - 250
	Moderately Low	250 - 400
Moderate	Moderate	400 - 1000
	Moderately High	1000 - 5000
High	High	5000 -10,000
	Very High	Over 10,000

LEVEL OF SERVICE CRITERIA

EVEL OF ERVICE	MOBILITY	(MPH)	VOLUME	(ADT)
0	V - Low	0 - 20	Nominal	0 - 25
1	V - Low	0 - 20	V - Low	25 - 100
1	V - Low	0 - 20	Low	100 - 250
1	V - Low	0 - 20	Moderately Low	250 - 400
2	Low	25 - 35	V - Low	25 - 100
2	Low	25 - 35	Low	100 - 250
2	Low	25 - 35	Moderately Low	250 - 400
3	Low	25 - 35	Moderate	400 - 1,000
3	Low	25 - 35	Moderately High	1000 - 5,000
4	Moderate	40 - 50	V - Low	25 - 100
4	Moderate	40 - 50	Low	100 - 250
4	Moderate	40 - 50	Moderately Low	250 - 400
5	Moderate	40 - 50	Moderate	400 - 1,000
5	Moderate	40 - 50	Moderately High	1000 - 5,000
6	Moderate	40 - 50	High	5000 - 10,000
7	High	Over 50	Moderately Low	250 - 400
8	High	Over 50	Moderate	400 - 1,000
8	High	Over 50	Moderately High	1000 - 5,000
9	High	Over 50	High	5000 - 10,000
[illegible]	High	Over 50	V - High	Over 10,000

7-301.4 Determining Roadway Categories.

This section explains the concept of Roadway Categories and presents the definitions or criteria which relate to each of the seven roadway categories.

Concept - The purpose of a Roadway Category is to provide a description for a road in terms of its basic physical or geometric features. The elements used to define these features are:

- The number of traffic lanes, and
- The relative width of the traveled way.

Based upon the application of these criteria to the County's roads, seven distinct categories of road have been developed.

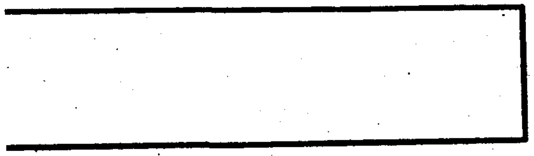
Element Descriptions - Descriptions of the two roadway elements are contained in the introductory section of this report.

Category Definitions - Figure 7-301E illustrates and describes the distinguishing elements of each roadway category.

ROADWAY CATEGORIES

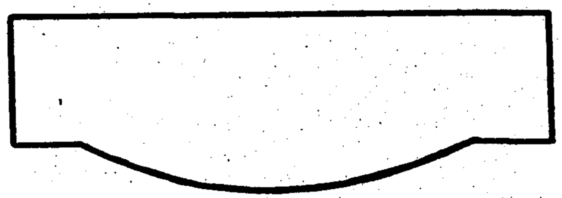
Physical, Use, and Service Features

① SINGLE LANE - NARROW*



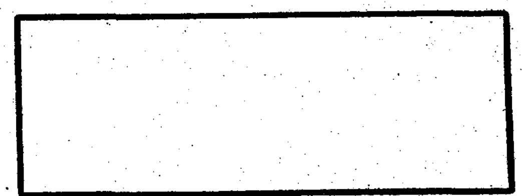
MOBILITY (MPH)	VOLUME (ADT)	PASSING
0 - 20	0 - 25	NO - will accommodate one legal sized vehicle only.

② SINGLE LANE - TURNOUTS



MOBILITY (MPH)	VOLUME (ADT)	PASSING
25 - 50	25 - 250	At turnouts

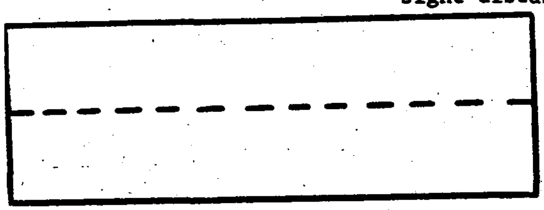
③ SINGLE LANE - WIDE*



MOBILITY (MPH)	VOLUME (ADT)	PASSING
25 - 50	100 - 400	At low speeds (35 mph or less)

④ TWO LANE - NARROW*

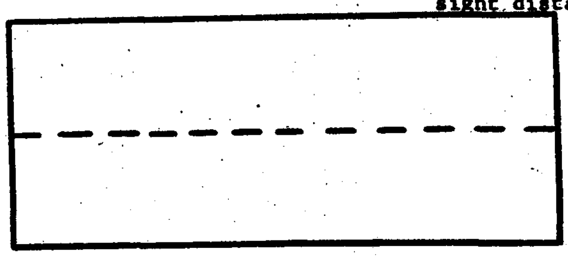
MOBILITY (MPH)	VOLUME (ADT)	PASSING
40 and above	250 - 1000	Restricted by sight distance.



Center line is normally delineated when surface is paved.
Shoulders may be required.

⑤ TWO LANE - WIDE*

MOBILITY (MPH)	VOLUME (ADT)	PASSING
40 and above	1,000 - 10,000	Restricted by sight distance.



Shoulders normally required.

⑥ TWO LANE - PARKING

Will usually have same features as roadway 5 except that on-street parking is provided as in urban areas. Lane width may be less than roadway 5.

⑦ MULTIPLE LANES

Provides high mobility for very high volumes. Will have 3 or more lanes, one of which may be for passing or turning. Lane width same as roadway 5.

* Refers to relative width of traveled way. See Section I for definitions.

Figure 7-301E

7-301.5 Inventory Coding System.

A coding system is required to facilitate the adaptation of classification and other inventory data to an electronic data processing system. The purpose of this section is to explain the coding system which has been developed for classification items and to suggest how this system might be integrated into an overall roadway inventory system.

Figure 7-301F contains code numbers and descriptions of the various elements of the roadway classification system. These elements represent the criteria which are essential to the three classification categories: Use, Level of Service, and Roadway Categories.

Figure 7-301G contains a sample format for displaying identification and classification component elements and lists other inventory components for which coding may be developed at a future date. These other components might include:

. Traffic Control/Traffic Safety

. Physical Inventory

. Priority/Maintenance

Some of the probable elements within these components are suggested for illustration purposes only. Figure 7-301G should assist the reader in visualizing how the roadway identification and classification components might fit into a total inventory system.

CODING SYSTEM FOR ROADWAY CLASSIFICATION ELEMENTS

CODE	DESCRIPTION
(1)	ROADWAY CATEGORIES
1	Single Lane - Narrow Traveled Way
2	Single Lane - Turnouts
3	Single Lane - Wide Traveled Way
4	Two Lane - Narrow Traveled Way
5	Two Lane - Wide
6	Two Lane - Wide Traveled Way with Parking
7	Multiple Lane - Wide Traveled Way (3 or more lanes)
(2)	TRAFFIC VOLUME (ADT)
0	0 - 24
1	25 - 49
2	50 - 99
3	100 - 249
4	250 - 399
5	400 - 999
6	1000 - 1999
7	2000 - 4999
8	5000 - 9999
9	10,000 and above

CODE	DESCRIPTION
(3)	MOBILITY-SPEED (MPH)
0	20 or less
1	25
2	30
3	35
4	40
5	45
6	50
7	55
8	60
9	65

CODE	DESCRIPTION
(5)	FUNCTIONAL CLASSIFICATION
1	Access
2	Collector
3	Arterial
(6)	PRIMARY USER
1	Private
2	Public
(7)	RESIDENCES/FACILITIES SERVED
1	One (1)
2	Two Thru Five(2-5)
3	More Than Five

(4)	LEVEL OF SERVICE CATEGORIES	
0	V-Low (0-20)	Nominal (0-25)
1	V-Low (0-20)	V-Low-Moderately Low (25-400)
2	Low (25-35)	V-Low-Moderately Low (25-400)
3	Low (25-35)	Moderate-Moderately High (400-5000)
4	Moderate (40-50)	V-Low-Moderately Low (25-400)
5	Moderate (40-50)	Moderate-Moderately High (400-5000)
6	Moderate (40-50)	High-V-High (5000-10,000)
7	High (Over 50)	Moderately Low (250-400)
8	High (Over 50)	Moderate-Moderately High (400-5000)
9	High (Over 50)	High - V-High (5000-10,000)

CODE	DESCRIPTION
(8)	LOCATION/LAND USE
0	Forest
1	Rural - Farm/Ranch
2	Rural - Recreational
3	Rural - Industrial
4	Rural - Commercial
5	Rural - Residential
6	Urban - Recreational
7	Urban - Industrial
8	Urban - Commercial
9	Urban - Residential
(9)	USE CATEGORIES
0	Single Access - Private
1	Single Access - Public
2	Access (2 - 5)
3	Multiple Access - Private
4	Multiple Access - Public
5	Collector (Connector)
6	Collector - Rural
7	Collector - Urban
8	Arterial - Rural
9	Arterial - Urban

Figure 7-301F

SAMPLE INVENTORY FORMAT - CLASSIFICATION ELEMENTS

SECTION IDENTITY				CLASSIFICATION SYSTEM CATEGORIES									
					SERVICE LEVEL			USE					
					ELEMENTS			ELEMENTS					
ROAD NUMBER	ROAD OR STREET NAME	POST MILES FROM-TO	SECTION LENGTH	ROADWAY CATEGORY	Traffic Volume (ADT)	Mobility (MPH)	Category	Functional Classification	Primary User	Residences-Facilities	Location-Land Use	CATEGORY
F3K010	New Navy Base Road	4.00 - 10.68	6.68	Two-Land Wide (5)	6700 (9)	65 (9)	High V-High (9)	Arterial (3)	Public (2)	Multiple (4)	Rural-Industrial (3)	Arterial - Rural (8)

NOTE: While the descriptions are shown above for each element and category (for illustration purposes), The inventory itself would indicate only the code number corresponding to the appropriate descriptor to conserve space

INVENTORY COMPONENTS

SECTION IDENTITY	CLASSIFICATION SYSTEM CATEGORIES	TRAFFIC CONTROL/SAFETY	PHYSICAL INVENTORY	PRIORITY/MAINTENANCE
See Above	See Above	Might Include Sign Inventory, Accident History, Traffic Control Device Inventory, Applicable Traffic Ordinances	Would include description of roadway itself including data about: Surface (Type and Condition) Base (Type, Thickness, Condition) Shoulders (Width and Condition) Traveled Way (Width) Drainage System Topography Grade	Priority Rating (Maintenance) Maintenance Area

7-301.6 Examples of Classification System Application.

The purpose of this section is to present, for information purposes only, more examples of how the classification system might be used by designers, maintenance personnel and administrators.

The first use would be as a base for an inventory system. Section 7-301.5 relates the inventory concept and how the classification system will support an inventory.

Secondly, the system will be used in the development of design standards. Figure 7-301H is a table which illustrates how this roadway category selection process might be structured to relate Use Category and Service Level Categories. As can be seen from the Exhibit, by considering the Use Category and the elements used to develop the category, and then relating these to the "desired" level of service for the road or road segment, a decision can be made regarding the appropriate road category or categories which can best provide the indicated service. For example, if for a given road it is determined that the use category is Collector-Rural, Code 5, and that the desired level of service is 4, (based upon a desired safe speed of 40 miles per hour, and a projected ADT of 300), the table indicates that the roadway categories most appropriate for consideration for this combination of use and service might be 3 and 4. Category 3 is a wide single-lane road and 4 is a narrow double-lane road. Of course, the ultimate decision regarding design standards would have to be based upon the consideration of many other factors.

The above examples of the potential application of the classification system are few; however, this should generate ideas in the reader's mind as to the many other uses for the system.

FOR ILLUSTRATION PURPOSES

TABLE FOR SELECTING ROADWAY CATEGORY

CODE	USE CATEGORY	SERVICE LEVELS 0	1			2			3		4			5		6	7	8	9	
		0-25 ADT	25-100	100-250	250-400	25-100	100-250	250-400	400-1000	1000-5000	25-100	100-250	250-400	400-1000	1000-5000	5000-10,000	250-400	400-1000 1000-5000	5000-10,000	Over 10,000
		0-20 MPH	0-20 MPH			25-35 MPH			25-35 MPH		40-50 MPH			40-50 MPH		40-50	Over 50 MPH	Over 50 MPH	Over 50 MPH	
0	Single Access - Private	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Single Access - Public	1	2	2	3	2	2	3	4	5	3	3	4	5	5	-	-	-	-	-
2	Access - Private (2-5)	1	1	2	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Multiple Access - Private	1	2	3	-	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Multiple Access - Public	1,2	2	2	3	2	2	3	4	5	3	3	4	4	5	-	-	-	-	-
5	Collector - Rural	-	-	-	-	2	2	3	4	5	3	3	4	4	5	-	5	5	-	-
6	Collector - Urban	-	-	-	-	3	3	4	4	5	3	3	4	5	5	-	5	5	-	-
7	Collector -Connector	-	-	-	-	3	3	4	4	5	3	3	4	5	5	-	5	5	-	-
8	Arterial - Rural	-	-	-	-	-	4	5	4	5	-	4	5	5	5	-	5	5	5	7
9	Arterial - Urban	-	-	-	-	-	4	5	4	5	-	4	5	5	5	5-7	5	5	5	7

APPLICABLE ROADWAY CATEGORY CODE --(SEE EXHIBIT V)

*This combination of relatively high volume and relatively low speed may call for consideration of 4-lanes, category 7.

NOTES:

1. Dashes (no roadway category number) incidate that these combinations of Use and Level of Service are not typical. You should re-evaluate your criteria if you have selected a column with no indicated roadway category.
2. Standard roadway category 6 is not shown on this table. The selection of a category 6 roadway requires the application of "on-street parking" criterion.

The roadway category codes above are not recommended. They are for <u>illustration purposes only.</u> Decisions regarding the most appropriate categories will be made at a later date.

Figure 7-301H

7-302 Standards for Roadway Categories.

The geometric design standards which correspond to each of five roadway classification categories are related on Figures 7-302A through 7-302E. Other pertinent design information and roadway classification system recommendations are also shown on these figures.

Roadway Category 6 will have the same standards as Category 5, except that 8-foot paved shoulders will be provided for roadway parking. Standards for Category 7, multiple-lane roadway, may be found in the State Design Manual. All other design standards, not peculiar to any particular roadway category may be found in various sections throughout this Manual (see Figure 7-200).

DESIGN STANDARDS AND USE AND SERVICE LEVELS

ROADWAY CATEGORY 1 (SINGLE LANE - NARROW TRAVELED WAY)

Service Provided:

Mobility	Volume
Approximately 20 MPH Safe Driving Speed	Nominal-Around 25 ADT - May Be Slightly Higher

Roadway Classification Categories (Section 7-300):

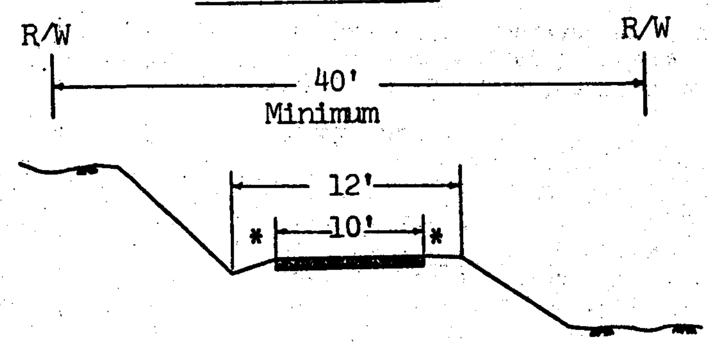
Function	Use	Service Level
Access Road ONLY	Single Access - Private	0
	Single Access - Public	0
	Access Private - (2-5)	0, 1,
	Multiple Access - Private	0
	Multiple Access - Public	0

Geometric Standards (Section 2):

Element	DESIGN SPEEDS/TERRAIN					
	Flat		Rolling		Mountainous	
	10-20	30	10-20	30	10-20	30
Grade	7	7	10	9	12	10
Tolerable Grade *	11	11	15	14	18	15
	10	20	30			
Sight Distance						
Stopping	125'	150'	200'			
Intersection	100'	200'	300'			
Minimum Curve Radius	120'	120'	300'			
Horizontal Clearance to Obstructions	10'	10'	10'			
Surface Cross Slope	4%	4%	4%			

* For short distances.

TYPICAL SECTION



(1) Traveled Way Width: 10 feet
(2) Shoulder Width: -0-
(3) Roadbed Width: 12 feet
(4) Right of Way Width: Minimum 40 feet for new road or road not previously County maintained. Must be adequate for maintenance. Currently maintained roads may have less than 40 feet right of way.

Structural Section: Depends upon engineering analysis of materials and soil by County laboratory.
Surface Recommendation: Native earth or gravel. (Seal Coat or A.C. may be used.)
Design Period: 5 - 10 years.

Notes: Length Limitation - quarter mile.

* Gutter and backup to vary to suit conditions.

Figure 7-302A

ROADWAY CATEGORY 2 (SINGLE LANE - NARROW TRAVELED WAY - TURNOUTS)

Service Provided:

Mobility	Volume
25-35 MPH Safe Driving Speed	Low 25-250 ADT

Roadway Classification Categories (Section 7-300):

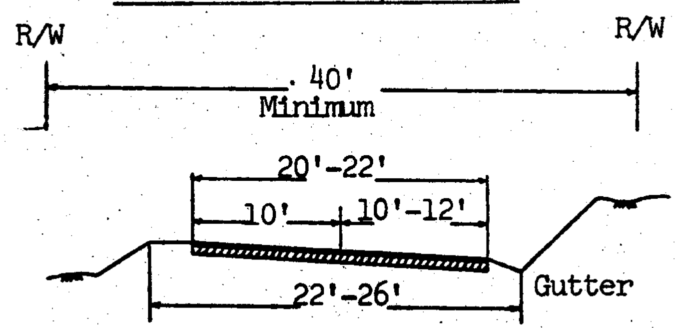
Function	Use	Service Level
Access Road	Single Access - Public	1, 2
	Access - Private (2-5)	1, 2
	Multiple Access - Private	1, 2
	Multiple Access - Public	0, 1, 2
Collector	Collector - Rural	2

Geometric Standards (Section 2):

ELEMENT	DESIGN SPEED/TERRAIN Flat 20	Flat 30	Flat 40	Rolling 20	Rolling 30	Rolling 40	Mountainous 20	Mountainous 30
Grade	7	7	7	10	9	8	12	10
Tolerable Grade *	11	11	11	15	14	12	18	15
	20	30	40					
Sight Distance								
Stopping	150'	200'	275'					
Intersection	200'	300'	400'					
Minimum Curve Radius	120'	300'	550'					
Horizontal Clearance to Obstructions	10'	10'	10'					
Surface Cross Slope	4%	4%	4%					

* For short distances.

TYPICAL SECTION (Turnout)



	Traveled Way	Turnout Section	Total at Turnout
(1) Traveled Way Width:	10 - 12 ft.	10 ft.	20 - 22 ft.
(2) Shoulder Width:	-0-	-0-	-0-
(3) Roadbed Width:	12 - 16 ft.	10 ft.	22 - 26 ft.

(4) Right of Way Width: Minimum 40 feet for new road or road not previously County maintained. Must be adequate for maintenance. Currently maintained roads may have less than 40-foot right of way.

(5) Turnout Section: 10 feet at deepest point - minimum length - 80 feet.

Structural Section: Depends upon engineering analysis of materials and soil by County laboratory.

Surface Recommendation: Native earth, gravel or Seal Coat (double). (A.C. may be used.)

Distance Between Turnouts: 500-1000 feet. See note below.

Design Period: 10 - 20 years.

Notes: See publication "Turnout Spacing on Logging Roads" by Conrad L. Mandt (ITTE-University of Calif.)

DESIGN STANDARDS AND USE AND SERVICE LEVELS

ROADWAY CATEGORY 3 (ONE LANE - WIDE TRAVELED WAY)

Service Provided:

Mobility	Volume
25-35 MPH Safe Driving Speed	Low 100-400 ADT

Roadway Classification Categories (Section 7-300):

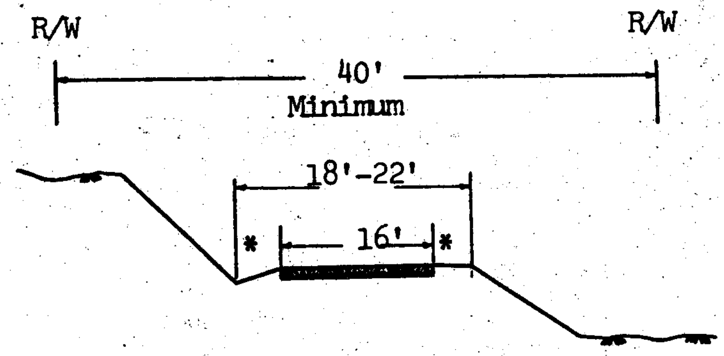
Function	Use	Service Level
Access	Single Access - Public	1, 2, 4
	Multiple Access - Private	1, 2
	Multiple Access - Public	1, 2, 4
Collector	Collector - All	2, 4

Geometric Standards (Section 2):

ELEMENT	DESIGN SPEED/TERRAIN: Flat 30	Flat 40	Flat 50	Rolling 30	Rolling 40	Rolling 50	Mountainous 30	Mountainous 40
Grade	7	7	6	9	8	7	10	10
Tolerable Grade *	11	11	9	14	12	11	15	15
	30	40	50					
Sight Distance								
Stopping	200	275	350					
Passing	1100	1500	1800					
Intersection	300	400	500					
Minimum Curve Radius	300	550	850					
Horizontal Clearance to Obstructions	10	10	10					
Surface Cross Slope	2% *	2% *	2% *					

* For short distances.
* If surfaced with Seal Coat or A.C. - 4% if gravel.

TYPICAL SECTION



(1) Traveled Way Width: 16 feet
(2) Shoulder Width: 4 feet (when required
(3) Roadbed Width: 18 - 20 ft.

(4) Right of Way Width: Minimum 40 feet for new road or road not previously County maintained. Must be adequate for maintenance. Currently maintained roads may have less than 40-foot right of way.

Structural Section: Depends upon results of engineering analysis of materials and soil by the County laboratory.
Surface Recommendation: Gravel, Seal Coat (double) or A. C.
Design Period: 10 - 20 years.

Notes:

* Gutter and backup will vary to suit conditions.

Figure 7-302C

DESIGN STANDARDS AND USE AND SERVICE LEVELS

ROADWAY CATEGORY 4 (T[illegible] LANE - NARROW TRAVELED WAY)

Service Provided:

Mobility	Volume
25-50 MPH Safe Driving Speed	Low to Moderate 250 - 1000 ADT

Roadway Classification Categories (Section 7-300):

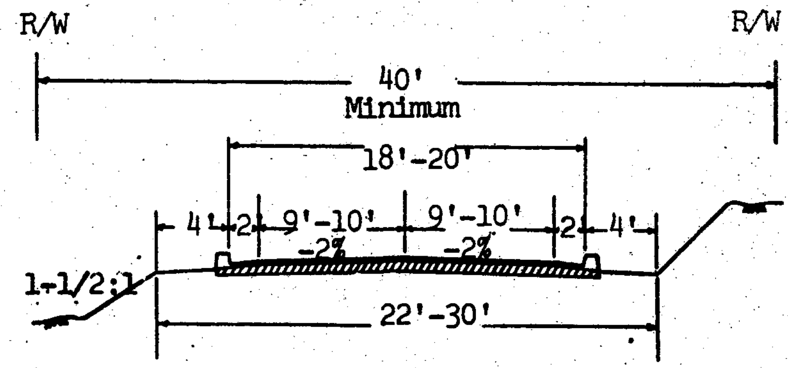
Function	Use	Service Level
Access	Single Access - Public	3, 4
	Multiple Access - Public	3, 4, 5
Collector	Collector - Rural	3, 4, 5
	Collector - Urban	2, 3, 4
	Collector - Connector	2, 3, 4
Arterial	Arterial - Rural	2, 3, 4
	Arterial - Urban	2, 3, 4

Geometric Standards (Section 2):

ELEMENT	DESIGN SPEED/TERRAIN Flat 30	Flat 40	Flat 50	Rolling 30	Rolling 40	Rolling 50	Mountainous 30	Mountainous 40
Grade	7	7	6	9	8	7	10	10
Tolerable Grade *	11	11	9	14	12	11	15	15
	30	40	50					
Sight Distance								
Stopping	200	275	350					
Passing	1100	1500	1800					
Intersection	300	400	500					
Minimum Curve Radius	300	550	850					
Horizontal Clearance to Obstructions	10	10	10					
Surface Cross Slope	2% @	2% @	2% @					

* For short distances.
@ If surfaced with Seal Coat or A. C. - 4% if gravel.

TYPICAL SECTION



(1) Traveled Way Width: 18 - 20 feet
(2) Shoulder Width: 4 ft. (when required)
(3) Roadbed Width: 22 ft. (30 ft. with shoulders)
(4) Right of Way Width: Minimum 40 ft. for new road or road not previously County maintained. Must be adequate for maintenance. Currently maintained roads may have less than a 40 foot right of way.

Structural Section: Depends upon results of engineering analysis of materials and soil by County laboratory.

Surface Recommendation: Seal Coat (double) or Asphalt Concrete.

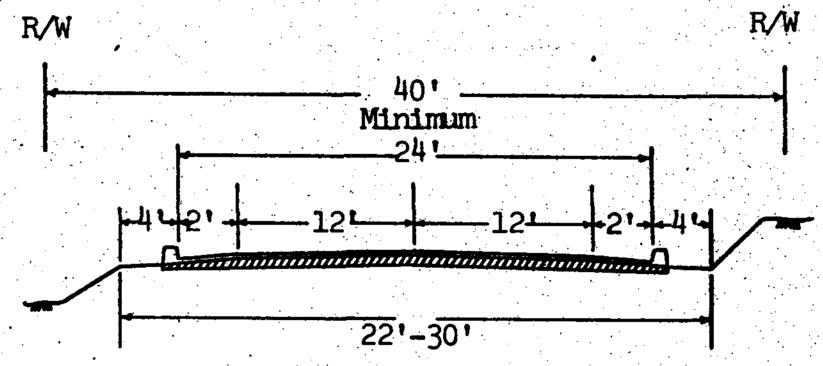
Design Period: 20 years

Notes:

DESIGN STANDARDS AND USE AND SERVICE LEVELS

ROADWAY CATEGORY 5 (TWO LANE - WIDE TRAVELED WAY)

TYPICAL SECTION



Service Provided:

Mobility	Volume
Moderate to High Over 40 MPH	Over 400 ADT

Roadway Classification Categories (Section 7-300):

Function	Use	Service Level
Access	Single Access - Public	3, 5
	Multiple Access - Public	3, 5
Collector	Collector - Rural	3, 5, 7, 8
	Collector - Urban	3, 5, 7, 8
	Collector - Connector	3, 5, 7, 8
Arterial	Arterial - Rural	2 thru 9
	Arterial - Urban	2 thru 9

(1) Traveled Way Width: 24 feet.
(2) Shoulder Width: 4 feet.
(3) Roadbed Width: 32 - 40 ft.
(4) Right of Way Width: Minimum 40 ft. for new road or road not previously County maintained. Must be adequate for maintenance. Currently maintained roads may have less than a 40 foot right of way.

Structural Section: Depends upon results of engineering analysis of materials and soil by County laboratory.

Surface Recommendation: Asphalt Concrete (A.C.) Double Seal if for stage construction.

Design Period: 20 years.

Notes:

Geometric Standards:

ELEMENT	DESIGN SPEED/TERRAIN										
	Flat				Rolling				Mountainous		
	40	50	60	65	30	40	50	60	30	40	50
Grade	7	6	5	4	9	8	7	6	10	10	9
Tolerable Grade *	11	9	8	6	14	12	11	9	15	15	14
	30	40	50	60	65	70					
Sight Distance											
Stopping	200	275	350	525	600	See State Design Manual					
Passing	1500	1800									
Intersection	300	400	500	600	650						
Minimum Curve Radius											
Horizontal Clearance to Obstructions	10	10	10	10	10						
Surface Cross Slope	2%	2%	2%	2%	2%						

* For short distances.

Figure 7-302E

SECTION 8 - COUNTY FAS PROGRAM STANDARDS

8-100 General.

Section 109 (a) of Title 23 requires that plans and specifications must provide for a facility that will adequately meet the existing and probable future traffic needs and conditions in a manner conducive to safety, durability and economy of maintenance.

The 1954 Secondary Road Plan provides that AASHO Standards, entitled "Geometric Design Standards for Highways Other Than Freeways," (contained in this Section) will be met or exceeded except as modified. For specific conditions not covered in the above standards, either "A Policy on Geometric Design of Rural Highways, 1965," or "A Policy on Arterial Highways in Urban Areas, 1957," should be used.

8-101 Objective and Scope.

The objective of this Section is to present the Geometric Design Standards which AASHO recommends for low-volume rural roadways.

8-102 Policy.

8-102.1 Use of FAS Standards - It is the policy of Humboldt County that Federal Aide Secondary (FAS) recommended standards will be used on FAS designed roads only when County standards (contained in this Manual) are not acceptable to the Federal agency controlling the FAS project.

Introduction.

Geometric highway design deals with the dimensions of those highway features such as alignment, grades, widths, sight distance, clearances and slopes as distinguished from structural design which deals with such features as thickness, composition of materials and load carrying capacity.

Frequently, available finances do not permit the construction of the ideal in highway design. Where economy is necessary it is suggested that it be practiced on some feature other than the principal geometric features. The roadway section can be improved and widened at reasonable cost. The surfacing can be widened and strengthened at any future date that finances will permit. But the geometric features of alignment, grade, and sight distance, when once molded into the landscape and tied down by right-of-way and surfacing, are most difficult and expensive to correct. It appears, therefore, that in discussion and decision on these principal geometric features a generous factor of safety should be added, and unquestioned adequacy rather than strict economy should be the criterion.

These standards are intended to be applied as general design controls regardless of the system of which the highway is a part. The use of more liberal values than the indicated minimum values herein is recommended where conditions are favorable and costs are not excessive. For specific conditions not covered herein, reference should be made to A Policy on Geometric Design of Rural Highways, 1965, abbreviated GHD in table references herein, and A Policy on Arterial Highways in Urban Areas, 1970.

RURAL HIGHWAYS

Design Hourly Volume, DHV.

Highways shall be designed for specific traffic volumes as determined by accepted procedures. The design hourly volume, DHV, will be the basis for design except that the current annual average daily traffic, ADT, may be the basis for design for low volume roads. Normally this will be the 30th highest hourly volume for the design year. Usually the design year is about 20 years from date of completion of construction, but may be anywhere within a range of 15 to 25 years.

Design Speed.

A design speed of 30, 40, 50, 60, 65, 70, 75*, or 80 mph as appropriate for conditions, shall be selected.

Sight Distance**.

Minimum stopping sight distances for all highways and passing sight distance for 2-lane highways shall be as shown in Table 1. Criteria for measuring sight distance, both vertical and horizontal, shall be:

For stopping sight distance, height of eye 3.75 feet and height of object 0.5 foot.

For passing sight distance, height of eye 3.75 feet and height of object 4.5 feet.

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* Design speeds of 75 and 80 mph are applicable only to highways with full control of access or where such control is planned in the future, see pages 5 and 145 of A Policy on Geometric Design of Rural Highways, 1965.

** These height criteria for measuring sight distance supersede those in A Policy on Arterial Highways in Urban Areas, AASHO, 1957.

TABLE 1

MINIMUM SIGHT DISTANCES IN FEET

Ref. table III-1, p. 136, table III-4, p. 145, table III-14, p. 206, and table III-15, p. 211, GHD

Design speed, mph	30	40	50	60	65	70	75	80
STOPPING SIGHT DISTANCE								
Stopping distance, ft.	200	275	350	475	550	600	675	750
K value for: 3/ Crest vertical curve	28	55	85	160	215	255	325	400
Sag vertical curve	35	55	75	105	130	145	160	185
PASSING SIGHT DISTANCE								
Passing distance, ft., 2-lane	1100	1500	1800	2100	2300	2500	2600	2700
K value for: 3/ Crest vertical curve	365	686	985	1340	1605	1895	2050	2210

3/ K value is a coefficient by which the algebraic difference in grade may be multiplied to determine the length in feet of the vertical curve which will provide minimum sight distance.

Grades.

Maximum grades shall be as shown in Table 2.

Climbing Lanes.

A climbing lane, or added lane for upgrade slow-moving vehicles, should be provided where critical length of grade is exceeded, the percentage of trucks is high, and the traffic volume is high in relation to capacity.

Alignment.

Alignment between control points should be of as high standard as is commensurate with the topography, the existing traffic, and the probable future traffic in order that future improvements may be made with a minimum of investment loss due to obsolescence. Sudden changes between curves of

TABLE 2

MAXIMUM GRADES IN PERCENT 4/

Ref. table III-13, p. 195, GHD

Type of Topography	Design speed, mph							
	30	40	50	60	65	70	75	80
Flat	6	5	4	3	3	3	3	3
Rolling	7	6	5	4	4	4	4	4
Mountainous	9	8	7	6	6	5	-	-

4/ Short grades less than 500 feet in length and one-way downgrades may be 1 percent steeper. For extreme cases, in urban areas and at some underpasses and bridge approaches, steeper grades for relatively short lengths may be considered. For low volume rural highways grades may be 2 percent steeper.

widely different radii or between long tangents and sharp curves should be avoided by the use of curves of gradually increasing or decreasing radii without at the same time introducing an appearance of forced alignment. In relatively level topography on multilane highways the use of long curves of very small degree are preferred to long tangents connected by relatively sharp curves, except that on 2-lane roads tangents are less a deterent to passing than flat radius curves even where adequate passing sight distance is provided on the latter. Where crest vertical curves and horizontal curves occur at the same location, there should be above-minimum sight distance design, and the relation between horizontal and vertical sight distance should be checked to assure that the horizontal curve is visible as drivers approach.

Depending on the maximum superelevation value, the maximum curvature for different design speeds is shown in Table 3.

TABLE 3

MAXIMUM DEGREE OF CURVE AND MINIMUM RADIUS DETERMINED FOR LIMITING VALUES OF e and f 5/

Ref. table III-5, p. 158, GHD

Design speed	Max. e	Total (e+f)	Minimum radius	Max. degree of curve	Max. degree of curve(rounded)
mph			feet	degrees	degrees
30	.06	.22	273	21.0	21.0
40	.06	.21	508	11.3	11.5
50	.06	.20	833	6.9	7.0
60	.06	.19	1263	4.5	4.5
65	.06	.19	1483	3.9	4.0
70	.06	.18	1815	3.2	3.0
75	.06	.17	2206	2.6	2.5
80	.06	.17	2510	2.3	2.5
30	.08	.24	250	22.9	23.0
40	.08	.23	464	12.4	12.5
50	.08	.22	758	7.6	7.5
60	.08	.21	1143	5.0	5.0
65	.08	.21	1341	4.3	4.5
[illegible]0	.08	.20	1633	3.5	3.5
75	.08	.19	1974	2.9	3.0
80	.08	.19	2246	2.5	2.5
30	.10	.26	231	24.8	25.0
40	.10	.25	427	13.4	13.5
50	.10	.24	694	8.3	8.5
60	.10	.23	1043	5.5	5.5
65	.10	.23	1225	4.7	4.5
70	.10	.22	1485	3.9	4.0
75	.10	.21	1786	3.2	3.0
80	.10	.21	2032	2.8	3.0
30	.12	.28	214	26.7	26.5
40	.12	.27	395	14.5	14.5
50	.12	.26	641	8.9	9.0
60	.12	.25	960	6.0	6.0
65	.12	.25	1127	5.1	5.0
70	.12	.24	1361	4.2	4.0
75	.12	.23	1630	3.5	3.5
80	.12	.23	1855	3.1	3.0

5/ e = rate of roadway superelevation, foot per foot
f = side friction factor for design

For small central or deflection angles the curve should be long enough to avoid the appearance of a kink. For a central angle of 5 degrees the curve should be at least 500 feet long and for each decrease of one degree in the central angle the length should be increased at least 100 feet.

Crown and Superelevation.

Pavement crown shall be a minimum which will provide proper drainage. Cross slope normally should be as shown in Table 4.

For rural highways superelevation should be not more than 0.10 or 0.12 foot per foot, except that where snow and ice conditions prevail the superelevation should be not more than 0.06 or 0.08 foot per foot. For urban highways superelevation should be not more than 0.06 or 0.08 foot per foot.

Superelevation runoff is the length of highway needed to accomplish the change in cross slope from a normal crown section to a fully superelevated section. Minimum lengths of runoff for 2-lane pavements or for two lanes in one direction of a 4-lane divided highway are shown in Table 5. Adjustments in design runoff length, curves at changes in gradients of pavement edges, and warping of pavements are necessary for smooth riding, surface drainage and good appearance.

Number of Lanes.

The number of lanes shall be determined on the basis of highway capacity and design volume.

For low volume roads, 2-lane roads are appropriate regardless of other conditions.

Where the design volume exceeds the capacity of an existing 2-lane road or a proposed design for a 2-lane road, the following measures shall be considered:

Improve alignment and profile to decrease gradient and increase the percentage of total length of highway with sufficient sight distance to afford opportunities for passing.

Improve capacity by the addition of climbing lanes or construction of 4-lane sections.

TABLE 4

NORMAL PAVEMENT CROSS SLOPES

Ref. table IV-1, p. 224, GHD

Surface Type	Range in rate of cross slope	
	inch per foot	foot per foot
High	1/8 - 1/4	.01 - .02
Intermediate	3/16 - 3/8	.015 - .03
Low	1/4 - 1/2	.02 - .04

TABLE 5

MINIMUM LENGTH FOR SUPERELEVATION RUNOFF 2-LANE PAVEMENTS 6/

Ref. table III-11, p. 176, GHD

Superelevation rate	L-Length of runoff in feet for design speed, mph of:							
	30	40	50	60	65	70	75	80
foot per foot								
.02	100	125	150	175	190	200	220	240
.04	100	125	150	175	190	200	220	240
.06	110	125	150	175	190	200	220	240
.08	145	170	190	215	230	240	255	265
.10	180	210	240	270	290	300	330	330
.12	215	250	290	325	345	360	390	395

6/ For wider pavements lengths shown in table should be as follows:
3-lane pavements; 1.2 times length for 2-lane highway
4-lane undivided pavements;1.5 times length for 2-lane highway
6-lane undivided pavements;2.0 times length for 2-lane highway

Improve capacity through intersections by added lanes.

Modify design to provide a 4-lane highway initially or as planned stage construction.

Capacities of 2-lane two-way highways and lane capacities for multilane highways shall be determined on the basis of highway characteristics, composition of traffic, and an appropriate speed of operation during the design year.* Design should be based on one of the three ranges of running speeds listed below.

1. Average running speed 45-50 mph: Applicable for most main rural 2-lane, two-way highways and all rural multilane highways in level and in rolling terrain.

At this running speed the capacity of a 2-lane highway varies from 900 passenger cars per hour under ideal conditions to 270 vehicles per hour in rolling terrain with a design speed of 60 mph, with 20 percent trucks, and with 80 percent of the highway length having sight distance of less than 1500 feet. The capacity of a single lane of a multilane freeway at this running speed varies from 1000 passenger cars per hour per lane under ideal conditions, to 630 vehicles per hour per lane in rolling terrain with 20 percent trucks.

2. Average running speed 40-45 mph: Applicable for highways approaching urban areas, for multilane highways in mountainous terrain, and wherever feasible for 2-lane highways in mountainous terrain.

At this running speed the capacity of a 2-lane highway varies from 1150 passenger cars per hour under ideal conditions to 240 vehicles per hour in mountainous terrain with a design speed of 60 mph, with 20 percent trucks

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* A Policy on Geometric Design of Rural Highways, AASHO, 1965, pages 101-109/

and with 80 percent of the highway length having sight distance of less than 1500 feet. The capacity of a single lane of a multilane freeway at this running speed varies from 1200 passenger cars per hour per lane under ideal conditions, to 500 vehicles per hour per lane in mountainous terrain with 20 percent trucks.

3. Average running speed 35-40 mph: Applicable to 2-lane rural highways in mountainous terrain where design for higher running speed is not feasible. Also applicable to controlled access highways in urban areas where during the design hour it is expected that freedom to travel at high speed will be curtailed by DHV traffic.

At this running speed the capacity of a 2-lane highway varies from 1500 passenger cars per hour under ideal conditions to 320 vehicles per hour in mountainous terrain with a design speed of 50 mph, with 20 percent trucks, and with 80 percent of the highway length having sight distance of less than 1500 feet.

The capacity of a single lane of a multilane freeway under urban conditions at this running speed varies from 1500 passenger cars per hour per lane under ideal conditions, to 950 vehicles per hour per lane in rolling terrain with 20 percent trucks.

Width of Roadway.

For roads with current ADT under 50 vehicles per day, the minimum width of roadway between intersections of side slopes shall be 26 feet. For all other roads the minimum width of roadway shall be the sum of the minimum width of surfacing and usable shoulder widths as described hereafter.

Width of Surfacing.

Minimum widths of surfacing for 2-lane roads for various combinations of traffic volume and design speed shall be as shown in Table 6.

For multilane highways lane widths shall be 12 feet.

TABLE 6

MINIMUM WIDTHS OF SURFACING FOR 2-LANE
RURAL HIGHWAYS

Ref. table V-1, p. 261, GHD

Design speed, mph	Minimum widths of surfacing in feet for design volumes of: 8/				
	Current ADT 50-250	Current ADT 250-400	Current ADT 400-750 DHV 100-200	DHV 200-400	DHV 400 & over
30	20	20	20	22	24
40	20	20	22	22	24
50	20	20	22	24	24
60	20	22	22	24	24
65	20	22	24	24	24
70	20	22	24	24	24
75	24	24	24	24	24
80	24	24	24	24	24

8/ Design volume in terms of mixed traffic. For design speeds of 30, 40, and 50 mph, surfacing widths that are two feet narrower may be used on minor roads with few trucks.

Right Shoulders.

Minimum width of usable right shoulder for rural highways shall be as shown in Table 7.

The usable width of shoulder is that which can accommodate a vehicle partailly or wholly when it is stopped. Wherever feasible it is to be surfaced or stabilized. Where the traveled way and shoulders are surfaced alike some delineation between the two is desirable.

Where guardrail is installed the lateral distance to the face of the guardrail shall be at least equal to the minimum usable shoulder width and desirably two feet greater.

TABLE 7

MINIMUM WIDTHS OF USABLE SHOULDERS
FOR RURAL HIGHWAYS 9/

Ref. table V-2, p. 261, GHD

Design volume		Usable shoulder width, feet	
Current ADT	DHV	Minimum	Desirable
50-250		4	6
250-400		4	8
400-750	100-200	6	10
-	200-400	8	10
-	Over 400	8 10/	12

9/ For low volume roads, use of a roadway width that is the sum of values in tables 6 and 7 is acceptable regardless of the actual width of shoulder.

10/ Changed from 10 feet in previous editions of these standards. This change, which was officially approved subsequent to the adoption of A Policy on Geometric Design of Rural Highways, 1965, also supersedes the 10-foot value shown in table V-2 (page 261) and on page 21 of that Policy.

Bridges to Remain in Place.

Where an existing highway is to be reconstructed, an existing bridge which fits the proposed alignment and profile may remain in place when its structural capacity in terms of design loading and clear roadway width are at least equal to the values shown for the applicable traffic volume as given in Table 8.

TABLE 8

MINIMUM STRUCTURAL CAPACITIES AND MINIMUM ROADWAY WIDTHS FOR BRIDGES TO REMAIN IN PLACE

Traffic		Design loading structural capacity		Roadway clear width*, feet	
Current ADT	DHV	Desirable minimum	Minimum	Desirable minimum	Minimum**
50-250	-	H-15	H-15	26	20
250-400	-	H-15	H-15	28	22
400-750	100-200	H-15	H-15	28	22
	200-400	HS-15	H-15	32	24
	Over 400	H-20	H-15	36	30

* Clear width between curbs or rails, whichever is the lesser.

** For design speeds of 50 mph or less, minimum clear widths that are two feet narrower may be used on minor roads with few trucks. In no case shall the minimum clear width be less than the approach traveled way width.

Multilane Highways.

Where a 2-lane two-way highway is not sufficient to carry the estimated DHV, a multilane highway should be provided. Rural multilane highways should be divided. A highway is not normally considered to be a divided highway unless two or more lanes are provided in each direction of travel and the median is 4 feet or more in width and constructed or marked in a manner to discourage its use by moving vehicles except in emergencies.

Multilane undivided highways may be permissible, (a) as segments of an otherwise 2-lane highway where there would be substantial lengths with sight distances insufficient for safe passing, (b) where lanes are added in both directions on long steep grades, and (c) where the roadside is heavily developed and local service is one of the primary objectives. In each case a divided highway is preferable. If desired, a paved flush but contrasting median may be provided.

Medians.

There are many advantages in wide medians and widths of 60 or more feet should be provided where feasible. The minimum width of median to effectively separate traffic moving in opposite directions is about 4 feet. For protection of vehicles at grade crossings the width of median should be at least 30 to 40 feet. Where left turn lanes are to be provided in the median area a width of 22 feet or more is preferable and at least 14 feet should be provided.

The median adjacent to the left edge of each pavement should be designed to enable vehicles to safely encroach thereon in emergencies.

Where a divided highway is being considered, the advantages of independent roadway design should be explored to secure a pleasing and economical design that fits the topography.

On high speed, high volume highways with medians 30 feet or less in width, a suitable median barrier should be installed. Where the median is 30 feet or less in width and a median barrier is used, median curbs should not be used.

Right-of-Way Width.

Right-of-way width should be not less than that required for all elements of the cross section and appropriate border areas. Additional width may be necessary for construction.

Curbs.

Except where necessary to control traffic or drainage, the use of curbs on roadways should be avoided for safety in enabling vehicles to veer from the pavement in emergencies, for economy and for simplicity. Where barrier curbs are continuous along a low speed highway they should be offset at least one foot and preferably at least 2 feet from edge of traffic lane and so carried across all structures. Barrier curbs introduced on bridges or intermittently elsewhere should be offset at least 2 feet and preferably at least 3 feet.

Normally median curbs are not used with medians of about 15 feet or more in width except where a median turning lane is provided. Medians of lesser width may be curbed or treated in some other way to provide a more positive separation. Median curbs are not to be used on high speed highways.

Side Slopes.

Slopes should be as flat as feasible. Flat side slopes increase safety by providing maneuver area in emergencies, are more stable than steep slopes and simplify the establishment and maintenance of plant growth. The intersection of slope planes should be well rounded.

Where right-of-way is available it frequently is less costly to flatten embankment slopes to 6:1 or flatter for appreciable depths, instead of constructing guardrail. Maintenance cost is also reduced.

Vertical Clearance.

Vertical clearance at all new underpasses on State trunk highways in rural areas shall be at least 16 feet over the entire roadway width, to which an allowance should be added for resurfacing. On State trunk highways through urban areas a 16-foot clearance shall be provided under new underpasses except in highly developed areas. A 16-foot clearance should be provided in both rural and urban areas where such clearance is not unreasonably costly and where needed for defense requirements. Vertical clearance at underpasses on all other highways shall be at least 14 feet over the entire roadway width, to which an allowance should be added for resurfacing.*

Horizontal Clearances.

The full approach roadway width shall be provided across all new bridges. Exception is made on major structures on which, due to their high unit cost, the selection of the cross section dimensions should be subject to individual economic studies.

Also exception is made where the design speed is less than 50 mph and the current ADT is less than 750 and it is not practicable and feasible to provide shoulder widths across structures. In such case, the minimum horizontal clearance both right and left on structures from the edge of traffic lane to the face of parapet or railing shall be not less than 4 feet.

At underpasses the lateral distance from the edge of through traffic lanes to the face of walls, piers or abutments should be at least 2 feet greater than the usable shoulder width.

Roadside Design and Appurtenances.

A clear recovery area, preferably of about 30 feet, should be provided along high speed rural highways. Such a recovery area should be clear of unyielding objects if practicable. If not practicable, protective devices should be installed where indicated to protect the traveling public.

Driveways.

Access from roadsides to the roadways of arterial highways should be controlled by regulations.

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* This change was officially approved subsequent to the adoption of A Policy on Geometric Design of Rural Highways, 1965. It supersedes the values given in the sections entitled "Vertical Clearance" on pages 46 and 521 of that policy with the exception of the values given for parkways.

The previous design controls applicable to rural highways are applicable generally to urban highways. The following additional controls cover items of difference.

Pavement Width.

Pavement should have, where feasible, sufficient width to accommodate the traffic volume without exceeding capacity during the design hour. Design capacity should be calculated on the basis of roadway and traffic conditions, taking into consideration such variables as frequency of intersections, volume of cross traffic at intersections, parking practices, turning movements, and volume of truck and bus traffic.

Width, Arrangement and Utilization of Lanes.

The width and number of lanes on major streets is frequently governed by practical limitations, such as existing building lines and other limitations on available width of right-of-way. Lanes should be 12 feet wide where feasible, but not less than 11 feet.

Where the directional distribution during peak hours exceeds 60 percent on undivided two-way streets, reverse flow lanes should be considered.

Advantage may be taken of a street with an odd number of lanes, as a 5 or 7-lane street, to convert the center lane to a storage lane for left turning vehicles by pavement marking at appropriate intersections. This arrangement is especially fitting on streets under traffic signal control with a separate signal phase for left turns. On sections having sufficient width, a full median and median lanes would be in order.

The operation of streets for one-way traffic is an accepted standard practice. Geometric standards for two-way streets are applicable also to one-way streets.

Curbs.

Where there are continuous barrier curbs but no shoulders or parking lanes the barrier curbs should be offset at least 1 foot and preferably at least 2 feet from edge of traffic lane.

Barrier curbs along narrow medians are fitting on low speed highways if midblock turns are to be prohibited.

Curbs within the usable shoulder width should not be used along high speed highways.

Parking Lanes.

Diagonal parking adjacent to through traffic lanes is hazardous and shall not be permitted. Where parallel parking is contemplated, parking lanes should be, wherever feasible, at least 10 feet in width, and preferably 12 feet.

9-100 General.

9-101 Objective and Scope.

The objective of this Section is to present the design standards for County subdivision roads.

9-102 Policy.

It is the policy of Humboldt County that the standards in this Section of the Manual will be the standards to which roads must be built or improved before they will be accepted into the County Maintained System. (See Humboldt County Subdivision Ordinance.)

9-103 Standards.

The design standards for geometric cross sections are shown on Figure 9-102A through 9-102U for the various categories of roads as defined by the subdivision ordinance.

Special attention should be given to the location of utility and sewer lines and standards for curbs, gutters, dikes and slopes. The various subdivision standards relate to roads according to:

- Road classification (arterial, collector, minor, one way),
- Population density (high, medium, low), and
- Topography (hillside, level).

Definitions of these terms are found in the subdivision ordinance. Roadway classification terms and criteria for potential subdivisions are not identical to those of the County's classification for roads already in their system. The following basic roadway standards apply to potential subdivisions:

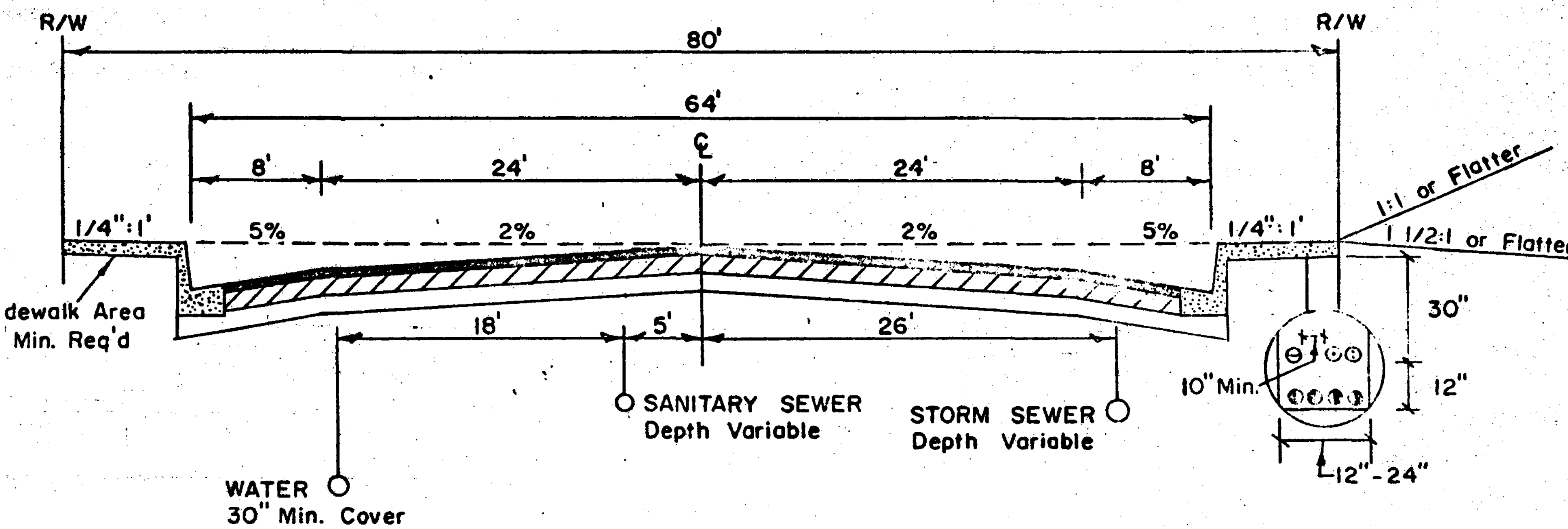
TABLE 9-102.1

BASIC SUBDIVISION ROADWAY STANDARDS

Classification/ Terrain Density	Design Speed	Maximum Grade	Right of Way Width	Traveled Way Cross Slope	Shoulder Width	Number Lanes T/W Width
<u>ARTERIALS</u>	40					
Level - High Density		6%	80	2%	8	4-12
<u>COLLECTORS</u>	40					
Level - High Density		8%	50	2%	8	2-12
Level - Medium Density		8%	50	2%	8	2-12
Level - Low Density		8%	50	2%	8-3	2-12
<u>Hillside-High & Medium Density</u>						
Parking		10%	50	3% *	8-3	2-12
No Parking		10%	50	3% *	3	2-12
<u>Hillside - Low Density</u>		12%	50	3% *	8-3	2-12
<u>MINOR</u>						
<u>Level - High Density</u>	30	10%	50	2%	8	2-10
Less than 200 ADT - Parking		10%	50	2%	8-3	2-12
Less than 200 ADT-No Parking		10%	50	2%	8-3	2-10
<u>Level - Medium Density</u>						
Parking		10%	50	2%	8-3	2-12
No Parking		10%	50	2%	8-3	2-10
<u>Level - Low Density</u>		10%	50	2%	8-3	2-10
<u>Hillside-High & Medium Density</u>						
Parking		16%	50	3% *	8-3	2-10
No Parking		16%	50	3% *	3	2-10
<u>Low Density</u>						
Under 100 ADT		16%	50	3% *	3	1-12
100 - 250 ADT		16%	50	3% *	3	1-12
Turnouts		16%	50	3% *	3	1-20⊖
250 - 490 ADT		16%	50	3% *	3 ⊕	2-12
<u>ONE-WAY STREET</u>	30					
<u>Hillside-High & Medium Density</u>						
Parking		16%	50	3% *	8-3	1-12
No Parking		16%	50	3% *	3 ⊕	1-14

* No Crown
⊕ [illegible] Side
⊖ No Turnout

HIGH DENSITY LEVEL LAND SUBDIVISION



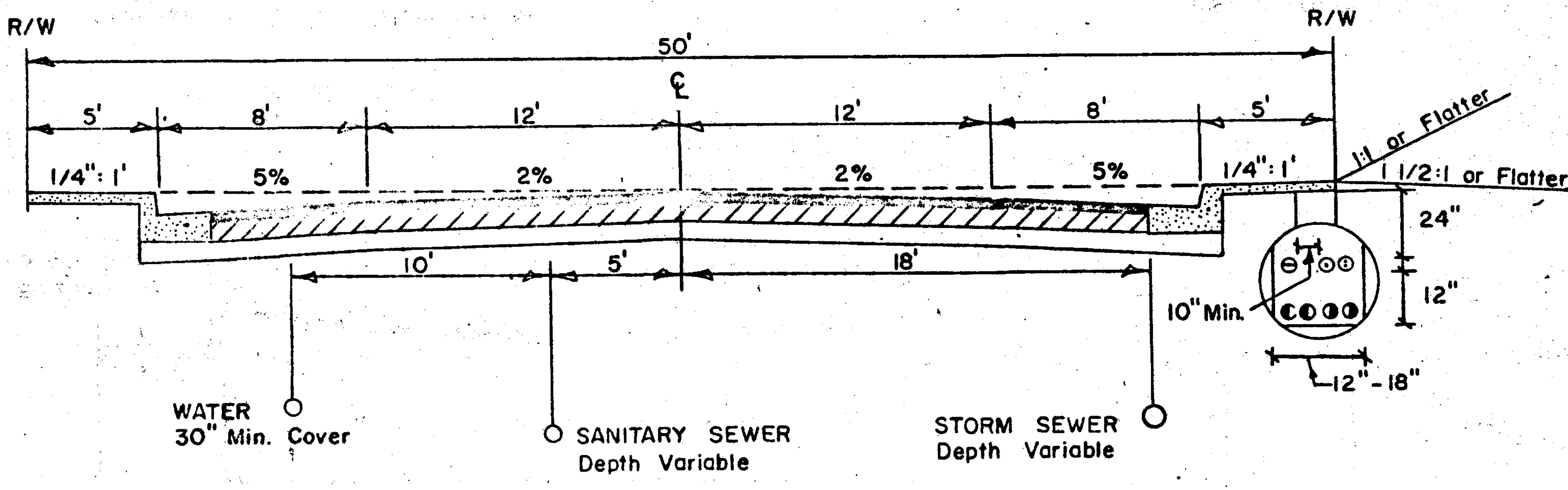
Structural Section To Be Determined By Utilizing The Formula For The California Resistance "R" Value On Basement Soils And By Means Of Traffic Indexes.

PIPES, CONDUITS OR CABLES

- ⊖ GAS
- ◐ ELECTRIC PRIMARIES
- ● ELECTRIC SECONDARIES
- ⊙ TELEPHONE
- ⊙ TELEVISION

ARTERIAL ROAD

HIGH DENSITY LEVEL LAND SUBDIVISION



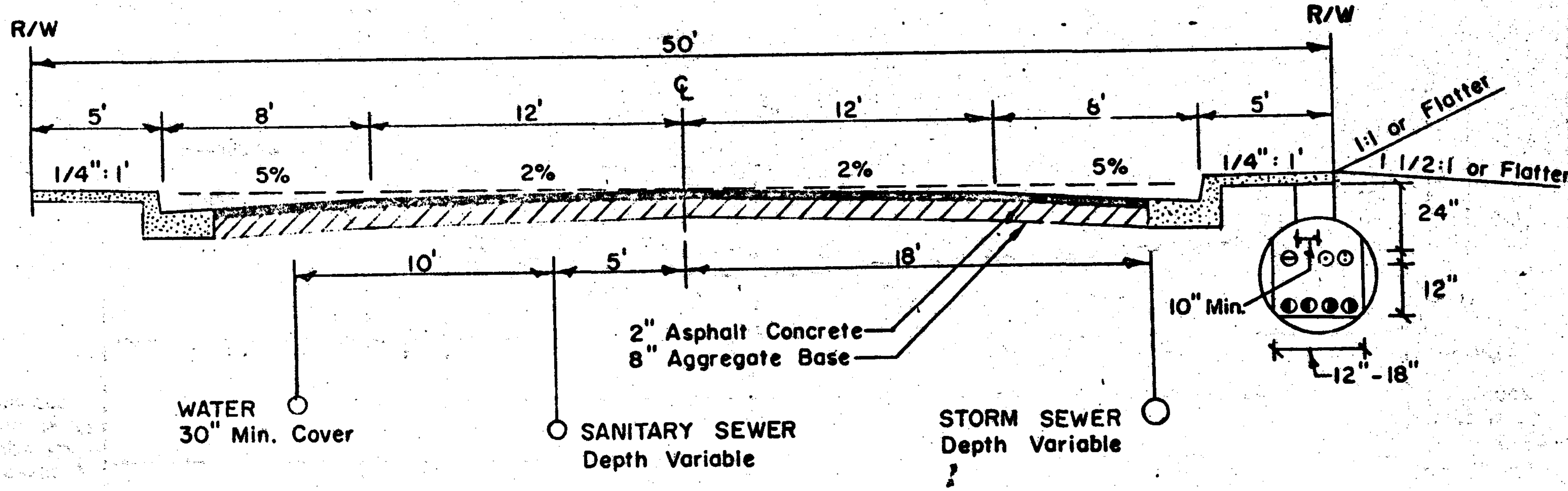
Structural Section To Be Determined By Utilizing The Formula For The California Resistance "R" Value On Basement Soils And By Means Of Traffic Indexes.

PIPES, CONDUITS OR CABLES

- ⊖ GAS
- ◐ ELECTRIC PRIMARIES
- ◑ ELECTRIC SECONDARIES
- ⊙ TELEPHONE
- ⦶ TELEVISION

COLLECTOR ROAD

HIGH DENSITY LEVEL LAND SUBDIVISION

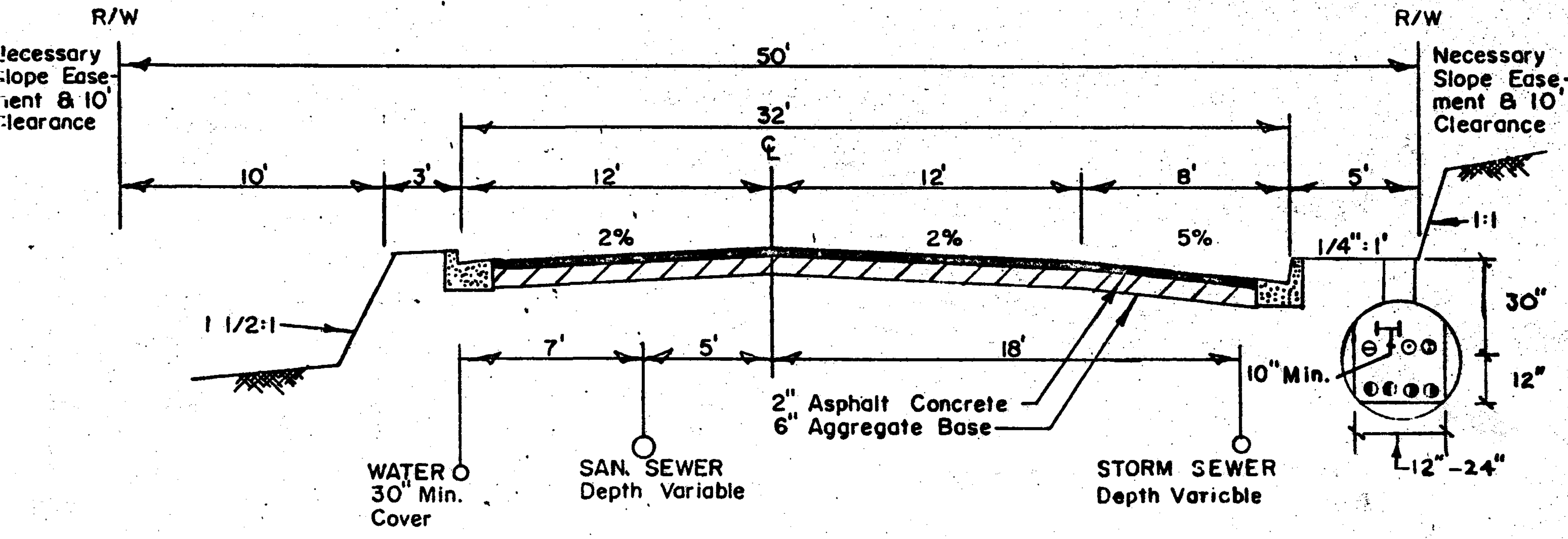


PIPES, CONDUITS OR CABLES

- ⊖ GAS
- ◐ ELECTRIC PRIMARIES
- ● ELECTRIC SECONDARIES
- ⊙ TELEPHONE
- ⦶ TELEVISION

MINOR ROAD

HIGH DENSITY LEVEL LAND SUBDIVISION



PIPES, CONDUITS OR CABLES

- GAS
- ELECTRIC PRIMARIES
- ELECTRIC SECONDARIES
- TELEPHONE
- TELEVISION

MINOR ROAD

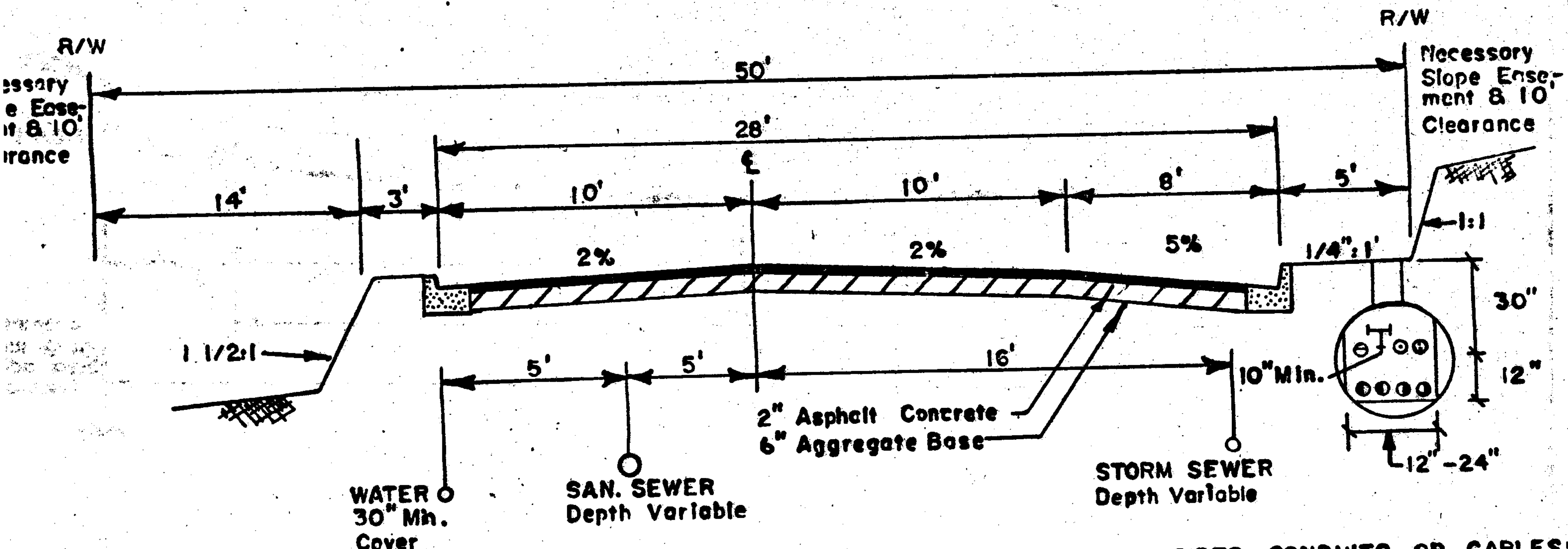
ADT Less Than 200

NOTE: Parking Permitted One Side Only

FIGURE 9-102D

11 of 28

HIGH DENSITY LEVEL LAND SUBDIVISION



PIPES, CONDUITS OR CABLES

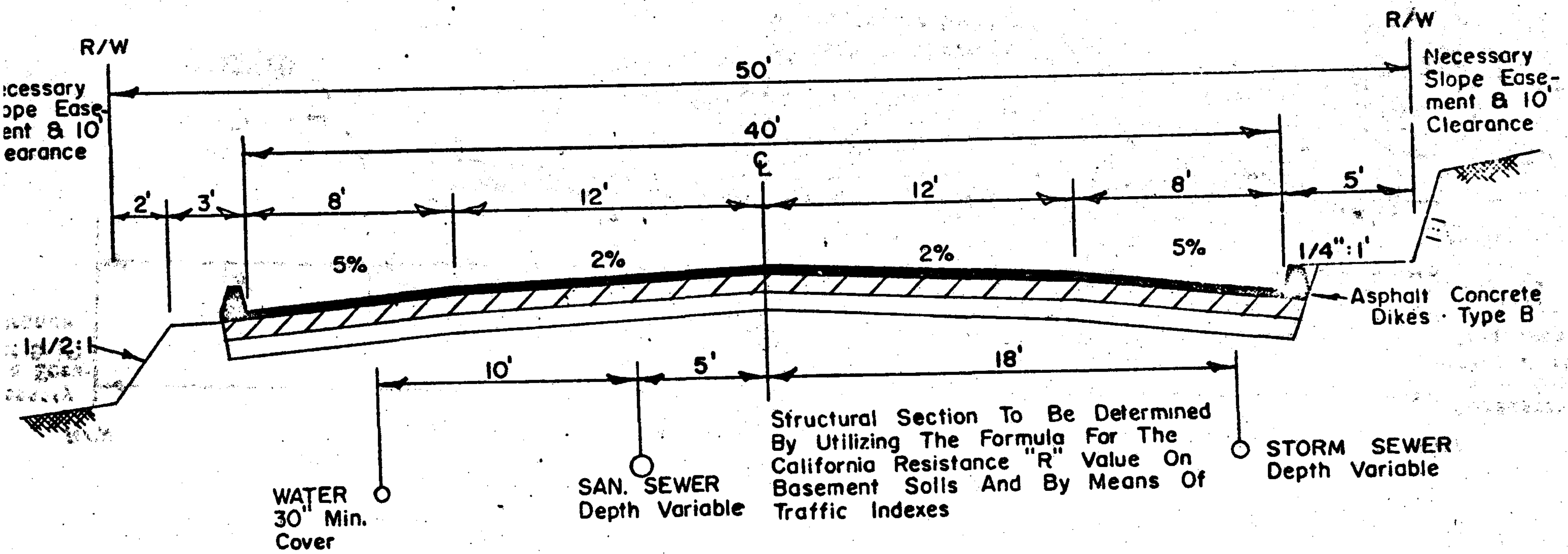
- GAS
- ELECTRIC PRIMARIES
- ELECTRIC SECONDARIES
- TELEPHONE
- TELEVISION

MINOR ROAD

ADT = Less Than 200

NOTE: Off Street Parking Only

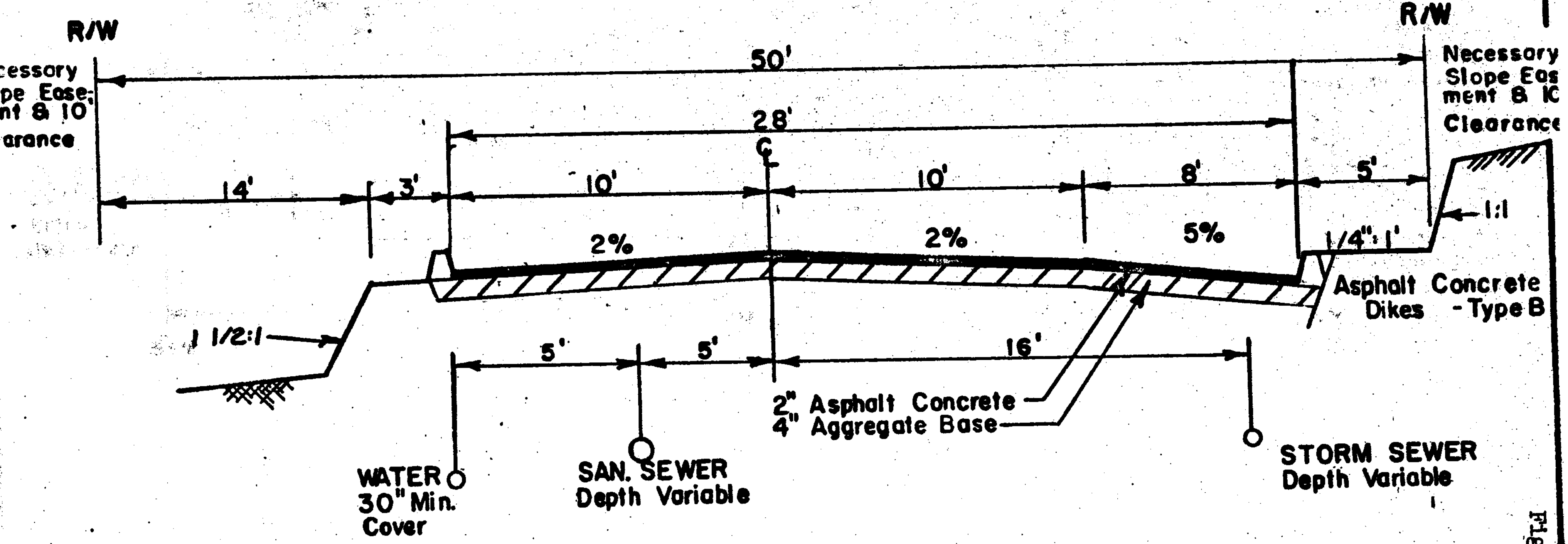
MEDIUM DENSITY LEVEL LAND SUBDIVISION



COLLECTOR ROAD

13o 28

MEDIUM DENSITY LEVEL LAND SUBDIVISION



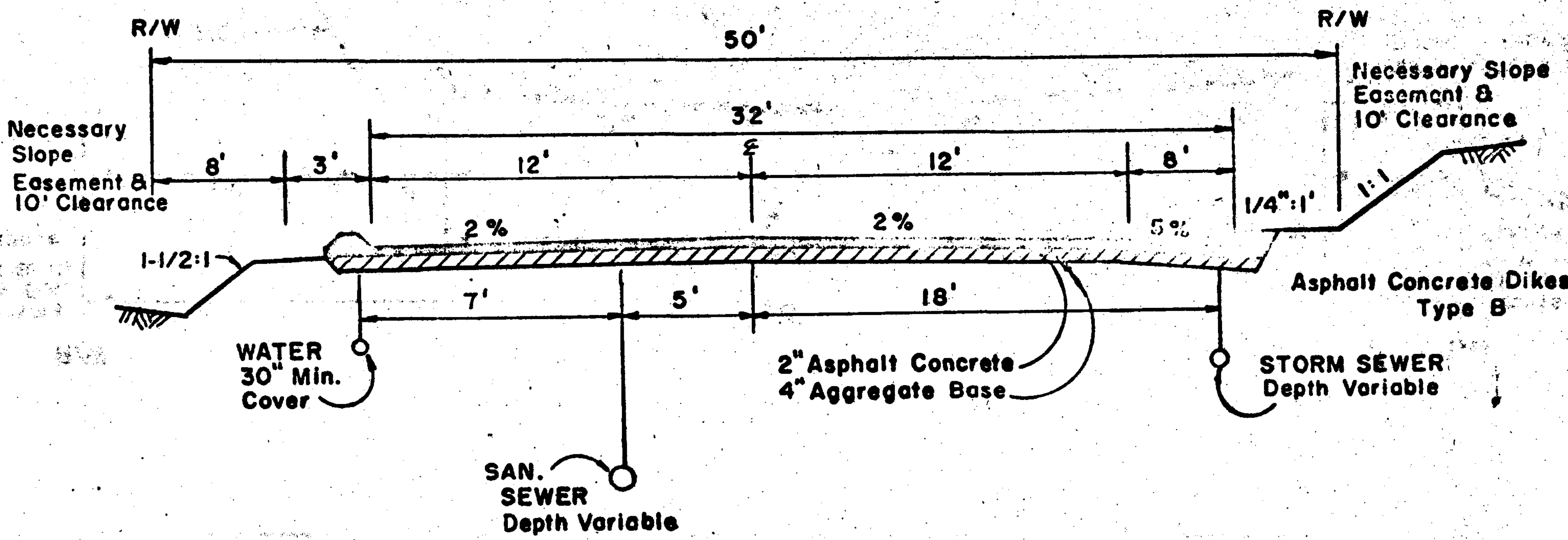
MINOR ROAD

NOTE: Off Street Parking Only

Figure 9-102H

Figure 9-102G

MEDIUM DENSITY LEVEL LAND SUBDIVISION

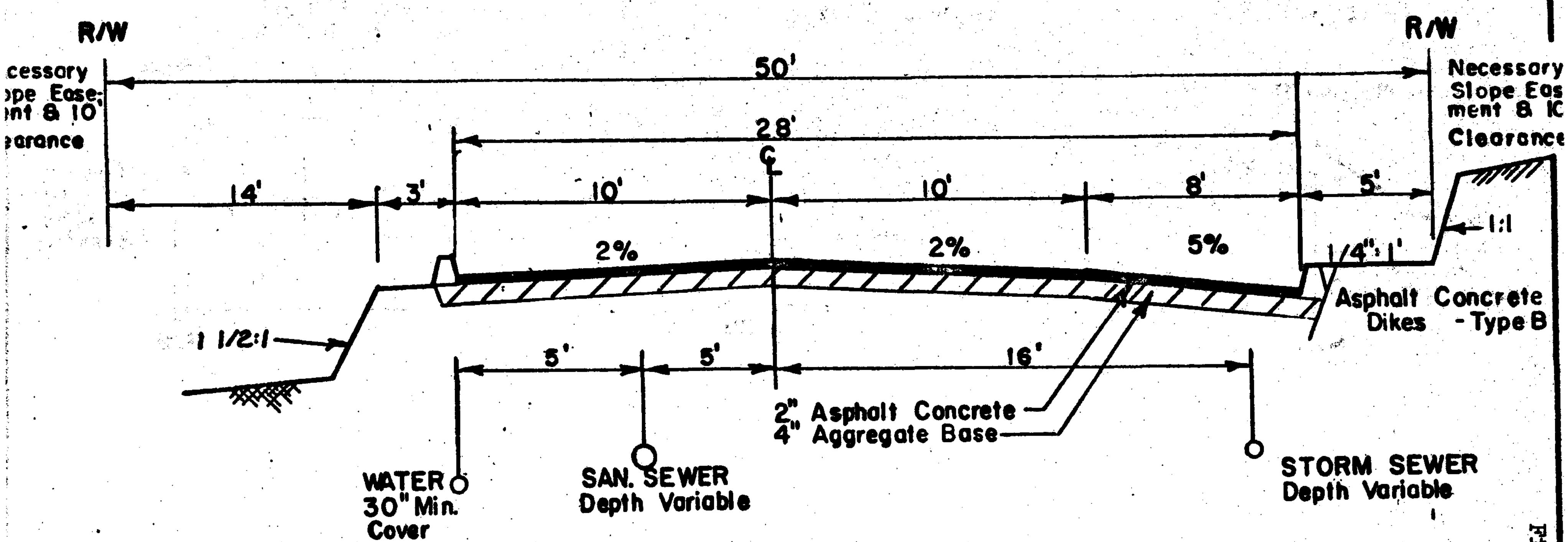


MINOR ROAD

NOTE: Parking Permitted One Side Only

5-'70
E.A.

MEDIUM DENSITY LEVEL LAND SUBDIVISION



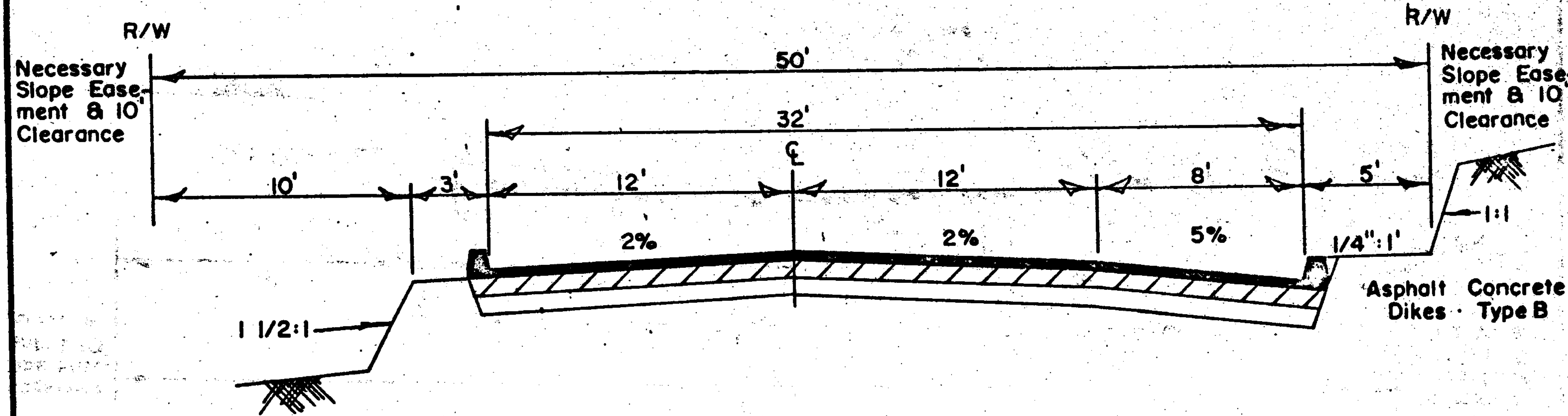
MINOR ROAD

NOTE: Off Street Parking Only

Figure 9-102H

Figure 9-102I

LOW DENSITY LEVEL LAND SUBDIVISION



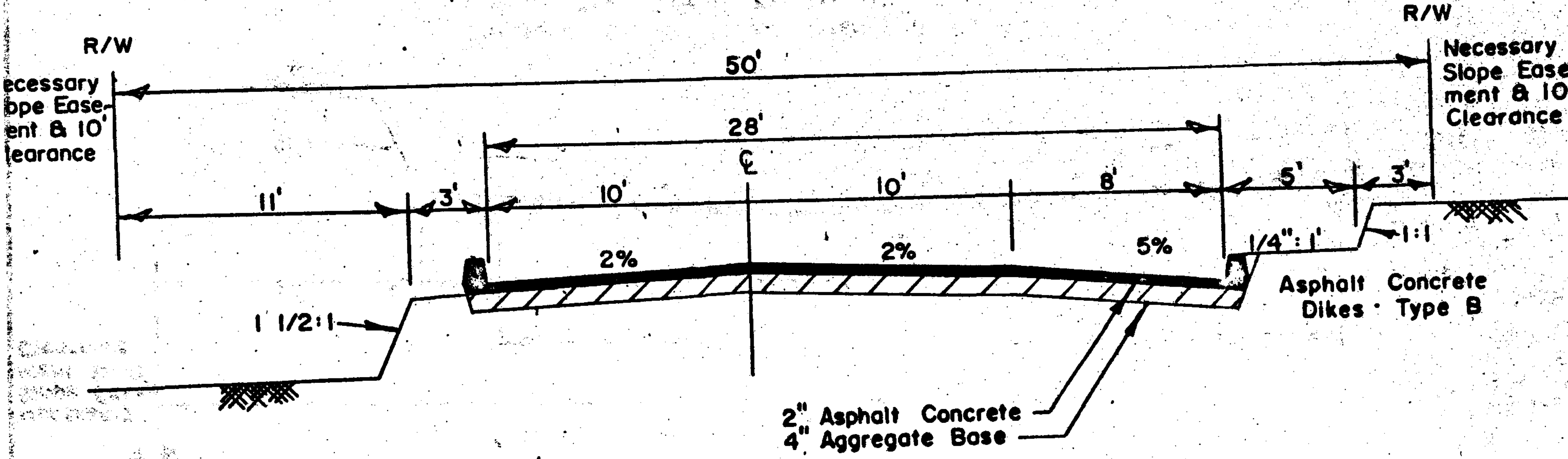
Structural Section To Be Determined By Utilizing The Formula For The California Resistance "R" Value On Basement Soils And By Means Of Traffic Indexes

COLLECTOR ROAD

NOTE: Off Street Parking Only

Figure 9-102J

LOW DENSITY LEVEL LAND SUBDIVISION

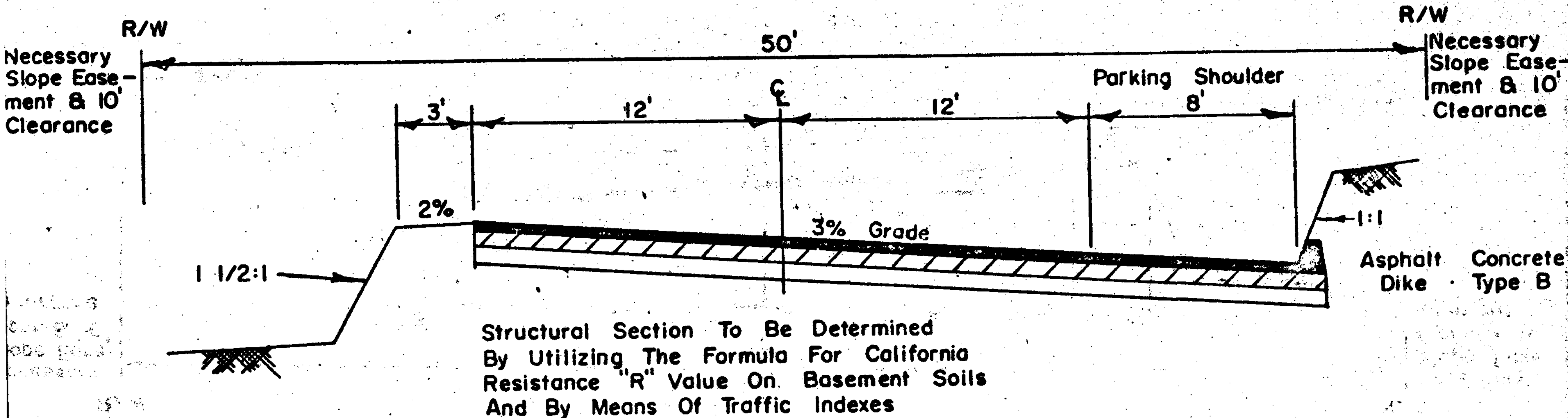


MINOR ROAD

NOTE: Off Street Parking Only

Figure 9-102K

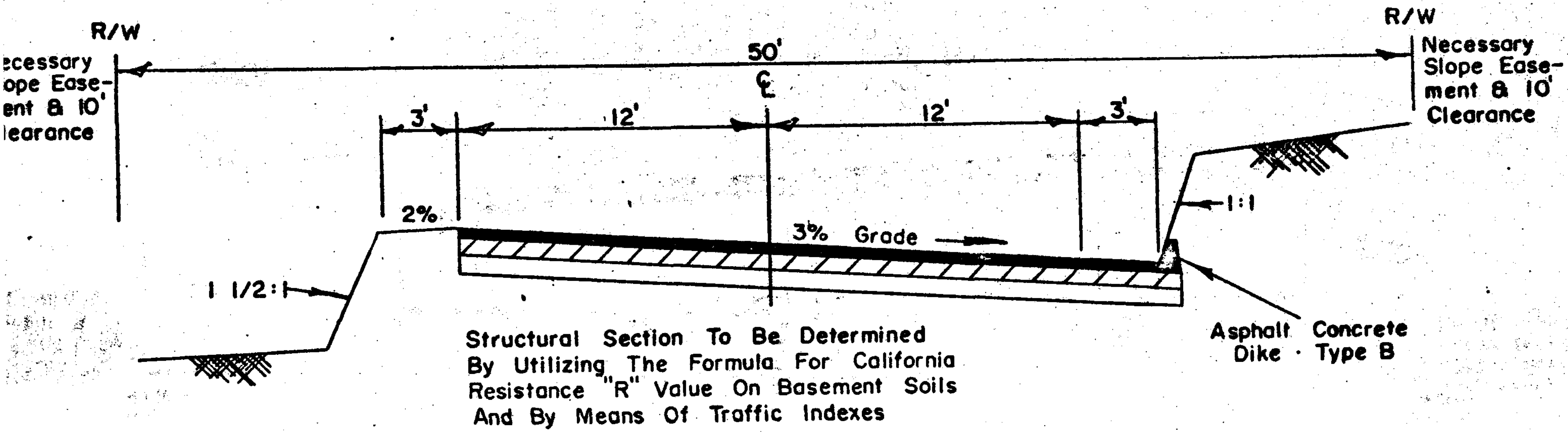
HIGH & MEDIUM DENSITY HILLSIDE SUBDIVISION



COLLECTOR ROAD
ADT = Over 400

NOTE : Parking Permitted One Side Only

HIGH & MEDIUM DENSITY HILLSIDE SUBDIVISION

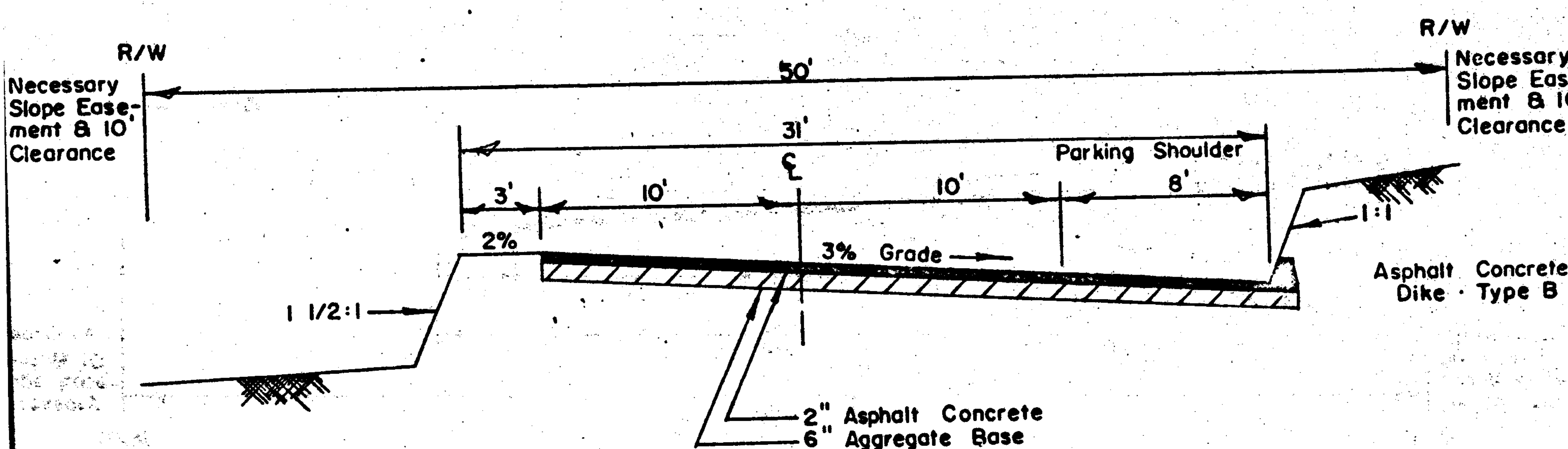


COLLECTOR ROAD

ADT = Over 400

NOTE : Off Street Parking Only

HIGH & MEDIUM DENSITY HILLSIDE SUBDIVISION

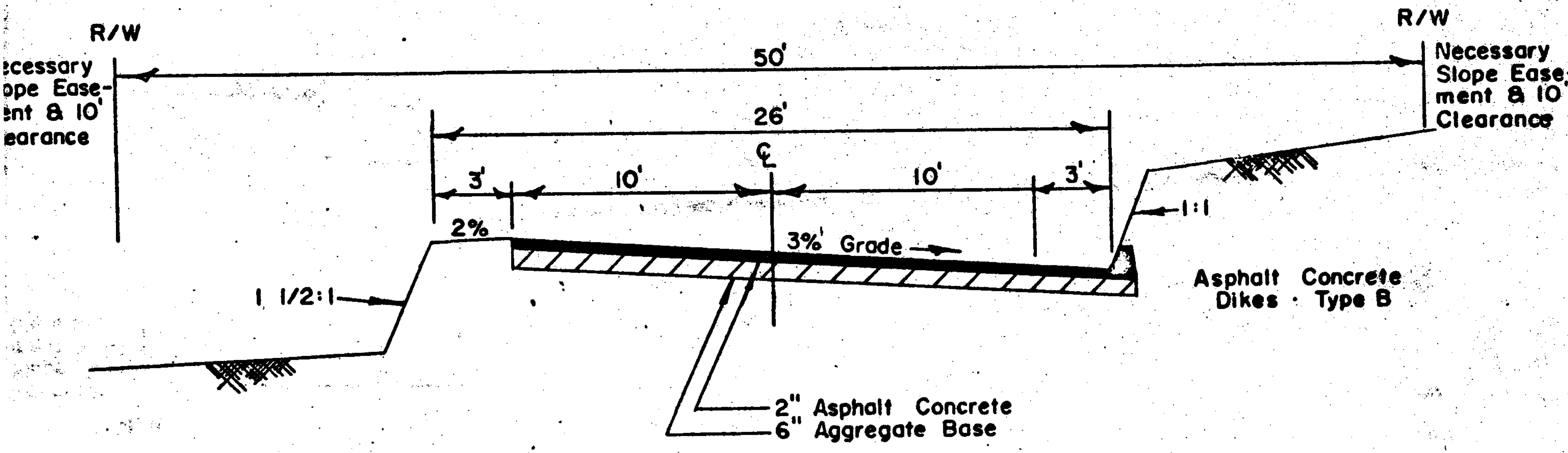


MINOR ROAD

ADT = Under 400

NOTE: Parking Permitted One Side Only

HIGH & MEDIUM DENSITY HILLSIDE SUBDIVISION



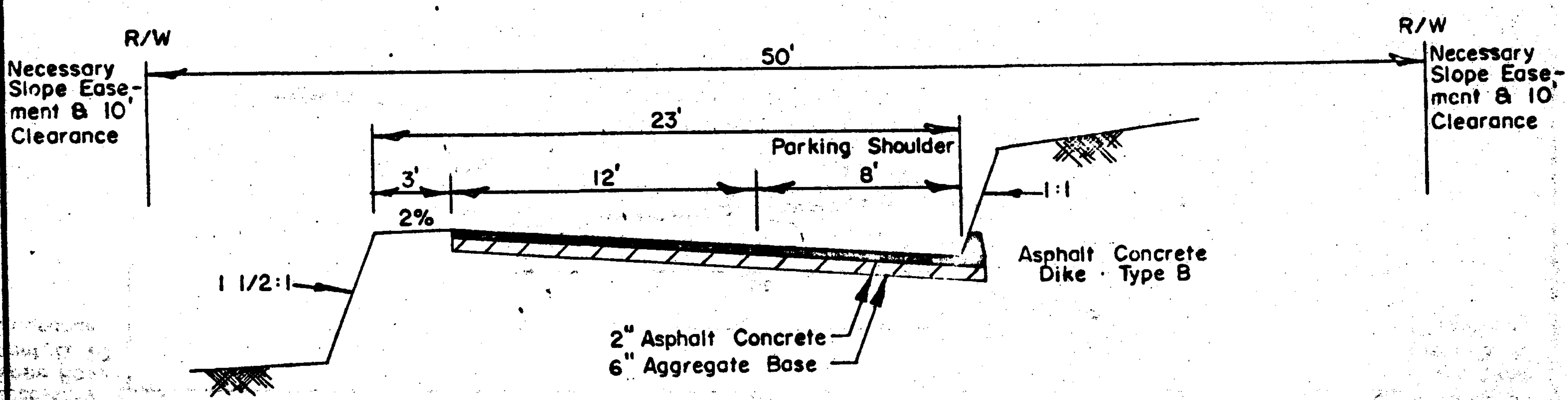
MINOR ROAD

ADT = Under 400

NOTE : Off Street Parking Only

Figure 9-102N

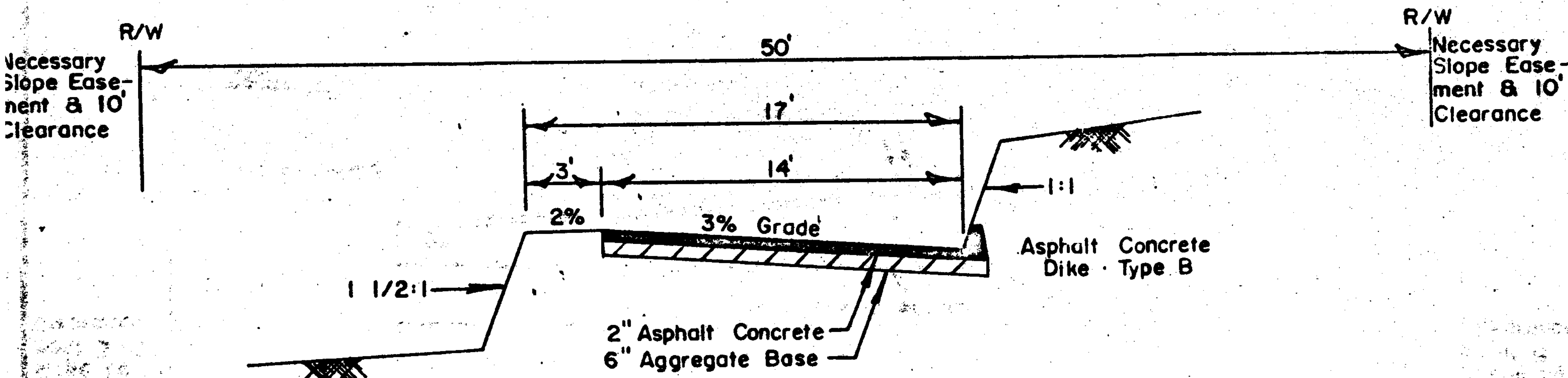
HIGH & MEDIUM DENSITY HILLSIDE SUBDIVISION



ONE WAY STREET

NOTE : Parking Permitted One Side Only

HIGH & MEDIUM DENSITY HILLSIDE SUBDIVISION

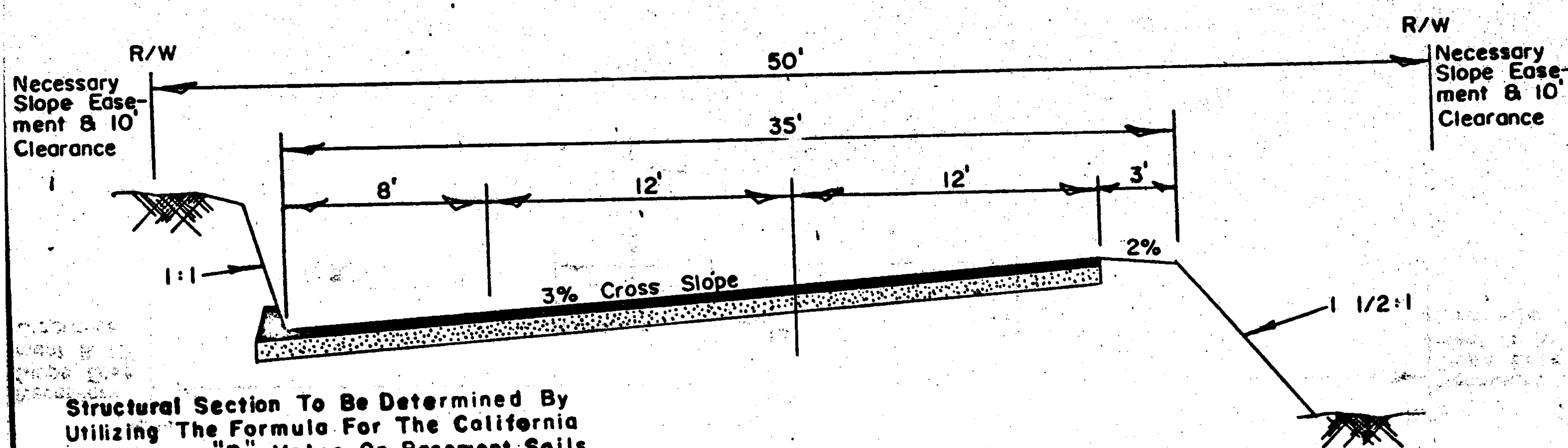


ONE WAY STREET

NOTE : Off Street Parking Only

Figure 9-102P

LOW DENSITY HILLSIDE SUBDIVISION



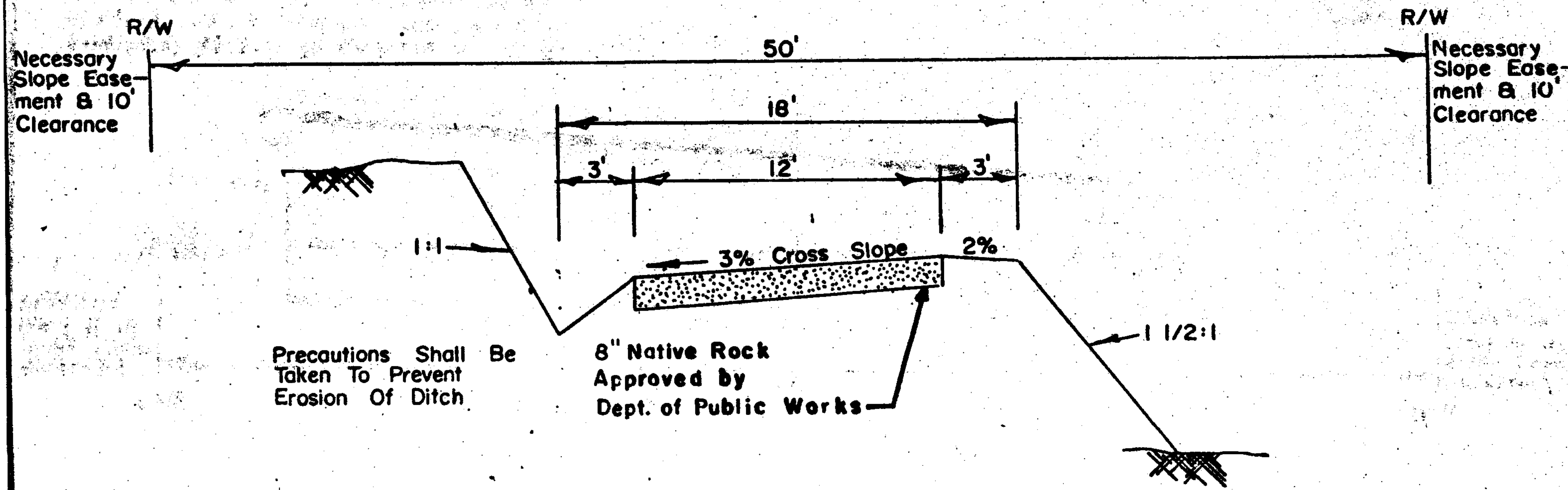
Structural Section To Be Determined By Utilizing The Formula For The California Resistance "R" Value On Basement Soils And By Means Of Traffic Indexes.

COLLECTOR ROAD

ADT = 400-1000

Figure 9-102R

LOW DENSITY HILLSIDE SUBDIVISION



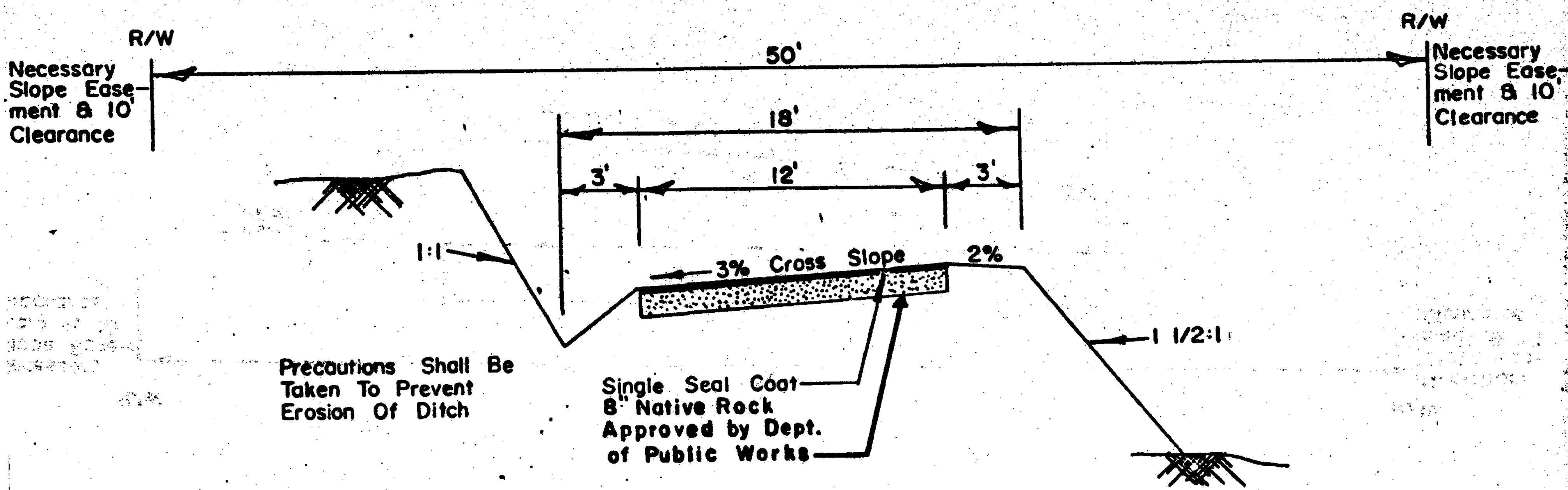
MINOR ROAD

TYPE I

ADT = Under 100

NOTE : Passing Turnouts Must Be Provided.

LOW DENSITY HILLSIDE SUBDIVISION



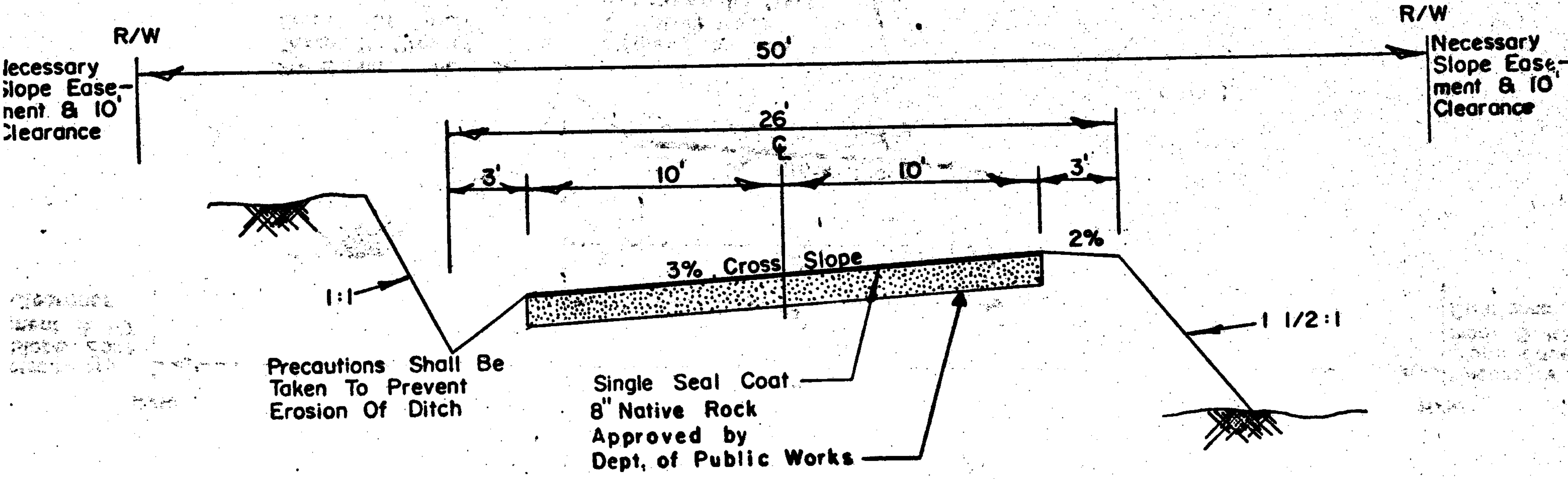
MINOR ROAD

TYPE II

ADT = 100-250

NOTE : Passing Turnouts <u>Must</u> Be Provided.

LOW DENSITY HILLSIDE SUBDIVISION

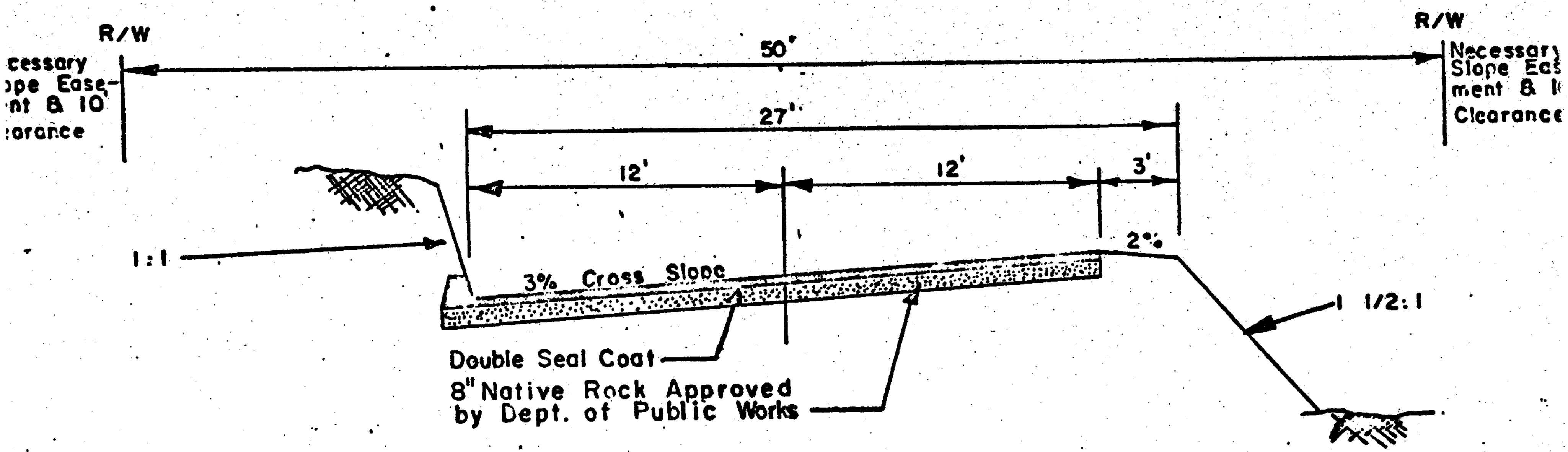


MINOR ROAD

TYPE I & II
TURNOUT FOR PASSING

NOTE : To Be Constructed At 1000' Intervals Max. and/or Intervisible. Turnouts Shall Be 40' In Length & Have Adequate Flares.

LOW DENSITY HILLSIDE SUBDIVISION



MINOR ROAD

TYPE III

ADT = 250 - 400