

Appendix D

Steep Slope Guidelines

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CACHUMA RESOURCE CONSERVATION DISTRICT

920 E. Stowell Rd. Santa Maria, CA 93454

**A GUIDE TO
STEEP LAND ORCHARD DEVELOPMENT
for
Santa Barbara County**

Introduction

Proper planning on existing and future orchards can help to avoid, minimize, and mitigate the potential for impacts on slopes. Without proper planning, threats to watershed health and downstream properties from recurring erosion and sediment deposition, and threats to the site from significant erosion and nearly irreversible landslides become much more likely. This set of Guidelines is intended for use as a reference tool for the design concepts associated with proper orchard planning. Additionally, productive, safe, environmentally and aesthetically appropriately designed hillside orchards can be achieved through consultation with the Natural Resource Conservation Service (NRCS) and Resource Conservation District's (RCDs) "USDA Certified Conservation Planners". As each area is unique, developers should contact professional consultants for site specific planning. USDA Certified Conservation Planners provide Conservation Technical Assistance (CTA), develop site specific "Conservation Farm/Ranch Plans", and utilize the most current and up-to-date Best Management Practices (BMPs). Other qualified planning specialists are available through the University of California Cooperative Extension (UCCE), and numerous private engineering firms.

SITE SELECTION

Several conditions must be met to develop a successful avocado orchard, including a favorable climate, a dependable water supply, adequate water quality, suitable soil, and stable slopes.

CLIMATE

Avocados must be grown in relatively frost free areas. Although certain commercial varieties can tolerate temperatures as low as 24° F, the more popular types are susceptible to damage at 30° F. Localized air movement is an important consideration at each site since poorly drained low areas may be several degrees colder than the surrounding uplands.

WATER SUPPLY

Assuming typical planting densities (20ft. x 20ft.) the average mature avocado orchard will require a total of about 36 inches of precipitation per year. Based on average rainfall of 18 inches per year, a net irrigation application of 18 inches per year must be supplied to meet the requirements of the plants. This net amount will change annually based on the year's actual precipitation rates, and environmental conditions such as temperature and humidity that affect the plant's need for water.

Actual irrigation demand will also vary based on soil type, leaching needs, and the efficiency of the irrigation system. In general, a good micro-irrigation system will have a Distribution Uniformity (DU) of 85 percent, requiring an additional 15-20 percent more water than the net irrigation demand to ensure all plants are properly watered. This leads to a gross requirement of 21 inches of irrigation application or a volume of 1.75 acre feet per acre of orchard. Irrigation systems with poor uniformity may require a much greater volume to effectively irrigate the orchard.

The system selected must also be capable of meeting the peak demand of a mature avocado tree. During peak periods this requirement may be as much as 50 gallons per tree per day which translates to 6500 gallons per acre per day based on the assumptions above. Peak consumption periods in this area normally occur from June through September.



Crop Damage Due to Heat Stress and Insufficient Water

WATER QUALITY

Water quality is important as avocado trees are sensitive to a variety of salts. The salt content of water is typically expressed as total dissolved solids (TDS) in concentrations of milligrams/liter (mg/l) or as electrical conductivity with units of decisiemens/meter (dSm). The salt content of soil is usually expressed in percent salt or as electrical conductivity of the soil water extract at 250 C.

Avocados have a low salt tolerance and any water with an electrical conductivity above 1.0 dS/m may be harmful to the plant. Yields can be expected to decrease by 10% at 1.8 dS/m, 25% at 2.5 dS/m, 50% at 3.7 dS/m. Problems from salt concentrations are most likely to occur in soils with poor sub-surface drainage because most of the water extraction occurs within the root zone.

Sodium and chloride concentrations can also be harmful to the plant. Sodium causes clay particles to disperse and lose their permeability. The sodium content of irrigation water or soil extract is usually expressed as the sodium adsorption ratio (SAR) which is a measurement of the relative activity of sodium ions in exchange reactions. Tree problems can start to occur with an SAR of 3.0 and increase rapidly as sodium concentrations exceed this level. Chlorides can cause leaf damage and problems can occur when chloride concentrations reach 140 mg/l.



Crop Damage Due to High Concentration of Salts

SOIL QUALITY

Avocado trees can be grown on practically any soil if it provides a rooting depth of at least 2 feet (preferably 3ft.) and has good internal drainage. Poorly drained soils can cause physiological and pathological problems for the plant. Saturated soils inhibit proper air exchanges in the root systems and slow growth. In the most severe cases trees in saturated soils may be killed.



A more serious problem associated with poor drainage is the Root Rot Disease which can develop if the soil contains the fungus (*phytophthora einnamoni*). A common vector for infection in otherwise disease free soils is

water transport through the drainage pattern. A close inspection of the drainage area should be conducted above the selected site to ensure that the area is disease free. At present there is no known cure for this disease.

Crop Damage Due to Root Rot Disease

SLOPE STABILITY

Steep slope developments obviously create opportunities for erosion. Erosion control techniques are discussed in detail later in the guide. A more severe problem, and one which is almost impossible to correct is landslides. The natural factors known to promote landslides include steep, relatively thick, soils and excessive moisture. The opportunity for slips is greatly enhanced if the soils overlay impervious parent material which is positioned parallel to the soil surface. Manmade disturbances on geologically unstable slopes increase the opportunities for slope failure. Some of the most common causes for slope failures include year-round wetted soil from irrigation, removal of natural ground cover, and reduction of slope stabilities by steepening the slope angle with road or terrace cuts.

Existing and potential slide prone areas should be excluded from developments. Evidence of slides may be readily apparent or it may be in a more subtle form. The most recognizable evidence on otherwise uniform slopes is characterized by steep escarpments above bowl-like depressions with irregular soil deposition on the lower end. Other features which may indicate unstable slopes include curved tree trunks, oddly angled fences or poles, large transverse soil cracks, springs on steep slopes, and unusual patterns in drainage courses.

SITE PLANNING

The most critical element in the development of steep land orchard is the preparation of Conservation based Farm/Ranch Plan. Corrective actions to repair erosion damages are usually much more expensive than preventative measures, and a landowner could be liable for downstream problems if they are products of construction activities.

INITIAL SITE MAP

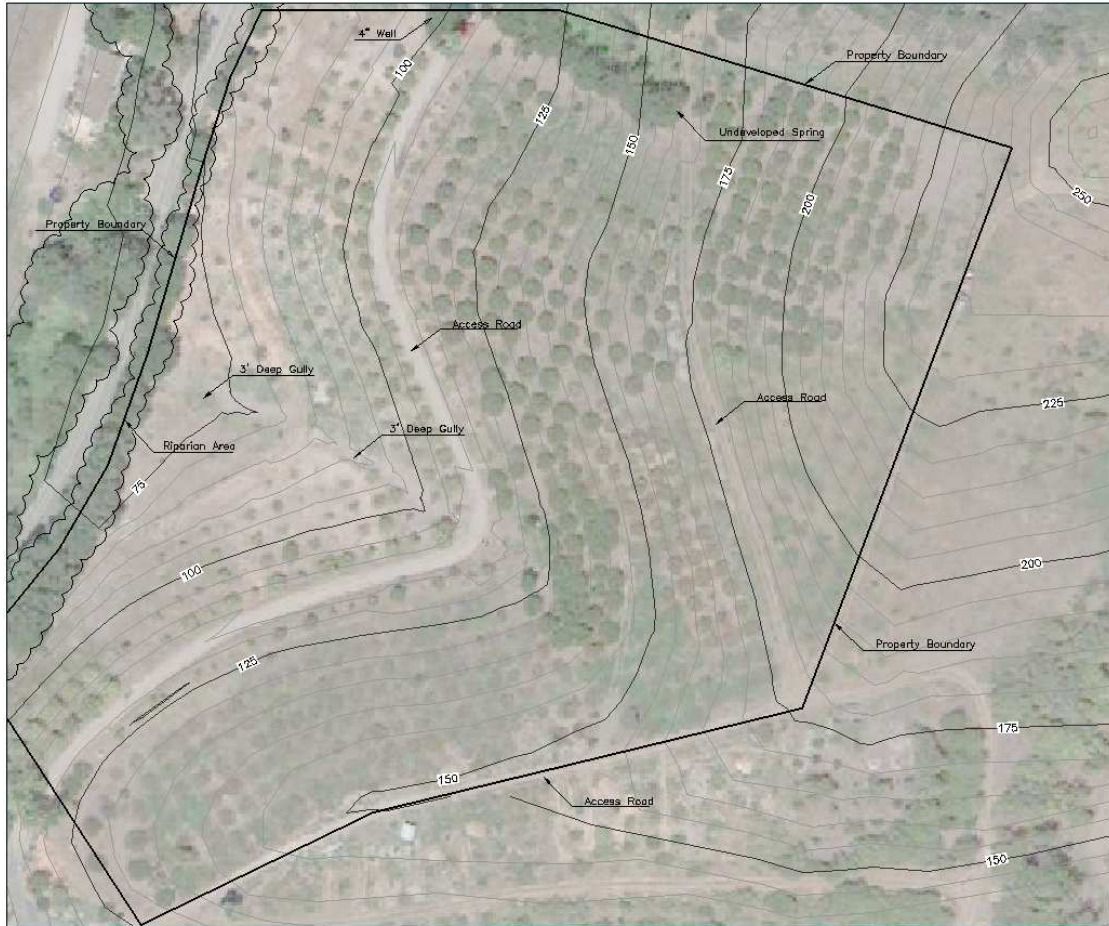
A detailed map illustrating the basic resources and concerns must be prepared in order to assess the site limitations. From this map grading schemes, planting plans and erosion concerns can be logically addressed.

The initial site map should include the following:

- Aerial or satellite image background,
- Property Boundaries, Easements, Utility Lines,
- Map extension to include affected off-site lands, particularly drainage systems,
- California Natural Diversity Database overlay showing known occurrences of rare, threatened, and endangered species. Available through your local NRCS/RCD office,
- Topographic contouring. Ideally, minimum contours should be at 2 foot intervals for slopes less than 15%, and at 5 foot intervals for slopes in excess of 15%,
- Soils descriptions including texture types; depth, permeability, soil pH, depth to, and type of parent material,
- Location of geologically unstable areas and the location and apparent cause of current erosion,
- Location of usable water resources,
- Location of trapped surface or sub-surface water including springs and seeps,
- Location of riparian corridors typically along existing streams or wetlands, and
- General map of natural vegetation and identification of key species in plant community.

Site maps should be prepared to scale at a sufficient size to accommodate all planning information. Generally orchards of 40 acres or less will require a scale of at least 100 feet per inch. Areas with irregular land forms may require larger scales.

Sample Basic Site Map



SITE DEVELOPMENT PLAN

After the limitation and hazards of the site are noted, the specific development plan can be addressed. On steep lands topography will dictate the tree planting scheme. In most cases access roads, erosion control practices, and irrigation laterals must be compatible with the natural contours. As a result, the most effective plantings are placed on contours and parallel to roads. Later sections in this guide will address specific design criteria associated with the infrastructure shown in this plan.

The site development plan should include the following:

- Aerial or satellite image background,
- Property Boundaries,
- Location of areas to be planted and row orientation,
- Location of proposed access roads,
- Location of irrigation infrastructure including water source, mainlines, and laterals,
- Location of runoff control infrastructure including,
- Location of drainage infrastructure including channels and pipelines,
- Proposed site contouring based on final topographic design of the site, and
- Location of rare, threatened, or endangered species, and corresponding critical habitats.

The site development plan should be an active document. Changes to the orchard, infrastructure, or topography should be recorded in the map to ensure its continued relevance and effectiveness as a planning tool.

Sample Development Plan



HYDROLOGIC ANALYSIS

A critical step to site planning is an estimate of the anticipated runoff water. In order to estimate runoff water volumes the site must first be divided into watersheds. Each watershed represents an area that drains to a specific point on the orchard. It is important to define independent watersheds for each individual drainage component where the volume of flow is necessary for design. Watersheds are determined by selecting a point on a map and then drawing the watershed boundary in both directions from the point perpendicular to the contour lines. Keep in mind watersheds often include areas outside of the orchard property.



This Guide uses the NRCS EFH2 method for determining runoff volumes.

The method requires an estimate of the infiltration rate, rainfall intensity, and time of concentration. Infiltration rate can be estimated by splitting the watershed into areas by the categories in the table below and using the weighted average table to determine the average CN for the watershed.

Soil type and hydrologic soil group is mapped at websoilsurvey.sc.egov.usda.gov

Cover Type	Soil Type (hydrologic soil group)			
	Gravel/Sand (A)	Loam (B)	Clay Loam(C)	Clay/Bedrock(D)
Pasture	49	69	79	84
Meadow	30	58	71	78
Brush	35	56	70	77
Woods	36	60	73	79
Orchard	57	73	82	86

Section Name	Area (acres)	CN (from above)	Area x CN
Total Area:		Total Area x CN:	

$$\text{Weighted Average CN} = \frac{\text{Total Area x CN}}{\text{Total Area}}$$

To determine the estimated runoff flow rate find the appropriate factor in the table below based on weighted average CN and the length of the watershed. The length of the watershed is the distance from the low point on the watershed to the most distant point in the watershed. Multiply the factor by the area of the watershed to determine an estimate of the flow anticipated for the given watershed. These tables are for estimating purposes only and are based on approximate factors for the type of land typically used for orchards. A NRCS, RCD, UCCE, or other professional should be contacted to determine actual flow rates before beginning construction.

Weighted Average CN	Watershed Length					
	100	200	400	800	1600	3200
50	0.7	0.6	0.5	0.4	0.3	0.2
60	1.8	1.5	1.2	1.0	0.8	0.6
70	3.0	2.6	2.1	1.7	1.4	1.1
80	5.0	4.2	3.4	2.7	2.2	1.7
90	9.2	7.4	5.9	4.6	3.6	2.7

$$10 \text{ year storm flow rate} = \text{watershed area} \times \text{runoff factor}$$

LAND CLEARING

The method employed in clearing land is one of the most critical phases in the development process. A superficial analysis of costs may indicate that the use of straight-bladed bulldozers is the most economical clearing method. However, bulldozers usually increase the vulnerability of the soil to erosion and significantly increase the erosion control costs. Topsoil is also permanently damaged because of surface disturbance and the mixing of excessive amounts of soil with piled brush. A more desirable mechanical clearing method resulting in less soil disturbance is to use a brush mower, rake, or disc. Generally brush mowers or discs are used on light brush and rakes on heavy material. While, hand removal is the most desirable technique as a primary method of brush clearing, it can be very limited in its effectiveness. Initial costs may not appear to favor of alternatives to use of heavy equipment. However, a close analysis of costs may prove otherwise and needs to be addressed on a case-by-case basis.

Consideration prior to and during the brush clearing operation should include:

- Clear identification and avoidance of geologically unstable areas.
- Identification of primary surface drainage systems and environmentally sensitive riparian corridors. Undisturbed buffer zones should be left on each side of drainage courses to inhibit erosion.
- Check local ordinances regarding brushing and land clearing. All permits must be obtained as required by regulatory agencies. This Guideline is not intended to replace any permit requirements.
- Some riparian areas are critical to wildlife needs. All streambed alterations come under the purview of the California Department of Fish and Wildlife and a Streambed Alteration Agreement may be required. Alterations to certain watercourses may also require an approval permit from the U.S. Army Corps of Engineers (USACE).
- Identification and location of any rare, threatened or endangered species and corresponding critical habitat. If impacts are unavoidable, consultation and/or permits would be required by regulatory agencies including, but not limited to CDFW and USFWS.
- Some areas which are developable for orchards are within the Jurisdictional Boundaries of the California Coastal Commission or may be within incorporated areas. Additional regulations apply in these zones.
- Identify spoils areas and disposal methods for cleared material beforehand. Ideally brush should be processed through a shredder and disposed of as mulch over the cleared area. Mulch provides protection from soil erosion and improves soil fertility by returning bound nutrients and carbon to the soil, and will increase water-holding capacities, and improving soil tilth.
- Excavated material should not encroach on water courses or be deposited in areas subject to flooding.
- Clearing should be done far enough in advance of the rainy season to allow ample time to install erosion control measures.

ROADWAYS

After land clearing, road construction is the most critical element affecting the long term viability of an orchard. When road patterns are in place and trees are planted, the layout of an orchard is virtually impossible to modify without a significant expense. Orchard roads serve a variety of purposes and they are constructed in a variety of ways to satisfy these needs.

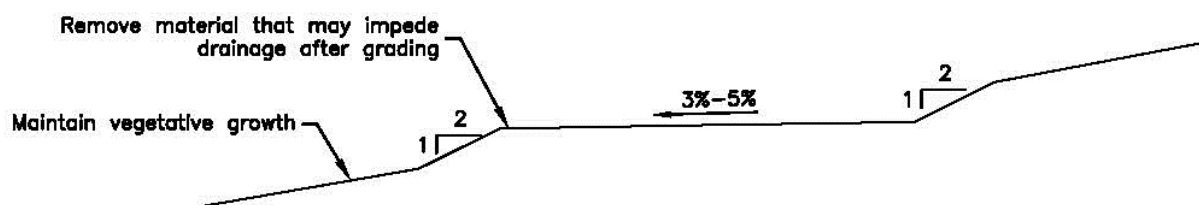
TYPICAL ROADWAY DESIGN

Typical roadway width is 10 to 12 feet, widened as necessary to accommodate vehicle turning radius. All cut and fill slopes should be limited to a 1.5:1 slope for clay soil and a 1:1 slope for all other soil types, and be well vegetated. Fill material should be free of organic material as it will eventually decompose leaving voids in the fill.

Most roads should be constructed along the contour lines with connecting roads linking these on-contour roads to allow for ease of access. Roads along a contour line with a slope of 15% or less and relatively low erosion hazard should be graded to drain in the downhill direction of the natural grade, referred to as out-sloped. Roads along a contour line with a steeper slope or significant erosion hazards should be graded to collect water and convey it to a stabilized drainage facility, referred to as in-sloped.

OUT-SLOPED ROADS

Out-sloped roads are usually installed only to facilitate picking and crop management operations. Adequate orchard ground cover is necessary for the proper functioning of these roads. Out-sloped roads should be graded at 3 to 5 percent to allow surface water to sheet flow across. This helps to prevent the water from concentrating and as a result limits the destructive energy of the runoff. Generally, out-sloped roads are designed at a level grade along their length. If conditions dictate a need to provide a rise in elevation it should be designed at a uniform grade not exceeding 2 percent.



IN-SLOPED ROADS

In-sloped roads serve both as access and as a surface water diversion and conveyance system. These roads should be graded to collect runoff water and convey it to drainage features. Road spacing on steep slopes should provide for uniform contour of tree rows. The distance between roads will be dictated by the degree of the slope. To accommodate cultural operations and minimize erosion, this spacing should allow for not more than 6 tree rows on slopes of 20% or less, 4 tree rows from 20% to 35% and not more than 2 tree rows on slopes in excess of 35%.

In-sloped roads should be graded at 3 to 5 percent to allow surface water to sheet flow across and flow along the inside of the roadway. A berm on the outside of the road should be installed to contain runoff in heavy storm events and should be a minimum of 2' wide at its top and 1' above the road low point. Generally in-sloped roads are designed at a level grade along their length. If conditions dictate a need to provide a rise in elevation it should be designed at a uniform grade not exceeding 1.5 percent.

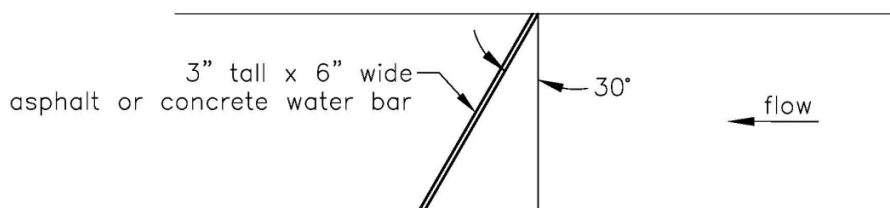
The maximum flow in one direction should not exceed 5 cubic feet per second (cfs) on 1.5% slopes and 4 cfs on 1.0% slopes. Hydrologic output is a product of multiple factors including drainage area, soil and cover types, storm intensity, and slope. As there are multiple factors affecting runoff, each orchard will have a unique set of characteristics dictating diversion limitations.



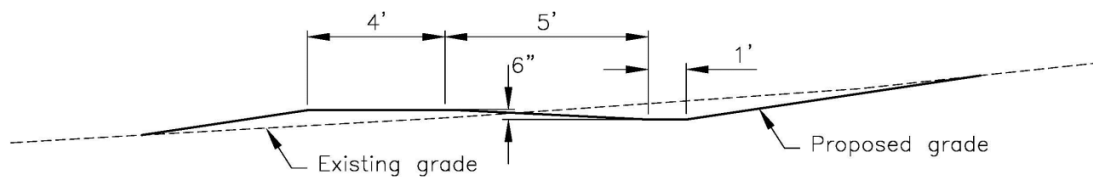
CONNECTING ROADS

Connecting roads are often constructed on relatively steep gradients. To mitigate the erosion potential, these roads should be built to exclude overland flows as much as possible. The exclusion of surface water can be accomplished using the following strategies:

- Locate connecting roads along ridges where the volume of runoff water is limited
- Locate connecting roads along drainage features and grade road to sheet flow into feature
- Construct water bars or rolling dips to force water off of roadway. These features should outlet to a well vegetated area with an energy dissipating feature such as rock riprap at the outlet.
- In extreme situations paving and gutters may be necessary to avoid erosion.



WATER BAR DETAIL



ROLLING DIP DETAIL

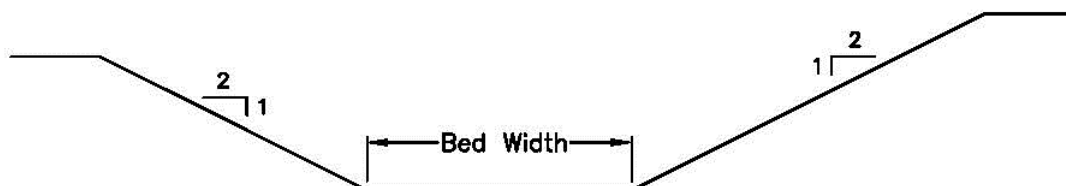
DRAINAGE FACILITIES

EARTHEN CHANNELS

Concentrated runoff water is most economically conveyed by earthen channels. The capacity of an earth channel is limited by the ability of the soil in the channel to resist the erosive force of the water flowing in the channel. Therefore, channel design is primarily based on the type of soil in the channel bottom and the volume of anticipated storm runoff flow.

Earth channels should be constructed by incising the channel into the existing ground as opposed to building up levees if possible. This reduces the chances of failure due to rodent activity or levee erosion if it is overtopped. Earth channels should be constructed in a trapezoidal shape as shown below with a bottom width based on the design flow rate and side slopes limited to a 2:1 to slope. The table below provides general information on channel capacities based on soil type, slope and bottom width. As with all drainage structures this information is for planning purposes and it is highly recommended that a professional be consulted before installing any drainage structure.

All channels should be inspected after large storm events to identify trash build-up and erosion problems. Remove trash piles in channel to maintain channel capacity and prevent overflow. Localized erosion at a specific section of the channel bank is often the result of concentrated flow entering the channel. This can be remedied by installing rock riprap on geotextile fabric along the specific section of channel bank. Alternatively install an inlet and pipeline to collect the concentrated water and outlet to the bottom of the channel with rock rip rap to dissipate energy. Both of these options will make maintenance of the channel more difficult. Mass erosion along the length of the channel likely indicates that the channel is incorrectly designed and requires an increase in size or the addition of vegetative or structural reinforcement as discussed in later sections.



Flow Capacity(cfs): Sand Soil (1.5 foot per second velocity limit)

Grade (%)	Bottom Width (ft)					
	2	4	6	8	10	12
0.5	1.0	1.7	2.4	2.9	3.7	4.4
1	0.5	0.9	1.2	1.6	2.0	2.4
2	0.3	0.5	0.8	1.0	1.3	1.5
3	0.2	0.4	0.6	0.8	1.0	1.1

Flow Capacity(cfs): Loam Soil (2.5 foot per second velocity limit)

Grade (%)	Bottom Width (ft)					
	2	4	6	8	10	12
0.5	6	7	9	12	14	17
1	2	3	4	6	7	9
2	1	2	2	3	4	5
3	1	1	2	2	3	3

Flow Capacity(cfs): Clay Soil (3.5 foot per second velocity limit)

Grade (%)	Bottom Width (ft)					
	2	4	6	8	10	12
0.5	21	24	28	33	37	42
1	7	10	13	16	19	23
2	3	5	7	8	10	12
3	2	3	4	6	7	9

VEGETATED CHANNELS

In situations where the concentrated flow is too large to be safely conveyed in earthen channels, the same channel geometry may be vegetated. The structural integrity of a vegetated channel is limited by the ability of the soil, augmented by the roots and stems of the vegetation, to resist the erosive force of the water flowing in the channel. While vegetated channels offer more protection from erosion over earth channels, they may require increased maintenance, such as providing irrigation to the vegetation and mowing the vegetation to maintain a clear flow path. In addition, channels that are prone to filling with sediment are difficult to clear without damaging the vegetation and typically should not be vegetated.

Vegetated channels should be constructed by incising the channel into the existing ground as opposed to building up levees if possible. This reduces the chances of failure due to rodent activity or levee erosion if it is overtopped. Vegetated channels should be constructed in a trapezoidal shape as shown below with a bottom width based on the design flow rate and side slopes limited to a 2:1 to slope. The table below provides general information on vegetated channel capacities based on soil type, slope and bottom width. As with all drainage structures this information is for planning purposes and it is highly recommended that a professional be consulted before installing any drainage structure.

Flow Capacity(cfs): Sand Soil (1.5 foot per second velocity limit)

Grade (%)	Bottom Width (ft)					
	2	4	6	8	10	12
0.5	8	11	13	15	18	20
1	3	4	5	7	8	9
2	1	2	2	3	4	5
3	1	1	2	2	3	4

Flow Capacity(cfs): Loam Soil (2.5 foot per second velocity limit)

Grade (%)	Bottom Width (ft)					
	2	4	6	8	10	12
0.5	28	32	34	39	42	44
1	10	11	13	17	19	23
2	4	5	6	9	10	12
3	3	3	4	6	7	9

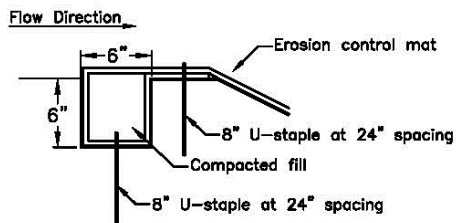
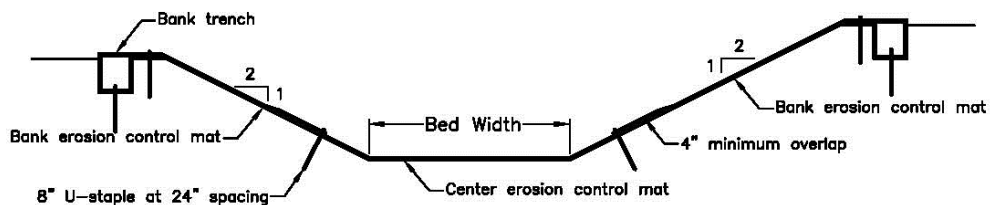
Flow Capacity(cfs): Clay Soil (3.0 foot per second velocity limit)

Grade (%)	Bottom Width (ft)					
	2	4	6	8	10	12
0.5	140	146	155	166	173	176
1	52	55	60	68	74	78
2	19	21	25	30	34	36
3	11	13	16	19	21	25

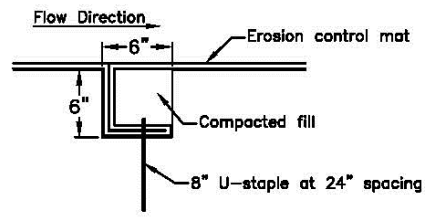
TURF REINFORCEMENT MATS

The use of turf reinforcement mats can greatly increase the capacity of vegetated channels. These mats consist of several layers of turf and bio-degradable netting, and often include an organic matrix to protect the soil while vegetation is being established. Use of turf reinforcement mats is limited by the same factors as vegetated channels as they require irrigation, mowing, and should not be installed in channels subject to sediment deposition.

Install turf reinforcement mats per the detail below with adjustments made as necessary to meet the manufacturer's recommendations. The capacity of channels lined with turf reinforcement mats is largely based on the specific product selected. Consult with a professional to determine if this treatment is applicable and which product would be most effective for your specific situation.



BANK AND TERMINAL TRENCH



CUTOFF TRENCH
Install perpendicular to flow direction every 50 feet

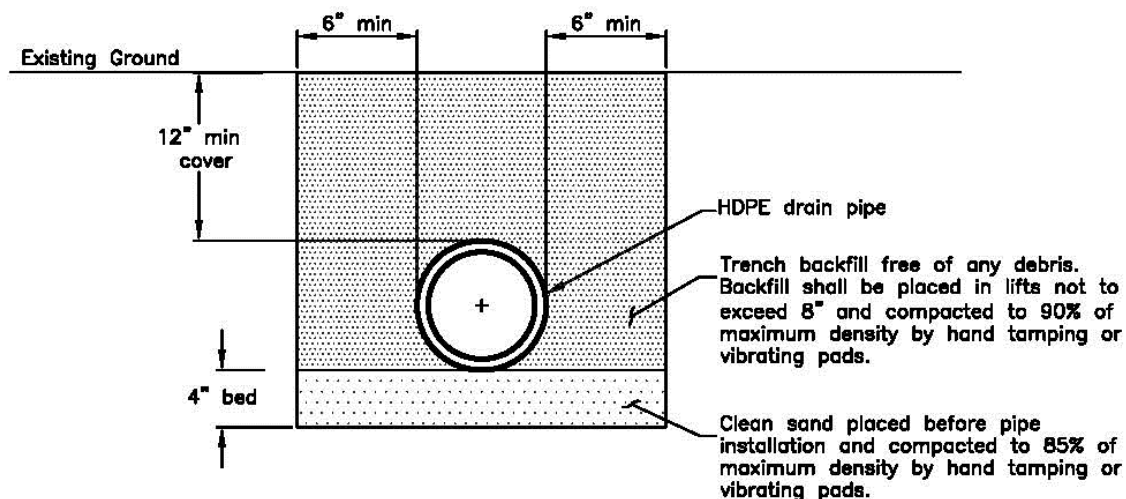
DRAIN PIPES

Pipelines typically allow water to be conveyed at relatively high flow rates compared to channels. They can be installed along steep slopes where channels typically are not useable. In addition, pipelines allow access across the drainage path which would be restricted by channels and do not require the sacrifice of as much land for drainage facilities. However, pipelines are typically much more expensive to install than channels. The table below provides general flow limits for a variety of pipe sizes and slopes. Final design should be completed by a qualifier professional before construction.

Dual Wall HDPE Flow Capacity (cfs)

Pipe Slope	Pipe Diameter (Inches)				
	12	18	24	36	48
1%	4	11	25	40	110
2%	4	12	26	60	130
3%	4	13	28	70	160
5%	5	14	32	80	180
10%	5	16	37	100	220

Proper installation of pipelines is critical to avoid potential failures. Typically single or dual wall HDPE pipe is used due to its low cost and ease of installation compared to metal or concrete pipes. It is recommended that all pipelines be a minimum of 10 inches in diameter to avoid clogging. The detail below shows a typical trench section for installing HDPE pipeline. Most HDPE pipe requires a minimum of 12 inches of cover from the top of the pipe to the ground level in order to protect it from vehicle traffic. The pipe trench should be at least 12 inches wider than the pipe outer diameter to allow for room to work around the pipe in the trench and accessibility for proper compaction. Check manufacturer recommendations for the specific pipe selected for cover requirements, pipe width and maximum vehicle loading. In addition to proper pipe installation it is recommended to include concrete or plastic cut off walls along the pipe at 200' intervals or after every inlet.

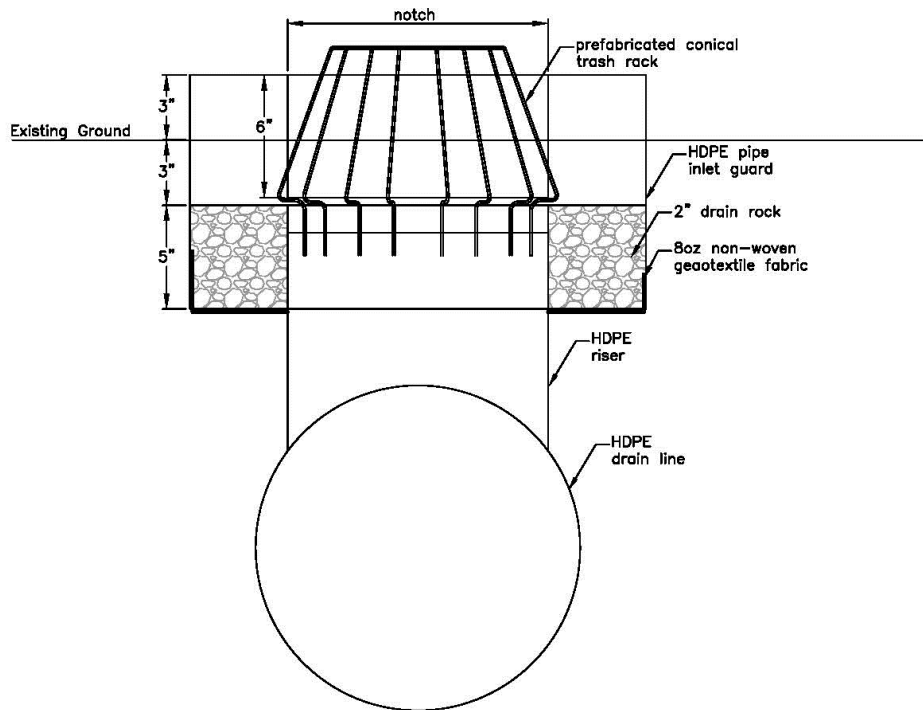


Inlets are a critical element to a drain pipe system. Inlets should be sized based on the design flow for the inlet watershed. See the sizing chart below for general guidelines on inlet sizing based on design flow. Inlets should be protected from vehicle traffic, and trash racks should be installed to protect the storm drain system from clogging due to debris. As with pipelines, it is recommended that inlets be a minimum of 10 inches in diameter to avoid clogging issues.

Monitor inlets after storm events and remove trash or debris that may reduce inlet capacity. Also check for settlement or damage of the inlet structure.

Inlet Capacity (cfs)

Head (in)	Pipe Diameter (Inches)				
	12	18	24	36	48
3	2	3	4	5	6
6	3	5	7	10	15
12	10	15	20	30	40



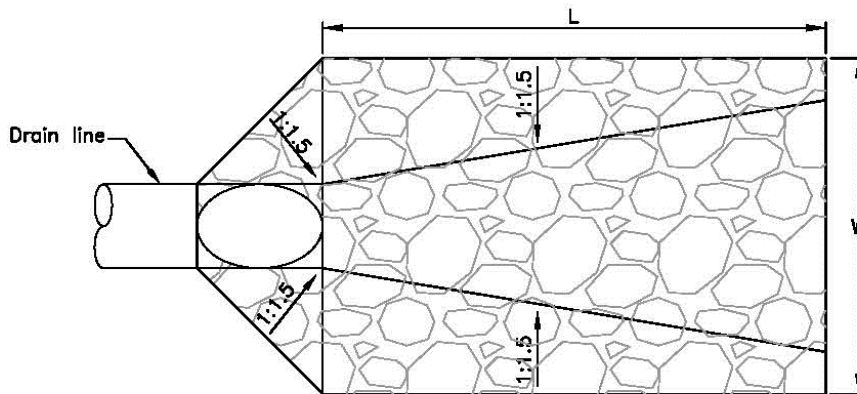
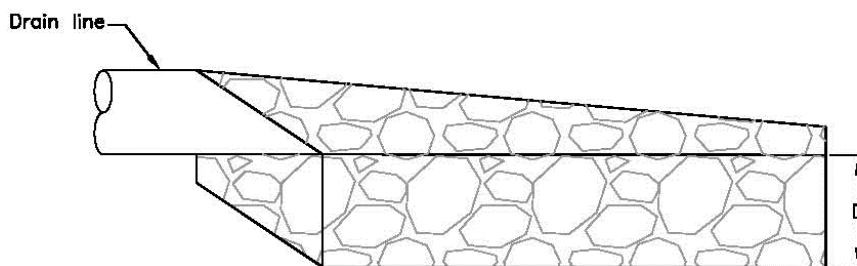
The outlet of a drain pipe is a critical location as the water leaving the pipe is often traveling at high velocities and needs to be slowed before it can be conveyed in a surface channel without risk of erosion. It is also critical to ensure that the downstream infrastructure is properly sized for the water being delivered by the pipeline.

Rock is the most common method of slowing runoff water. The rock apron can be sized and rock graded per the table below assuming the outlet is on flat ground. For outlets onto steep slopes or high velocity applications a custom designed outlet feature may be necessary.

Monitor rock after large storm events and replace or relocate rocks as necessary to maintain proper ground cover and energy dissipation.

Approximate Riprap Dimensions and Rock Size for 5% slope pipe at capacity

Pipe Size	Depth -D (in)	Length - L (ft)	Width - W (ft)	D50 Rock size (in)	D100 Rock size (in)
12 in	12	4	4	5	6
18 in	18	8	6	8	10
24 in	24	10	8	12	16
36 in	28	18	12	15	20
48 in	36	28	16	24	30



COVER CROPS

One of the most effective and economical means of reducing erosion on sloping land is through the use of cover crops. There are a variety of methods regarding establishing cover crops including propagating existing seed, seeding improved varieties, seeding cereal grains, and seeding perennial plants. Each of these options has advantages and limitations that are discussed later in this section. The method of establishment and the cover species selected will affect the degree of management required and the effectiveness for erosion control.

Benefits provided by cover crops:

- Extremely effective erosion control
- Improved water penetration
- Improved soil structure
- Reduced water velocities and quantities
- Dust control
- May provide an environment which promotes the propagation of beneficial insect
- Increased humidity and reduction of reflected heat

Potential problems with cover crops:

- Competition with trees for water and nutrients
- Undesirable weeds may be harder to control
- Potential increase in fire hazard
- May improve habitat for rodents or some undesirable insects

Proper management of cover crops will help to mitigate associated problems. Cover crop height should be controlled by mowing or tilling depending on the type of cover crop used. This will help reduce competition with trees, fire hazard, and pest habitat. Undesirable weeds can sometimes be managed with selective herbicides or weeding.

Areas with high potential for erosion such as eroding slopes and road fills should be mulched during establishment. Grain straw mulch applied at a rate of at least 2 tons / acre, or about one 90 pound bale over 100 square feet provides a superior cover. The straw should be anchored by punching into the soil with a straight disc, shovel or similar device. Brush or tree chippings are also an acceptable form of mulch although they can be more difficult to incorporate into the soil. For areas with very high potential for erosion such as drainage courses erosion control mats can be applied over the prepared seed bed. See the turf reinforcement section of the drainage facilities chapter for more information on installation.

PROPAGATION OF EXISTING NATIVES

Propagation of existing native plant species is the best cover crop option, but it is dependent on suitable existing site conditions and may require more complicated management compared to other options. In order for a site to be suitable, at least 30% of the existing plant cover has to contain desirable species and this cover type must be uniformly distributed throughout the area. This method may not be possible on existing orchards with no native seed bank or on areas where extensive earthwork has occurred. The existing seedbed is allowed to establish with weeding to remove undesirable species. The cover crop is mowed as necessary to maintain access and irrigation patterns. The mowing dates should be selected to allow for self-seeding before mowing.

Advantages:

- No establishment or reseeding cost
- Existing native species are best suited for the environment
- Less ground disturbance improves erosion control
- Native grasses have deeper roots than non-natives and are better for erosion control
- Variety of plants is most likely to host a variety of beneficial insects

Disadvantages:

- Native plant communities will contain a variety of plant species and a wide range of growth characteristics. Management may be more difficult.
- If you are successful and native habitat is established, the area may be Environmentally Sensitive Habitat (ESH), you may need a permit to modify your cover crops in the future.

SEEDING WITH IMPROVED VARIETIES

Seeding with improved varieties allows for plant types to be selected to meet specific management criteria, such as growth season or plant height. Select self-seeding species to reduce the amount of seeding necessary the next year. Typically, planting occurs in fall allowing for growth to establish good cover during the months with the most precipitation. Light disking may be necessary to prepare the seed bed. Seed should be broadcast at a rate of 5 to 10 pounds per acre depending on species and covered lightly with a harrow, heavy chain drag, or similar implement. Seed covers should not exceed one-half inch. The cover crop is typically mowed in spring to facilitate orchard operations. The mowing dates should be selected to allow for self-seeding before mowing.

Advantages:

- Monoculture allows growth characteristics to be selected
- High degree of erosion protection
- Doesn't require irrigation
- Self-seeding reduces required inputs in future years

Disadvantages:

- Monoculture reduces variety of beneficial insects
- Early storm events may cause erosion before cover crop is established

SEEDING WITH CEREAL GRAINS

Seeding with cereal grains allows for rapid and competitive plant growth. Typically, planting occurs in fall allowing for growth to establish good cover during the months with the most precipitation. Light disking may be necessary to prepare the seed bed. Seed should be broadcast at a rate of 10 to 15 pounds per acre depending on species and covered lightly with a harrow, heavy chain drag, or similar implement. Seed covers should not exceed one-half inch. The cover crop is typically mowed in spring to facilitate orchard operations. Cereal grains may produce a large amount of hay material that may be difficult to remove.

Advantages:

- Fast and aggressive growth helps to ensure good cover
- Monoculture allows growth characteristics to be selected
- High degree of erosion protection
- Doesn't require irrigation

Disadvantages:

- Monoculture reduces variety of beneficial insects
- Early storm events may cause erosion before cover crop is established
- Large amount of hay material may be difficult to remove
- Most cereal grains do not reseed well requiring full seeding every year

SEEDING OR SPRIGGING PERENNIAL PLANTS

Seeding or sprigging perennial plants is the most expensive method for initial cost and maintenance, but provides the highest degree of erosion control. Typically, planting occurs in the winter after the first three storm events. Methods of seeding or sprigging will vary based on plant species. Perennial plants typically require irrigation during the summer, and need to be trimmed or mowed to maintain access and irrigation patterns. Perennial plant cover crops establish a complex root system critical for erosion protection and allow for minimal ground disturbance after planting.

Advantages:

- Provides highest degree of erosion control
- Less need to disturb the ground improves erosion control
- A variety of plants can be selected to host a variety of beneficial insects

Disadvantages:

- Higher installation costs and plants can be difficult to establish
- Required irrigation and maintenance during the growing season
- Difficult to eradicate once established
- If you are successful and native habitat is established, the area may be Environmentally Sensitive Habitat (ESH), you may need a permit to modify your planted area in the future.

IRRIGATION

There are many factors affecting the design and management of an irrigation system including water supply, topography, soils, climate and cost. This guide will address irrigation by splitting it into system design and scheduling. It is important that the designed system is capable of delivering water to meet the proposed irrigation schedule so both sections must be designed before an irrigation system should be installed.

SYSTEM DESIGN

The primary goal of an irrigation system design is to provide water to all trees as evenly as possible. Systems that provide uneven water application will require more water to ensure the trees with the lowest water application are adequately irrigated. This leads to increased water demand and cost along with a greater potential for erosion due to irrigation. The flow rate of most emitters is based on pressure in the pipeline making proper system layout critical. The layout of a typical irrigation system consists of irrigation mains, manifolds and laterals.

MAIN LINES

Mains distribute water from the water source throughout the orchard. Typically, mains are buried PVC pipe. The trench should be two to three feet deep from the top of the pipe to ground level and the bottom of the trench and backfill soil should be free of rocks to avoid damaging the pipe. Backfill should also be free of organic material which will decompose and leave voids. Mains need to be sized based on the flow rates of the manifolds they service. Undersized main lines will require extra energy from the pump to provide the same amount of water and may cause low pressures at the far ends of the orchards. The table below can be used to size irrigation mains based on the recommended maximum flow rate.

MANIFOLDS

Pipe Diameter (in)	4	6	8	10	12	15	18	21	24
Flow Rate (gpm)	200	400	800	1200	1800	2800	4000	5500	7000

Manifolds deliver water to the irrigation laterals. They differ from mains in that they include a series of risers along their length to connect to the laterals. Typically manifolds are separated from mainlines by a valve which allows the manifold to be shut off for scheduling or to repair a break. In steep orchards manifolds are typically installed perpendicular to the contour lines. This allows for pressure reducers to be installed at each lateral connection which provides even pressure to all of the laterals serviced by the manifold. Manifolds are typically PVC buried pipeline and are installed the same way as mains. They can be sized using the same table as the mains above, however, pipe size at the end of the manifold can often be reduced as there are less laterals being serviced and therefore lower flow rates.

LATERALS

Laterals follow the tree lines along the contour and are directly connected to the micro-sprinkler or emitter. Typically, laterals are above ground polyethylene tubes anchored with wire staples to keep them in place. Laterals should be installed to minimize elevation change as changes in elevation effect the pressure in the pipe which in turn affects the flow rate out of the emitters. Sizing of laterals is a complicated procedure that requires analysis of the emitter type, emitter spacing, system pressure, lateral length, and lateral slope. The table below gives rough guidelines for sizing but an irrigation designer should be consulted for specific recommendations.

EMITTERS

The most important part of irrigation design is the selection of the emitter. For orchards on steep slopes the two suggested forms of emitters are drip emitters and micro-sprinklers. The design considerations along with advantages and disadvantages of each type are outlined below.

DRIP EMITTERS

Drip emitters are typically installed directly into the lateral and provide a steady drip of water for the tree. Multiple emitters per tree are recommended to provide adequate water distribution and often multiple laterals are installed for each tree row. Pressure compensating emitters provide a more even flow rate over a range of pressures and are useful in situations where significant elevation change in the lateral cannot be avoided.

Advantages:

- Provides direct application to the soil with minimal evaporation loss
- Application area mostly not effected by cover crop or leaf litter
- Lower flow rate allows for the use of smaller pipelines compared to micro-sprinklers

Disadvantages:

- Small coverage area may require multiple emitters per tree
- More prone to clogging than micro-sprinklers
- Slow application rate inhibits “catching-up” during times of high water demand

MICRO-SPRINKLERS

Micro-sprinklers are typically installed on a steel rod or plastic barb stuck into the ground and connected to the lateral with a small hose. There are several different types of micro sprinkler spray patterns. Consideration should be given to the cover crop height, tree foliage height, and prevailing wind conditions when selecting a micro-sprinkler emitter. Most emitters have a flow rating based on pressure provided by the manufacturer. The sum of the flow rate for each emitter in a lateral can be used to size the pipelines in the system.

Advantages:

- Large coverage area reduces emitters required and supports large root structure
- Less prone to clogging than drip emitters

Disadvantages:

- Potential evaporation loss due to wind or pooling
- Application area may be significantly affected by blocking cover crop or tree foliage
- Higher flow rate requires larger pipelines compared to drip emitters

APPURTENANCES

There are several additional components that are crucial to safe and effective operation of an irrigation system

Pressure Relief Valves: Installed directly after the or at low points that may experience high pressures. These valves are set to open at a set pressure allowing water to escape from the line. This reduces system pressure in order to avoid potential failure of the pipeline due to high pressure.

Air/Vacuum Relief Vent: Installed at the pump, before every valve, and at the end of every manifold line. These vents allow air to enter and exit the system and should be sized according to pipe size. Without vents air is pressurized when the line is filled which may cause excessive pressure leading to pipe failure. In addition, a vacuum can be left when lines drain which may collapse the pipeline.

Flush Valves: Installed at the end of every manifold they can be opened to flush out built up debris in the line. Flushing schedules vary based on the cleanliness of water but one flush per month during irrigation season is generally recommended. Flushing of laterals is also recommended on a regular basis, although a valve at the end of each line is not necessary as the ends can be opened for flushing.

Flow Meter: Installed at the pump to measure flow in the system, Flow meters should have a totalizing readout (ac-ft) and an instantaneous readout (gpm) similar to an odometer and speedometer in a car. The totalizing readout allows for the total water applied in an irrigation to be measured and recorded which is useful for irrigation management. The instantaneous readout allows for the status of the system to be monitored and may help identify under-performing pumps or breaks in the system.

IRRIGATION MANAGEMENT

Irrigation management is based on the concept of matching the water application rate with the soil intake capacity and crop irrigation demand. Trees and fruit may suffer from under irrigation while over irrigation lead to erosion and will result in higher irrigation costs than necessary.

APPLICATION RATE

Water application rate can be estimated by dividing the amount of water provided by the emitters serving a tree by the area of the ground under the tree. The equation with necessary unit conversions is shown below. Note this equation is only an estimate and soil moisture measurements discussed in the next section should be used to fine tune irrigation duration.

$$\frac{96.25 \times \text{Emitter flow rate (gallons per minute)} \times \text{Number of emitters}}{\text{Tree spacing (feet)} \times \text{Row spacing (feet)}} = \text{Irrigation Rate (inches per hour)}$$

Water demand can be determined using several different methods. Soil moisture can be estimated by feel using the guide provided below.

SOIL INTAKE CAPACITY

The allowable application rate of the irrigation system is limited by the intake capacity of the soil. Intake capacity is most significantly affected by the type of soil with sandy soil having a relatively high intake capacity and clay soil having a relatively low intake capacity. As soil becomes moister through the irrigation cycle its intake capacity decreases. In addition, changes to the soil properties or physical structure through processes such as compaction, ripping and salinity may affect the intake capacity. The table below references approximate intake rates for different soil types.

Soil Texture	Intake Capacity (in/hr)
Clay	0.1 – 0.2
Silty Clay Loam	0.1 – 0.4
Clay Loam	0.1 – 0.5
Loam	0.5 – 0.7
Very fine Sandy Loam	0.3 – 1.0
Fine Sandy Loam	0.3 – 1.3
Sandy Loam	0.4 – 1.5
Coarse Sandy Loam	0.5+
Loamy Fine Sand	1.0+

CROP IRRIGATION DEMAND

The irrigation demand for avocado orchards is typically determined by sampling of the soil for moisture content. The moisture retention ability of soil is expressed as the available water holding capacity (AWC). Available water is the difference between the maximum amount of water a well-drained soil can hold against gravity and the permanent wilting point. AWC is most closely associated with soil texture. The minimum amount of moisture necessary before damage to the crop is expressed as the management allowable deficiency (MAD). For most avocados the MAD is 40% of the AWC. Note that high salt concentrations in the will reduce the amount of water available to the plants and increase the MAD.

The table below provides a guide for the most common textural classes. AWC and MAD in inches of water per inch depth of soil are provided in the second and third column. The AWC and MAD for typical 3 foot rooting depth are provided in the fourth and fifth column in total inches of water. The MAD is assumed to be 40% of AWC. Irrigation should be provided to avoid soil moisture dropping below the MAD range.

Soil Texture	AWC (in/in)	MAD (in/in)	AWC (in/3ft.)	MAD (in/3ft.)
Clay	0.12 - 0.15	0.05 - 0.06	4.2 - 5.4	1.7 - 2.2
Silty Clay Loam	0.17 - 0.21	0.07 - 0.08	6.0 - 7.5	2.4 - 3.0
Clay Loam	0.17 - 0.21	0.07 - 0.08	6.0 - 7.5	2.4 - 3.0
Loam	0.14 - 0.18	0.06 - 0.07	5.1 - 6.6	2.0 - 2.6
Very fine Sandy Loam	0.14 - 0.17	0.06 - 0.07	5.1 - 6.0	2.0 - 2.4
Fine Sandy Loam	0.13 - 0.15	0.05 - 0.06	4.8 - 5.4	1.9 - 2.2
Sandy Loam	0.10 - 0.13	0.04 - 0.05	3.6 - 4.8	1.4 - 1.9
Coarse Sandy Loam	0.09 - 0.12	0.04 - 0.05	3.3 - 4.2	1.3 - 1.7
Loamy Fine Sand	0.08 - 0.11	0.03 - 0.04	3.0 - 3.9	1.2 - 1.6

Soil moisture content can be determined through several different methods. Soil moisture can be estimated by feel using the methods outlined in the following section. It is important that the soil samples be taken from several depths to determine the depth of the irrigation. A soil probe can be used to obtain soil samples for moisture testing while minimizing disturbance to the soil.

Tensiometers can also be installed in the orchard to measure soil water content. Tensiometers measure the suction of water in the soil directly. They must be calibrated for specific soil types and require some maintenance but provide soil moisture readings without the need for taking soil samples.

**ESTIMATING SOIL MISTURE BY FEEL AND APPEARANCE
FINE SAND AND LOAMY FINE SAND SOILS**

Available Water Capacity = 0.6 to 1.2 inches per foot

0 to 25 percent available 1.2 to 0.5 inches per foot depleted

Dry, loose, will hold together if not disturbed, loose sand grains on fingers with applied pressure. (Not pictured)

25 to 50 percent available 0.9 to 0.3 inches per foot depleted

Slightly moist, forms a very weak ball with well- defined finger marks, light coating of loose and aggregated sand grains remains on fingers.



50 to 75 percent available 0.6 to 0.2 inches per foot depleted

Moist, forms a weak ball with loose and aggregated sand grains on fingers, darkened color, moderate water staining on fingers, will not ribbon.



75 to 100 percent available 0.3 to 0.0 inches per foot depleted

Wet, forms a weak ball, loose and aggregated sand grains remain on fingers, darkened color, heavy water staining on fingers, will not ribbon.



100 percent available 0.0 inches per foot depleted

Wet, forms a weak ball, moderate to heavy soil/water coating on fingers, wet outline of soft ball remains on hand. (Not pictured)

ESTIMATING SOIL MISTURE BY FEEL AND APPEARANCE SANDY LOAM AND FINE SANDY LOAM SOILS

Available Water Capacity = 1.3 to 1.7 inches per foot

0 to 25 percent available 1.7 to 1.0 inches per foot depleted

Dry, forms a very weak ball, aggregated soil grains break away easily from ball. (Not pictured)

25 to 50 percent available 1.3 to 0.7 inches per foot depleted

Slightly moist, forms a weak ball with defined finger marks, darkened color, no water staining on fingers, grains break away.



50 to 75 percent available 0.9 to 0.3 inches per foot depleted

Moist, forms a ball with defined finger marks, very light soil/water staining on fingers, darkened color, will not slick.



75 to 100 percent available 0.4 to 0.0 inches per foot depleted

Wet, forms a ball with wet outline left on hand, light to medium staining on fingers, makes a weak ribbon between the thumb and forefinger.



100 percent available 0.0 inches per foot depleted

Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking, medium to heavy soil/water coating on fingers. (Not pictured)