Road Maintenance Training Short Course

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Introduction

This workshop is intended to discuss the how and the why of maintaining low volume roads used in the management and utilization of forest lands. The emphasis will be directed toward the single lane, low volume roads but the principles apply to virtually all roads regardless of the number of lanes or the volume of traffic that uses them.

Most forest management activities require some form of road access. These roads are generally a high cost item in any operation and will require maintenance over time for transportation efficiency, to protect the investment and to prevent degradation of water quality.

Graveled and native surfaced roads open to traffic will require grading to maintain a smooth running surface. Brush encroaching on the road will have to be cut back to prevent damage to it and to provide safe sight distances for the users. Culverts, ditches and bridges will require maintenance to insure that they will be able to carry the design traffic loadings and to handle storm runoff. The cost to maintain a road will vary with the location, the grades, the soil types encountered, the road surfacing and the type and the speed of the traffic using it. Some of the benefits derived from maintaining the road will be show up in lower vehicle operating costs, extend operating seasons and enable more efficient transportation of products from the forest. Good maintenance will also reduce costly reconstruction resulting from washouts, road settlement, off site damage attributed to runoff from the road and at the same time protect the water quality in the surrounding watershed.

This workshop will cover the economics of road maintenance, the elements of road design that can reduce long term maintenance costs, the installation and maintenance of culverts and bridges, traffic and non-traffic generated maintenance, recurrent and deferred maintenance, and road closures. It is not intended to alter proven maintenance practices currently in use by the Hawai'i Forest Industries Association, but rather to supplement them or add new techniques where they apply. The overall objective is to assist in developing a stronger road maintenance program that will protect the investments in the road system and at the same time protect the quality water coming from Hawaii's industrial forest lands.

Economics of Road Maintenance

Why do we spend money maintaining roads and is there any pay back for the investment in the equipment and time that it takes to keep a road in a useable condition? Part of the answer to this question can be reduced to dollars and cents but an often larger part can only be addressed in public relations terms such as image or environmental ethic.

The tangible part of the maintenance equation is one where is often difficult to say for certain that a maintenance activity has a direct pay off. For example, a two- man crew that costs a company $100 an hour spends four hours clearing a downed tree away from the inlet of a large culvert that cost $3600. A damage assessment after a flood shows that the maintained culvert performed as designed but similar culvert on an adjoining property down stream failed when a root wad from a tree lodged in the inlet causing the road to wash out. This is an example where there is no proof that flood would have dislodged the tree above the upper culvert but there is reason to believe that the $400 dollars spent maintaining the culvert was a prudent investment.

Example 2: Six log haul trucks using the main haul road on a timber sale were averaging a 3.5 hours per round trip. The road was dusty and washboarded. The trucking company put a motor grader and a water truck on the road and the road was graded twice a week during the haul period. The cost per grading was $380. The result of the grading was that the round trip time was reduced to 2.75 hours. The benefits of this investment were increase production from 12 to 18 loads a day while reducing driver fatigue that resulted from operating on a rough road. The hauling company received $160 a load delivered at the mill so the daily income increase directly attributable to the improved driving conditions was $960 per day at a cost of $152 per day.

Example 3: The maintenance records for a fleet of log haul trucks show that, on average, each truck in the fleet loses one headlight a week due to vibration and a tire a week to sidewall cuts in addition to occasional cracks in the body. The owner decides to grade and compact the haul roads weekly to reduce the maintenance costs on his fleet. The grading will maintain a smooth running surface and compaction will break down the oversized rock that is damaging the tires. The cost of the grading break down the oversized rock that is damaging the tires. The cost of the grading and compaction are more than offset by the savings in maintaining his fleet of log haul trucks.

These last two examples show how the cost of road maintenance can be weighed against the savings in vehicle operating and maintenance costs. The non-monetary benefits to maintaining roads can be equally beneficial to the company or a resource agency but may be difficult to quantify.

There is a saying in the engineering profession that no one gets credit for preventing a landslide. The same can be said for preventing erosion that would contaminating a stream or a private water source. Even in the best of circumstances, slides will occur and water may be muddied but the effects will be minimized if the company or agency has an aggressive road maintenance program and takes immediate action to minimize the damage.

Another area where costs and benefits are difficult to analyze are the costs of litigation. A company that has a proven track record of maintaining its roads in good condition may end up in a law suit arising from offsite damage that can be traced back to say, a failed culvert on their road system. The benefit of being able to show the company has an aggressive and effective road maintenance program may limit the loss to civil damages rather than adding punitive damages to the award.

Road maintenance is a cost that all road owners will have to pay at some time. A good rule of thumb is that the annual maintenance cost for a road will run in the order of 2% to 3% of the construction cost, annually. This effort should keep the road in its approximate as constructed condition for the design life of the road. Without maintenance, the low volume, low speed road with native soil or gravel surfacing will become impassible with time. The only recourse will then be to reconstruct the road at significantly more cost than what would have been spent on maintaining it.

These are but a few examples of the value of maintaining roads. More examples will become apparent as the other topics in this workshop are addressed.

Water

Water is one of the most important compounds on the earth. Without it, humans would survive no longer than eight days. It is not only essential to human survival but for virtually all living things on the earth.

From a highway engineering perspective, water is critical for the construction and maintenance of the road system. An aggregate road surface will not hold together with out enough moisture in the soil and gravels that make up the road structure,. Back slopes and fill slopes will unravel if there is not enough moisture to hold the soil particles together and vegetation needed to stabilize the slopes will not survive.

Too much water is also a problem for both the construction and maintenance personnel. Excessive rains will cause flooding in the rivers and streams. The flooding will dislodge trees and debris that can plug drainage culverts and bridges and lead to their failure or the wash out of the road served by them. Sediments carried in the runoff water from roads can contaminate drinking water sources putting the population at risk to water borne diseases. It is therefore important to understand how water works for us and the actions that are required in the maintenance operations to prevent excessive damage from the inevitable flooding that will occur.

Water trapped between two flat surfaces will hold the surfaces together. If you take two plates of glass and put water between them, it will be almost impossible to pull them apart with out breaking the glass. The force holding them together is called cohesion. The glass will slide apart and if the water between the plates is allowed to dry, the plates will also come apart. It is also possible to get the two plates of glass apart if they are submerged in water. The same principals apply to soil particles. If the soil is moist the soil particles tend to cling together. If the soil is allowed to dry, the soil particles have little bonding them together and they can be easily detached. You have seen this when driving on a dry unpaved road. The dust is actually small soil particles that became detached from the other soil particles due to lack of moisture in the road surface.

Soil particles that become saturated will lose their bond. This is evident in sands. Damp sand can be molded but will fall apart when it becomes saturated. The same molded sand will fall apart if it is allowed to dry out. Anyone who has built a sand castle has experienced this. The sand will regain its strength when the moisture level is allowed to reach the point where it can be remolded. This is an example of the importance of water in road construction and maintenance.

It should be noted here that soil has three components, rock particles, water and air. The water may cling to the rock fragments or it may fill in the voids in between them. Air will be present in the soil unless all of the voids are filled with water. The soil is considered saturated when all of the air voids are filled with water. The point of maximum strength for any soil will, like the sand example, depend on its moisture content.

Another characteristic of water is that it can not be compressed. If water is in a confined space such as a pipe and a shock load is applied to it, the pipe may split. Water confined between soil particles will react the same way when a shock load is applied to a road surface that is saturated. A vehicle driving over the road will provide the shock load and soil particles will be displaces by the water between them. This is one of the ways that ruts form in a road. The same action takes place when a vehicle drives through a puddle. Water is forced into the surrounding soil by the shock loading. This will dislodge smaller soil particles thus weakening the soil structure in the soil surround the puddle and it will increase in size. The color in the muddy water in the puddle is actually small soil particles that have been dislodged by the action of the water.

Water is also capable of eroding soil and rock. The ability of water to erode soil is directly related to the speed of the water. Likewise, the speed of water is is directly related to the slope that it is running over. If the grade of a roadside ditch increases from 2% to 8% the speed of the water will double. The particle size that the water can now carry will increase by a factor of four. Controlling the speed and volume of water running down a road then becomes both a design and a maintenance problem.

Water is an essential consideration in the design, construction, operation and maintenance of a road. Too much or too little of it will alter the strength of the soil that supports the road. Too much may exceed the capacity of the culverts or ditches leading to unacceptable erosion. Too little may dry out the road surface making it impractical to maintain. Therefore, controlling soil moisture and runoff water will be one of the key elements in the design process.

Soils Engineering

Soils are composed of fine or course rock fragments or a mixture of fragment sizes plus air and water. The fragments are the result of the disintegration of larger rocks by erosion and the effects of acids formed from decaying vegetative matter and naturally occurring acidic gasses. The soils in Hawaii are particularly fragile and are easily eroded. Any soil disturbing activities such road construction must therefore be done in a manner that will minimize erosion.

Soil particles will vary in size and shape. The size will vary from boulders, (rocks larger than 3inches) to fine clays whose particle sizes are so small that it will float for long periods of time in water. Boulders, gravels, sands and silts are all derived from the breaking down of larger rocks. Although silts are often confused with clays, the soil particles are still angular and as opposed to platy and they will have a gritty feel when rubbed between the fingers. If there is still doubt, a small amount of the soil can be lightly ground between the front teeth. If it feels gritty, it is silt.

Clays are formed from weathered rock. The particles are flat. If one takes a small sample and grinds it between your fingers or front teeth, it will feel smooth or slick. This distinction between silt and clay is important because of the way the soils react during construction, maintenance or operation of the road.

Organic soils can be identified by the smell. A small amount of an organic soil held to the nose will smell sour. The soil is also identifiable because of its dark color and often times, the presence of decomposing vegetable material. These soils should be avoided in construction and should not be used for maintenance materials unless there is a need for organic soil to revegetate a slope.

The difference between silt and clay is the shape of the soil grains. Granular material, how ever small will hold a great amount of moisture. The surface of each particle will hold moisture as well as the voids between the particles. If materials have an excess of moisture in them they will move when a load such as a passing vehicle runs over them. This is because the moisture can not be compressed and the pressure created by the passing vehicle forces the particles to move outwardly.

When this occurs, the road surface may show signs of distress such as cracking or rutting.

Clays have a platy shape. Because of their small size, they will hold great amounts of moisture also. The moisture allows the particles to slide over each other when a load is applied to it. Clay surfaces rut easily when wet as the soil slides out from under the load. The displacement will lead to rutting that will get worse as long as the surface is wet. Clay soils also become slick during wet weather causing vehicles to lose traction and become difficult to steer. Roads constructed in clay soils should either be capped with aggregate or closed to use during wet weather.

Another characteristic of soils is their ability to carry an applied load. Silts and clays can carry large loads without deforming when they have little moisture in them and they have been compacted. As the moisture continues to increase their load carrying capacity decreases to the point that, when they become saturated they will fail.

The load carrying capacity of gravels will vary with their shape as well as how the mix of gravels is made up. Clean, rounded, 1 in. - 3/4 in. gravel will not support a load. Gravels like this are used on truck runaway ramps because the vehicle can only plow through it. If the same gravel is combined with angular gravels, sands, silts and clays in the right proportion, along with some moisture and then compacted, it will withstand a large load without deforming. The compacted mix will be tight enough that rain water will run off of it rather than soak through into the subgrade.

Few roads are located in soils that have sufficient strength, when wet, to support the loads applied when vehicles travel over them. The best practice for constructing a road is to first removing the vegetation, second, compact the sub grade soils that make up the cuts and fills and then cap the running surface with a well mixed and compacted gravel. The capping protects the subgrade from moisture and has greater strength than the soils in the subgrade.

Roads are constructed by cutting soil from one place and filling in another place with it. The result of this construction method is that there will be cut slopes and fill slopes that may fail when saturated or in rare occasions when they become too dry. The cut slope failure occurs when the slope slides down into the ditch or the roadway. These failures can be predicted using engineering analysis of the soils. A second method is to check out the steepness of road cuts in vicinity of the planned road construction. Some road cuts have stood nearly vertically for years with little if any sloughing. These will generally be soils with a high clay or silt content. The slopes on newer construction have been laid back and although stable, they have failed to re-vegetate have continued to erode over time.

All roads are constructed on soils in some manner, even a causeway constructed on piling driven into the sea floor. A good understanding of the basics of the soils that a road is constructed will make the selection of maintenance materials and methods more effective.

Road Location

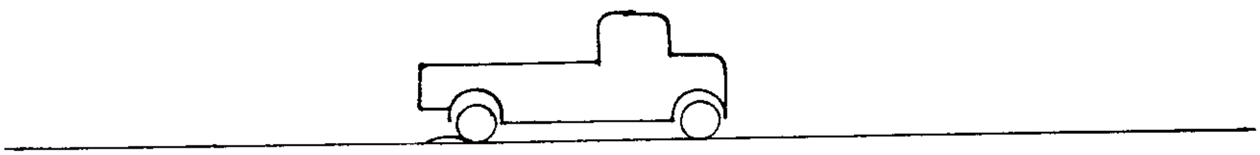
The location selected for a road will determine to a large degree the whether or not the road can be constructed and maintained with a minimum impact on the land. A road good road locator will learn as much about the land he is going locate a road on before ever starting out to actually flag the location on the ground. There are numerous aides available including aerial photographs, topographic maps, soils maps, and rainfall intensity maps to aid in becoming better acquainted the locator with the land. Local people who may have local knowledge of the area that the road is to access are another valuable source of information.

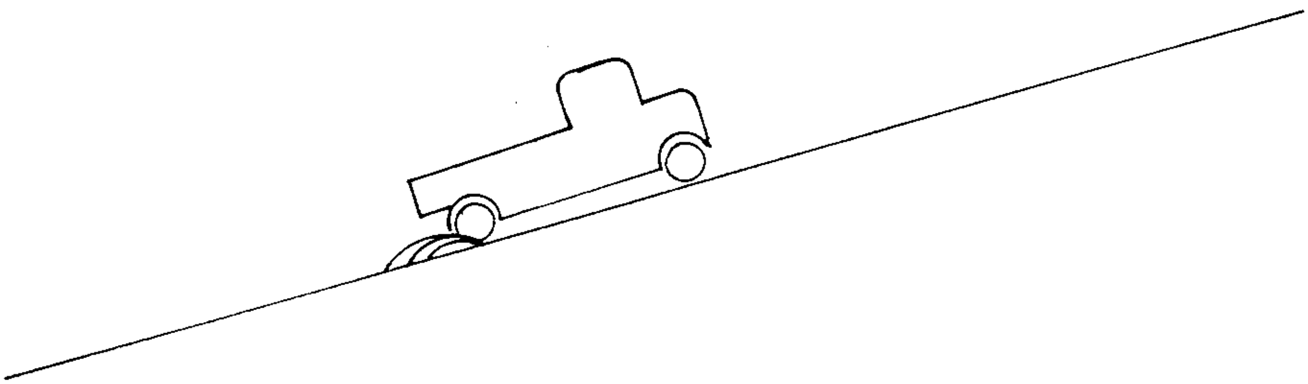
After reviewing the available information on the project area the locator can then begin the process of making a paper location of the proposed road. The first step is to establish the purpose for the road, the termini, and any control points that the road goes through. Any known risk areas such as over steepened slopes, critical wildlife habitat or flood plains should also be delineated on the location map. With the controls now established trial grades can be laid out on paper considering the topography, the natural drainages and the soil types.

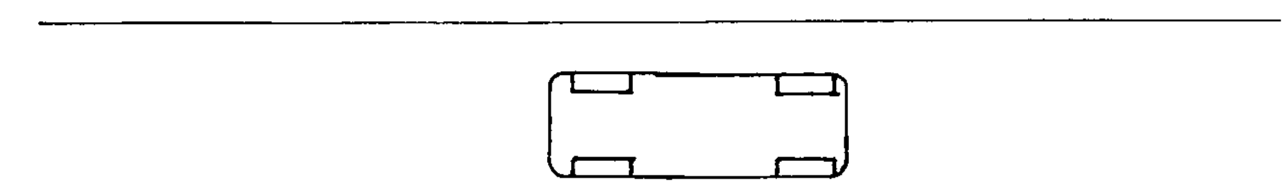
In the ideal world, grades would not exceed 6% and all curves would have radii greater than 500-feet. In the real world of resource development roads, sustained grades may exceed 12% with steeper pitches and the minimum radius for curves may be 50-feet. Steep grades create the potential for serious erosion if there is a drainage failure. Likewise flat grades should be avoided if possible because of the difficulty of draining roads on flat grades. How the locator matches grade with alignment will in large part determine cost of constructing and maintaining the road.

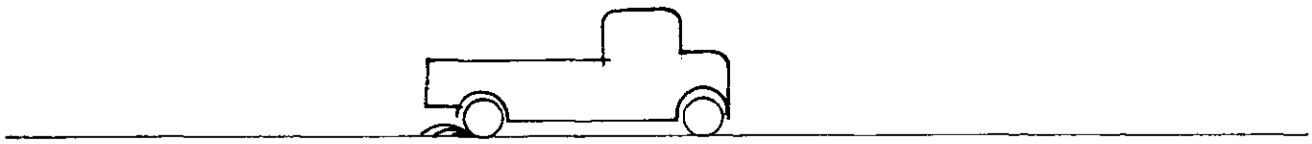
As a general rule, a road that will have numerous horizontal curves should have slack grades while roads that will be essentially straight can have steeper grades. The grades through small radius curves should not exceed 4%. The drive wheels on vehicles that are climbing a grade will tend to slip with the slippage increasing with the increase in grade. This slippage will contribute to surface roughness. If the grade remains steep through a curve the drive wheel slippage will increase because the vehicle has to overcome both the effects of grade and turning. The result will be excessive washboarding on the inside of the curve. See 10 a and 10b

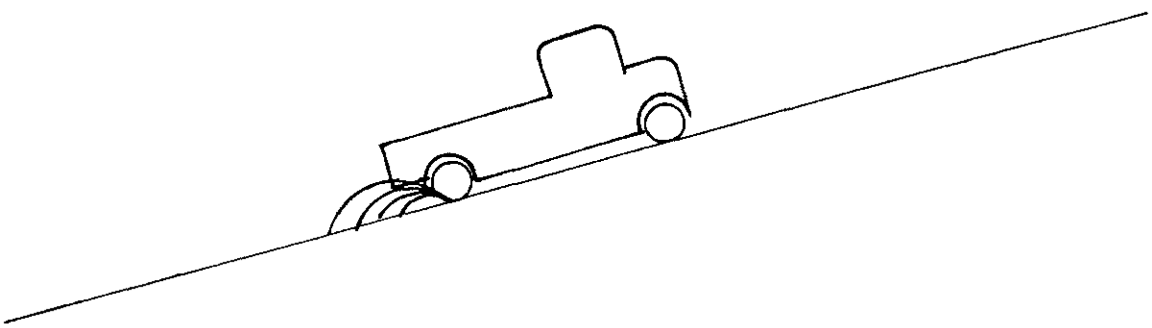
EFFECTS OF GRADE CREED ENGINEERING RFC 4-3-00

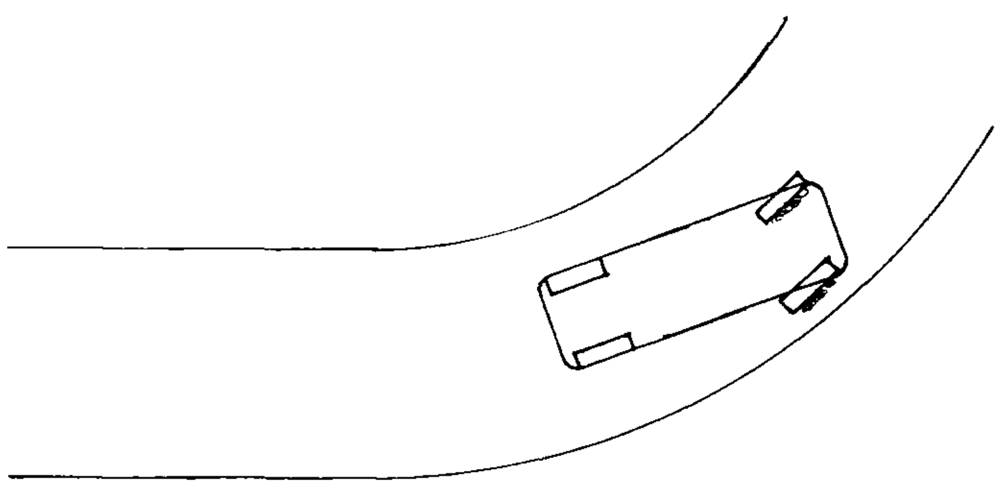












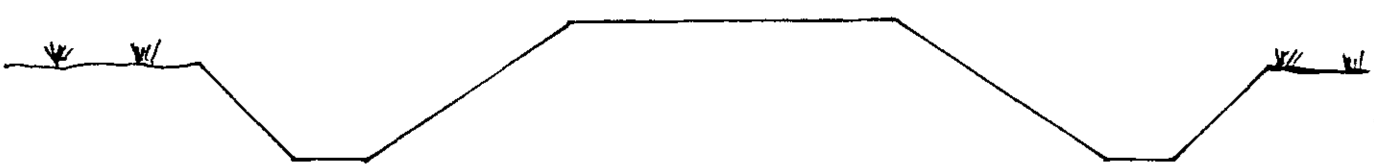
Long sustained grades should be avoided if it is possible. Any drainage failure on long grades will generally result in serious damage to the road. Rolling grades will confine the damage of a failed culvert to a smaller area. Grades should sag through stream crossings or other drainage ways. Again any failure or overtopping will be confined to the crossing rather than using the road grade as a ditch.

Roads should never be located in the bottom of draws or canyons. Roads in these locations will be washed out by most storms causing additional sedimentation and costly road repairs. The best locations for resource development roads is on side slopes where they an freely drain and large cuts and fills can be avoided. See 11a, 11b, and 11c.

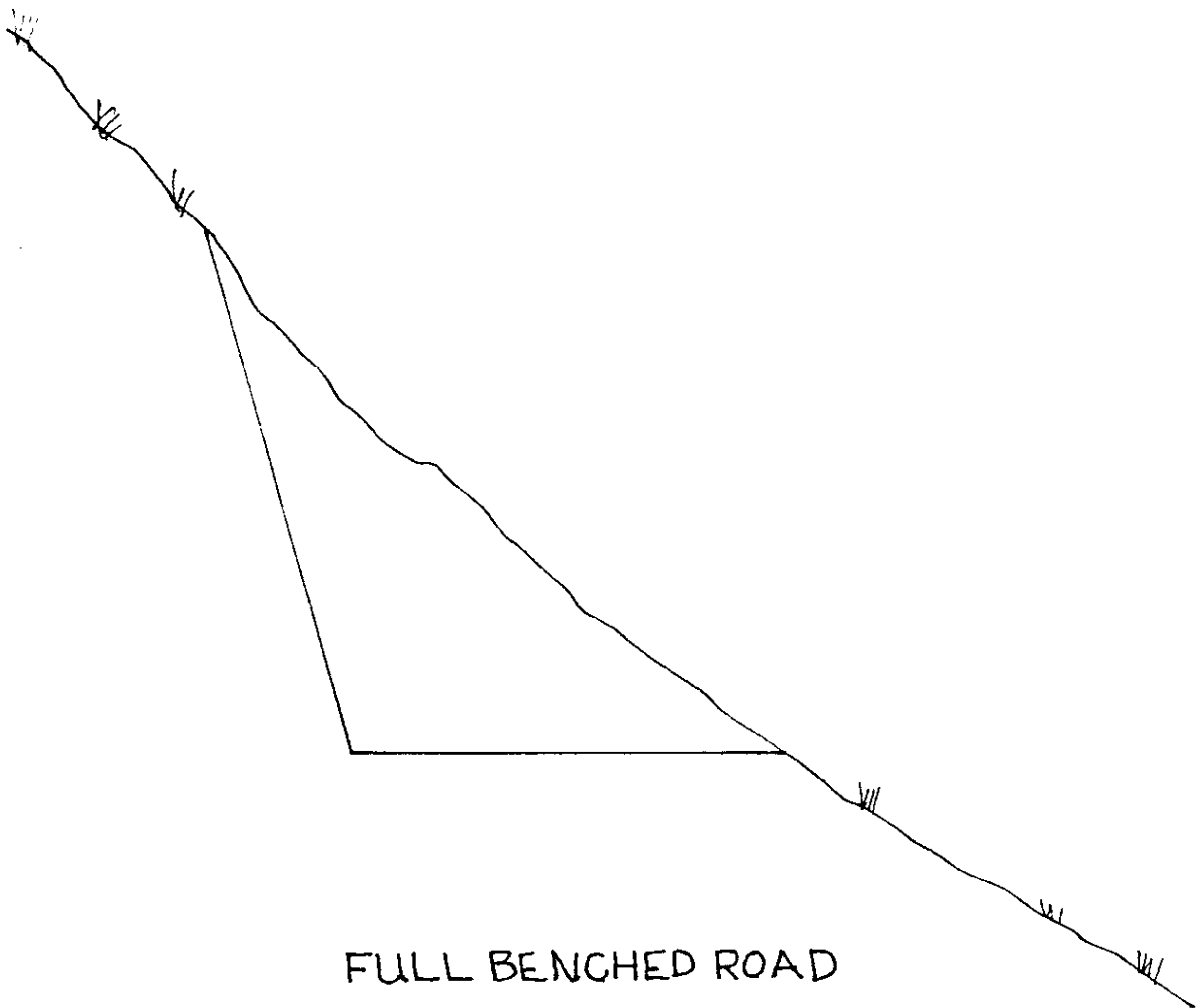
By placing extra emphasis on the location, the resulting road should meets the planned need for the road and minimize the potential for serious damage from storm runoff. The road will also be one that can be economically maintained.

ENTRENCHED ROAD

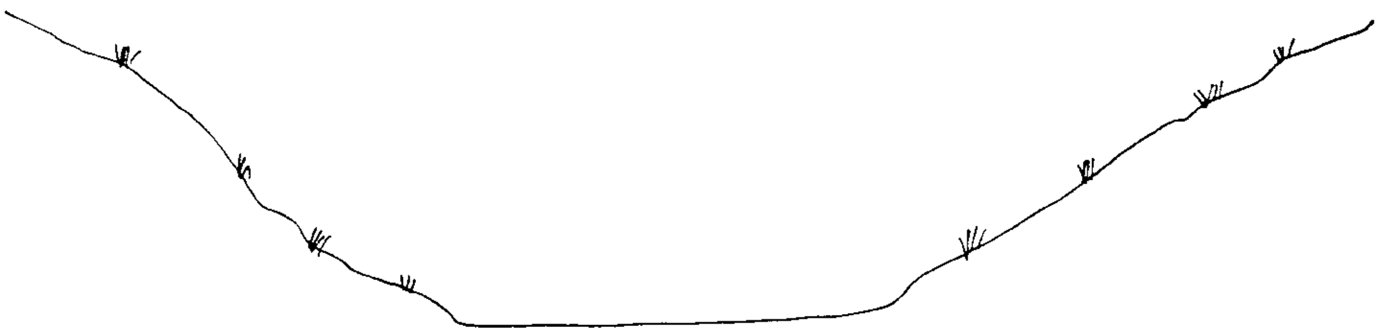
(RELOCATE)



TURNPIKED ROAD

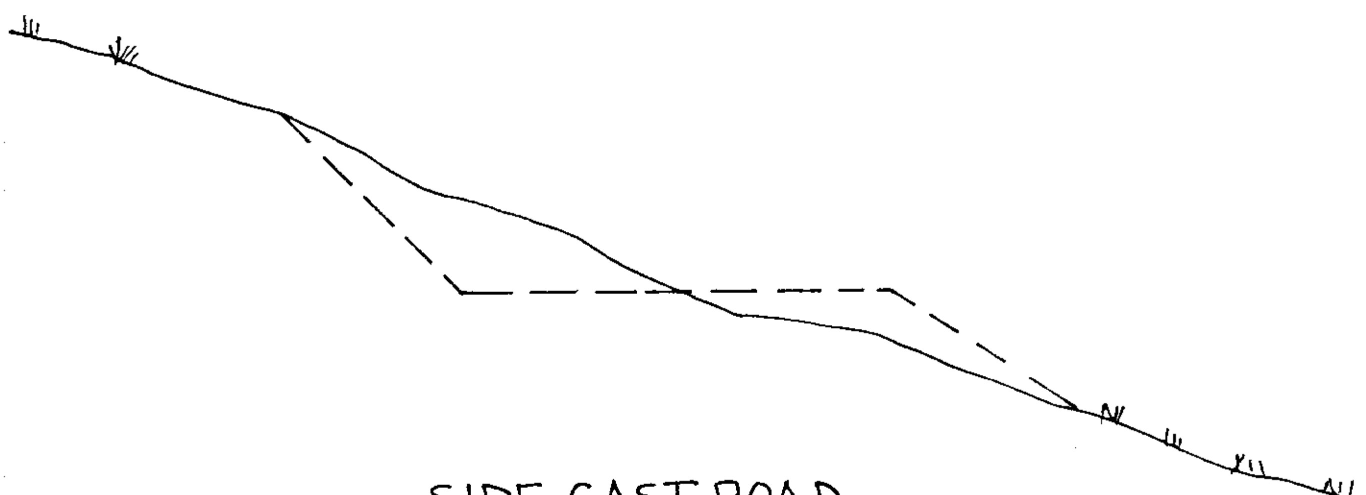


FULL BENCHED ROAD



STREAM CHANNEL ROAD

(RELOCATE IF POSSIBLE)



SIDE CAST ROAD

Road Design

The objective for the design of low volume, low speed resource management roads is land access. The designer of low volume, low speed roads is not bound by the same guides controlling the design of roads where transportation efficiency is the primary objective. The land access road may be designed for year round, seasonal, or intermittent use. The design criteria may be based on a certain class of vehicle being able to cover fifteen miles of road in an hour. The grade on a segment of the road may be so steep that an assist vehicle such as a motor grader must be attached to a loaded truck to climb the hill legally. Low water fords may be used rather than a bridge to cross a live stream. Crushed rock may be required for both the running surface and the ditch line on short segments of the road while other sections may merely be outsloped to handle runoff. The over riding criteria is that the road must be safe to drive within established guidelines, it must be capable of being constructed, it must be maintainable at all times and it must not cause erosion and/or sedimentation of the adjoining lands or waterways. The two extremes that the designer must stay between then are great expense on one side and insuring the utility of the finished road on the other while meeting the objectives set out for the road.

The usual first step in designing is the establishment of the grades based on the reduced survey data. Grade lines should stay within the climbing limitation of the vehicles that will be using the road and should provide enough grade changes to aid in controlling runoff. The grades should sag through natural drainage ways, when rounding points of ridges and at all other places where there will be short radius curves. The next step is to fit the grade line to the cross section data and test the design template to the grade and cross section. The template must fit the cross section, that is the back slope and the fill slope must catch within each cross section. It may be necessary, during this process, to adjust the grade line up or down to accommodate the template. The design to this point should insure that all of the grades fall within the limitations established for the road, that the road will have drainage on at least one side at all times and that no section of the road will be constructed with zero grade.

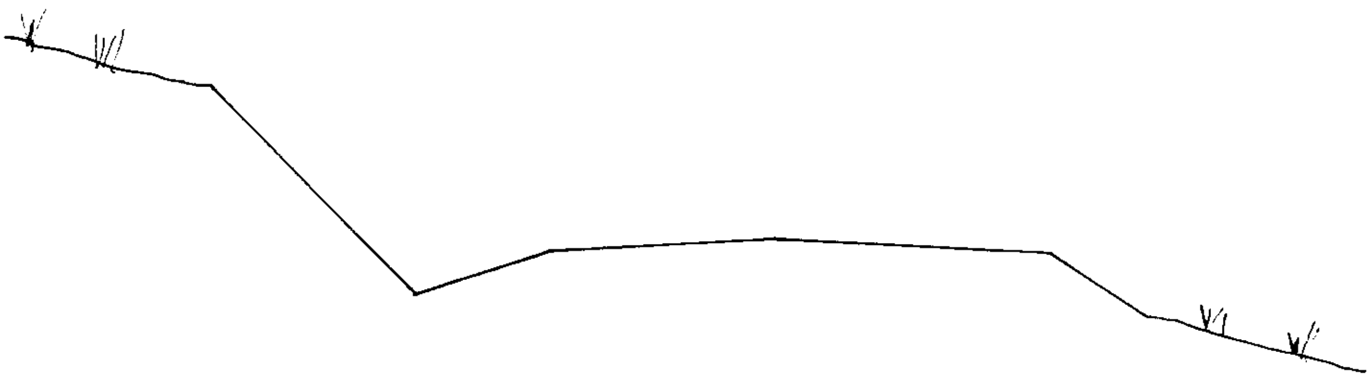
The horizontal alignment may be the irregular curves that the locator established or the designer may elect to lay out circular curves for the road. In either case, once the horizontal and vertical alignment is established the designer can begin laying out the drainage for the road. The first step will be to determine the amount of runoff that can be expected for the length, the steepness and vegetative cover for the slopes and drainages that the road will cross. This information can usually be found in highway department design offices or by using existing hydrology computer models by inputting local precipitation and runoff data. It is recommended that the runoff analysis be done in two phases. The first should determine the runoff that can be expected for the drainages with live streams or dry draws and the second should determine the runoff per foot of slope at right angles to and above the centerline of the road. The last step will be used to determine the spacing of the cross drains that will be used in the road.

The road template or the cross section of the road will have to be decided upon at this time because the runoff from the road can effect the spacing of the culverts. The three templates available are to inslope, to outslope and the third is to crown the road. See 13 a and 13 b. An insloped road accumulates all of the runoff from the road and the uphill slope either along the inside road shoulder or ditch. This system is effective when roads are constructed in erosive soils and have a graveled surface. The runoff from the road does not flow over the road fill and is effective in preventing the erosion of the fill material. Cross drains have to be provided at planned intervals to take the runoff to the downhill side of the road. The outsloped road is suited to areas where the parent soil is essentially non-erosive. The road may have a ditch on the uphill side or all of the runoff from the uphill slope and the road may drain across the road. This is an economical design in those locations where slopes are stable and can withstand the effects of the runoff. To be effective, the cross slope of the road must be at least 2% greater than the grade of the road to insure drainage.

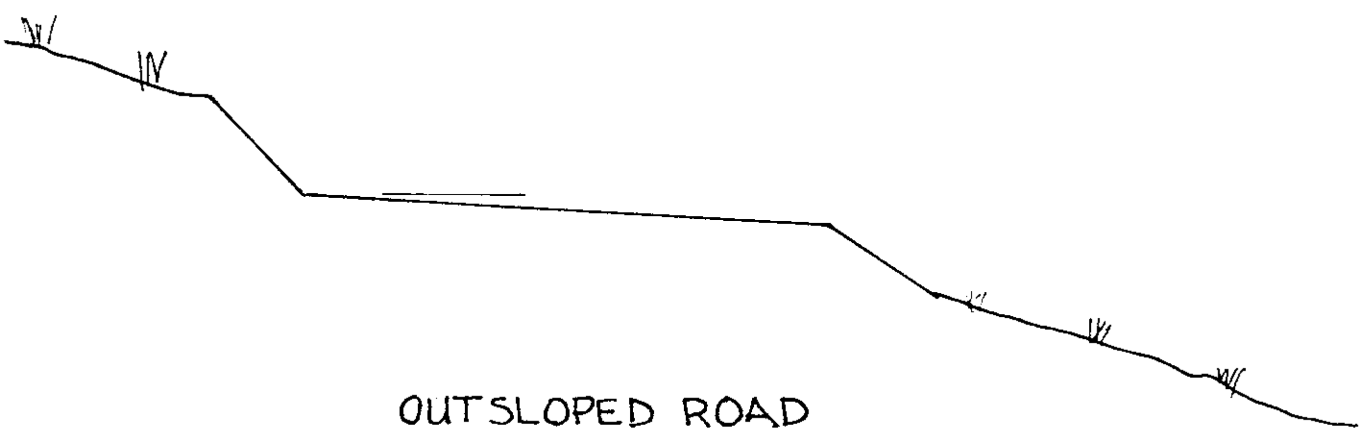
The crowned road is sloped from the centerline to both shoulders. Runoff from the centerline to the fill slope shoulder will flow down the fill slope and the runoff from the centerline to the cut slope plus any runoff from the uphill slope will flow into the ditch. The road will have cross drains to take the runoff from the ditch under the road.

All three of these road templates can be effective in the appropriate soil but will only be effective if they are maintained as constructed. Both the inslope and outslope have a safety aspect that can influence the design decision. Vehicles can slide into

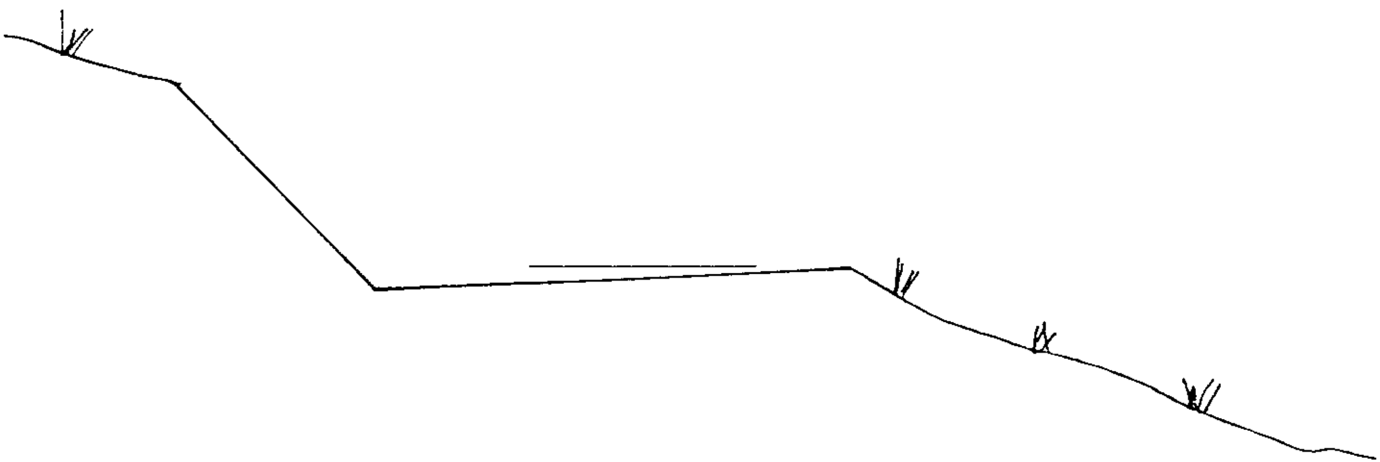
ROAD TEMPLATES CREED ENGINEERING RFC 4-3-00



CROWNED ROADS



OUTSLOPED ROAD



INSLOPED ROAD

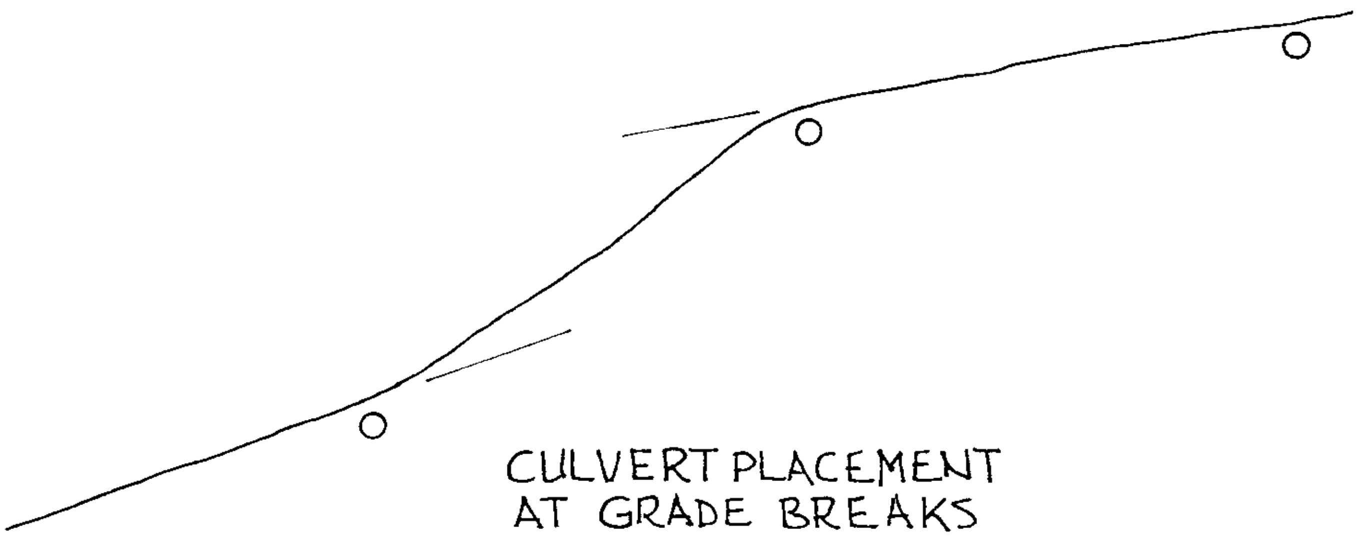
the shoulder or over the side if the road surface has much clay content in it. The crowned road conversely has the advantage that the driver can straddle the crown with reasonable assurances that the vehicle will stay on the road.

The location or spacing for most of the cross drains or ditch relief culverts will be dictated by the anticipated runoff from the uphill slopes based on the gradient, vegetative cover and the length of the slope and the road grade. The steeper the road grade the more frequent the need for culverts to minimize erosion in the ditch line. Additional culverts will be needed at grade breaks. Water flowing at a given velocity will have the capacity to carry a given amount of sediment. If the velocity of the water is increase the sediment carrying capacity will increase and likewise if the water velocity decreases some of the sediment in suspension will drop out. In the latter case the sediment coming out of suspension will accumulate and eventually plug the ditch below the grade brake and in all probability damage the road. See 14 a

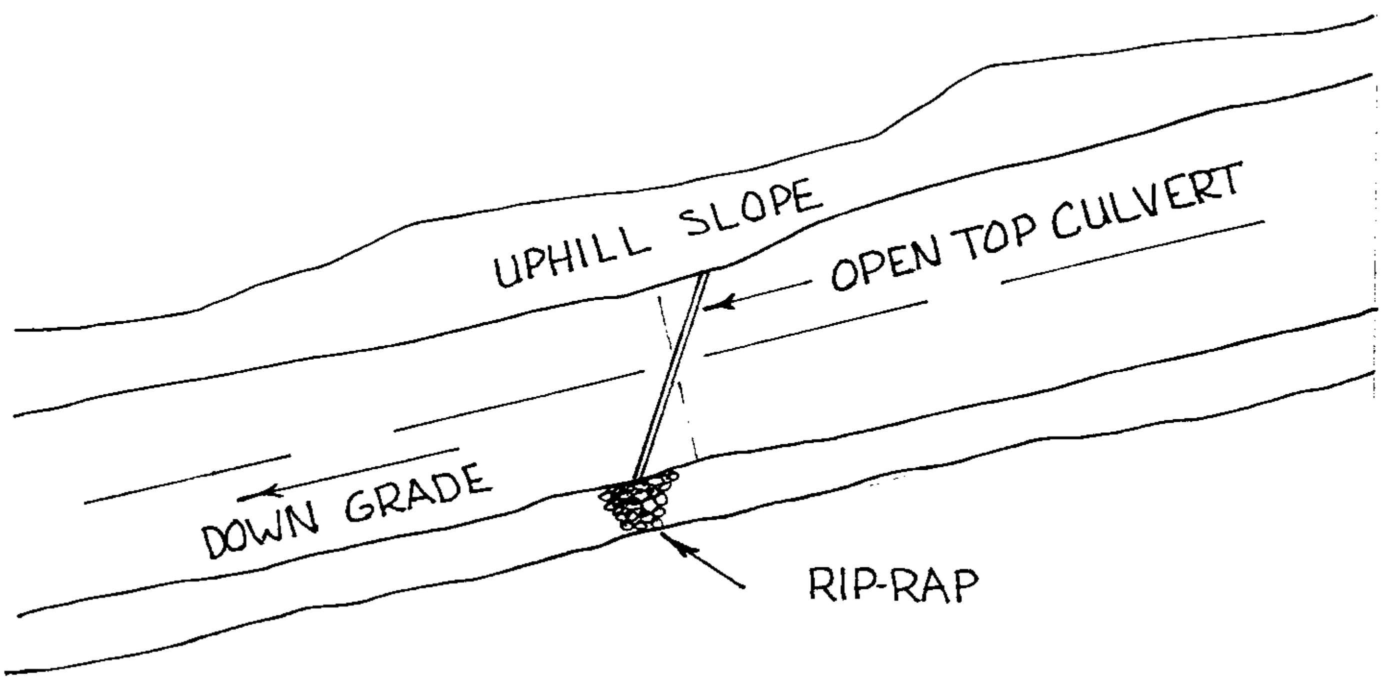
Another effective drainage structure is the open top culvert. See 14a and 14 b. The open top is as the name implies an open culvert that is placed diagonally across the road and at the same grade as the top of the road. They can be made of corrugated steel but most of them that are in use on resource development roads are made of wood. The sides and bottom are made of full pressure treated 2x6 lumber. The sides are nailed through the bottom of the base. Top spacers are made from pieces of ¾" galvanized pipe and are held in place with a 6" x3/4" bolt.

The open top serves two purposes. It drains the surface runoff water from the road and acts as a water bar stopping gullies that form in wheel ruts from moving progressively down the road. The bars are easy to install, economical to maintain and are effective in preventing road surface damage on roads that do not receive much traffic.

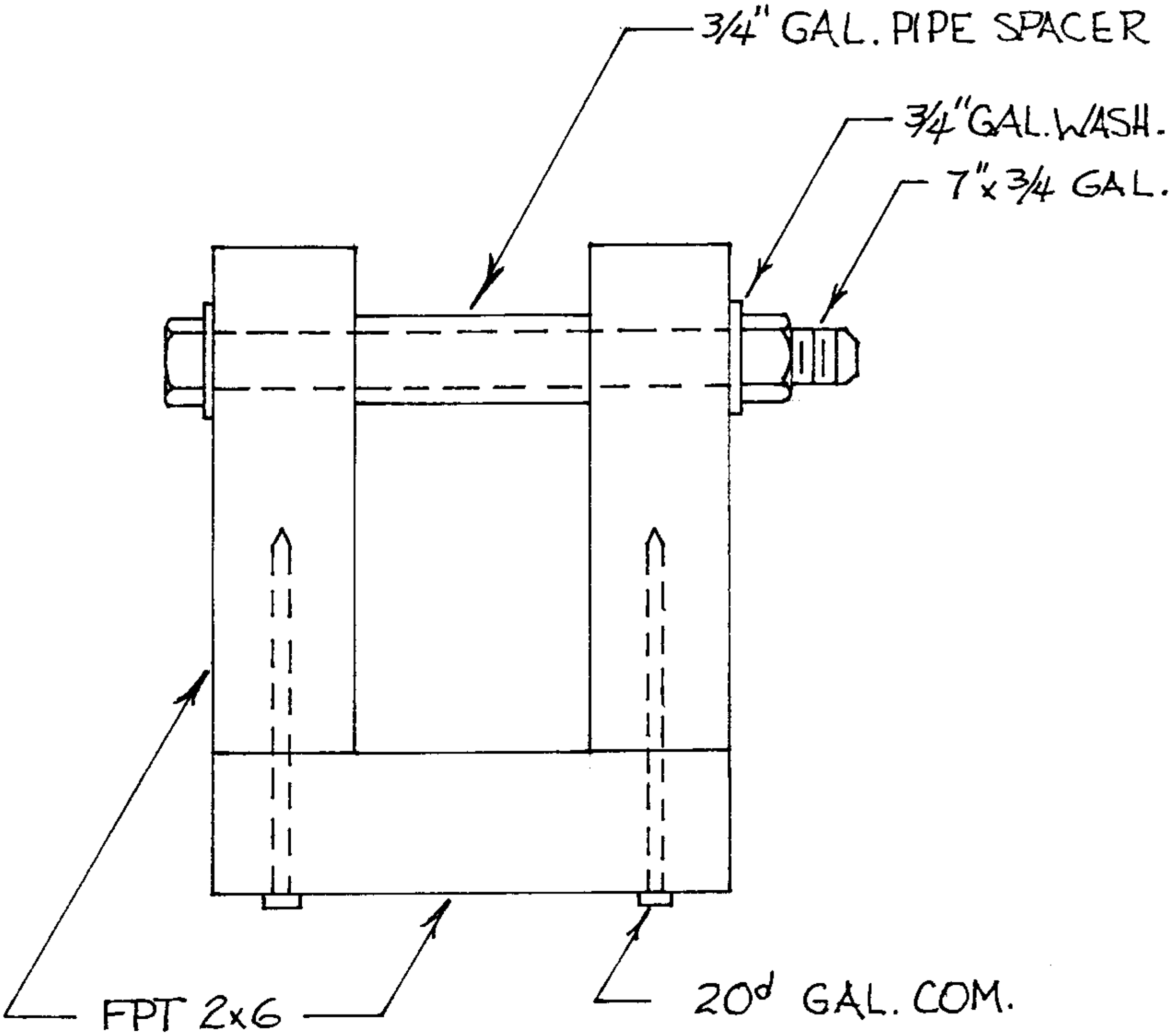
Another form of open top is the water bar or driveable dip. The intent the water bar is to drain the surface water from the road and to stop gullies from forming in the wheel tracks. The grade into the water bar will be approximately .5% greater than the road grade. The cut will vary in length but should not exceed 100 feet. The reverse slope will be approximately 15 feet long and match the original road grade at the down slope end. The "V" formed in the bottom should be diagonal to the road with the outside end ahead. The bottom of the water bar should be lined with course gravels to prevent down cutting by the runoff. The water bar should only be used on

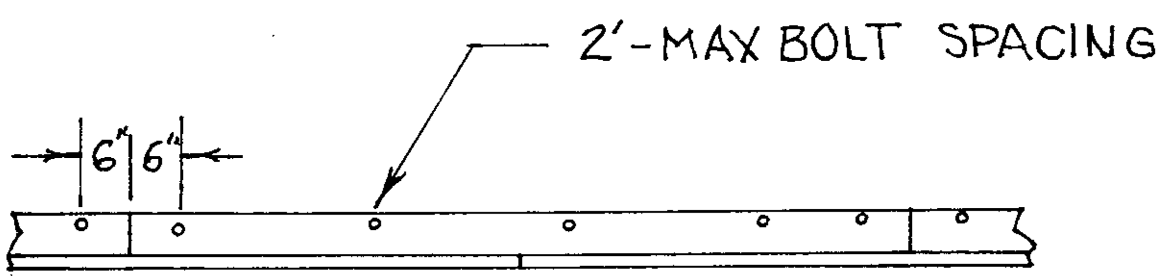


CULVERT PLACEMENT AT GRADE BREAKS



OPEN TOP CULVERT INSTALLATION





SPLICE DETAIL

roads with grades less than 10% and then only when there will only be limited traffic on the road. They are effective in those cases where a road is to be closed for an extended period of time and the intent is to defer all maintenance until the next entry. See 15 a.

The outfalls of all drainage structures will require some form of energy dissipator. This can take the form of riprap, sacked soil cement, a gabion basket or a log crib. The dissipator is necessary to prevent scouring of the ground under the outfall. It may also be necessary to riprap the entrance of the culverts to prevent sour of the approach fills during high runoff evens.

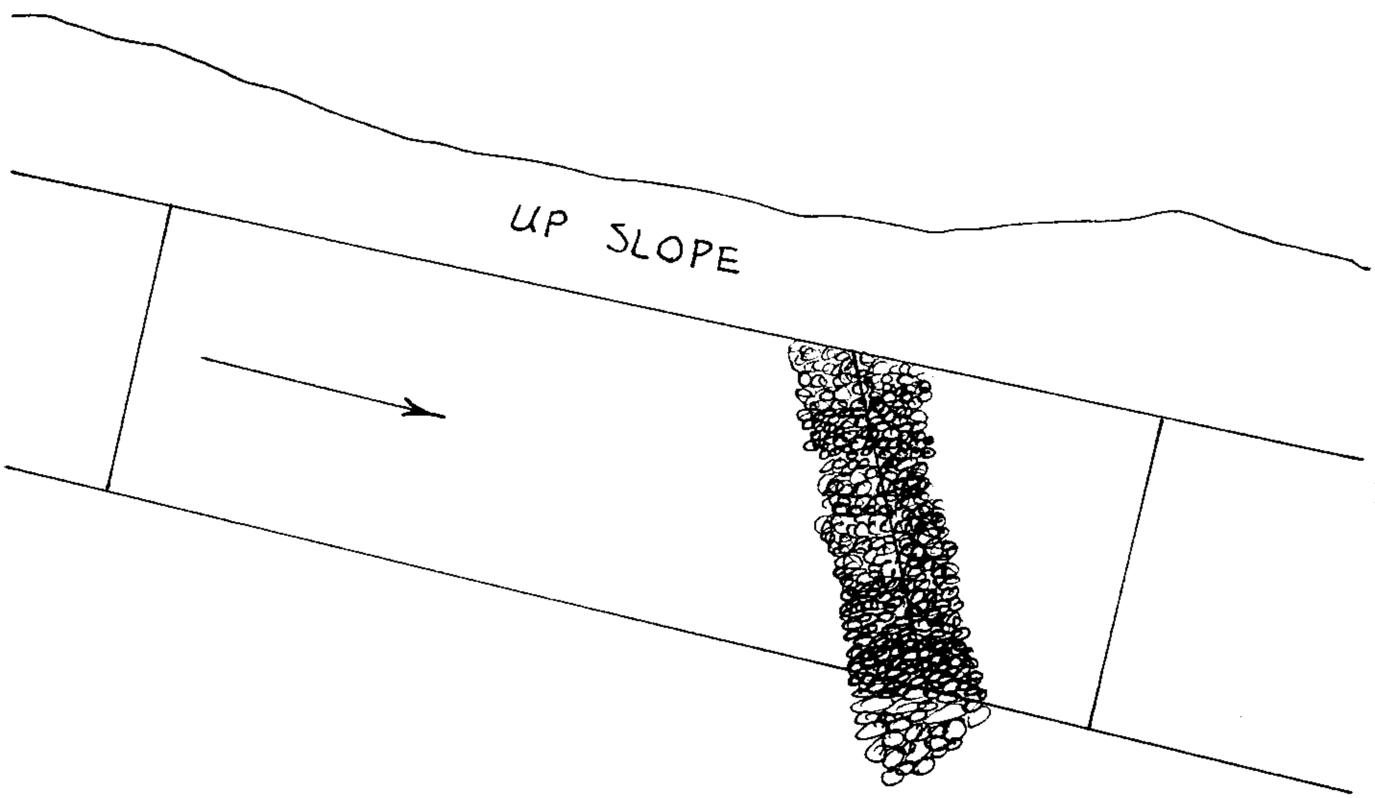
Live stream and dry draws require additional design considerations for drainage structures. Cost becomes a major consideration when designing drainage structures on low volume, low speed resource development roads. The hydrologic analysis will be the source of data to determine the runoff that can be expected at the crossing but cost and planned use will often dictate the final design. There are a number of design options for crossing streams and dry washes. The can be crossed using a culvert, multiple culverts, a bridge or a low water ford.

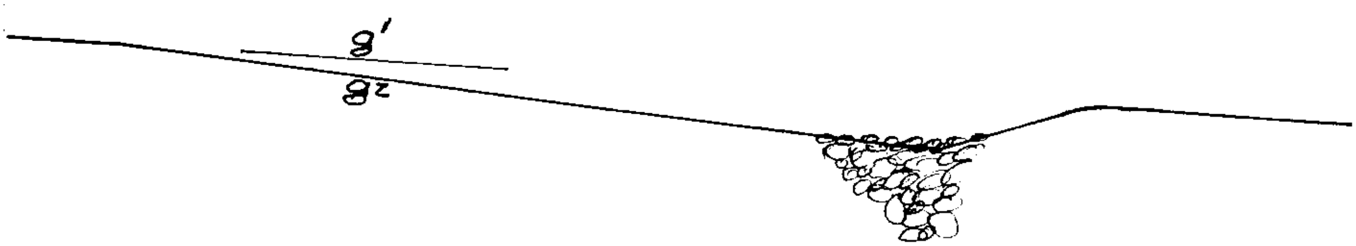
The ford has application in those situations where an interruption of use a road is acceptable. Most fords are designed so that there is sufficient capacity in a culvert or several culverts to handle the normal low flow in the stream. The crossing is designed to withstand the effects of a large flood without loss of the basic structure. The ford is a low cost crossing alternative because it provides the needed access without having to build a structure that can handle large floods. See 15b.

Some stream crossings are in broad valleys that flood periodically. The stream channels are relatively small and flooding will often spread across the most of the valley. The stream may be crossed with a bridge or a large culvert. The approach fill to the structure will cross the width of the valley. The fill will become an effective dam and the road a spillway when the stream overflows unless relief culverts are installed in the approach fill. The best alternative is to attempt to avoid crossings like this in part due to the high cost and potential disruption of the groundwater flow due to consolidation of the soil under the road fill.

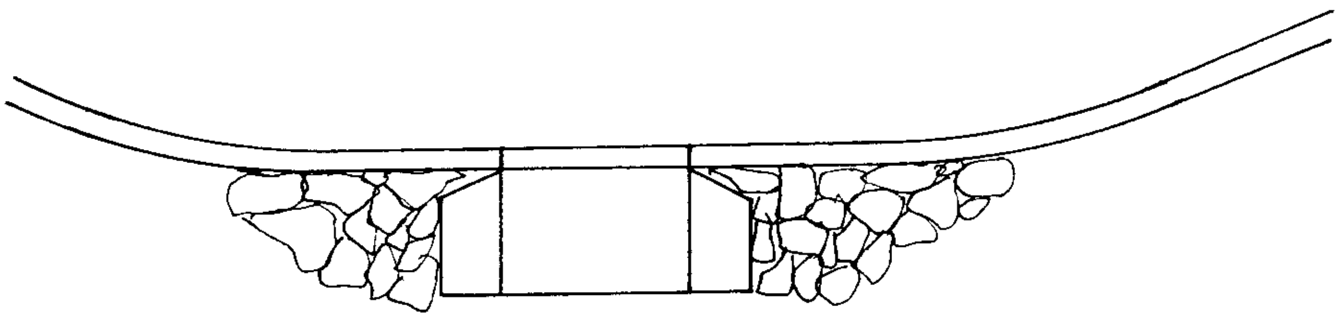
Stream crossings in confined channels can be made with either a large culvert or a bridge. The choice will inevitably be decided on cost. The critical aspect of installing

DRIVEABLE DIP CREEDENGINEERING RFC 4-3-00 15/

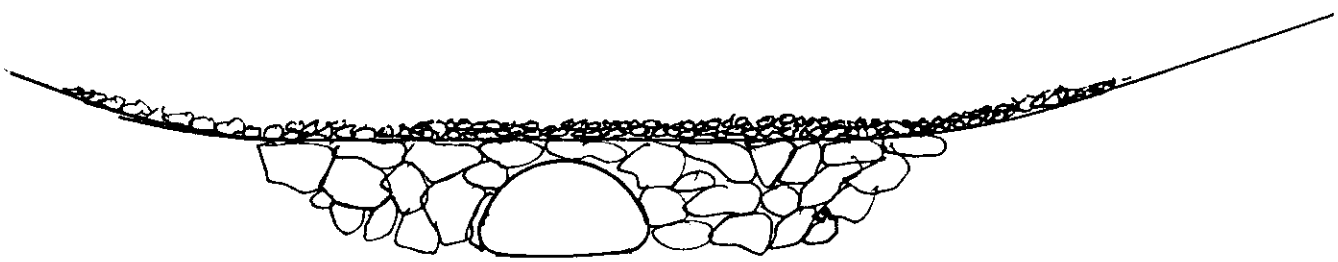




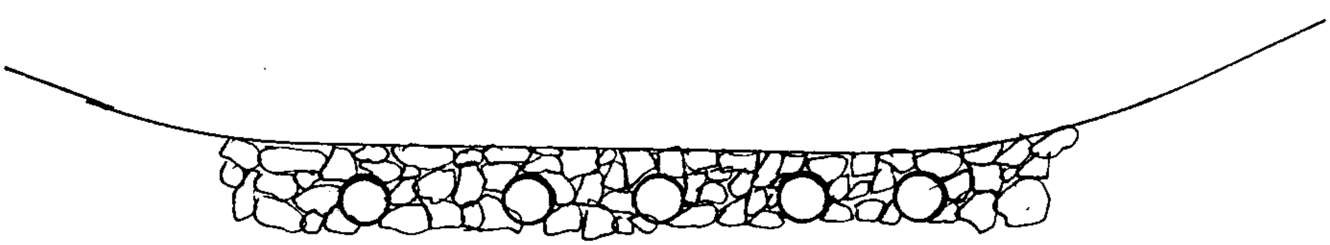
g^1 = APPROACH GRADE
$g^2 = g^1 + 0.5\%$



CONCRETE PAVED BOX CULVERT
LOW WATER CROSSING



RIP RAPED PIPE ARCH
LOW WATER CROSSING

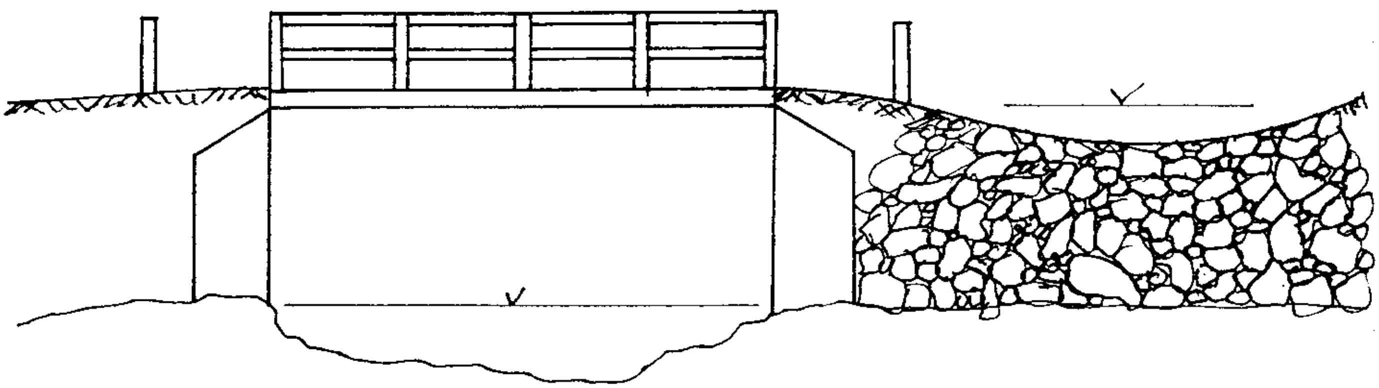


MULTIPLE CULVERT
LOW WATER CROSSING

a costly bridge or culvert is to insure that the road grade sags through the crossing. It is also desirable to have an armored section of the road on one side of the structure that can act as a spill if the runoff exceeds the capacity of the culvert in a large storm. See 16a.

An alternative to providing a spillway on the road is to armor the culvert in. This can be accomplished by placing riprap or other fill reinforcement around and over the culvert during construction. In the event of a major storm that exceeded the capacity of the culvert, the flood could overtop the road in the armored section without damaging the culvert. This creates an added construction cost but will go a long way toward protecting the investment.

Road design is a lengthy process requiring a combination of technical skills and a feel for the land. This combination will produce a road that will meet the planned transportation need with a minimum ground disturbance. The end product will be one that can be economically maintained and protect the adjoining resources.



Maintaining Unsurfaced Roads

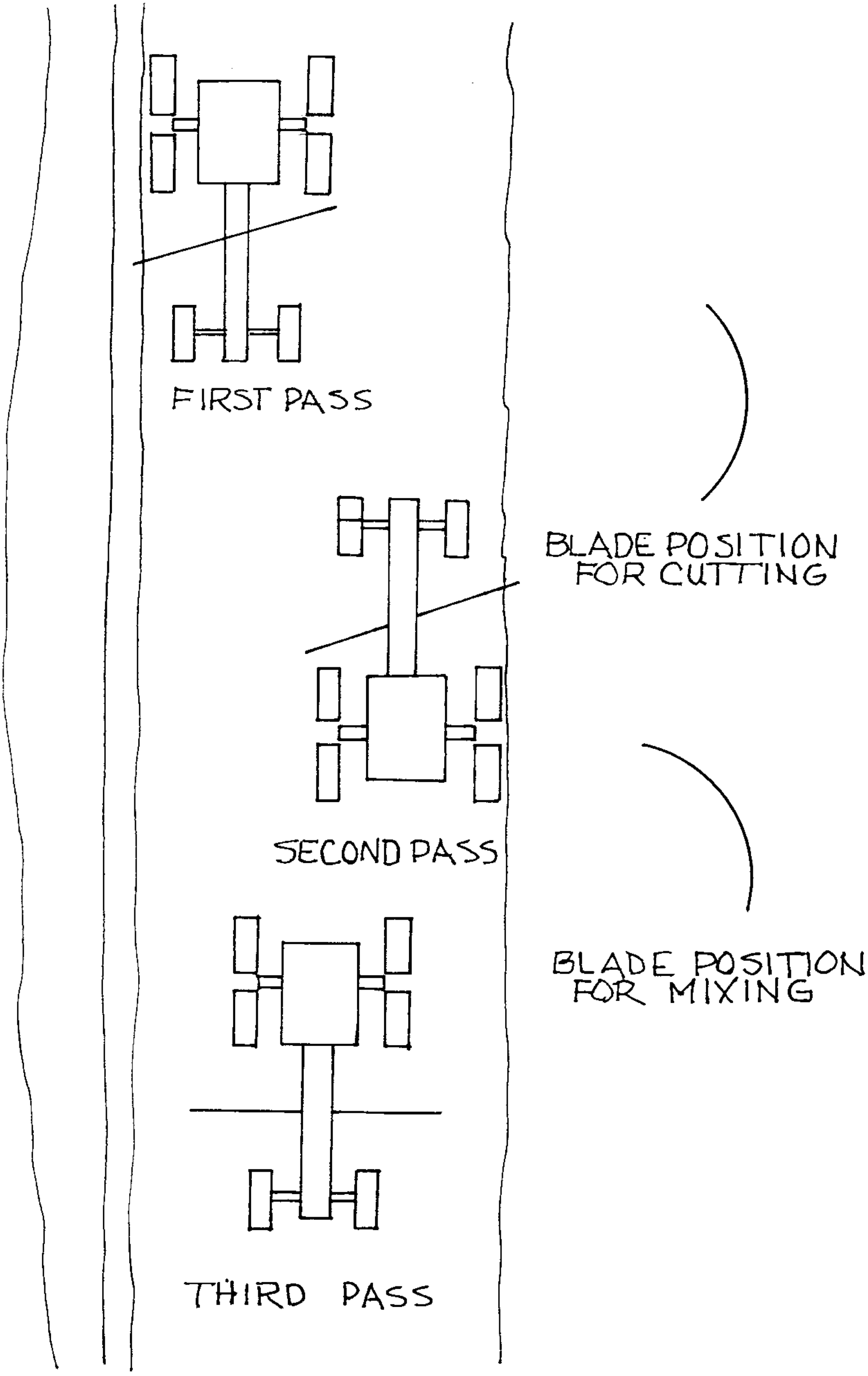
Routine Maintenance

Unsurfaces roads are those roads which have been constructed or which have developed from use that have native soils for the running surfacing. The surface may be sandy, gravely, silty clay or clay. The roads are generally maintainable if they are dry and there is drainage to get the runoff water away from the road when it rains. Most unsurfaced roads are easily damaged by traffic when the surface has been softened by rain. The damage will consist of ruts, pot holes and surface erosion. Repairs to the road surface are a maintenance responsibility and should be undertaken as soon as equipment can get on the road with out causing additional damage.

A motor grader with ripper teeth is the standard piece of equipment for repairing and maintaining unsurfaced roads. The repairs begin by insuring that any water remaining in ruts or pot holes is drained off and that any culverts that may be plugged with debris are opened. It may be necessary to cut a drain to get the water out of larger pot holes. See 17 a. Most of the work required to drain the road and clean out the culverts can be done using hand tools.

Ruts form when the road surface does not support the traffic. They are more likely to be the worst on the steeper grades because the tires will lose traction and spin on the wet surface. The spinning action throws soil out from under the tire. Each successive vehicle will make the condition worsen. Unlike ruts, pot holes tend to form where the road surface is softened either by ponded water or where there is a bog or spring under the road.

Once the water is drained, the surface should be scarified or cut to the depth of the ruts or pot hole. This can be achieved but using the ripper teeth or the mold board, (blade) on the motor grader. The soil can then be mixed on the road surface and relaid. The surface must then be compacted either by successive passes of loaded trucks or heavy equipment or by a roller. Some operations will have a roller fixed to the ripper bar on the grader. The grading should be done in a manner that will drain the road surface. Insloping may be the best alternative for roads in erosive soils. Outsloping may be best for roads in non-erosive soils. Crowning should be used where

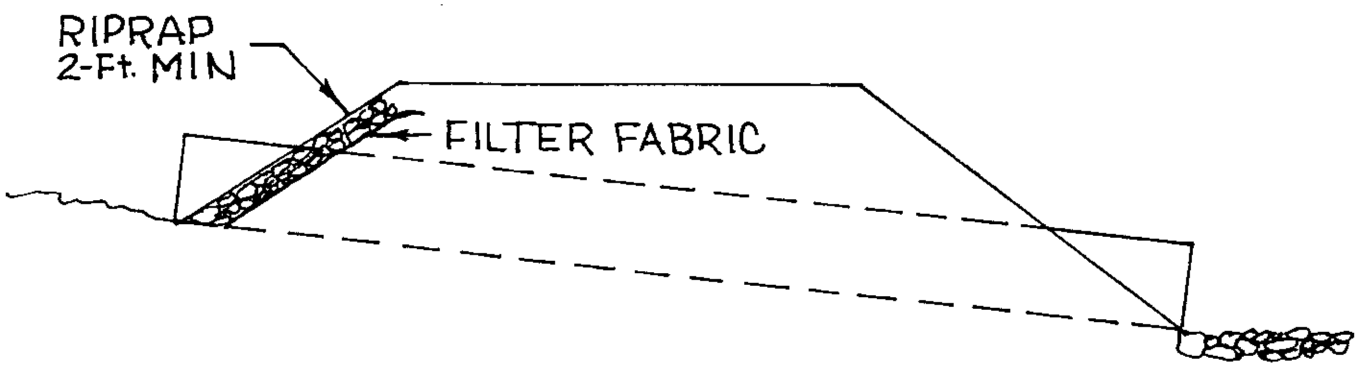

FIRST PASS
SECOND PASS
THIRD PASS
BLADE POSITION FOR CUTTING
BLADE POSITION FOR MIXING

the road is ditched. In no case should the road be flat bladed. Flat blading will concentrate runoff on the road surface and will accelerate erosion and wheel rutting. The blading should also insure that there is no berm on the shoulder to trap runoff water on the road surface.

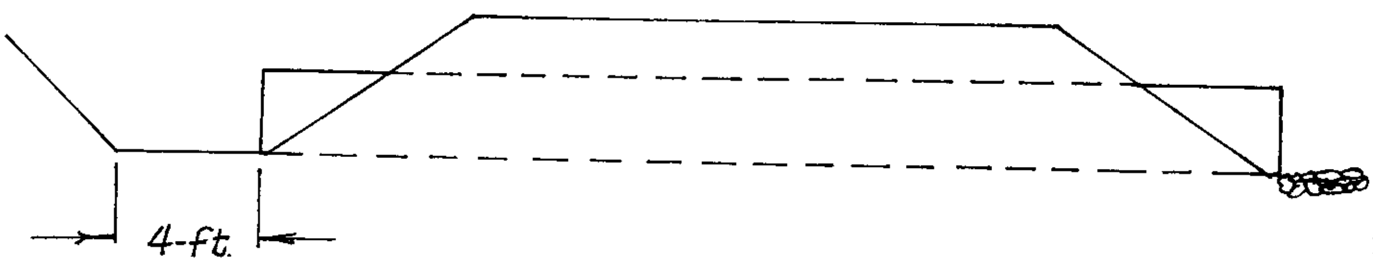
The grading operation will generally require three passes to insure that the surface material is mixed, laid down and recompacted to the extent that it can be done with a motor grader. The mold board should be tipped into the mixing position. See 17a. The operator then makes a pass up each side of the road pulling material in from the edge of the road. The last pass is used to spread the excess material on the center third of the road. The operator may make additional passes to insure that areas that were scarified have been compacted. See 17a.

Most roads that develop from use in meadows or bogs become the lowest spot in the surrounding area. This is compounded by the fact that the road grade will be essentially flat so all water is concentrated in the road prism and the soils encountered are generally fine grained and have poor load carrying capacities. The road becomes a ditch and will only dry out when the surrounding meadow dries up. This may be satisfactory if the road use can be limited to the few periods of the year when the surface will support the traffic. See 11 a.

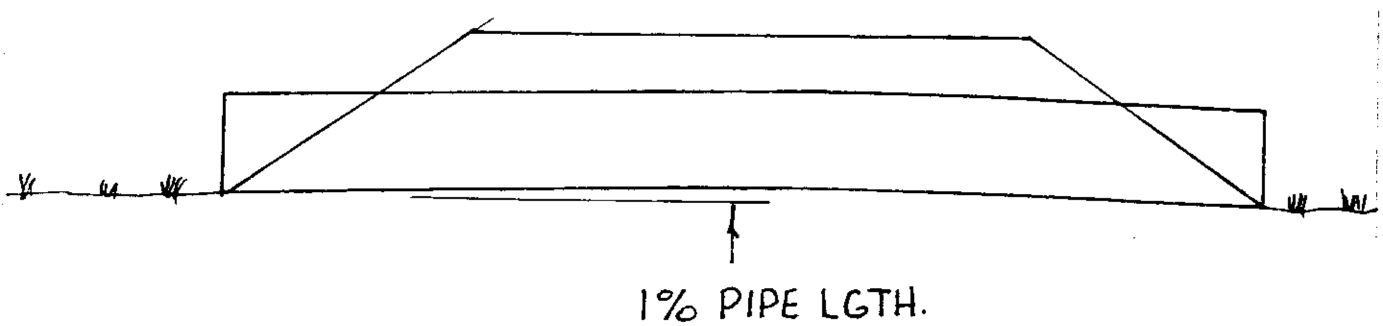
The only practical way of maintaining these roads is to drain the water away from them. This can be accomplished by cutting a lead off ditch, installing a subdrain, by turnpiking or by relocating the road around the meadow. The relocation option is probably the best alternative. Draining is possible only of the drainage ditch can take the water away from the road. The drainage ditch can be cut with a grader or a backhoe. Turnpiking is the best alternative if the road cannot be relocated. This can be accomplished by either filling across the meadow or by cutting a ditch on either side of the road and using the material for the road fill. The latter option will require the placement of an aggregate base course for a running surface if the road is to be operational during wet weather. Cross drains will be requirement so that surface water will not be trapped on either side of the fill. The culverts will have to be cambered so that they will continue to function as the fill settles. See 18 a. These options may fall outside the generally accepted description of road maintenance but must be a consideration when trying to maintain the utility of a road that has become the low spot in the surrounding country.



LIVE STREAM CULVERT INSTALLATION

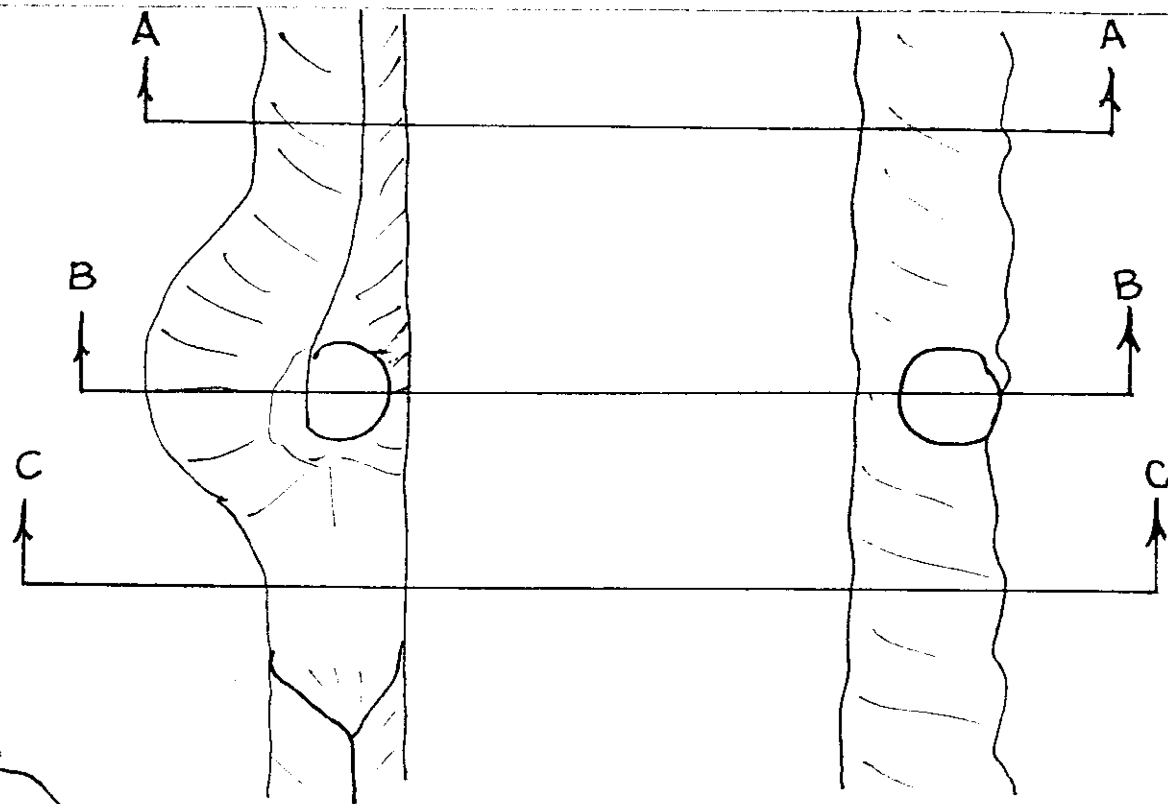


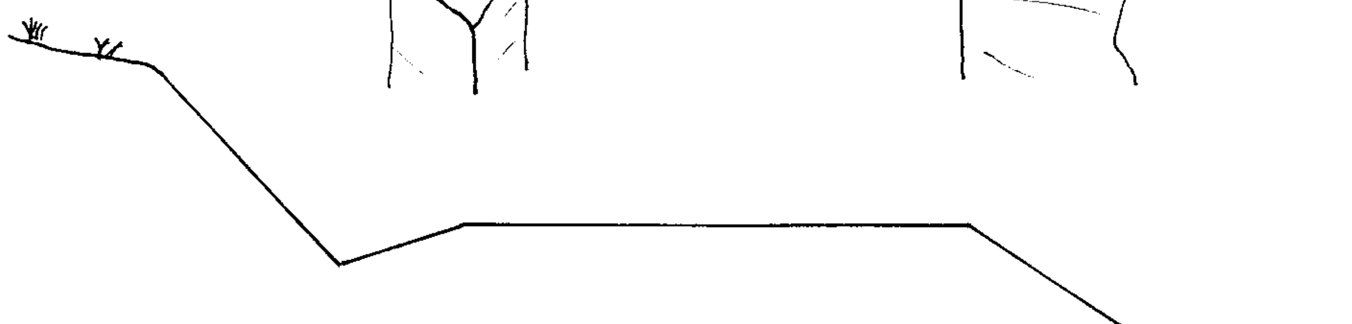
CROSS DRAIN CULVERT INSTALLATION



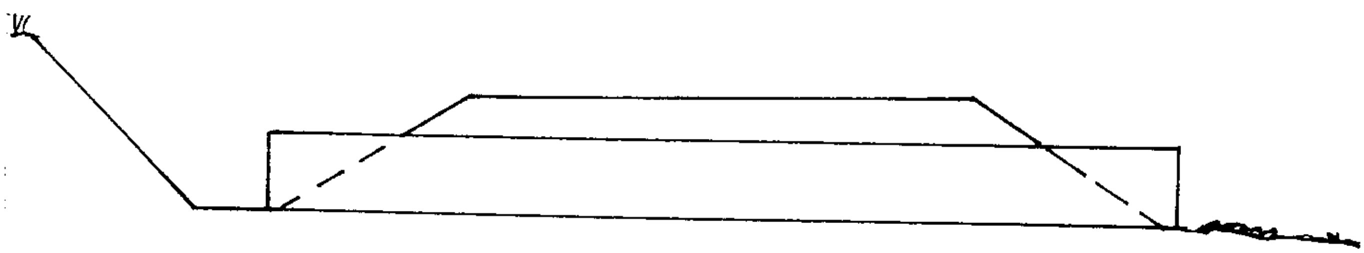
MEADOW CULVERT INSTALLATION

CULVERT CATCH BASIN CREED ENGINEERING RFC 4-7-00

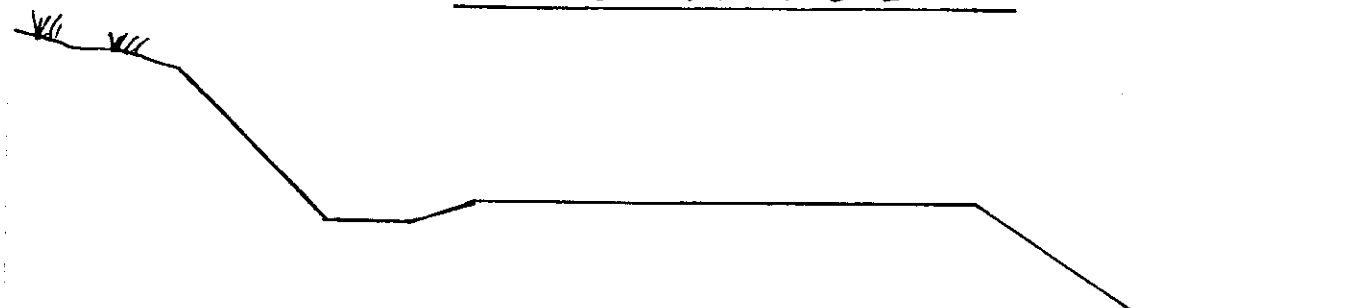




SECTION A-A



SECTION B-B



SETION C-C

All culverts and ditches need to be cleaned and ditch blocks checked to insure that they are working. See 18 b. Ditches can be cleaned by hand if they are in good condition but badly damaged ones should be re-cut using a grader, a back-hoe or a loader. Any materials brought out of the ditch should be removed from the road either by trucking them away or as a minimum, by blading them across the road. Cleanings placed uphill from the ditch will probably wash back in after the first rain.

Unsurfaced Roads (Deferred)

Unsurfaced roads are often low investment, low use roads. Some or all of the maintenance that is performed on them is often deferred between periods of planned use if the road is to be closed for an extended period of time, (years). Some maintenance items on open roads can also be deferred until it is economical to perform them. In all cases, the road should be graded and all drainage structures cleaned to insure that the road will be drained at all times. Roads that are closed to traffic should be checked on foot periodically to insure that the drainage is still working as designed and that the road closure device is still functional but all other maintenance can be deferred until the road is open again for traffic. Maintenance items that can be deferred on open roads include brushing, spot surface reinforcement, and any other item unrelated to drainage.

Maintenance of unsurfaced roads is not complicated and will generally be the least costly of the maintenance obligation on a road system. The simplicity of the maintenance doesn't reduce the responsibility of maintaining it on a regular basis if the road is not to become source of sedimentation and is to provide the intended level of service.

Maintenance of Aggregate Surfaced Roads

Routine maintenance of an aggregate surfaced road will be essentially the same as for an unsurfaced road. All of the drainage structures in the road including culverts, road side ditches and lead off ditches must be cleaned and maintained so that they are functional at all times. The aggregate surface must be graded as needed to maintain a smooth running surface and to insure that runoff from the road will enter the drainage system rather than collect on the road surface. The grading must also preserve the road template, i.e. insloping, outsloping or crown.

Of equal importance is to insure that the grading operation does not waste the aggregate surfacing by blading it over the side. A simple test is to mark off a one foot section of the side slope on a freshly graded road. All of the fresh aggregate within the one foot section is scooped up and placed in a large can or bucket and weighed. If, for example the can holds three pounds of aggregate, it is possible that the grader operator is grading six cubic yards of aggregate off of the road with each grading. A road that is graded six times a year will lose about three ten cubic yard truck loads of aggregate a year. This is equivalent to losing roughly $450 a year per mile of aggregate surfaced road assuming that a ten cubic yard truck load of aggregate will cost $150 delivered to the road.

The grading operation should start with grading the outside edge of the road toward the center of the road. The second pass will pull the opposite side in. The third and possible fourth pass will smooth out any excess aggregate that remains, leaving it in the middle third of the road. The aggregate loosened during the grading operation should be compacted either by routing heavy trucks over it or by use of a roller.

Deferred Maintenance

Gravel replacement and brushing will be the largest deferred maintenance items for the aggregate surfaced roads. The amount of aggregate lost will vary with the type and weight of traffic on the road, the durability of the aggregate used, the grades and curves on the road and how the road was maintained. Aggregate is lost through poor grading practices, by the action of tires which create a grinding action that reduces the larger aggregate to increasingly fine dusts, erosion by runoff water and from the dust that is created when vehicles travel the road during dry periods.

It is impractical to consider replacing a aggregate running surface on a seasonal or yearly basis. Therefore, the replacement is deferred until a minimum of five to six loose inched can be placed. The replacement aggregate is then mixed, watered, spread and compacted. The lower traffic speeds on resource development roads will generally result in longer life for the road surfacing. This is provided the maintenance effort is directed to conserving the aggregate surfacing. It is probable that an aggregate surfaced road that is open to traffic rear round would require surfacing replaced on an average of every five to seven years. It would take approximately 2400 cubic yards per mile to have an end product of four inched of compacted aggregate on a single lane resource development road. A failure to provide for the timely replacement of surfacing will result in the conversion of the once aggregate surfaced road to an unsurfaced road.

Brushing is an ongoing project on many roads where encroaching vegetation can reduce sight distance. A truck at 20 MPH or thirty feet per second will take 2.5 seconds to react and start braking. The distance traveled in the 2.5 seconds is 75 feet. Breaking to a stop will add an additional 35 feet for a total stopping sight distance 110 feet. Two trucks approaching each other a single lane road will then need a minimum sight distance of 220 feet to avoid colliding on the road. Brushing is therefore an essential safety item.

Brush and tree canopies can also contribute to extending the effects of rain on the running surface. Roads that are open to the sun and have good air circulation will dry out faster than those that are shaded or in a heavy forest environment. The result is that the road surfaces in shaded areas will be subject to damage for longer periods following storms. Vegetation can also clog drainage ditches to the point that they cannot handle the storm runoff. This can result in flooding and additional damage to the road. The amount of brushing required on any given road will depend to a large degree on how wide the original clearing was and the type of vegetation that is growing along the road but it can not be ignored on any road that is open to traffic.

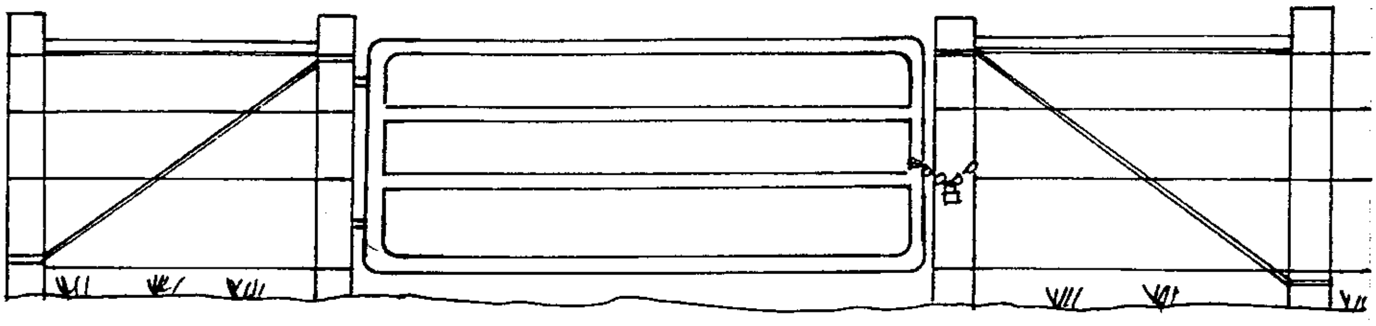
Road Closures

One of the most cost effective tools available to resource development road managers is the ability to close roads that are not needed for current management activities. Some roads may be closed permanently while others may be closed for indefinite periods. Still other roads may be closed to general use but may be required for management activities for only a few days a year. The closure method that is selected should be based on the long-term management plans for the lands tributary to the road. Another consideration that may enter the decision making process is whether road closures will be vandalized. See 22 a and 22b.

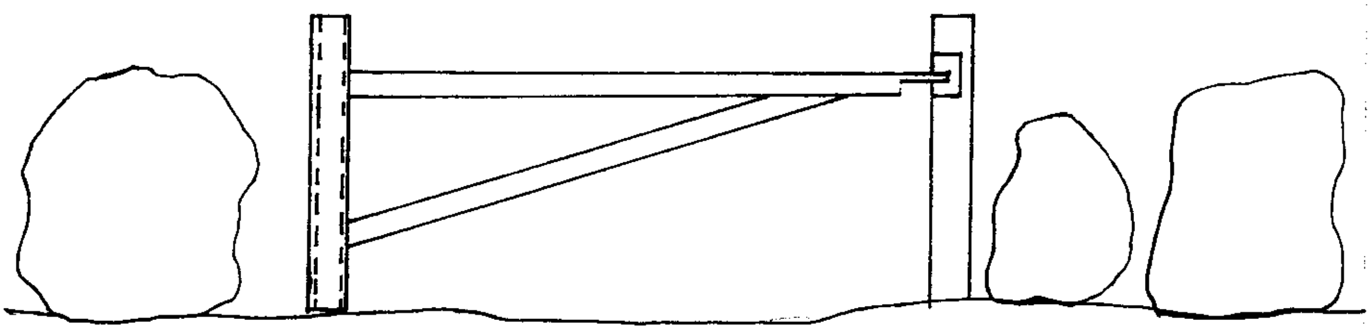
A decision to permanently close a road should include a plan to remove most if not all of the culverts, fill in any ditches and outslope the road from the cut bank to the outside shoulder. The only culverts that may possible be left in the road are ones on large fills where removal of the fill would cause more damage than cutting a spillway and allowing the fill to fail over time. The entrance to the road should be barricaded with a large earth berm and planted to native shrubs or trees that will, over time, visually hide the fact that there was a road there at one time.

An alternative road entrance closure would be an earth berm with a pit behind. These are referred to as tank traps and should only be used if the berm will not discourage vehicular use. The berm closure is not effective on ground that is flatter than 20%. In this case a conventional four or five strand barbed wire fence should be build across the road and long enough to discourage anyone from attempting to go around the end. Laying large logs diagonally across the road behind the berm in a random fashion will further discourage unauthorized use. The trees can be dug in so that they can also serve the added purpose of a water bar.

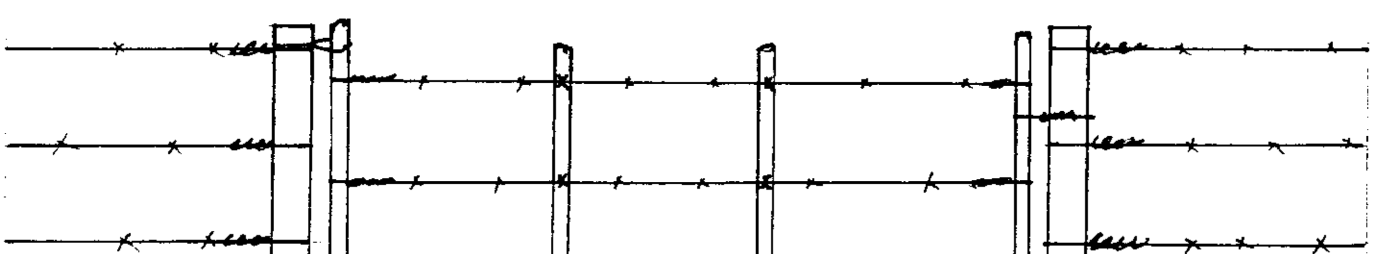
Roads planned for closure for an indefinite period but which will be needed for future management activities could either be gated or closed with a berm. All of the culverts, ditches and other drainage structures should be clean and functioning prior to closure. The road should be graded to prevent runoff from being trapped on the surface. The surface should be scarified and seeded to native species to reduce the potential for future erosion. A plan should be implemented to insure that the road is inspected periodically to insure that the drainage is still working and to make repairs as necessary to protect the investment in the road. The decision to gate or berm the entrance should be based on how long the road is going to remain closed and whether or not a gate closure will be effective in



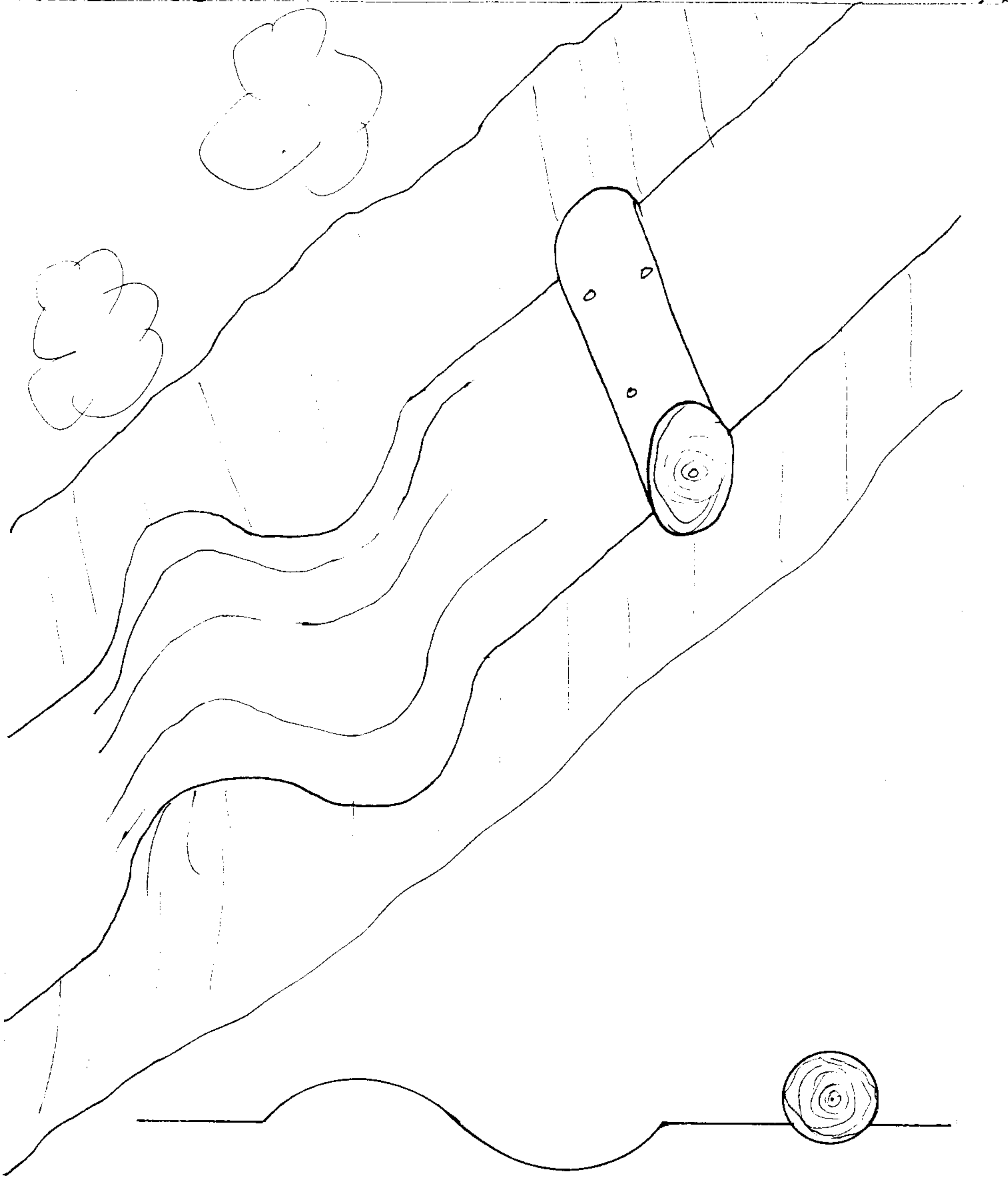
PANEL GATE



PIPE GATE



BARBED WIRE GATE



preventing people from attempting to drive on the road during the closure.

Roads that are to be closed seasonally should be gated. The choice of gate should be one that will effectively prevent use of the road during the closure period. Road maintenance activities should be scheduled around the closure periods. An inspection prior to the closure should be made to insure that the drainage is operational and that runoff will not be trapped on the road surface.

The type of gate used for road closures will vary with the situation. Farm style gates are effective and relatively inexpensive. Gates made from six to eight steel pipe have been fabricated and have been effective in closing roads in areas where vandalism is a serious problem. Cable has been used as a gate but cables are difficult to see at night. Accidents resulting from people driving into cable gates have ended up in the courts and landowners have paid damages to the claimants. An alternative cable closure is to sleeve the cable with four to five foot sections of two inch white plastic pipe. This will make the gate highly visible and should prevent night time accidents. Another gate that can be used is the four or five strand barbed wire gate. These gates used extensively by the livestock industry and are an effective gate. They can be secured by chain and lock if necessary to prevent entry.

Road closures are an effective method of minimizing maintenance liability during periods when roads could be easily damaged by vehicular traffic. The closures can also be a point of contention with the public at large if they have had unlimited access to the road system in the past. It may be prudent to meet with interest groups to explain the reasons for the closure and if possible permit non-motorized use of the road during the closure periods in an effort to gain acceptance of the traffic control program.