Glenn Borkenhagen
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Cody, Wyoming 82414
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19 October 2018

Mr. Kai Nielson
Marathon Oil Company
5555 San Felipe Road
Houston, Texas 77056

Group Counsel – Regulatory Affairs and Government Relations
Marathon Oil Company
5555 San Felipe Road
Houston, Texas 77056

Re: Environmental Assessment License – Section 3.0 Site Condition
Restoration of Property to condition prior to disturbance by Marathon

This letter, combined with the email message I sent to Mr. Kai Nielson on 19 September 2018 (receipt acknowledged by Mr. Nielson via email on 20 September 2018 and printout attached hereto) constitute my response to Mr. Nielson's letter dated 12 September 2018.

The primary, but not the only, issue at hand is whether Marathon's past and proposed activities directed toward the steep disturbed hillside referred to as "Area 2" on page 5 of the Arcadis "Remediation & Restoration Work Plan for the Borkenhagen Property Legacy Crude Oil Truck Loading Facility" dated 25 March 2016 (that same general area is labeled "B" on the Project Area Excavation Map that is the last page of the aforementioned Arcadis document) comply with the terms set forth in the referenced Section of the Environmental Assessment License (License) dated 04 February 2016.

The specific License language to be addressed at this time states:

> After performing Activities, Marathon agrees to restore the areas of the Property that were disturbed by Marathon's Activities to, as nearly as reasonably possible, the same condition as existed on the date that such areas were disturbed by Marathon.

It is my position that the site conditions that exist now on the hillside and that would exist after Marathon's proposed minor re-grading above the hillside do not comply with that standard.

In a nutshell, prior to Marathon's 2016 activities the steep (60 to 65 percent grade) hillside was naturally armored against erosion by the native cobbles (clastic rocks sized 2.52 to 10.1 inches) and larger pebbles (clastic rocks sized 0.08 to 2.52 inches) that covered the surface and protected the underlying substrate from splash erosion (detachment and downhill movement of soil particles caused by direct impact of raindrops). Now there exists about 1700 square feet of surface covered only with easily erodible fine material and a sparse stand of wheatgrass. Marathon and its consultant contend that their planting of grass on the steep hillside during 2016 and 2017 will permanently prevent soil erosion, but after three growing seasons that grass has not grown dense enough to prevent erosion. To date I have found nothing in on-the-ground evidence or published literature that suggests that vegetative cover will ever successfully prevent soil erosion on this specific site.

Before Marathon's removal of crude-oil-contaminated material from the hillside, the topography of the uncontaminated portions of disturbed area was too complex to allow for precise verbal description, but it can generally be described as an upper area of native fine sandy loam topsoil at moderate slope populated with the typical vegetation of the surrounding area including sagebrush, rabbitbrush, and prickly pear cactus, along with some native forbs and grasses. The topsoil was typically about one foot thick. At the northerly lower edge of the topsoil-covered area was a nearly vertical drop of one to three feet to the lower hillside area which was covered with larger pebbles and cobbles sloping at 60 to 65 percent grade (essentially angle of repose for rounded clastic rocks) all the way down to within a few horizontal feet from the south curb line of Sheridan Avenue. The same general situation exists today immediately to the east and west of the disturbed area.

Please recognize that I am not suggesting that Marathon should replicate the exact pre-existing conditions on the hillside complete with topsoil, mature sagebrush, and all the rest. All I am requesting is a final situation bearing the attributes of the natural eventual developed condition in the area of the hillside, specifically a durable and maintenance-free armored-against-erosion surface, where the slope is covered from top to bottom with large pebbles and cobbles supported by an adequate substrate similar to that formerly provided by the pre-existing hillside.

Marathon's consultant oversaw placement and grading of the replacement material on the subject hillside during the week of 09 May 2016. The replacement material was verbally described to me as reject fine aggregate for hot-mix asphalt pavement. It is understood that this material was sourced from legacy stockpiles in a gravel pit east of Wyoming Highway 120 a few miles south of its intersection with U.S. Highway 14-16-20. Apparently the area where this reject material was stockpiled was also used to dispose of clasts too large for the crushing equipment in use at various times in that gravel pit because some larger cobbles and boulders came to the Property with the replacement material.

Aside from the "accidental" larger clasts, the replacement material consists entirely of small particles. In December 2016 I had DOWL of Billings, Montana perform a sieve analysis of a sample of the replacement material. The report (copy attached) indicates 82% of the material passed the Number 4 (0.187 or 3/16 inch openings) screen, which is often considered the dividing point between coarse and fine construction aggregates. In addition, when Marathon's consultant was preparing to plant grass on the hillside they directed the dumping of two trailer loads (20 to 25 tons each) of topsoil (virtually all of which would pass the Number 4 screen) down the hillside. All of this material is easily eroded by rainfall and surface flow.

An intense rainfall event on Friday 20 May 2016 (the nearby Cody Airport Automated Weather Observing Station (AWOS) reported 0.93 inches precipitation that day) resulted in severe erosion and formation of rills and gullies on this hillside, as reported and pictured in my letter of 08 June 2016 to Marathon.

Since that time I have availed myself of various sources of information related to erosion prevention on steep hillsides, including publications, on-the-ground observations, and discussions with individuals with knowledge of and experience in the subject.

At the beginning of my knowledge quest I became aware that it is important to clearly distinguish between "slope stability", which refers to the mechanical stability of a hillside to prevent mass movements such as landslides, and "slope erosion", which concerns the detachment and movement of material down a hillside primarily due to the effects of precipitation and gravity.

Later in this letter I will cite references to literature and other published sources on soil erosion, but will first present various things a person can easily observe on the ground in the immediate area of the subject hillside and other nearby sites.

It is critical to understand that this is a semi-arid climate that receives between 9 and 10 inches of precipitation in an average year. Grass here does not develop the density required to effectively prevent soil erosion unless the grass receives adequate and regular watering, which can be from irrigation, proximity to standing or flowing water, being adjacent to impervious surfaces, or other mechanisms. Viewing the satellite images available from Google Earth or simply looking at the ground at one's feet reveals large expanses of bare or nearly bare earth with the only dense green groundcover in areas where grass gets adequate and consistent water.

The Wyoming Department of Transportation (WYDOT) conducted two construction projects in the immediate area in recent years. Sheridan Avenue was completely rebuilt from around the bottom of the hill to near the top of the hill about 1999. The area close to the intersection of Sheridan Avenue and 29th Street was included with the major upgrade of Sheridan Avenue that extended to east of the then-new Sunset School in 2010. Both projects included reseeding of disturbed areas (with much flatter slopes that that of the subject hillside) adjacent to the roadway. The results of those seeding efforts are difficult or impossible to see on the ground today except for a few steel staples that once secured the erosion-control blankets.

Since 2016 I have openly and repeatedly expressed my skepticism about the chances of grass preventing erosion of fine material on such a steep slope in this dry climate. Marathon's former (Arcadis) and current (Absaroka Energy and Environmental Solutions, LLC, hereinafter referred to as Absaroka) consultants have contended that the site is not exceptional and that given adequate time the grass will develop to a condition that will effectively prevent soil erosion.

I believe I have been more than patient in waiting to see the promised results, but beginning in 2017 I have responded to the assurances of eventual success from Absaroka with a simple challenge (hereinafter referred to as the Simple Objective Test) presented as follows:

> If the solution endorsed by Marathon's consultant is likely to be successful, the consultant should be able to identify a site or multiple sites with similar climate and hydrology within ten (10) air miles of the subject hillside where vegetative growth is successfully preventing soil erosion on an unirrigated hillside of similar slope (60 percent or steeper) consisting of materials with particle-size gradation similar to those presently covering the subject hillside.

To my way of thinking this is a completely reasonable, objective, and fair way to evaluate if the consultant-favored solution is likely to be successful.

So far Absaroka has not shown me such a site and from what I can see they have not expended anything more than a token effort to identify one.

Mr. Randolph Moses of Absaroka last visited the Property on 13 June 2018. In the email thread in which we scheduled his visit as well as when he was at the Property I suggested Mr. Moses spend some time scouting around the area looking for a site that would meet the Simple Objective Test presented above. I mentioned that there were some steep and long slopes along Wyoming Highway 120 on both sides of the Shoshone River as the road leaves Cody to the north and west.

On 09 July 2018 I sent an email to Mr. Moses, part of which inquired as to whether he had found a site that met the Simple Objective Test. Mr. Moses replied by email on 10 July 2018 and his paragraph replying to my inquiry reads:

> *I did investigate some other areas along the local terraces. At your suggestion, I looked at the road cut are on Hwy 120 in and out of the Shoshone River. My observation was that the road-cut looked relatively revegetated, well stabilized, and of similar slope to the rest of the terrace, including the hillside along your parcel. I took some pictures for point of reference. I see no reason that given reasonable time, the hillside at your parcel won't reach full stabilization (under reasonably foreseen circumstances).*

Since my impressions from driving through that area were mainly of rocky slopes like the ones adjacent to the disturbed area on the Property, on 02 August 2018 I send a follow-up email to Mr. Moses including a paragraph in which I requested information that would help me understand what he saw that I had not noticed. Mr. Moses replied by email the same day but his message seemed dismissive in tone and did not address my request.

Now that it was apparent that Mr. Moses was not going to share with me the revelations of his observations, on 03 and 04 August 2018 I went to the area along Wyoming Highway 120 being discussed where I made slope measurements at 20 points throughout the area and added additional comments about observed conditions for certain points.

If you have Google Earth installed on your computer (Google Earth Pro is free for the downloading, and runs on Windows, Macintosh, and Linux), you can see my results by pointing your web browser to:

> http://www.inlandwyo.com/pub/Marathon Pipe Line Parcel/

Then left-click the hyperlink labeled "09 Wyoming Highway 120 slopes". Inside that directory are two KMZ files.

Left-click the file named "Wyo Hwy 120 Hillside Points 04.kmz" and Google Earth will open showing 20 blue pushpin icons at the locations of my slope measurements and a yellow pushpin icon at the location of an image showing the conditions at the top of slope.

As you left-click the blue pushpin icons a text box will open for each one with slope information presented in three formats – degrees inclination above horizontal, percentage (100 times the tangent of degrees inclination above horizontal), and ratio in the form X units horizontal : 1 unit vertical, where X equals the inverse of the tangent of degrees inclination above horizontal.

The text boxes for Points 052, 054, and 055 also include comments related to visible erosion of fine soil at those points. The material at those points appears to be imported fill, not native material. All the other points with slopes greater than 60 percent are on slopes covered with large pebbles and cobbles.

The yellow pushpin icon marks the location at the top of one of the hillsides from which an image was taken showing the cobble-rich material at the top of the slope as is typical of the alluvial benches in the area. Left-click that icon and a text box containing a hyperlink to that image will appear. Left-click the hyperlink to see the image. Then there should then be a button labeled "Back to Google Earth" above the upper-left corner of the image. Left-click that button to go back to the satellite view.

Back in your web browser, left-click the file named "Walked 2018-10-03.kmz" and you will see in Google Earth four red loops showing the paths I walked on 03 October 2018 examining conditions at the tops of the various slopes. There may also be blue squares at the vertices of those paths.

The portion of Wyoming Highway 120 being discussed was completely rebuilt when the current bridge across the Shoshone River was constructed. If memory serves, that project was completed in 1992.

Now a quarter century after project completion there is virtually no sign of vegetative growth that may be a result of WYDOT's seeding effort performed toward conclusion of the project even being present in the area, let alone being effective at preventing soil erosion.

Looking back at the walked-path loops presented in the file named "Walked 2018-10-03.kmz", the area within the farthest northwest loop does have significant grass growth. But that whole area is immediately adjacent to and downhill from a generously irrigated horse pasture so it is not relevant to the situation at hand. I did not make any slope measurements in that area.

My inspection of this area did not find any locations meeting the Simple Objective Test.

The last readily observable local condition I have for now is the reality of the invasive and aggressive annual grass downy brome, commonly known as cheatgrass. A growing number of jurisdictions have designated cheatgrass as a noxious weed. Cheatgrass is definitely present on the Property, and as of this writing there are plants present within the seeded area on the steep hillside that exhibit the drooping head that is characteristic of cheatgrass. There is much bare soil within the seeded area which presents a prime opportunity for cheatgrass infestation.

It is well known that cheatgrass utilizes a high percentage of available soil moisture at the beginning of the growing season (which is probably the reason for its common name) to the detriment of other grasses. Annual precipitation for 2016 and 2017 as recorded at the nearby Cody Airport AWOS was significantly higher than the long-term average. This helps desirable perennial grasses compete against cheatgrass. But in years where precipitation is lower than average cheatgrass can advance toward dominance in a given area, eventually completely displacing the other grasses. Although cheatgrass can rapidly achieve a dense stand, it is a winter annual with a shallow root system which makes it of little value in preventing soil erosion.

Now we can consider three published items of particular relevance to the subject of using vegetation to prevent soil erosion.

The Natural Resources Conservation Service (NRCS) is part of the U.S. Department of Agriculture. It was previously known as the Soil Conservation Service. NRCS provides technical assistance to agricultural producers and private landowners.

The NRCS publication titled *Prevent Soil Erosion on your Property* (copy attached) includes a diagram rating the chance of successfully preventing soil erosion on a range of slopes. At 50 percent slope the diagram predicts "Revegetation success poor" and for slopes greater than 50 percent the forecast is "Revegetation improbable". The subject hillside is considerably steeper than 50 percent.

My searches found a conference paper titled *Vegetative-based technologies for erosion control* by a researcher in the United Kingdom. I did not purchase the complete paper but did download a two-page abstract and preview (copy attached). Two important points drawn from the abstract are:

1. A stem density of at least 10,000 stems per square meter is recommended if grass is expected to prevent soil erosion by surface runoff. That density can be visualized by a grid of grass stems spaced at 10 mm (0.39 inch) apart north-to-south and east-to-west. It is unlikely one will find such a stem density in this area except for irrigated tracts.

2. Vegetative cover must be uniform to prevent erosion because clumpy growth patterns can concentrate water flow (thereby increasing water velocity and erosion) in the bare areas between the plant groups. The wheatgrass varieties planted on the subject hillside definitely exhibit the growth pattern typical of the "bunchgrass" species prevalent in the western United States. The first sentence of the abstract states in part "…in some situations, a vegetation cover can have adverse effects and actually increase the rate of erosion."

The final source I will cite at this time comes from the New South Wales (Australia) Department of Primary Industries and is titled *Maintaining groundcover to reduce erosion and sustain production*. Readers can easily access and obtain a PDF of that document by searching for its title. This publication classifies any slope greater than 20 percent as "steep" and provides a series of tables providing minimum groundcover percentages required to reduce soil erosion for various regions, soil types, and slope classifications. The lowest groundcover percentage shown for any set of presented conditions that include a "steep" slope is 85 percent, far greater groundcover percentage than is found in unirrigated areas in this region. Add to that the fact that the subject hillside is much steeper than 20 percent slope and the likelihood of preventing erosion with probable groundcover is slim indeed.

Moving to the subject of slope stability, I cannot offer much except to suggest the pre-existing hillside could reasonably be considered stable by virtue of comparison with slopes adjacent to other alluvial benches in the immediate area that have stood for many decades with no indication of slope failures.

Determining if the present steep hillside consisting of replacement material placed as directed by Marathon's consultant is likely to be stable is the domain of qualified geotechnical engineers. A definitive answer will require significant on-site investigation and measurement including soil borings/sampling and testing.

In my 10 July and 02 August 2018 emails to Mr. Moses I offered a general description of a possible solution for this steep hillside, as follows:

1. Removal of an appropriate amount of the May 2016 fine-grained replacement material, with consideration to eventual slope stability
2. Placement and compaction in lifts of material several feet wide in cross section similar to native material, perhaps a mix of clasts 1 inch to 6 inches with just enough finer material to fill the voids, to provide a durable substrate at the pre-existing slope.
3. Placement of an appropriate thickness of loose rock veneer similar to that presently existing on adjacent hillsides

For Item 2 above, it is possible that the solution may require material more angular than the rounded pebbles and cobbles native to the hillside. It may also be necessary or advisable to use some sort of geotextile in the mix, likely below Item 2 above.

I am investigating some possible situations where similar things may have been done in the region. In any case, it is my opinion that the plans and specifications for the implemented solution must be prepared by and bear the seal of a qualified professional engineer with a proven record in geotechnical engineering and constructed with construction observation under the direction of that same engineer.

Another factor in restoring the Property to pre-existing condition is the matter of topsoil. Prior to disturbance by Marathon the Property was covered with well-developed native topsoil (described in the National Cooperative Soil Survey conducted by the NRCS as Naturita fine sandy loam) typically about one foot thick. In addition to the area from which contaminated material was removed, there is also a portion of the Property that did not contain contaminated material but where the native topsoil is now covered with imported replacement material. Instead of waiting until removal excavation was completed to bring replacement material to the Property, Marathon's contractor backhauled replacement material on the return trip of each trailer load of contaminated material taken to the landfill, building a large, fairly flat drive-over stockpile outside the excavated area. This haulage method either reduced Marathon's hauling cost or increased the contractor's profit; it did not benefit me or the Property.

The total area now covered with imported replacement material (exclusive of the area covered by erosion-control blankets on the steep hillside) is 24,375 square feet or 0.56 acre. It will require just over 900 cubic yards of topsoil to restore the one foot of topsoil that covered the area before disturbance. I recall an earlier telephone conversation in which Mr. Nielson suggested we could negotiate a reasonable settlement amount based on the estimated cost of replacement topsoil delivered to the site.

On 07 April 2016 I sent to Mr. Nielson a letter itemizing and documenting my $915.93 of out-of-pocket expenses associated with removal of the large cottonwood tree that was within the contaminated area and had to be removed before remediation. I am not requesting reimbursement for my labor or the use of my tools and equipment in removing this tree.

Please remember that I provided or took responsibility for some additional items to Marathon's benefit, including:

1. I am not requesting reimbursement for the use of my excavator and loader provided when Arcadis was collecting soil samples on site. The abject failure encountered at the first hole they attempted using their pickup-mounted drill rig showed that device was completely unsuitable for the cobble-rich material of the site.

2. Because I was in the process of installing underground pipe for the irrigation ditch that crosses the property, Marathon did not need to restore that ditch to an appropriate condition for permanent service. Marathon's contractor did assist by digging about 250 feet of temporary ditch, all of which is now retired and backfilled.

3. I am not asking Marathon to replace any of the chain-link fence that was on the Property. Approximately 75 feet of fence, including five line posts and two termination posts, was removed to provide access to the hillside portion of the Property. In April 2017 I determined the remaining fence in that part of the Property was of no value to me and removed a few hundred more feet of fence both east and west of the hillside area. I do not understand why Mr. Moses of Absaroka continues to ask me to provide fence-alignment information when I have told him at least two times via email that I have no intention of replacing the fence that previously was on that portion of the Property.

Throughout this transaction it has been my intention to be fair and reasonable. In my estimation this letter supports my position on soil erosion with readily observable on-the-ground evidence supported by actual measurements as well as objective recommendations from subject experts presented in published literature. In contrast, Marathon's consultants have only provided vague assurances that somehow sometime a dense stand of perennial grass will eventually blanket the steep hillside and prevent soil erosion in perpetuity, without anything to support those assertions other than their wisdom as consultants. Remember that Marathon's consultant directed the placement and grading of the replacement material such that during the 20 May 2016 rainfall event considerable rainwater flowed off the upland area and went down the steep hillside, which greatly exacerbated the erosion damage to the hillside in that event. No grading project should ever commence without first determining where the water will go.

It is hoped that all these issues can soon be resolved in an amicable and efficient manner. Thank you for your kind consideration.

Sincerely,

Glenn Borkenhagen

Attachments: Printout of 19 September 2018 email to Mr. Kai Nielson
DOWL Particle Size Distribution Report dated 14 December 2016
NRCS Publication *Prevent Soil Erosion on your Property*
Two-page abstract and preview of *Vegetative-based technologies for erosion control*

To: Kai Nielson <knielson@marathonoil.com>
From: Glenn Borkenhagen <glenn@inlandgps.com>
Subject: Kai Nielson letter dated 12 September 2018
Cc: Andrea Earhart <andrea@mreattorneys.com>
Bcc:
Attached:

Dear Mr. Nielson -

Your letter dated 12 September 2018 and sent via certified mail arrived at the Cody post office on Monday 17 September. I picked it up yesterday, Tuesday 18 September.

Due to a travel commitment made literally half a century ago (my 50-year high school reunion is Friday 21 and Saturday 22 September in a city over 900 miles away) I do not have time right now to prepare a reply other than to state that my position remains as presented in my letter of 08 June 2016 (which your most recent letter was written in response to) and my 02 August 2018 email thread to Mr. Randolph Moses of Absaroka Energy and Environmental Solutions, LLC, on which you were copied. You acknowledged receipt of that email when you phoned me on 03 August 2018.

One statement in your 12 September letter cannot stand unchallenged, specifically:

"However, in recent conversations, you indicated MOC no longer had permission to enter the Property"

I never made any such statement or made any comment that could be reasonably construed as such. If you have basis for such a belief, please specify in which of our conversations you claim to have heard such a statement.

Our person-to-person dealings go back to our first telephone conversation on 07 December 2015. After almost three years of interaction you surely realize that I can and do put things in writing. If it was my intention to rescind access authorization it would most certainly be clearly expressed in writing and delivered in an appropriate manner.

On the subject of access to the site, the second paragraph of the aforementioned 02 August email was the single sentence:

"Now that the irrigation ditch is all in pipe and buried, access to the site will never be better."

That hardly sounds like I am impeding MOC's access to the Property in any way. Furthermore, I invite you to visit the site and see for yourself the existing conditions immediately adjacent to the disturbed area and in the general vicinity.

Since it took you over two years to respond to my 08 June 2016 letter I trust you can afford me a couple of weeks forbearance in preparing a comprehensive reply to your most recent letter. In the meantime I ask you to review my 02 August email and let me know where you find fault in my position.

To repeat from the first paragraph of my 02 August email:

" I would like to get things moving toward a permanent and durable solution to the hillside erosion and stability issues and have the whole project wrapped up so I can proceed with development plans."

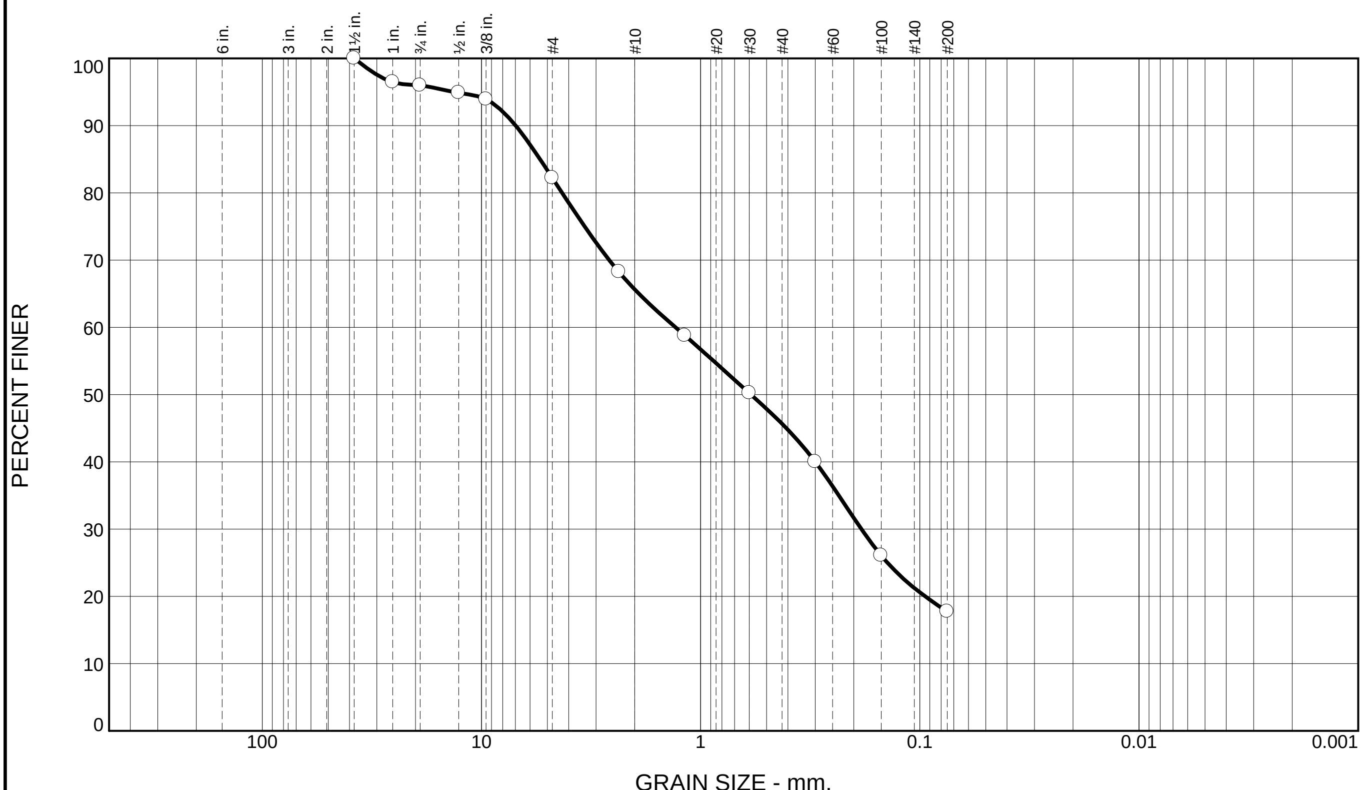
It is in everyone's best interest to achieve that goal. The path to that goal must include a better process than that which resulted in the problems that have appeared on the Property.

Please acknowledge receipt of this message by email reply.

Regards,

Glenn Borkenhagen
307-272-5044

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	4.0	13.8	16.6	20.0	27.9	17.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100.0		
1	96.5		
.75	96.0		
.5	94.9		
.375	93.9		
#4	82.2		
#8	68.2		
#16	58.8		
#30	50.2		
#50	40.0		
#100	26.1		
#200	17.7		

* (no specification provided)

Material Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 6.9813 D_{85}= 5.4051 D_{60}= 1.3028
D_{50}= 0.5898 D_{30}= 0.1847 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Sampled By: Client
F.M.=2.85

Location: Site Gradation Sample

Date: 12/14/16

DOWL

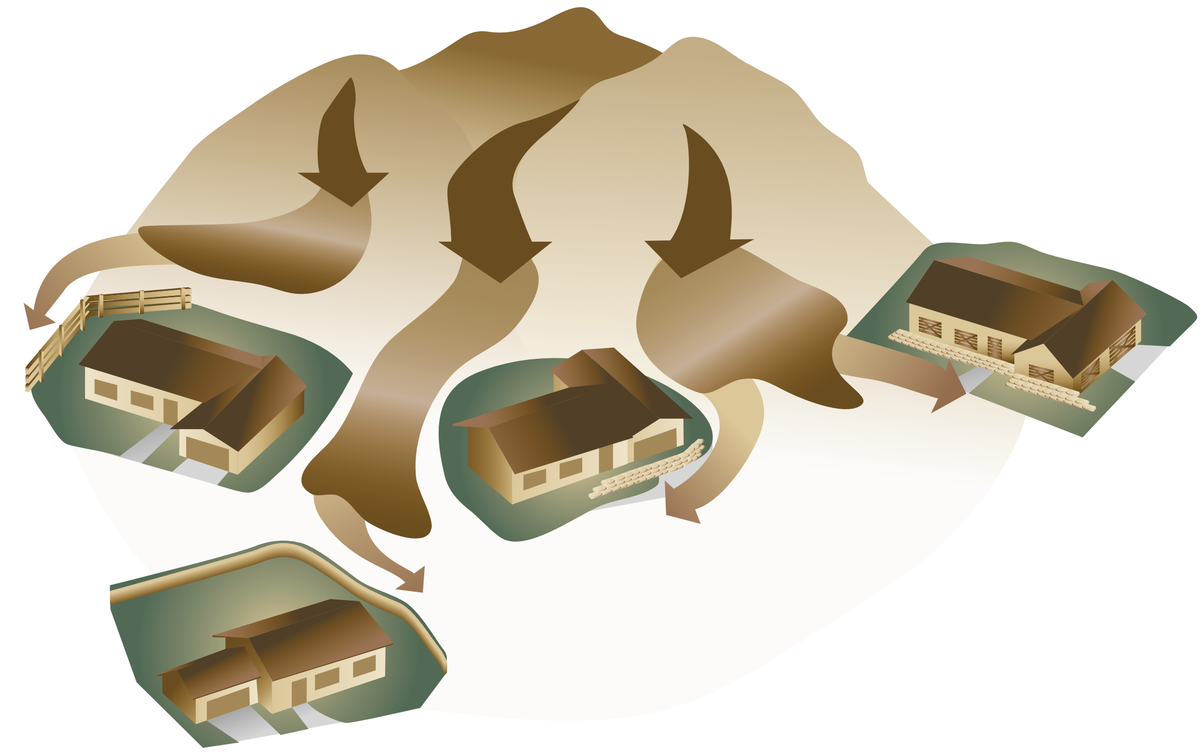
Client: Glenn Borkenhagen
Project: Misc. Testing

Project No: **Figure** 01

Tested By: RS **Checked By:** NEZ

Prevent Soil Erosion on your Property

A homeowner's guide to erosion control

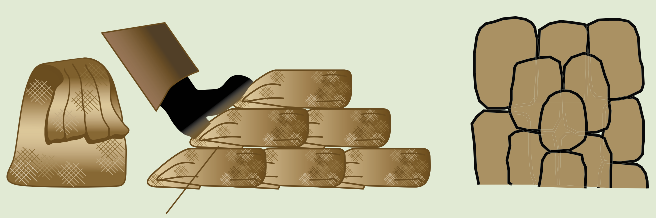


Soil erosion can happen slowly, gradually washing away top soil, or it can happen quickly in heavy rain events. In either scenario, the land is stripped bare of valuable natural resources.

In an effort to help landowners protect their property, professional NRCS Conservationists developed erosion control practices for areas where trees have been removed.

In this Homeowner's Guide to Erosion Control, you will find common NRCS practices that can be implemented to protect your property and prevent mudslides. Expanded fact sheets are also available at:
www.ca.nrcs.usda.gov/programs/ewp

How to Use Sandbags



Filling

Filling sandbags is best done with two people. Fill half full with sand if available or local soil.

Stacking

Fold top of sandbag down and rest the bag on its top on the stack. Top should be facing upstream. Stamp the bag into place. Complete each layer before starting the next layer. Stagger the layers. Stack no more than three layers high unless they are against a building or stacked pyramid-style.

Sandbag diversion

Sandbags will redirect water away from property but will not seal out water. Place sandbags with the folded top toward the upstream or uphill direction. Sandbags are temporary and will deteriorate after several months.

DO'S AND DON'TS

Do:

- Contact your local Flood Control Agency or Public Works Authority- *Installing these erosion control devices on your property may not be sufficient to thwart extreme flows.*
- Try to direct debris flows away from your property to a recognized drainage device or to the street.
- Clear a path for debris.
- Place protective measures to divert debris, not dam it.
- Board up windows facing the flow
- Work with your neighbors.

Don't:

- Under-estimate the power of debris flows.
- Walk or drive across swiftly flowing water.
- Wait until storms arrive to make a plan.
- Try to confine the flows more than is necessary.
- Direct flow to neighbor's property.

Don't Forget to Plan for Erosion Control ALL YEAR ROUND

Preventing runoff during the spring and summer is equally as important as preventing erosion. A major source of dry season pollution of lakes and streams near urban areas is runoff from landscape watering. This water carries oil and gasoline residue from roadways, fertilizers, pesticides, and other undesirable material as it flows away from our homes and drains into streams and lakes.

Irrigating on slopes can be tricky. Emitters are preferred but require monthly inspections to detect clogging. The freeze/thaw cycle at higher elevations can also damage tubing. Bubblers require less maintenance than drip emitters and may be highly effective. New plants should have earthen dams or watering basins around them to capture the water they receive.

www.ca.nrcs.usda.gov

NRCS Natural Resources Conservation Service

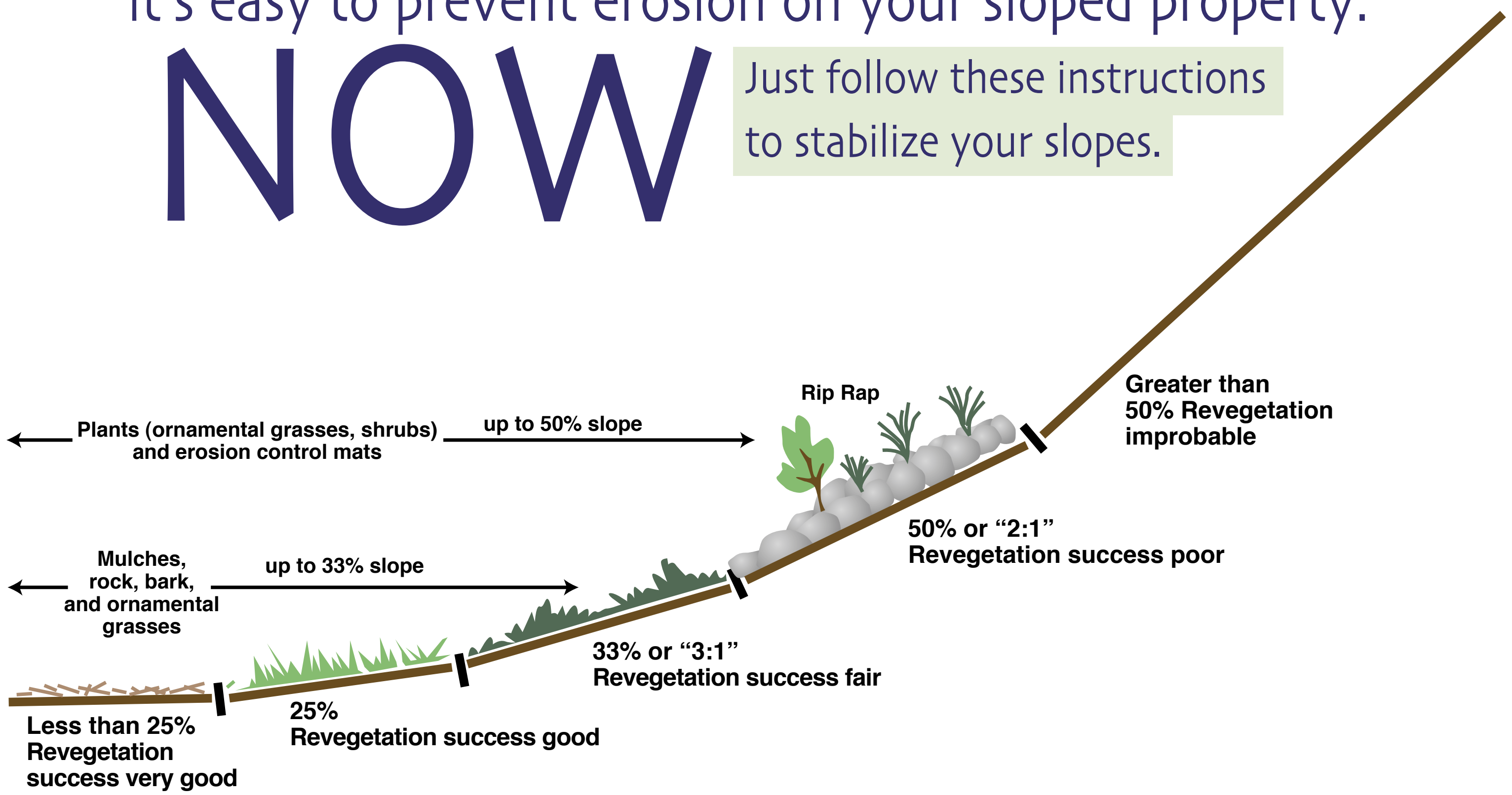
California Watershed Recovery Project

Prevent Erosion

it's easy to prevent erosion on your sloped property.

NOW

Just follow these instructions to stabilize your slopes.



What Kind of SLOPES Do You Have?

Take a look at your slopes. How steep they are will tell you what will work.

Moderate slopes (less than 33%) have a good chance of success at controlling runoff using plant materials and mulch.

Cover bare soils with mulch of bark chips, pine needles, wood chips, and even stones or river rock. Up to two inches of bark, wood chips or pine needles will not create a fire hazard.

When landscaping, select plants for slope stabilization and use bubblers or drip emitters for irrigation. When watering season starts again, watch the length of time you water and the amount of water delivered. Make sure the plants get only what will soak in.

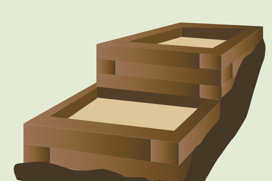
Slopes between 33% and 50% require special care.

Plant on slopes that are this steep, but be aware you may need to use an erosion control blanket, mats of coconut fiber, or jute netting to hold slopes in place until plants can become established.

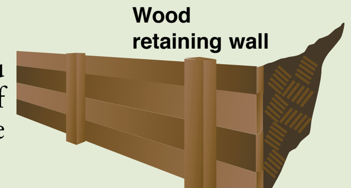
Once established, the roots of the plants will knit together to hold soils in place. Their limbs, leaves and branches will diffuse the force of rain and wind. These steep slopes require irrigation systems that will not create runoff.

Slopes over 50% will require structures or special techniques for stabilization.

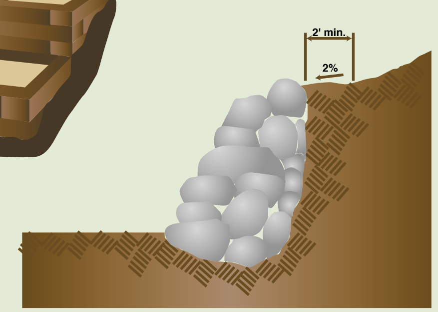
Techniques for steep slopes include wood retaining walls, interlocking concrete blocks, rock retaining walls, riprap (loose rock) areas, and terracing. If you choose wood, make sure the wood is treated with a wood preservative to prevent rotting. Terraces and wood retaining walls require approval by government agencies; please contact your local Building and Safety office.



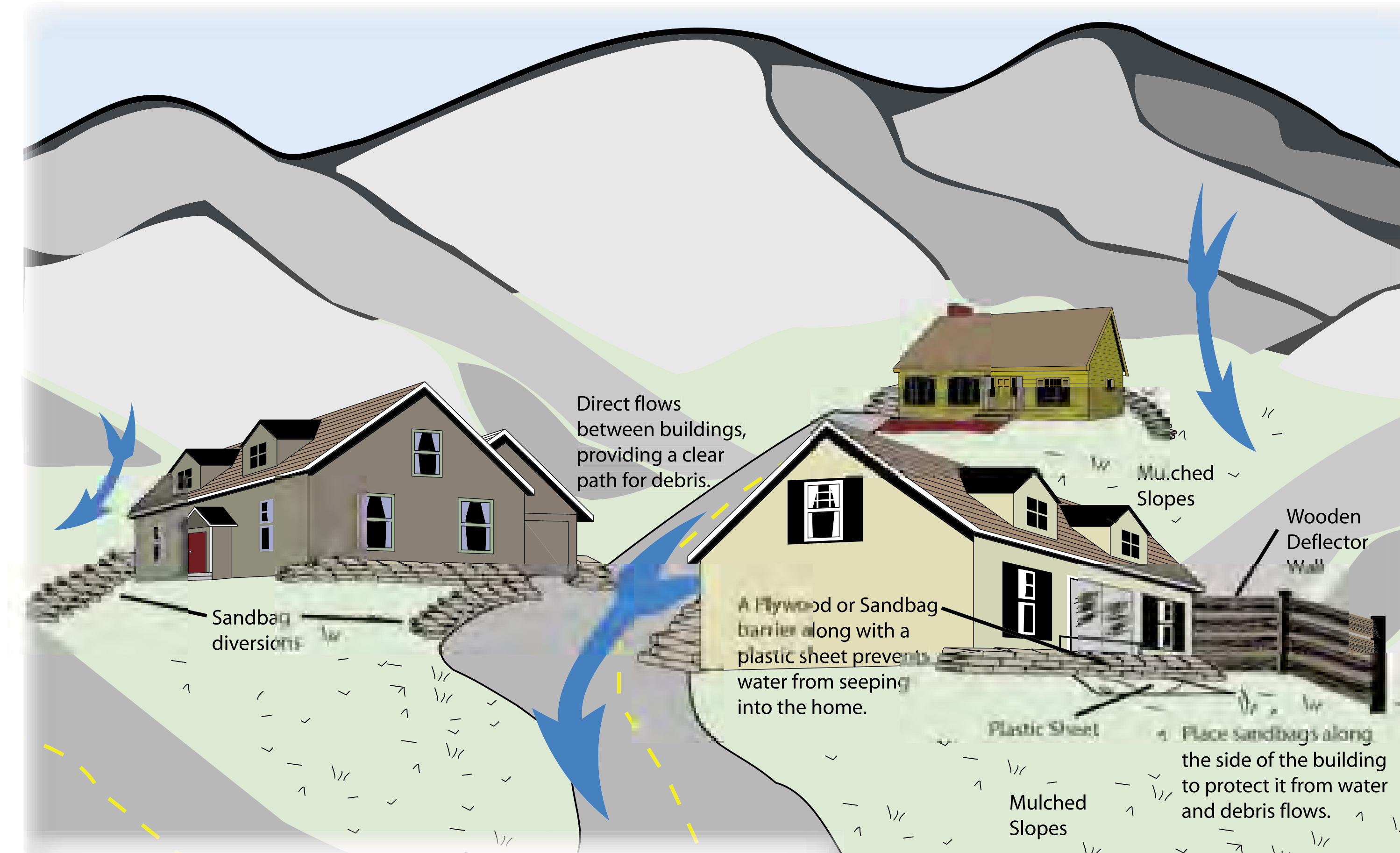
Terraces



Wood retaining wall



Rock retaining or breastwall



Battling MUDSLIDES & FLOODS

If you have removed vegetation, dead or dying trees from your property, you need to take defensive measures to protect against flooding and mudslides. When too much protective material is removed, soil is left bare and vulnerable to erosion. Defensive measures for your property can provide protection in the form of mulch, deflection walls, diversion ditches, and sandbag diversions.

Materials

The materials needed are readily available and inexpensive and can be installed with normal household tools: sandbags, sand, lumber and plywood.

Paved driveways are often an important factor in controlling erosion.

Paving prevents erosion resulting from snow removal, vehicle traffic in and out of your driveway and soils unable to absorb moisture because they have been compacted by vehicle weight. Small ditches or swales that capture runoff and return precipitation to your landscape should border your driveway. Semi-permeable coverings such as gravel can also be effective if slopes are not too steep.

Choose plants for slope stabilization.

Contact your local NRCS office for a list of plants and trees suitable for your area.

Mulching

A mulch consisting of two inches of wood chips, oak leaves and pine needles should be spread across burnt or baren areas of soil. This will:

- help to protect and keep soil in place
- increase water penetration
- keep soil cool and maintain moisture
- increase organic content of soil (you may want to add nitrogen if mulch is applied around existing vegetation, since the break down of mulch utilizes some nitrogen)

Protecting windows and doors

In areas where mudslides are possible use plywood to board up windows and doors. Overlap windows, vents or doors at least three inches on each side. Secure plywood with four or more nails, screws or bolts.

Wooden deflector walls

Use lumber for walls. Drive stakes to at least half their length into the ground for proper anchorage. Place deflectors on solid, level soil to prevent erosion. Earth packed behind the deflector will make it stronger. Contact your local NRCS office for more information.

Diversion ditches

Dig a small ditch close to the upper edge of the property to slow water movement. Provide for the ditch to drain into a drainage device, street pavement or a well-vegetated area.

Vegetative-based technologies for erosion control

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Key words: erosion control, screening models, vegetation

Abstract

Vegetation is widely used for the control of surface erosion on slopes but different vegetation types vary in their effectiveness and, in some situations, a vegetation cover can have adverse effects and actually increase the rate of erosion. Where climatic or soil constraints exist, there are also concerns about how quickly an effective cover can be obtained. Simple screening models can be used to indicate the likely severity of these issues prior to designing an erosion-control system. As soon as the canopy cover is higher than 0.3 m above the surface, there is a risk that satisfactory protection against soil particle detachment by raindrop impact will not be obtained. With canopies higher than 1.0 m, detachment rates may exceed those from natural rainfall on bare ground. The amount of vegetation needed to prevent soil particle detachment by surface runoff depends upon the steepness of the slope but, for grasses, a stem density of at least 10,000 stems/m^2 is recommended. Uniformity of distribution is important because a clumpy vegetation cover can lead to concentrations of flow between the plants with consequent increases in velocity. A vegetation cover can be used to induce sediment deposition. Where grass is used as a buffer strip, a width of 10–12 m is usually sufficient to trap even the fine sediment. For large areas of the world where water erosion is a problem, it is feasible to establish sufficient grass cover within 1 year.

Introduction

Vegetation is widely used to protect the soil against water erosion. However, vegetation varies widely in its height and density, from grasses through to shrubs and trees, giving rise to differences in the degree of protection that can be attained. Under some circumstances, vegetation can actually enhance the erosion process (Morgan, 2005); for example, where raindrops intercepted by the vegetation fall as leaf drip from tall canopies on to bare soil, they can detach more soil particles than rain impacting directly on the soil surface. Also, where runoff is concentrated in the gaps between clumps of vegetation, it can detach and transport more soil than runoff flowing more uniformly through a more evenly distributed vegetation cover. Before considering vegetative-based technologies, it is therefore helpful to have some simple models to evaluate the beneficial or adverse effects of vegetation and to establish some basic design parameters. Screening models, designed to be indicative rather than precise, can perform this function. In addition, they can be used to determine whether the required level of vegetation cover can be established reasonably quickly under given soil and climatic conditions. This paper describes some simple screening models to address these issues.

Raindrop impacts

The detachment of soil particles by raindrop impact is the first phase of the water erosion process. The detachment rate is generally regarded as a function of either the intensity or the kinetic energy of the rain and a vegetation cover is viewed as a good protector of the soil because it intercepts the rainfall, thereby reducing its intensity and energy at the soil surface. Unfortunately, this view ignores the transfer of a proportion of the intercepted rainfall from the canopy to the ground surface as leaf drainage. For a wide range of vegetation types, the median volume drop diameter of leaf drips

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is 4.8–5.0 mm (Brandt, 1989) compared with 2.0 mm for natural rainfall (Hudson, 1981). Although drops of this size can reach 97% of their terminal velocity when falling from a canopy of 10 m in height (Epema and Riezebos, 1983), assessments of their kinetic energy tend to underpredict their ability to detach soil particles because kinetic energy underplays the importance of drop size. Styczen and Høgh-Schmidt (1988) showed that detachment rates (D_r), as measured in a number of experiments, were better predicted by the following relationship:

$$D_r \infty m^2 v^2 \tag{1}$$

where m is the mass of the raindrops and v is their impact velocity. More recently, Salles et al. (2000) found that, even for bare soil, the product of $d^4 v^1$, where d is the drop diameter, gave the best predictions of detachment rate, again indicating the importance of the mass or size of the drops in the splash process.

As an example, the following simple calculations are made, using $m^2 v^2$ for a design storm of 50 mm/h intensity and duration of 15 min, giving a total rainfall of 12.5 mm. For screening purposes, calculations are based on the median volume drop diameters of 2.0 mm for the natural rainfall and 5.0 mm for the leaf drainage. It is assumed that the interception capacity of the vegetation cover has been reached and that there is no stemflow, so that all the rainfall reaches the soil surface either as direct throughfall or leaf drainage. The $m^2 v^2$ of the rainfall is then calculated for percentage vegetation covers of 0, 25, 50, 75 and 100% and canopy heights of 0.05, 0.25, 0.5, 1.0, 2.0 and 10.0 m (Table 1). If the values of squared momentum under the vegetation cover are expressed as a ratio of the value of the rainfall on bare ground, it can be seen that once the canopy height exceeds 2.0 m, the potential for soil particle detachment exceeds that from having no vegetation cover at all (Figure 1); further with a 1.0 m canopy height, the detachment rate virtually equates to that on bare ground. The greatest reductions in detachment are obtained from the cover at 0.05 m height. At that height, a percentage cover of at least 75% is needed to reduce detachment to less than 30% of that on bare ground. These results match those of studies of detachment rates under low-growing covers of maize, sugar beet and Brussels sprouts (Finney, 1984; Morgan, 1985) and indicate that, unless the vegetation canopy is in contact with or close to the soil surface, vegetation is likely to have an adverse effect on soil particle detachment by raindrop impact. It should be noted that under forest covers, the protection of the soil is afforded by the litter layer. Once a decision has been made to establish a low-growing vegetation such as grass to control the first phase of the water erosion process, the question arises as to how well it will control the detachment of soil particles by surface runoff.

Table 1. Values of $m^2 v^2$ for rainfall of 50 mm/h intensity and duration of 15 min for different percentage covers and heights of vegetation

	Percentage cover				
Height (m)	0.00	0.25	0.50	0.75	1.0
0.05	15.63	11.88	8.13	4.38	0.63
0.25	15.63	12.78	9.94	7.09	4.25
0.50	15.63	13.51	11.40	9.28	7.17
1.00	15.63	15.16	14.69	14.22	13.75
2.00	15.63	18.55	21.48	24.41	27.33
10.00	15.63	27.27	38.92	50.57	62.21

Calculations are for: (1) median volume drop diameters of 2.0 mm for natural rainfall and 5.0 mm for leaf drainage, with drop mass calculated assuming a spherical shape; (2) drop velocities of 6.5 m/s for the 2.0 mm drops in natural rainfall and velocities for different fall heights for leaf drainage taken from Epema and Riezebos (1983); (3) rainfall proportioned between natural rain and leaf drainage according to percentage vegetation cover.

Surface runoff

Vegetation reduces the potential of surface runoff to detach soil particles by imparting roughness to the flow

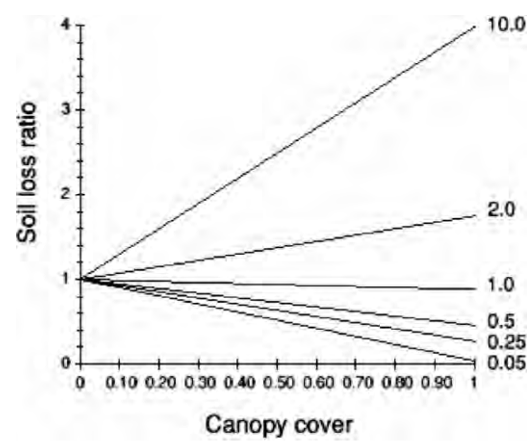

Figure 1. Soil loss ratios for soil particle detachment by raindrop impact based on $m^2 v^2$. The ratio represents the ratio of soil loss with a vegetation cover to the soil loss from bare soil. Canopy cover is the proportion of the soil protected from raindrop impact by the vegetation. Lines denote vegetation at different heights (m).