SECTION A
MASS WASTING

INTRODUCTION

This section summarizes the methods and results of a mass wasting assessment conducted on the Mendocino Redwood Company, LLC (MRC) ownership in the Ackerman Creek and Reeves Canyon areas. The Ackerman Creek area is comprised of the Upper Ackerman Creek and Lower Ackerman Creek planning watersheds. The Reeves Canyon area is comprised of the Jack Smith Creek and Mill Creek planning watersheds. Watercourses of both areas are tributaries of the Russian River at the Northern end of its watershed. Throughout this report, MRC ownership in these areas will collectively be termed the Northern Russian Watershed Analysis Unit (WAU). This assessment utilizes watershed analysis methodology adapted from procedures outlined in the Standard Methodology for Conducting Watershed Analysis manual (Version 4.0, Washington Forest Practices Board).

The principle objectives of this assessment are to:

1) Identify the types of mass wasting processes active in the basin.
2) Identify the link between mass wasting and management related activities.
3) Identify where the mass wasting processes are concentrated.
4) Partition the ownership into zones of relative mass wasting potential (Terrain Stability Units) based on the likelihood of future mass wasting and sediment delivery to stream channels.

Additionally, the role of mass wasting sediment input to watercourses is examined. This information combined with the results of the surface and fluvial erosion module will be used to construct a sediment input summary for the Northern Russian River WAU, contained in the Sediment Input Summary section of this watershed analysis.

The products of this report are: a landslide inventory map (Map A-1), a Terrain Stability Unit (TSU) map (Map A-2), a mass wasting inventory database (Table A-1) for the Northern Russian River WAU. The basis for these products are: aerial photograph interpretation of four sets of aerial photographs, dated 1981, 1987, 1996, and 2000, field observations during the summer of 2000, and interpretation of SHALSTAB data. The analysis was done without the use of historic aerial photographs (pre-1970s). Therefore the analysis presented is only representative for current mass wasting conditions (last 30 years).

The assembled information will enable forestland managers to make better forest management decisions to reduce management-created mass wasting. The mass wasting inventory will provide the information necessary to understand the spatial distribution, causal mechanisms, relative size, and timing of mass wasting processes active in the basin with reasonable confidence.

LANDSLIDE TYPES AND PROCESSES IN THE NORTHERN RUSSIAN RIVER WAU

The terminology used to describe landslides in this report closely follows the definitions of Cruden and Varnes (1996). This terminology is based on a noun and verb, the first describing the material that the landslide is composed of and the second describing the type of movement. Landslides identified in the Northern Russian River WAU were described using the following names: debris slides, debris torrents, debris flows, rockslides, and earth flows. These names are described in Cruden and Varnes (1996) with the exception of our use of debris torrent and debris flow.

Shallow-Seated Landslides

Debris slides, debris flows, and debris torrents are the shallow-seated landslide processes that were identified in the Northern Russian River WAU. The material composition of debris slides, flows, or torrents is considered to be soil with a significant proportion of coarse material; 20 to 80 percent of the particles larger than 2 mm. Shallow-seated slides generally move quickly downslope and commonly break apart during failure. Shallow-seated slides commonly occur in converging topography where colluvial materials accumulate and subsurface drainage concentrates. Susceptibility of a slope to fail by shallow-seated landslides is affected by slope steepness, saturation of soil, soil strength (friction angle and cohesion), and root strength. Due to the shallow depth and fact that debris slides, flows, or torrents involve the soil mantle, these are landslide types that can be significantly influenced by forest practices.

Debris slides are, by far, the most common landslide type observed in the WAU. The landslide mass typically fails along a surface of rupture or along relatively thin zones of intense shear strain. The landslide deposit commonly slides a distance beyond the toe of the surface of rupture and onto the ground surface below the failure. While the landslide mass may deposit onto the ground surface below the area of failure, it generally does not slide more than the distance equal to the length of the failure scar. Landslides with deposits that traveled a distance below the failure scar would be defined by debris flow or debris torrent. Debris slides commonly occur on steep planar slopes, convergent slopes, along forest roads and on steep slopes adjacent to watercourses. They usually fail by translational movement along an undulating or planar surface of failure. Upon reaching a watercourse, by definition debris slides do not continue downstream.

A debris flow is similar to a debris slide with the exception that the landslide mass continues to "flow" down the slope below the failure a considerable distance on top of the ground surface. A debris flow is characterized as a mobile, potentially rapid, slurry of soil, rock, vegetation, and water. High water content is needed for this process to occur. Debris flows generally occur on both steep, planar hillslopes and confined, convergent hillslopes. Often a failure will initiate as a debris slide, but will change as its moves downslope to a debris flow. During this analysis these types of failures were mapped as debris flows.

Debris torrents are relatively rare, but have the greatest potential to destroy stream habitat and deliver large amounts of sediment. The main characteristic distinguishing a debris torrent is that the failure "torrents" downstream in a confined channel and scours the channel. As the debris torrent moves downslope and scours the channel, the liquefied landslide material increases in mass. A highly saturated soil or run-off in a channel is required for this process to occur. Debris torrents move rapidly and can potentially run down a channel for great distances. They typically initiate in headwall swales and torrent down intermittent watercourses. Often a failure will initiate as a debris slide, but will develop into a debris torrent upon reaching a channel. While actually a combination of two processes, these features were considered debris torrents.

Sediment Input from Shallow-Seated Landslides

The overall time period used for mass wasting interpretation and sediment budget analysis is thirty-two years. Sediment input to stream channels by mass wasting is quantified for three time periods (1969-1978, 1979-1987, 1988-2000). This is assumed because of the use of 1978, 1987/90, 1996, and 2000 aerial photographs and field observations in 2000. The evaluation is initiated at 1969 based on the earliest aerial photograph year of 1978 and the assumption that landslides farther back than about ten years are too difficult to detect, with much certainty, from aerial photographs. This is because landslide surfaces can re-vegetate quickly, making them too difficult to see. We acknowledge that we have likely missed some small mass wasting events during the aerial photograph interpretation. However, we assume we have captured the majority of the larger mass wasting events in this analysis. It is the large mass wasting events that provide the greatest sedimentation impacts. In the case of the landslides observed in the Northern Russian River Creek WAU, landslides greater than 300 cubic yards in size represented over 85% of the sediment delivery estimated. Landslides greater than 200 and 100 cubic yards in size represented approximately 90% and 97%, respectively of the sediment delivery estimated.

Sediment delivery estimates from mapped shallow-seated landslides were used to produce the total mass wasting sediment input. Some of the sediment delivery from shallow-seated landslides is the result of conditions created by deep-seated landslides. For example, a deep-seated failure could result in a debris slide or torrent, which could deliver sediment. Furthermore, over-steepened scarps or toes of deep-seated landslides may have shallow failures associated with them. These types of sediment delivery from shallow-seated landslides associated with deep-seated landslides are accounted for in the delivery estimates.

Deep-Seated Landslides

The two deep-seated landslide processes identified in the Northern Russian River Creek WAU are rockslides and earth flows. The failure dates of the deep-seated landslides generally could not be estimated with confidence and the landslides are likely to be of varying age with some landslides potentially being over 10,000 years old. Many of the deep-seated landslides are considered “dormant”, but the importance of identifying them lies in the fact that if reactivated or accelerated, they have the potential to deliver large amounts of sediment and destroy stream habitat. Accelerated or episodic movement in some landslides is likely to have occurred over time in response to seismic shaking or frequent high rainfall events. Deep-seated landslides can be very large, exceeding tens to hundreds of acres.

Rockslides are deep-seated landslides with movement involving a relatively intact mass of rock and overlying earth materials. The failure plane is below the colluvial layer and involves the underlying bedrock. Mode of rock sliding generally is not strictly rotational or translational, but involves some component of each. Rotational slides typically fail along a concave surface, while translational slides typically fail on a planar or undulating surface of rupture. Rockslides commonly create a flat or back-tilted bench below the crown of the scarp. A prominent bench is usually preserved over time and can be indicative of a rockslide. Rockslides can fail in response to triggering mechanisms such as seismic shaking, adverse local structural geology, high rainfall, or channel incision. The stream itself can be the cause of chronic movement, if it periodically undercuts the toe of a rockslide.

Earth flows are deep-seated landslides composed of fine-grained materials and soils derived from clay-bearing rocks. Earth flow materials consist of 80% or more of the particles smaller than 2mm. Materials in an earth flow also commonly contain boulders, some very large, which move downslope in the clay matrix. Failure in earth flows is characterized by spatially differential rates of movement on discontinuous failure surfaces that are not preserved. The "flow" type of movement creates a landslide that can be very irregularly shaped. Some earth flow surfaces are dominantly grassland, while some are partially or completely forested. The areas of grassy vegetation are likely due to the inability of the unstable, clay-rich soils to support forest vegetation. The surface of an earth flow is characteristically hummocky with locally variable slope forms and relatively abundant gullies. The inherently weak materials within earth flows are not able to support steep slopes, therefore slope gradients are low to moderate. The rates of movement vary over time and can be accelerated by persistent high groundwater conditions. Timber harvesting can have the effect of increasing the amount of subsurface water, which can accelerate movement in an earth flow.

Sediment Delivery from Deep-Seated Landslides

A large, active deep-seated slide can deliver large volumes of sediment. Delivery generally occurs over long time periods compared to shallow-seated landslides, with movement delivering earth materials into the channel. These materials are then confined to the channel, resulting in an increased sediment load downstream of the failure. Actual delivery can occur by over-steepening of the toe of the slide and subsequent failure into the creek, or by the slide pushing out into the creek. It is very important not to confuse normal stream bank erosion at the toe of a slide as an indicator of movement of that slide. Before making such a connection, the slide surface should be carefully explored for evidence of significant movement, such as wide ground cracks. Sediment delivery could also occur in a catastrophic manner. In such a situation, large portions of the landslide essentially fail and move into the watercourse "instantaneously". These types of deep-seated failures are relatively rare and usually occur in response to unusual storm events or seismic ground shaking.

Movement of deep-seated landslides has definitely resulted in some sediment delivery in the Northern Russian River WAU. Quantification of the sediment delivery from deep-seated landslides was not determined in this watershed analysis. Factors such as rate of movement, or depth of the deep-seated landslide are difficult to determine without in-depth geotechnical observations that were not included in this analysis. Sediment delivery to watercourses from deep-seated landslides (landslides typically $\geq$10 feet thick) can occur by several processes. Such processes can include surface erosion and shallow-or deep-seated movement of a portion or all of the deep-seated landslide deposit.

The ground surface of a deep-seated landslide, like any other hillside surface, is subject to surface erosion processes such as rain drop impact, sheet wash (overland flow), and gully/rill erosion. Under these conditions the sediment delivery from surficial processes is assumed the same as adjacent hillside slopes not underlain by landslide deposits. The materials within the landslide are disturbed and can be arguably somewhat weaker. However, once a soil has developed, the fact that a deep-seated landslide underlies the slope should make little difference regarding sediment delivery generated by erosional processes that act at the ground surface. Of course fresh, unprotected surfaces that develop in response to recent or active movement could become a source of sediment until the bare surface becomes covered with leaf litter, re-vegetated, or soils developed.

Clearly, movement of a portion or all of a deep-seated landslide can result in delivery of sediment to a watercourse. To determine this, the slide surface should be carefully explored for evidence of movement. However, movement would need to be on slopes immediately adjacent to or in close proximity to a watercourse and of sufficient magnitude to push the toe of the slide into the watercourse. A deep-seated slide that toes out on a slope far from a creek or moves only a short distance downslope will generally deliver little to a watercourse. It is also important to realize that often only a portion of a deep-seated slide may become active, though the portion could be quite variable in size. Ground cracking at the head of a large, deep-seated landslide does not necessarily equate to immediate sediment delivery at the toe of the landslide. Movement of large deep-seated landslides can create void spaces within the slide mass. Though movement can be clearly indicated by the ground cracks, many times the toe may not respond or show indications of movement until some of the void space is “closed up”. This would be particularly true in the case of very large deep-seated landslides that exhibit ground cracks that are only a few inches to a couple of feet wide. Compared to the entire length of the slide, the amount of movement implied by the ground crack could be very small. This combined with the closing up or “bulking up” of the slide, would not generate much movement, if any, at the toe of the slide. Significant movement, represented by large wide ground cracks, would need to occur to result in significant movement and sediment delivery at the toe of the slide.

Use of SHALSTAB by Mendocino Redwood Company and for the Northern Russian River WAU

SHALSTAB, a coupled steady state runoff and infinite-slope stability model, is used by MRC as one tool to demonstrate the relative potential for shallow-landslide hazard across the MRC ownership. A detailed description of the model is available in Dietrich and Montgomery (1998). In the watershed analysis mass wasting hazard is expanded beyond SHALSTAB. Inner gorge or steep streamside areas are mapped and designated as terrain stability units. Relative areas of mass wasting and sediment delivery hazards are mapped using field and aerial photograph interpretation techniques. However, SHALSTAB output was used to assist in this interpretation of the landscape and terrain stability units.

METHODS

Landslide Inventory

The mass wasting assessment relies on an inventory of mass wasting features collected through the review of aerial photographs and field observations. The 2000 (color), 1996 (color), and 1987 (B&W) photograph sets used to interpret landslides are 1:12,000 scale and are owned by MRC. The 1981 (B&W) photograph set is 1:20,000 scale and was loaned from the Mendocino County Assessors office. MRC collected data regarding characteristics and measurements of the identified landslides. Since mass wasting events were essentially “sampled”, we acknowledge that some landslides may have been missed, particularly small ones that may be obscured by vegetation. A description of select parameters inventoried for each landslide observed in the field and during aerial photograph interpretation is presented below and tabulated in Figure A-1.

Figure A-1. Description of Select Parameters used to describe Mass Wasting in the Mass Wasting Inventory.

- Slide I.D. Number: Each landslide is assigned two numbers, the first indicating the USGS designated map section number the slide is mapped in, and the second indicating the consecutive slide number within that map section.
- Planning Watershed: Denotes the MRC planning watershed in which the landslide is located.
  UU = Upper Ackerman Creek

UL = Lower Ackerman Creek
UJ = Jack Smith Creek
UM = Mill Creek

- TSU # – Terrain Stability Unit in which landslide is located.
- Landslide Process:
  DS = debris slide
  DT = debris torrent
  DF = debris flow
  RS = rock slide
  EF = earth flow
- Certainty: The certainty of identification is recorded.
  D - Definite, P - Probable; Q - Questionable.
- Approximate Failure Date: Minimum failure date is typically the photo year that the slide first appears on or the year observed in the field.
- Slope Form: Geomorphology of slope (D – divergent, P – planar, C – convergent).
- Physical Characteristics: Include average length, width, depth, and volume of individual slides.
- Sediment delivery and routing: Includes sediment delivered to streams (N - no sediment delivered; Y - sediment delivered), estimate of the percent of landslide mass delivered, the type of stream that sediment was delivered to (perennial or ephemeral).
  - Land Use Association: Road, landing, or skid trail association.

Landslides identified in the field and from aerial photograph observations are plotted on a landslide inventory map (Map A-1). Shallow-seated landslides are represented as a point on the map, and deep-seated landslides are shown as a polygon representing the landslide deposit. Following movement of a deep-seated failure, the geomorphic expression of the head and lateral scarps changes over time by erosional processes. Delineation of the landslide scarps as we see them today on aerial photographs does not truly represent the slide scarp at the time of failure and mapping them becomes very interpretive. Therefore, the deep-seated landslides identified are strictly the landslide deposit.

Physical and geomorphic characteristics of shallow-seated landslides are categorized in a database including identification number, planning watershed, type of landslide, approximate failure date, slope gradient, length, width, depth, volume, sediment delivery, sediment routing, and associated land use (Table A-1). Landslide dimensions and depths can be quite variable; therefore length, width, and depth values that are recorded should be considered the estimated average of these attributes. In conversion of the landslide masses from volumes to tons, we assume a uniform bulk density of 1.35 g/cc.

Table A-1. Landslide Inventory for the Northern Russian River WAU.

Slide Number	Planning Watershed	MWMU #	Landslides: Process	Landslides: Certainty	Approx. Failure Date	Field Checked	Slope Gradient (%) Field	Slope Form	Average Landslide Dimensions (feet): Length	Width	Depth	Sediment Volume (cu. Yds)	Sediment Delivery?	Delivery (%)	Delivery Volume (cu. yds.)	Delivery Mass (tons)	Sediment Routing	Land Use Association	Comments
1-3	UU	8	DS	D	98	Y	82	P	45	52	3	260	N	0	0	0		road	roadcut failure
1-4	UU	8	DS	P	96	Y	52	C	25	30	4	111	N	0	0	0		road	
1-5	UU	8	DF	P	81	N		C	147	39	4	849	Y	63	535	722	ephemeral		
1-6	UU	4	DS	Q	81	N		C	92	36	4	491	Y	63	309	417	ephemeral		
1-7	UU	4	DS	Q	81	N		C	225	108	4	3600	Y	63	2268	3062	ephemeral		
17-3	UU	2	DS	Q	96	N		C	64	32	4	303	Y	63	191	258	perennial		
31-1	UU	8	DS	D	97	Y	77	C	60	63	7	980	N	0	0	0		road	at edge of masonite rd. overhangs at scarp
31-6	UU	7	DS	D	95	Y	41	C	70	100	5	1296	N	0	0	0		road	fill failure on EF. unit surface with ground cracks
31-7	UU	2	DS	D	95	Y	40	C	120	105	6	2800	Y	50	1400	1890	perennial	road	probably induced by weight of fill material
31-8	UU	2	DS	D	95	Y	44	C	50	44	3	244	Y	15	37	50	perennial	road	~500' up road from quarry
36-1	UU	4	DS	D	96	Y	77	C	56	76	5	788	Y	70	552	745	ephemeral	road	scarp below masonite rd.
36-2	UU	8	DS	D	81	N		C	30	26	4	116	Y	80	92	125	ephemeral	road	DS-DF complex
36-3	UU	4	DS	P	96	Y	79	C	28	22	4	91	Y	80	73	99	ephemeral	road	
36-5	UU	7	DS	D	98	Y	64	C	60	185	3	1233	N	0	0	0		road	fill failure nested on EF
4-2	UU	1	DS	D	96	Y	105	C	30	270	1.5	450	Y	100	450	608	perennial	road	steep streambank
4-3	UU	1	DS	D	81	Y	58	C	90	98	4	1307	Y	80	1045	1411	perennial	road	culvert induced
5-1	UU	6	DS	P	81	N		P	27	30	4	120	Y	100	120	162	perennial		inner gorge
6-1	UU	8	DS	D	87	Y	67	D	100	67	4	993	Y	65	645	871	perennial	road	streambank undercut of fill slope
6-2	UU	8	DS	D	87	Y	64	C	115	206	5	4387	Y	85	3729	5034	perennial	road	streambank undercut of fill slope
6-3	UU	5	DS	P	80	Y	52	C	240	95	5	4222	Y	80	3378	4560	perennial	road	field estimated age. when failed
6-4	UU	8	DS	P	87	Y	57	P	140	168	2	1742	Y	50	871	1176	perennial	road	
7-2	UU	4	DS	P	87	N		C	35	32	4	166	Y	63	105	141	ephemeral		
7-4	UU	2	DS	Q	96	N		C	64	70	4	664	Y	63	418	564	perennial		
7-6	UU	8	DT	D	96	Y	61	C	70	10	5	130	Y	95	123	166	perennial	road	
8-2	UU	8	DS	D	98	Y	86	D	45	78	2	260	N	0	0	0		road	
8-6	UU	4	DS	D	81	N		P	50	89	4	659	Y	100	659	890	perennial		inner gorge
8-7	UU	4	DS	D	81	N		P	50	56	4	415	Y	100	415	560	perennial		inner gorge
8-8	UU	1	DS	D	81	N		P	44	103	4	671	Y	100	671	906	perennial		inner gorge
9-1	UU	5	DS	D	96	Y	86	C	340	132	8	13298	Y	30	3989	5386	ephemeral	road	by rock quarry. Backtilted unit surface
9-7	UU	7	DS	D	95	Y	51	C	46	63	4	429	Y	30	129	174	perennial	road	gully above road
9-9	UU	8	DS	D	97	Y	69	C	85	45	5	708	Y	90	638	861	perennial		inner gorge
31-1	UM	3	DS	D	96	N		P	30	90	3	300	Y	43	129	174	ephemeral		
31-2	UM	3	DS	D	96	N		C	40	80	3	356	Y	43	153	206	ephemeral		
31-3	UM	3	DS	Q	96	N		P	25	20	3	56	Y	43	24	32	ephemeral		
31-4	UM	3	DS	Q	96	N		P	30	30	3	100	Y	43	43	58	ephemeral		
31-5	UM	3	DS	Q	87	N		C	30	20	3	67	Y	43	29	39	ephemeral		
31-7	UM	5	DS	P	2000	N		C	117	82	3	1066	Y	43	458	619	ephemeral		
31-8	UM	5	DS	Q	96	N		C	54	16	3	96	Y	43	41	56	ephemeral		
11-1	UL	3	DS	D	90	Y	69	C	160	140	6	4978	Y	80	3982	5376	perennial	road	
11-2	UL	4	DS	P	81	N		C	133	75	4	1478	Y	63	931	1257	ephemeral	road	
12-1	UL	4	DS	D	96	Y	75	P	80	62	6	1102	Y	20	220	298	perennial	road	scarp at masonite rd
12-2	UL	4	DS	D	96	Y	72	D	70	38	5	493	N	0	0	0		road	masonite rd.
12-3	UL	5	DS	D	95	Y	93	C	115	37	5	788	Y	90	709	957	perennial	road	
12-4	UL	4	DS	D	87	Y	62	C	45	105	3	525	N	0	0	0		road	fill failure
12-5	UL	4	DS	P	87	Y	82	P	85	41	4	516	Y	40	207	279	perennial	road	fill failure
2-1	UL	4	DF	D	81	N		C	112	51	4	846	N	0	0	0		road	DF runout 300' long
2-2	UL	4	DF	P	81	N		C	222	25	4	822	Y	63	518	699	perennial	road	
4-1	UL	8	DS	D	87	Y	71	C	71	39	5	513	N	0	0	0		road	fill failure on bark dump rd. culvert at lateral edge of slide
4-4	UL	8	DS	D	95	Y	57	C	25	180	3	500	Y	50	250	338	perennial	road	culvert at west edge of slide. DS in melange terrain
31-6	UJ	5	DS	P	96	N		C	65	35	3	253	Y	43	109	147	ephemeral		
4-1	UJ	4	DS	D	87	N		P	56	40	3.5	290	Y	43	125	169	perennial	road	
4-2	UJ	4	DS	D	87	N		P	88	64	3.5	730	Y	43	314	424	perennial	road	
4-3	UJ	4	DS	P	90	Y	68	C	170	60	3	1133	N	0	0	0			grassy surface
4-4	UJ	5	DS	P	98	Y	54	P	10	12	2	9	N	0	0	0		road	
4-5	UJ	5	DS	P	96	N		C	75	30	3	250	N	0	0	0			
4-7	UJ	5	DS	D	97	Y	41	P	45	20	4	133	N	0	0	0		road	cut bank
4-8	UJ	5	DS	D	98	Y	46	C	98	46	3.5	584	N	0	0	0		road	cut bank
4-9	UJ	4	DS	D	2000	N		C	49	25	3	136	N	0	0	0			failure below rock outcrop
5-1	UJ	2	DS	D	87	N		C	44	33	3	161	Y	43	69	94	ephemeral		
5-11	UJ	2	DS	Q	96	N		C	40	85	3	378	Y	100	378	510	ephemeral		
5-12	UJ	5	DS	Q	96	N		P	60	70	3	467	N	0	0	0			upper slope. mod. vegetated 96 photo
5-13	UJ	5	DS	P	97	Y	89	P	30	35	2	78	Y	20	16	21	perennial		cut bank
5-14	UJ	2	DS	P	95	Y	64	P	15	25	3	42	N	0	0	0			toe out to terrace
5-15	UJ	5	DS	D	97	Y	94	P	40	40	2	119	Y	20	24	32	perennial	road	cut bank

Table A-1. Landslide Inventory for the Northern Russian River WAU.

Slide Number	Planning Watershed	MWMU #	Landslides		Approx. Failure Date	Field Checked	Slope Gradient (%)	Slope Form	Average Landslide Dimensions (feet)			Sediment Volume (cu. Yds)	Sediment Delivery?	Delivery (%)	Delivery Volume (cu. yds.)	Delivery Mass (tons)	Sediment Routing	Land Use Association	Comments
			Process	Certainty			Field		Length	Width	Depth								
5-16	UJ	5	DS	D	81	N		P	194	61	3	1315	Y	43	565	763	ephemeral		
5-2	UJ	3	DS	P	96	N		C	33	33	3	121	Y	100	121	163	ephemeral		
5-3	UJ	3	DS	P	81	N		P	72	64	3	512	Y	43	220	297	ephemeral	skid	
5-5	UJ	5	DS	D	98	Y	69	P	125	50	2	463	N	0	0	0		landing	failure at edge of landing
5-6	UJ	2	DS	D	96	Y	58	P	15	15	3	25	Y	100	25	34	perennial	road	fill failure into creek
5-7	UJ	5	DS	Q	95	Y	94	P	30	60	4	267	N	0	0	0		road	cut bank
5-8	UJ	5	DS	D	98	Y	76	P	35	20	3.5	91	Y	30	27	37	perennial	road	slide from upper road to lower road
5-9	UJ	5	DS	Q	96	N		C	60	40	3	267	Y	43	115	155	perennial		shrub vegetation - 96 photo
6-1	UJ	5	DS	P	81	N		P	96	48	3	512	N	0	0	0			
6-10	UJ	3	DS	Q	96	N		C	40	20	3	89	Y	43	38	52	ephemeral		
6-11	UJ	4	DS	P	96	N		C	20	40	3	89	Y	100	89	120	ephemeral		
6-12	UJ	4	DS	Q	96	N		C	40	30	3	133	Y	43	57	77	ephemeral		
6-13	UJ	5	DS	Q	81	N		P	144	167	3	2672	Y	43	1149	1551			
6-2	UJ	4	DS	P	96	N		C	20	25	3	56	Y	100	56	75	ephemeral		
6-3	UJ	4	DS	Q	96	N		C	20	30	3	67	Y	43	29	39	ephemeral		
6-4	UJ	3	DS	Q	96	N		D	30	40	3	133	Y	100	133	180	ephemeral		at nose on confluence of creeks
6-5	UJ	3	DS	P	96	N		C	35	25	3	97	Y	100	97	131	ephemeral		
6-6	UJ	5	DS	Q	96	N		P	30	60	3	200	Y	100	200	270	ephemeral		
6-7	UJ	5	DS	P	96	N		C	60	25	3	167	Y	43	72	97	ephemeral		
6-9	UJ	5	DS	D	87	N		P	77	48	3	411	Y	43	177	238	ephemeral	skid	
7-1	UJ	5	DS	Q	96	N		P	80	48	3	427	N	0	0	0			
8-1	UJ	4	DT	D	87	N		C	260	48	3	1387	Y	100	1387	1872	ephemeral		
8-2	UJ	5	DS	Q	96	N		C	16	16	3	28	N	0	0	0			midslope
8-3	UJ	3	DS	P	96	N		P	30	20	3	67	Y	43	29	39			
8-4	UJ	4	DS	Q	96	N		P	25	15	3	42	Y	43	18	24	ephemeral		
8-6	UJ	4	DS	D	87	N		C	68	20	3	151	Y	43	65	88	ephemeral		
9-1	UJ	5	DS	P	87	N		C	64	20	3	142	Y	43	61	83	ephemeral		appears shallow. Thin soil over knocker
4-6	UJ		EF	D					1510	400									likely inactive-surface hummocky and forested
4-10	UJ		RS	D					920	1060									
5-17	UJ		RS	Q					840	420									
5-18	UJ		RS	D					260	320									
6-8	UJ		RS	Q					680	610									
5-10	UJ		RS	P					900	520									
4-11	UJ		RS	Q					660	1000									contours do not represent slide well
4-12	UJ		RS	Q					740	710									contours do not represent slide well
8-5	UJ		RS	Q					810	620									does not appear active
7-2	UJ		RS	Q					270	400									
31-2	UU		EF	D					1120	660									tilted fenceposts above road
31-9	UU		EF	D					2780	1030									
36-4	UU		EF	D					720	970									fenceposts above rd. tilted. Hummocky, grassy
31-3	UU		EF	D					1080	440									acticve - grassy, hummocky
1-2	UU		EF	Q					850	510									
1-1	UU		EF	P					2230	910									
6-5	UU		RS	D					2030	2120									RS complex-prominent scarp and unit surfaces suggest rockslide type movement
6-6	UU		EF	D					1080	640									east edge of slide has long narrow EF that is active at upper end
8-3	UU		EF	D					930	1280									
9-3	UU		EF	Q					370	570									
7-5	UU		RS	D					1360	1520									RS complex in melange
7-1	UU		EF	D					740	320									
9-8	UU		EF	D					510	330									unit surface above lower road. unit surf.~10%slope. steep at creek
9-5	UU		EF	P					610	1970									
8-4	UU		RS	Q					370	610									
9-6	UU		EF	P					610	710									
7-3	UU		EF	P					480	780									
7-7	UU		EF	P					490	390									
8-5	UU		EF	P					920	290									
17-1	UU		EF	D					4150	1360									
7-8	UU		RS	P					360	510									
7-9	UU		EF	D					1060	230									
7-10	UU		RS	P					660	330									
17-4	UU		EF	P					610	550									
17-2	UU		EF	D					620	130									

Extensive effort was put into the identification of deep-seated landslides throughout the Northern Russian River WAU. The attributes of the deep-seated landslides received less attention in the landslide inventory than shallow-seated landslides mainly due to the fact that geotechnical analyses would be necessary to estimate such features as depth, failure date, activity, and sediment delivery. Only basic information on the deep-seated landslides such as location and surface area was collected. Only a couple of the mapped deep-seated landslides were observed to have recent movement associated with them. The deep-seated landslides will be treated on a site-by-site basis in the Northern Russian River WAU, likely during timber harvest plan preparation and review.

The certainty of landslide identification is also designated for each landslide. Three designations of certainty of identification are used: definite, probable, and questionable. Definite means the landslide definitely exists. Probable means the landslide probably is there, but there is some doubt (by the analyst) about its existence. Questionable means that the interpretation of the landslide identification may be inaccurate, the analyst has the least amount of confidence in the interpretation. Accuracy in identifying landslides on aerial photographs is dependent on the size of the slide, scale of the photographs, thickness of canopy, and logging history. Landslides mapped in areas recently logged or through a thin canopy are identified with the highest level of confidence. Characteristics of the particular aerial photographs used affects confidence in identifying landslides. For example, sun angle creates shadows which may obscure landslides, the print quality of some photo sets varies, and photographs taken at smaller scale makes identifying small landslides difficult. The landslide inventory results are considered a minimum estimate of sediment production. This is because landslides that were too small to identify on aerial photographs may have been missed, landslides could have reactivated in subsequent years and not been quantified, and secondary erosion by rills and gullies on slide surfaces is difficult to assess. However, small landslides cumulatively may not deliver amounts of sediment that would significantly alter total sediment delivery.

Dimensions (average length and width) for landslides not visited in the field were determined by measuring the failure as interpreted directly from aerial photographs and extrapolating the dimension to represent slope distance for a 70% slope gradient. The 70% slope gradient is assumed to be representative of average conditions for development of a shallow-seated landslide. To extrapolate depth to the shallow-seated landslides not visited in the field, the mean value of slide depths was extrapolated for shallow-landslides that were not visited in the field.

Two techniques were employed in order to extrapolate a sediment volume delivery percentage to landslides not visited in the field. Landslides that were determined to be directly adjacent to a watercourse were assigned 100% delivery. Landslides that were determined to deliver, but were not directly adjacent to a watercourse, were assigned the mean delivery percentage determined from landslides observed in the field.

The likelihood that some land use practice was associated with the slope failure was also noted. In this analysis, different silvicultural techniques were not recorded. This was because the Northern Russian River WAU has been managed, both currently and historically, for timber production, and the effect of these different silvicultural practices was too difficult to confidently interpret. There have been too many different silvicultural activities over time for reasonable confidence in a landslide evaluation based on silviculture. The land use practices that were assigned to landslides were associations with roads, skid trails, or landings. It was assumed that a landslide adjacent to a road, landing, or skid trail was triggered either directly or indirectly by that land use practice. If a landslide appeared to be influenced by more than one land use practice, the more causative one was noted. If a cutslope failure did not cross the road prism, it was assumed that the failure would remain perched on the road, landing, or skid trail and would not deliver to a watercourse. Some surface erosion could result from a cutslope failure; this is assumed to be addressed in the road surface erosion estimates (Surface Erosion module).

Terrain Stability Units

Terrain Stability Units (TSUs) are delineated by partitioning the landscape into zones characterized by similar geomorphic attributes, shallow-seated landslide potential, and sediment delivery potential to stream channels. A combination of aerial photograph interpretation, field investigation, and SHALSTAB output were utilized to delineate TSUs. The TSU designations for the Northern Russian River WAU are only meant to be general characterizations of similar geomorphic and terrain characteristics related to shallow-seated landslides. Deep-seated landslides are also shown on the TSU map (Map A-2). The deep-seated landslides have been included to provide land managers with supplemental information to guide evaluation of harvest planning and subsequent needs for geologic review. The landscape and geomorphic setting in the Northern Russian River WAU is certainly more complex than generalized TSUs delineated for this evaluation. The TSUs are only meant to be a starting point for gauging the need for site-specific field assessments.

The delineation of each TSU described is based on landforms present, mass wasting processes, sensitivity to forest practices, mass wasting hazard, delivery potential, hazard potential, and forest management related trigger mechanisms for shallow-seated landslides. In the TSU description, the mass wasting process section is a summary of the landslide types found in the TSU. Sensitivity to forest practice and mass wasting hazard is, in part, a subjective call by the analyst based on the relative landslide hazard and influence of forest practices. Sediment delivery potential is based on proximity of TSU to watercourses and the likelihood of earth materials generated by mass wasting in the unit to reach a watercourse. If greater than 66% of the landslides in a TSU deliver sediment then the TSU is designated as having a high delivery potential. If between 33% and 66% of the landslides in a TSU deliver sediment then the TSU is designated as having a moderate delivery potential, whereas less than 25% delivery would be a low delivery potential. The hazard potential is based on a combination of the mass wasting hazard and delivery potential (Figure A-2.). Finally in the TSU description the trigger mechanisms are a list of forest management practices that may have the potential to create mass wasting in the TSU.

Figure A-2. Ratings for Potential Hazard of Delivery of Debris and Sediment to Streams by Mass Wasting (letters designate hazard: L= low, M= moderate, H = high)(Version 3.0, Washington Forest Practices Board, 1995).

Mass Wasting Potential

		Low	Moderate	High
Delivery Potential	Low	**L**	**L**	**M**
	Moderate	**L**	**M**	**H**
	High	**L**	**M**	**H**

RESULTS

Mass Wasting Inventory

A Landslide Inventory Data Sheet (Table A-1) was used to record attributes associated with each landslide. The spatial distribution and location of landslides is shown on Map A-1. A total of 91 shallow-seated landslides (debris slides, torrents or flows) were identified and characterized in the Northern Russian River WAU. Thirty five deep-seated landslides (rock slides or earth flows) were mapped in the Northern Russian River WAU. A considerable effort was made to field verify as many landslides as possible to insure greater confidence in the results. A total of 43% of the identified shallow-seated landslides were field verified. From this level of field observations, extrapolation of landslide depth and sediment delivery was performed with a reasonable level of confidence. The difference between the mean depth of road-related shallow landslides and the mean depth of non road-related shallow landslides was determined to be significant for the Reeves Canyon area. Therefore, in Reeves Canyon the mean depth of road related landslides of 3.5 feet was assumed for road related landslides that were not visited in the field and the mean depth of non-road related landslides of 3 feet was assumed for all non-road related landslides not field checked. There was no separation of road-to-non-road associated landslide depths in calculation of the mean depth in Ackerman Creek due to a lack of non-road associated landslides. Therefore, the mean depth of all field checked shallow-seated landslides in Ackerman Creek is 4 feet and is assigned to all shallow landslides that were not field checked. The mean sediment delivery percentage assigned to shallow-seated landslides determined to deliver sediment (but not visited in the field) is 43% for Reeves Canyon and 63% for Ackerman Creek. Deep-seated landslides did not have depth or sediment delivery statistics calculated.

The temporal distribution of the 91 shallow-seated landslides observed in the Northern Russian River WAU is listed in Table A-2. The spatial distribution by landslide process is shown in Table A-3.

Table A-2. Shallow-Seated Landslide Summary for the Northern Russian River WAU Divided into Time Periods.

Planning Watershed	1972-1981 Landslides	1982-1987 Landslides	1988-2000 Landslides
Upper Ackerman Creek	10	4	17
Lower Ackerman Creek	3	3	5
Jack Smith Creek	4	7	31
Mill Creek	0	1	6

Table A-3. Slide Summary by Type and Planning Watershed for MRC Ownership in the Northern Russian River WAU.

Planning Watershed	Debris Slides	Debris Torrents	Debris Flows	Rock Slides	Earth Flows	**Total**	*Road Assoc.*
Upper Ackerman Creek	29	1	1	5	20	**56**	*20*
Lower Ackerman Creek	9	0	2	0	0	**11**	*11*
Jack Smith Creek	41	1	0	9	1	**52**	*9*
Mill Creek	7	0	0	0	0	**7**	*0*

The majority of deep-seated landslides in Reeves Canyon are rockslides, while in Ackerman Creek, the majority is earth flows. Only a few of the deep-seated landslides are known to be active and the remaining are assumed to be dormant features. The spatial distribution of deep-seated landslides in the two areas of the Northern Russian River WAU is indicative of differing hillslope processes between the dominating mélange-type terrain of Ackerman Creek and the relatively resistant bedrock terrain of Reeves Canyon. The majority of shallow-seated landslides observed in the Northern Russian River WAU are debris slides. Of the 91 shallow-seated landslides in the Northern Russian River WAU, 40 are determined to be road-related. This is approximately 44% of the total number of shallow-seated landslides. Only two debris torrents were observed in the entire Northern Russian River WAU. This is approximately 2% of the total shallow landslides. Also, only two debris flows were observed, accounting for approximately 2% of the total shallow-seated landslides. Debris torrents or flows are not common in the Northern Russian River WAU, but do occur and are processes that should be taken into account in relation to forest management practices.

Eighty-seven percent of the shallow landslides inventoried were initiated on slopes greater than 60% gradient, with the exception of 12 landslides with gradients in the 40% and 50% range. All of those landslides were attributed to road practices and some were likely affected to a degree by the unstable nature of the mélange terrain present in the Ackerman Creek area. The majority of inventoried landslides originated in convergent topography where subsurface water tends to concentrate or on steep, planar topography where sub-surface water can be concentrated at the base of slopes, in localized topographic depressions, or by subsoil geologic structures. Few landslides originated in divergent topography, where sub-surface water is routed to the sides of ridges. These observations were, in part, the basis for the delineation of the Northern Russian River WAU into Terrain Stability Units.

Terrain Stability Units

The landscape was partitioned into seven Terrain Stability Units (TSU) representing general areas of similar geomorphology, landslide processes, and sediment delivery potential for shallow-seated landslides (Map A-2). The units are to be used by forest managers to assist in making decisions that will minimize future mass wasting sediment input to watercourses. The delineation for the TSUs was based on qualitative observations and interpretations from aerial photographs, field evaluation, and SHALSTAB output. Deep-seated landslides are also shown on the TSU map (Map A-2). The deep-seated landslides have been included to provide land managers with supplemental information to guide evaluation of harvest planning and subsequent needs for geologic review.

Shallow-seated landslide characteristics considered in determination of map units are size, frequency, delivery to watercourses, and spatial distribution. Hillslope characteristics considered are slope form (convergence, divergence, planar), slope gradient, magnitude of stream incision, and overall geomorphology. The range of slope gradients was determined from USGS 1:24000 topographic maps and field observations. Hillslope and landslide morphology vary within each individual Terrain Stability Unit and the boundaries are not exact. This evaluation is not intended to be a substitute for site-specific field assessments. Site-specific field assessments will still be required in some TSUs and deep-seated landslides or specific areas of some TSUs to assess the risk and likelihood of mass wasting impacts from a proposed management action. The Terrain Stability Units are compiled on the entitled Terrain Stability Unit Map (Map A-2).

TSU Number: 1

Landform: Inner gorge or steep streamside slopes along low gradient watercourses

Materials: Commonly bedrock slopes with a veneer of colluvial or alluvial soil deposits. Also, may be composed of toe sediment of deep-seated landslide deposit.

Description: Characterized by steep streamside slopes or inner gorge topography along low gradient watercourses (typically less than 6-7%). An inner gorge is a geomorphic feature created from down cutting of the stream, generally in response to tectonic uplift. Inner gorge slopes extend from either one or both sides of the stream channel to the first break in slope. Inner gorge slope gradients typically exceed 70%, although slopes with lower inclination are locally present. Inner gorge slopes commonly contain areas of multiple, coalescing shallow seated landslide scars of varying age. Steep streamside slopes are characterized by their lack of a prominent break in slope. Slopes are generally planar in form with slope gradients typically exceeding 70%. The upper extent of TSU 1 is variable. Where there is not a break in slope, the unit may extend 300 feet upslope (based on the range of lengths of landslides observed, 20-300 feet). Landslides in this unit generally deposit sediment directly into Class I and II streams. Small areas of incised terraces may be locally present.

Slope: >70% to vertical, (mean slope of 2 observed mass wasting events is 82%, range: 58%-105%)

Total Area: 125 acres; 2 % of the total WAU area.

MW Processes: *2 road-associated landslide*

- 2 debris slides

3 non-road associated landslides

- 3 debris slides

Non Road-related Landslide Density: 0.024 landslides per acre for the past 29 years

Forest Practices Sensitivity: High sensitivity to roading because slopes are directly adjacent to watercourses, bedrock underlying inner gorge slopes generally results in increased stability. High sensitivity to harvesting and forest management practices due to steep slopes with localized colluvial or alluvial soil deposits next to watercourses.

Mass Wasting Potential: High localized potential for landslides in both unmanaged and managed conditions.

Delivery Potential: Very High

Delivery Criteria Used: Steep slopes adjacent to stream channels, all landslides delivered sediment into streams.

Hazard-Potential Rating: **High**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on steep slopes can initiate debris slides or flows in this unit.
- Concentrated drainage from roads onto unstable areas can initiate debris slides or flows in this unit.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit.
- Cut-slope of roads or skid trails can remove support of slope and/or expose potential failure planes (such as soil-bedrock contact) creating debris slides, torrents or flows in this unit.
- Sidecast fill material created from skid trail construction placed on steep slopes can initiate debris slides or flows in this unit.
- Concentrated drainage from skid trails onto unstable areas can initiate debris slides or flows in this unit.
- Root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.
- Concentrated drainage from roads can increase groundwater, accelerating movement of rock slides or earth flows and over-steepening inner gorge slopes.
- Loss of evapo-transpiration from forest harvest above unit can increase groundwater levels initiating or accelerating movement in rock slides or earth flows or aid in the initiation of debris slides, torrents or flows.

Confidence: High confidence for susceptibility of landslides and sediment delivery in this unit. High confidence in placement of this unit because of variable nature of materials comprising mélange terrain and lack of continuous, bedrock-controlled slopes. This unit is locally variable and exact boundaries are better determined from field observations.

TSU Number: 2

Landform: Steep slopes or inner gorge adjacent to select intermittent or ephemeral streams

Materials: Shallow soils formed from weathered marine sedimentary rocks.

Description: Characterized by steep streamside slopes or inner gorge topography along low gradient watercourses (typically greater than 6-7%). An inner gorge is a geomorphic feature created from down cutting of the stream, generally in response to tectonic uplift. Inner gorge slopes extend from either one or both sides of the stream channel to the first break in slope. Inner gorge slope gradients typically exceed 70%, although slopes with lower inclination are locally present. Inner gorge slopes commonly contain areas of multiple, coalescing shallow seated landslide scars of varying age. Steep streamside slopes are characterized by their lack of a prominent break in slope. Slopes are generally planar in form with slope gradients typically exceeding 70%. The upper extent of TSU 2 is variable. Where there is not a break in slope, the unit may extend 132 feet upslope (based on the range of lengths of landslides observed, 16-132 feet). Landslides in this unit generally deposit sediment directly into Class II and III streams.

Slope: 60%-vertical (mean slope of observed mass wasting events is 63%, range: 40%-94%)

Total Area: 235 acres; 4% of total WAU area

MW Processes: *11 non-road associated landslides*

- 10 Debris slides
- 1 Debris torrent

11 road associated landslides

- 11 Debris slides

Non Road-related Landslide Density: 0.047 landslides per acre for the past 29 years.

Forest Practices Sensitivity: High sensitivity to roads due to steep slopes adjacent to watercourses, high to moderate sensitivity to harvesting and forest management due to steep slopes next to watercourses. Localized areas of steeper slopes have an even higher sensitivity to forest practices.

Mass Wasting Potential: High, due to localized steep slopes in both unmanaged and managed conditions.

Delivery Potential: High

Delivery Criteria

Used: Steep slopes adjacent to stream channels, 95% of landslides observed in this unit delivered sediment.

Hazard-Potential Rating: **High**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on steep slopes can initiate debris slides, torrents or flows.
- Concentrated drainage from roads onto unstable areas can initiate debris slides, torrents or flows.
- Concentrated drainage from roads can increase groundwater, accelerating movement of rock slides or earth flows.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows.
- Cut-slope of roads or skid trails can over-steepen the slope creating debris slides, torrents or flows in this unit.
- Cut-slope of roads or skid trails can remove support of the toe or expose potential failure planes (such as soil-bedrock contact) of rock slides or earth flows.
- Sidecast fill material created from skid trail construction placed on steep slopes can initiate debris slides, torrents or flows.
- Concentrated drainage from skid trails onto unstable areas can initiate debris slides, torrents or flows.
- Root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.
- Loss of evapo-transpiration from forest harvest in unit or above it can increase groundwater levels initiating or accelerating movement in rock slides or earth flows or aid in the initiation of debris slides, torrents or flows.

Confidence: High confidence for susceptibility of unit to deliver sediment and in placement of the unit. Moderate confidence in the overall hazard rating of this unit. Some of the slopes may not be as susceptible to mass wasting as others do to localized variations in ground water, strengths of materials, and topographic conditions. Locally, the upper boundary can be difficult to define in the field.

TSU Number: 3

Landform: Dissected and convergent topography

Materials: Shallow soils formed from weathered marine sedimentary rocks with localized thin to thick colluvial deposits.

Description: These areas have steep slopes (typically greater than 65%) that have been sculpted over geologic time by repeated debris slide events. The area is characterized primarily by 1) steep convergent and dissected topography located within steep gradient collivial hollows or headwall swales and small high gradient watercourses, and 2) locally steep planar slopes where there is strong evidence of past landsliding. MRC intends this unit to represent areas with a high hazard potential for shallow landsliding, while not constituting a continuous streamside unit (otherwise it would classify as TSU 1 or 2). The mapped unit may represent isolated individual "high hazard" areas or areas where there is a concentration of "high hazard" areas. Boundaries between higher hazard areas and other more stable areas (i.e. divergent and lower gradient slopes) within the unit should be keyed out as necessary based on field observation of landslide features.

Slope: >60%, (mean slope of observed mass wasting events is 74% range: 62%-82%)

Total Area: 1499 ac., 26% of the total WAU

MW Processes:

11 road associated landslides

- 10 Debris slides
- 1 Debris flow

15 non-road associated slides

- 12 Debris slides
- 1 Debris torrent
- 2 Debris flows

Non Road-related Landslide Density: 0.027 landslides per acre for the past 29 years

Forest Practices Sensitivity: Moderate to high sensitivity to road building due to steep and/or convergent topography. Moderate to high sensitivity to harvesting and forest management practices due to localized areas of steeper and/or convergent slopes that can have higher sensitivity to forest practices.

Mass Wasting Potential: High

Delivery Potential: High

Delivery Criteria

Used: The converging topography directs mass wasting down slopes toward watercourses. Failures in headwater swales can torrent or flow down watercourses. Approximately 78% of landslides in this unit delivered sediment.

Hazard-Potential Rating: **High**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on steep slopes can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads onto unstable areas can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads can increase groundwater, accelerating movement of rock slides or earth flows in this unit.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit.
- Cut-slope of roads or skid trails can over-steepen the slope creating debris slides, torrents or flows in this unit.
- Cut-slope of roads or skid trails can remove support of the toe or expose potential failure planes (such as soil-bedrock contact) of rock slides or earth flows.
- Sidecast fill material created from skid trail construction placed on steep slopes can initiate debris slides, torrents or flows.
- Concentrated drainage from skid trails onto unstable areas can initiate debris slides, torrents or flows.
- Root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.
- Loss of evapo-transpiration from forest harvest can increase groundwater levels initiating or accelerating movement in rock slides or earth flows or aid in the initiation of debris slides, torrents or flows.

Confidence: High confidence in delineation of this unit based on its correlation with SHALSTAB. Some areas within this unit could have higher susceptibility to landslides and higher delivery due to localized areas of steep slopes, weaker soils, and proximity to a watercourse.

TSU Number: 4

Landform: Non-dissected topography

Materials: Shallow to moderately deep soils formed from weathered marine sedimentary rocks.

Description: Moderate to moderately steep hillslopes with planar, divergent, or broadly convergent slope forms with isolated areas of steep topography or strongly convergent slope forms. Unit 4 is generally a midslope region of lesser slope gradient and more variable slope form than unit 3.

Slope: >40%, (mean slope of observed mass wasting events 74%, range: 46%-94%)

Total Area: 396 acres, 7% of the total WAU

MW Processes: *6 road-associated landslides*

- 6 Debris slides

5 non-road associated slides

- 5 Debris slides

Non Road-related Landslide Density: 0.013 landslides per acre for the past 29 years

Forest Practices Sensitivity: Moderate to low sensitivity to road building, moderate to low sensitivity to harvesting and forest management practices due to moderate slope gradients and non-converging topography within this unit. Localized areas of steeper slopes can have a relatively higher sensitivity to forest practices

Mass Wasting Potential: Moderate

Delivery Potential: Moderate

Delivery Criteria Used: Sediment delivery in this unit is localized to landslides that occur adjacent to watercourses, or have long run-outs to a watercourse. Approximately 36% of landslides in this unit delivered sediment.

Hazard-Potential Rating: **Moderate**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on steep slopes can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads, skid trails, or landings can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads, skid trails, or landings can increase groundwater, potentially accelerating movement of rock slides in this unit.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit.
- Cut-slope of roads or skid trails can over-steepen the slope creating debris slides, torrents or flows in this unit.
- Cut-slope of roads, skid trails, or landings can remove support of the toe or expose potential failure planes (such as soil-bedrock contact) of rock slides.
- Sidecast fill material created from skid trail construction placed on locally steeper slopes can initiate debris slides, torrents or flows.
- Root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.
- Loss of evapo-transpiration from forest harvest can increase groundwater levels initiating or accelerating movement in rock slides or aid in the initiation of debris slides, torrents or flows.

Confidence: Moderate due to inexactness of boundary locations between this TSU unit and units 8, 6, and where earth flows of unit 7 are mapped as questionable deep-seated landslides. Some areas within this unit could have higher susceptibility to landslides and higher delivery rates due to localized areas of steep slopes with weak soils, and adverse groundwater conditions.

TSU Number: 5	
Landform:	Low relief topography
Material:	Moderately deep, to deep soils, formed from weathered marine sedimentary rocks. Also stream terrace deposits of Ackerman Creek.
Description:	Characterized by low gradient slopes generally less than 40%, although in some places slopes can be steeper. This unit occurs on ridge crests, low gradient side slopes, and terraces of Ackerman Creek. This unit can have some localized areas of moderately steep (>%), concave topography which can be more prone to mass wasting processes. Shallow-seated landslides seldom occur and usually do not deliver sediment to stream channels.
Slope:	<40%
Total Area:	105 acres, 2% of WAU area
MW Processes:	*No observed shallow-seated landslides*
Non Road-related Landslide Density:	0 landslides per acre for past 29 years.
Forest Practices Sensitivity:	Low sensitivity to road building and forest management practices due to low gradient slopes
Mass Wasting Potential:	Low
Delivery Potential:	Low
Delivery Criteria Used:	Mass wasting seldom occurs in this unit, therefore little sediment delivery occurs.
Hazard-Potential Rating:	**Low**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on locally steeper slopes can initiate debris slides, torrents or flows.
- Concentrated drainage from roads can initiate debris slides, torrents or flows.
- Concentrated drainage from roads can increase groundwater, potentially accelerating movement of rock slides or earth flows.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows.
- Cut-slope of roads can over-steepen the slope, potentially creating debris slides.
- Concentrated drainage from skid trails can initiate debris slides, torrents or flows.
- Concentrated drainage from roads and skid trails can initiate or accelerate gully erosion, which can increase the potential for mass wasting processes.

Confidence: Moderate, due to inexactness of boundary locations between this TSU unit and units 8, 6, and where earth flows of unit 7 are mapped as questionable deep-seated landslides. High confidence in mass wasting potential and sediment delivery potential ratings.

TSU Number: 6

Landform: Earth Flow Topography

Materials: Fine-grained soils and clays derived from highly weathered and sheared marine sedimentary rocks and mélange terrain. Soils contain >80% particles less than 2mm in size with blocks of rock, some very large, within the soil matrix. Very large blocks are generally hard and commonly known as “knockers”.

Description: Boundaries of this unit correspond to the mapped, deep-seated earth flows from mass wasting inventory, regardless of state of activity. Characterized by hummocky slopes with localized areas of steep, and areas of flat topography. Slopes commonly contain areas of backtilted topography, creating ponded water. Ground surfaces in this unit commonly contain areas of grassy vegetation, which is attributed to history of cattle grazing and the inability of the clay-rich soil to support dense forests. Gullies are abundant in this unit. Rate of movement within earth flows typically is variable and likely fluctuates seasonally according to groundwater conditions. Unit 6 is composed of earth flow complexes with many scarps and benches that create a step-like profile.

Slope: Variable, but typically moderate (<60%)

Total Area: 501 acres; 9% of the total WAU.

MW Processes: *21 Earthflows*

- 3 road associated shallow-landslides
- 3 Debris slides

Non Road-related Landslide Density: 0.048 landslides per acre for past 29 years (earthflows and debris slides).

Forest Practices Sensitivity: High sensitivity to roads, harvesting, and forest management practices on active earth flow surfaces. Moderate sensitivity to roads, harvesting, and forest management practices on non-active earth flow surfaces due to localized areas of variable topography. Potential forest practices in this unit should be assessed on a very local scale due to variable topography and differing rates of movement within an earth flow.

Mass Wasting Potential: High

Delivery Potential: High

Delivery Criteria Used: Many of the earth flows in the Willow/Freezeout Creek WAU have the toe or lateral edges along watercourses. If earth flow movement occurs the landslides will deliver sediment.

Hazard Potential Rating: **High**

Forest Management Related Trigger Mechanisms:

- Sidecast fill material placed on locally steep slopes can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads onto unstable areas can initiate debris slides, torrents or flows in this unit.
- Concentrated drainage from roads can increase groundwater, accelerating movement of earth flows of this unit.
- Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can over-steepen the slope creating debris slides in this unit.
- Concentrated drainage from skid trails onto unstable areas can initiate debris slides, torrents or flows in this unit.
- Loss of evapo-transpiration from forest harvest can increase groundwater levels initiating or accelerating movement of earth flows of this unit or aid in initiation of debris slides, torrents or flows.
- Concentrated drainage from roads and skid trails can initiate or accelerate gully erosion, which can increase the potential for mass wasting processes.
- Cut-slope of skid trails can remove support of the toe or expose potential failure planes of earth flows.
- Sidecast fill material created from skid trail construction placed on locally steep slopes can initiate debris slides, torrents or flows.
- Root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.

Confidence: Confidence in delineation of unit is consistent with confidence level in mass wasting inventory mapping of deep-seated earth flows. High confidence in hazard potential rating due to relatively low hazard for shallow-seated landslides

TSU Number: 7

Landform: Accelerated Soil Creep

Materials: Fine-grained soils from highly weathered and sheared marine sedimentary rocks and mélange terrain. Soils contain blocks of rock, some very large, within the soil matrix. Very large blocks are generally hard and commonly known as “knockers”.

Description: Characterized by hummocky slopes with localized areas of steep and flat topography. Ground surfaces in this unit commonly contain areas of grassy vegetation, which may be attributed to a long history of cattle grazing and the inability of the clay-rich soil to support dense forests. Gullies were observed in the headwalls of some drainages. Unit 8 is identified by “rumpled” look of ground surface, similar to unit 7, but lacking scarps and benches.

Slope: >20%, (mean slope of observed mass wasting events 71%, range: 52%-86%).

Total Area: 2410 acres; 42% of the total WAU

MW Processes: *6 road associated landslides*

- 6 debris slides

1 non-road associated landslides

- 1 debris slide

Non Road-related Landslide Density: 0.0004 landslides per acre for the last 29 years

Forest Practices Sensitivity: Generally a moderate sensitivity to roads, harvesting, and forest management practices except where localized areas of steep slopes exist.

Mass Wasting Potential: Low potential for shallow-seated landslides.

Delivery Potential: Low delivery potential for shallow-seated landslides.

Delivery Criteria Used: 28% of landslides in this unit delivered sediment.

Hazard Potential Rating: **Low**

Forest Management Related Trigger Mechanisms:	•Sidecast fill material placed on locally steep slopes can initiate debris slides, torrents or flows in this unit. •Concentrated drainage from roads onto unstable areas can initiate debris slides, torrents or flows in this unit. •Concentrated drainage from roads can increase groundwater, accelerating movement of rock slides in this unit. •Poorly sized culvert or excessive debris at watercourse crossings can initiate failure of the fill material creating debris slides, torrents or flows in this unit. •Cut-slope of roads can over-steepen the slope creating debris slides in this unit. •Concentrated drainage from skid trails onto unstable areas can initiate debris slides, torrents or flows in this unit. •Loss of evapo-transpiration from forest harvest can increase groundwater levels initiating or accelerating movement of rock slides in this unit or aid in initiation of debris slides, torrents or flows. •Concentrated drainage from roads and skid trails can initiate or accelerate gully erosion, which can increase the potential for mass wasting processes. •Cut-slope of skid trails can remove support of the toe or expose potential failure planes of earth flows. •Sidecast fill material created from skid trail construction placed on locally steep slopes can initiate debris slides, torrents or flows. • Root decay of hardwood or non-redwood conifer species can be a contributing factor in the initiation of debris slides, torrents or flows in this unit.
Confidence:	Moderate confidence in the delineation of this unit due to similarities of terrain of this unit with that of units 5,6, and 7. Moderate confidence in hazard rating.

Sediment Input from Mass Wasting

Sediment delivery was estimated for shallow-seated landslides in the Northern Russian River WAU. Landslides were determined to have either no sediment delivery or to deliver all or a percentage of their total volume. Of the shallow-seated landslides mapped by MRC in this watershed analysis, 76 percent of the landslides delivered some amount of sediment (Table A-4).

Table A-4. Total Shallow-Seated Landslides Mapped for each Watershed in the Northern Russian River WAU. (Road Associated Landslides are Included).

Planning Watershed	Total slides	Landslides with Sediment Delivery	Landslides with No Sediment Delivery
Upper Ackerman Creek	31	25	6
Lower Ackerman Creek	10	7	4
Jack Smith Creek	43	29	12
Mill Creek	7	7	0
Sum	91	68	23
Percentage	100%	76%	24%

Mass wasting was separated into three time periods for data analysis. The first time period is for mass wasting that occurred from 1972-1981, the second time period assessed is from 1979-1987, and the third time period assessed is from 1988-2000. The cut-off dates from each of the time periods are based on the date of aerial photographs used to interpret landslides (1981, 1987, 1996, and 2000) and field observations (2000). While the available aerial photograph years did not allow for perfect ten year time periods for mass wasting assessment, the time periods are as reasonably close to ten year periods as possible. The periods used in this analysis are useful to provide a general idea of the relative magnitude of sediment delivery for the time periods analyzed, particularly the sediment delivery rate estimates.

A total of 49,005 tons of mass wasting sediment delivery was estimated for the time period 1972-2000 in the Northern Russian River WAU. This equates to 191 tons/sq. mi./yr. Of the total estimated amount, 17,384 tons (35% of total) occurred from 1972-1981, 10,507 tons (21% of total) occurred from 1982-1987, and 21,114 tons (43% of total) occurred in the 1988-2000 time period (Table A-5).

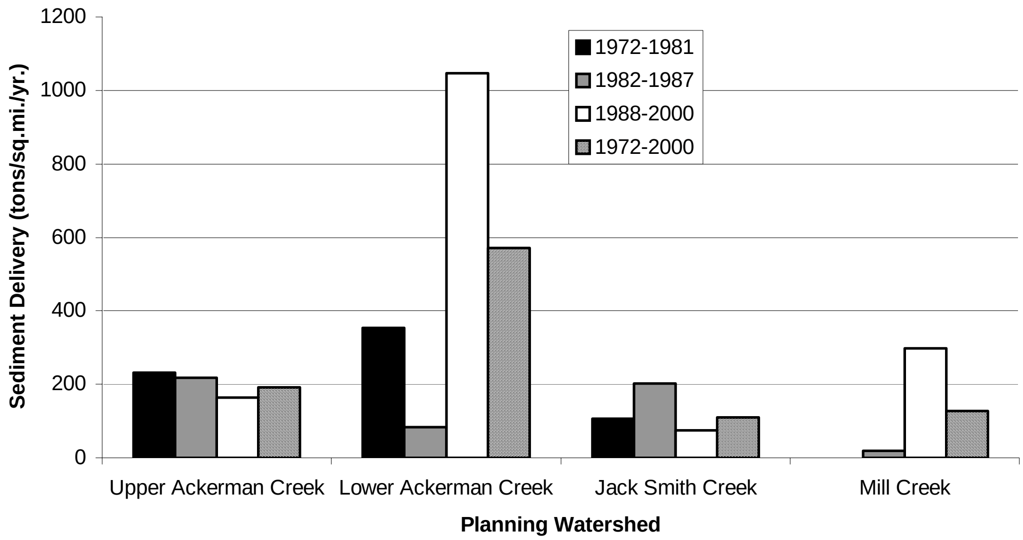
For the Lower Ackerman Creek and Mill Creek planning watersheds, sediment input from mass wasting was highest during the 1988-2000 period (Table A-5) (Chart A-1). For the Jack Smith Creek planning watershed, sediment input was highest during the 1982-1987 period. Sediment input was highest for the Upper Ackerman Creek planning watershed in the 1972-1981 period.

The highest sediment input from mass wasting occurs in the Upper Ackerman Creek planning watershed. The higher sediment delivery appears to be due to a relatively large area of ownership in the watershed and a relatively high concentration of road associated, streamside failures. The higher sediment input for the Ackerman Creek planning watersheds is mainly from a few, very large landslides that contributed a high amount of sediment. In contrast, Mill Creek planning watershed has an extremely low mass wasting input. The low input for Mill Creek is attributable to a very small amount of ownership that is in the headwalls of some relatively minor tributaries in the watershed.

Table A-5. Sediment Volume Input by Watershed for MRC Ownership. Data are Reported in Tons of Sediment Delivered.

Planning Watershed	1972-1981	1982-1987	1988-2000
Upper Ackerman Creek	12816	7222	10799
Lower Ackerman Creek	1956	279	6968
Jack Smith Creek	2612	2967	2202
Mill Creek	0	39	1145
Total	17384	10507	21114

Chart A-1. Total Mass Wasting Sediment Input Rate (tons/yr/sq. mi.) from Landslides for MRC Ownership Shown by Watershed and Time Period.



Road associated mass wasting was found to contribute 32,191 tons (125 tons/sq. mi./yr.) of sediment over the 29 years analyzed (1972-2000) in the Northern Russian River WAU (Table A-6). This represents approximately 66% of the total mass wasting inputs for the Northern Russian River WAU for 1972-2000. In the Lower Ackerman Creek planning watershed, all of the sediment delivery is attributed to road associated landslides mainly due to the location of the landslides on the steep slopes between Masonite Road and the stream channel. In the Upper Ackerman Creek planning watershed, road associated landslides were a major sediment source, contributing 72% of the Upper Ackerman Creek delivery. However, in all of Reeves Canyon, a lack of roads that are in close proximity to streams explains why only 9% of the sediment delivery is from road associated landslides. Where the main road in Reeves Canyon does follow along Jack Smith Creek, there is very little mass wasting sediment delivery.

Table A-6. Road Associated Sediment Delivery for Shallow-Seated Landslides for the Northern Russian River WAU by Watershed, 1972-2000.

Planning Watershed	Road Associated Mass Wasting Sediment Delivery (tons)	Percent of Total Sediment Delivery
Upper Ackerman Creek	22293	72%
Lower Ackerman Creek	9203	100%
Jack Smith Creek	695	9%
Mill Creek	0	0%
Total	**32191**	**66%**

Sediment Input by Terrain Stability Unit (TSU)

Total mass wasting sediment delivery for the Northern Russian River WAU, from mass wasting estimates, was separated into respective Terrain Stability Units. It should be noted that not all planning watersheds contain all seven TSUs.

The Terrain Stability Unit with the highest sediment delivery is TSU 1 (Table A-7); which is estimated to deliver 22,005 tons of sediment over the last twenty-nine years, 42% of the total sediment input. Combining the two streamside units (TSU 1 and 2) 57 % of the total sediment input is produced. TSU 4 is estimated to have delivered a moderate amount of sediment (17% of total) suggesting its moderate landslide hazard, however the majority of the landslides in TSU 4 are road associated. No delivery was estimated for TSU 5 because it is a low hazard area with very gently sloping to flat topography and typically does not deliver landslide material except in extraordinary events. No delivery was estimated for TSU 6 due to the lack of ability for us to estimate sediment delivery from the earthflows, however the few shallow landslides found in this unit were road associated and did not deliver sediment.

Table A-7. Total Sediment Delivery by Terrain Stability Units in the Northern Russian River WAU (1972-2000).

	TSU						
	1	2	3	4	5	6	7
Sediment Delivered (tons)	22,005	8,062	12,854	8,992	0	n/a	1,198
Proportion of total delivered	42%	15%	24%	17%	0	0	2%

CONCLUSIONS

In natural forest environments of the California Coast Ranges, mass wasting is a common occurrence. In the Northern Russian River WAU this is due to areas of relatively steep slopes, weak rocks (weathered, interbedded sandstone and shale and mélange terrain), locally thick colluvial soils, a history of timber harvest practices, and the occurrence of high intensity rainfall events. Mass wasting features of variable magnitude are observable throughout the Northern Russian River WAU. The vast majority of the shallow-seated landslides visited in the field during this assessment occurred on slopes greater than 60%, in areas of convergent and/or very steep planar topography. When conducting any type of forest management activity, particular attention should be given to areas with steep or locally steep topography. The topography of the Ackerman Creek planning watersheds is unique when compared to that of MRC ownership in other Coast Range watersheds. The presence of significant mélange terrain here explains the abundance of the grassy, earth flow topography which overall is less steep than slopes of other MRC watersheds.

Approximately 44% of the shallow-seated landslides are road associated in the Northern Russian River WAU, with Ackerman Creek accounting for most. Particularly, Masonite Road appears to have been, and continue to be a significant source of sediment delivery. Road construction proves to be a significant factor in the cause of shallow-seated mass wasting events. Better road construction practices combined with design upgrades of old roads will lower this amount over time.

Mass wasting sediment input is estimated to be at least 191 tons/sq. mi./ yr. over the 1972-2000 time period for the entire Northern Russian River WAU. Overall, in the Northern Russian River WAU, sediment delivery from mass wasting was highest in the Upper Ackerman Creek planning watershed in the 1972-1981 time period. This area was particularly high due to a history of poor harvest practices and the dominance of weak rocks of the mélange terrain compounded by the occurrence of a few very large landslides that significantly increased the sediment delivery amounts. Comparatively, sediment delivery in the Reeves Canyon area is much less, which is attributed to the relative lack of voluminous, shallow-seated landslides that deliver multiple thousands of tons of sediment as are seen in other watersheds. Overall, the Reeves Canyon area has steep slopes, which suggests the presence of relatively stable bedrock.

The Terrain Stability Unit with the highest sediment delivery is TSU 1 (Table A-7); which is estimated to deliver 22,005 tons of sediment over the last twenty-nine years, 42% of the total sediment input. Combining the two streamside units (TSU 1 and 2) 57 % of the total sediment input is produced.

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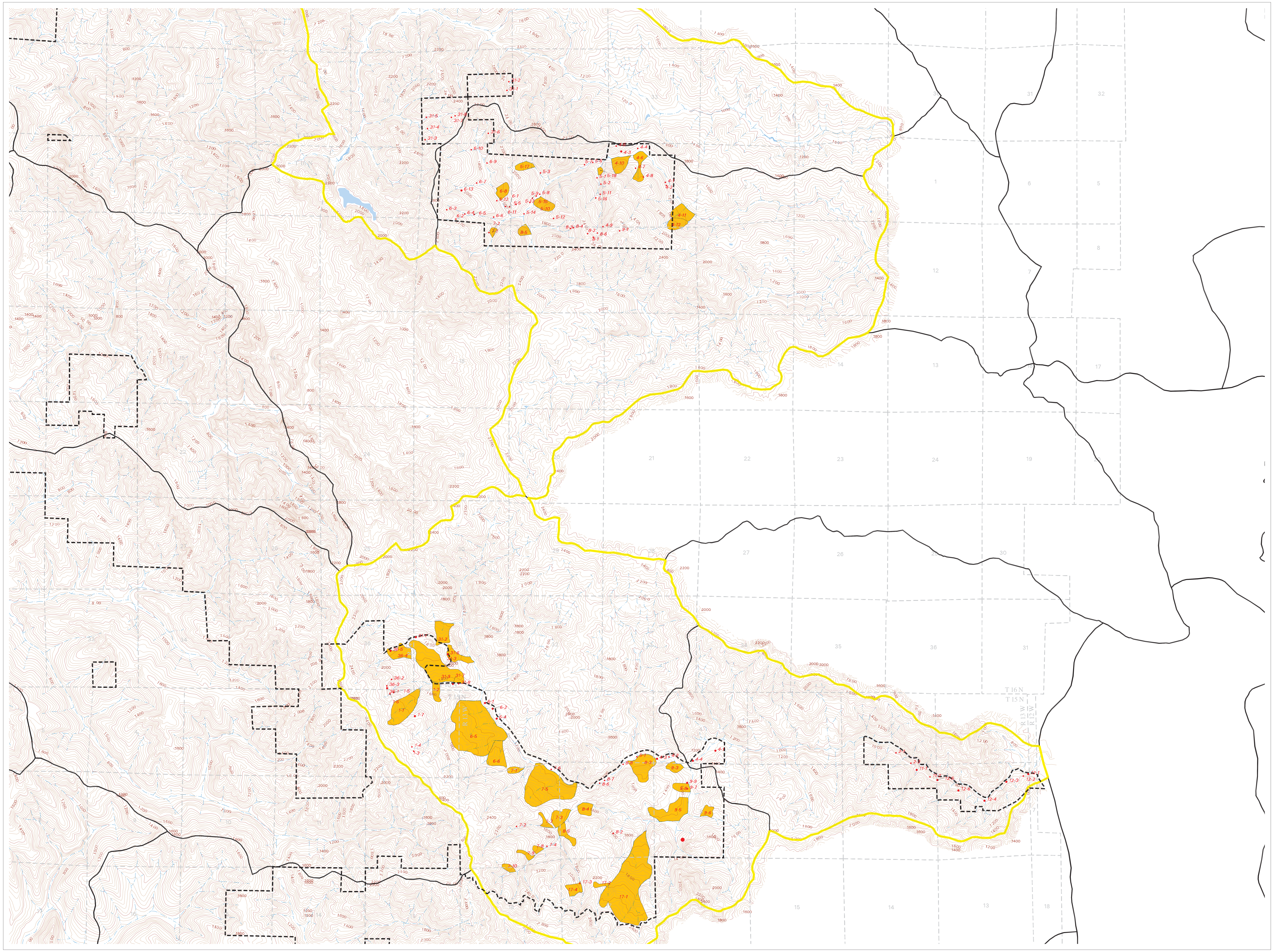
Northern Russian River WAU Mass Wasting Assessment

Appendix



Northern Russian River Watershed Analysis Unit

Map A-1 Mass Wasting Inventory

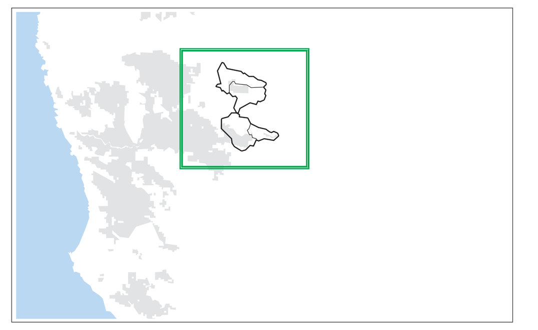
This map presents the location of mass wasting features identified on the MRC land in the Northern Russian WAU. The mass wasting features were developed from an interpretation of aerial photographs from the 1970's-2000 with field observations taken in 2000. All shallow-seated landslides are identified as a point plotted on the map at the interpreted head scarp of the failure. Deep-seated landslides are represented as a polygon representing the interpreted perimeter of the landslide feature. Physical and geomorphic characteristics of the landslides are categorized in a database in the mass wasting section of the Northern Russian watershed analysis.

Deep-Seated Landslides

Shallow-Seated Landslides
- < 500 cubic yards
- 500 - 5000 cubic yards
- > 5000 cubic yards

MRC Ownership
Planning Watershed Boundary
Northern Russian River Watershed Analysis Unit Boundary

Flow Class
- Class I
- Class II
- Class III



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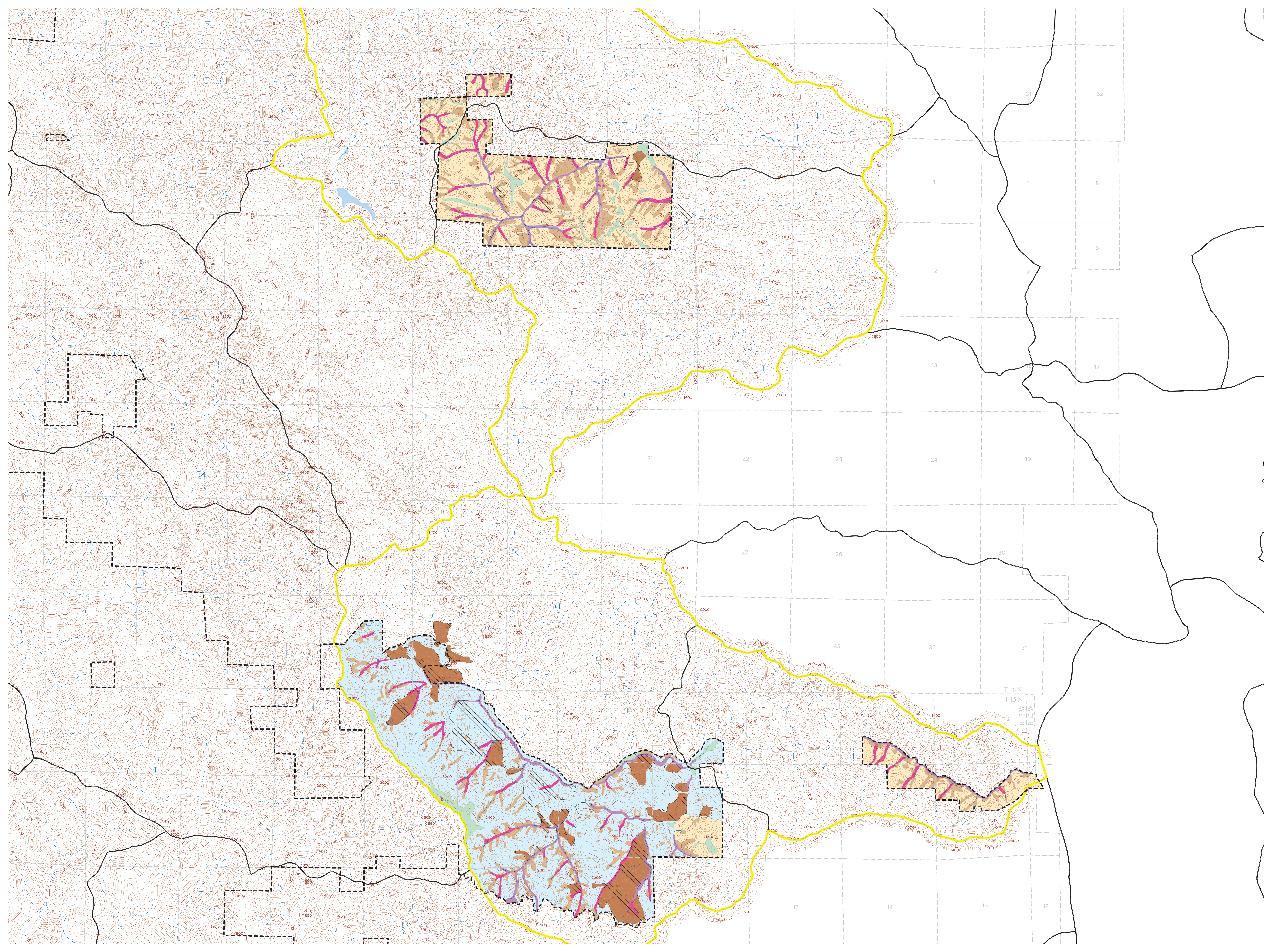
November 2004



Northern Russian River Watershed Analysis Unit

Map A-2
Terrain Stability Units

This map presents an interpretation of the terrain stability units (TSUs) delineated for the Northern Russian WAU. The TSUs characterize the landscape by similar geomorphic attributes, shallow-seated landslide potential, and sediment delivery potential. The TSU designations for the Northern Russian WAU are only meant to be general characterizations of similar geomorphic and terrain characteristics related to shallow seated landslides. Deep-seated landslides are also shown on this map. The deep-seated landslides have been included to provide land managers with supplemental information to guide evaluation of harvest planning and subsequent needs for geologic review. The landscape and geomorphic setting in the Northern Russian WAU is more complex than generalized TSUs delineated for this evaluation. The TSUs are only meant to be a starting point for gauging the need for site-specific field assessments. Field observations will over-ride unit boundaries of this map.

Unit 1: Inner gorge or steep slopes adjacent to low gradient watercourses

Unit 2: Inner gorge or steep slopes adjacent to high gradient intermittent or ephemeral watercourses

Unit 3: Dissected and convergent topography

Unit 4: Non-dissected topography

Unit 5: Low relief topography

Unit 6: Earthflow topography

Unit 7: Accelerated creep terrain

Deep Seated Landslides

MRC Ownership

Planning Watershed Boundary

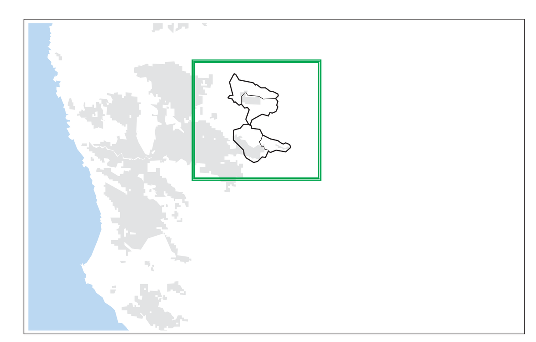
Northern Russian River Watershed Analysis Unit Boundary

Flow Class

Class I

Class II

Class III



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