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 Noyo River watershed, the watershed analysis unit (WAU). This assessment is part of a Level II Watershed Analysis initiated by MRC and utilizes watershed analysis modified methodology adapted from procedures outlined in the Standard Methodology for Conducting Watershed Analysis manual (Version 3.0, Washington Forest Practices Board).

This section was originally developed and completed in December, 2000. In February, 2003 this section was updated. The update consisted of modification of the titles and map for what are now called terrain stability units (TSU). These units were previously titled mass wasting map units (MWMU).

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 erosion module will be used to construct a rapid sediment budget input summary for the Noyo 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) and a mass wasting inventory database (Table A-1) for the WAU. The basis for these products are aerial photograph interpretation of 2 sets of aerial photographs, dated 1978 and 1996, field observations during the summer of 1998 and interpretation of SHALSTAB data. This level of observation is limited because the stochastic nature of mass wasting processes is difficult to capture using only 2 sets of aerial photographs. Furthermore the analysis is done without the use of historic aerial photographs (pre-1970s). Therefore the analysis presented must be interpreted with a measure of caution given the limited extent of the observations.

Nonetheless, the assembled information will enable forest-land managers to make better forest management operation 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.

Use of SHALSTAB by Mendocino Redwood Company for the Noyo 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. 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.

Landslides Types and Processes in the Noyo WAU

The terminology used to describe landslides in this report closely follows the definitions of Cruden and Varnes (1996). This terminology is based on 2 nouns, the first describing the material that the landslide is composed of and the second describing the type of movement. Landslides identified in the Noyo WAU were described by the following names: debris slides, debris torrents, debris flows, rock slides, and earth flows. These names are described in Cruden and Varnes (1996) with the exception of our use of debris torrent and debris flow.

Debris slides, debris flows and debris torrents are shallow seated landslides with soil thickness typically small compared to slope length or the length of the landslide. The material composition of debris slides, flows or torrents is considered soil with a significant proportion of coarse material; 20 to 80 percent (or more) of the particles are larger than 2 mm. Shallow seated slides move quickly downslope and commonly break apart during failure. Shallow seated slides commonly occur in converging topography where colluvial soil accumulates and subsurface drainage concentrates. Susceptibility of a slope to failure by shallow-landslides is affected by slope steepness, saturation of soil, soil strength (friction angle and cohesion), hydrostatic pressures 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 landslides composed of coarse earth materials. Downslope movement of the landslide mass occurs dominantly on a surface of rupture or on relatively thin zone of intense shear strain. The displaced mass can slide beyond the toe of the surface of rupture and over the ground surface of the slope below the landslide. Typically debris slides fail with a translational mode of failure, along a planar or undulating surface of rupture. Upon reaching a watercourse debris slides do not continue down the watercourse.

Debris flows and debris torrents are landslides composed of coarse earth materials characterized by movement as a mobile slurry of soil, rock, vegetation and water that can travel long distances from its point of initiation. Debris flows or debris torrents form when landslide material essentially liquefies concurrently with, or immediately after the initial failure. The difference between debris flows and debris torrents is that as a debris torrent moves downslope the mass or volume of material increases, sometimes by several orders of magnitude. A debris flow would travel downslope as a liquefied mass but not increase in volume or mass. Debris torrents are more destructive due to the increase in mass as they travel downslope. Debris torrents and debris flows typically initiate in confined, steep first- or second-order tributaries. Debris torrents and debris flows typically move down confined mountain channels, but debris flows can also flow across and deposit on planar or divergent topography, where a debris torrent typically will not.

Rock slides 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. Rock slides can be very large exceeding tens (or sometimes hundreds) of acres. Modes of rock sliding are either rotational or translational. Rotational slides typically move along a face of rupture that is curved and concave. Translational slides typically move along a planar or undulating surface of rupture. Rock slides can occur in response to seismic shaking, adverse geologic structure, or channel incision. Climatic changes, ranging from major (glacial-interglacial transitions), to intermediate (runs of several wet years), to short-term (extreme precipitation) can also trigger rock slides. The stream itself can be the cause of chronic movement, if it periodically excavates the tow of a large slide mass.

Earth flows are landslides composed of earth material, in which 80% or more of the particles are smaller than 2 mm and movement is characterized as a viscous flow. Earth flows are typically relatively slow moving failures commonly composed of clay rich materials or weathered clay-bearing rocks. Movement is spatially continuous and occurs on shear surfaces within the slide mass that can be short-lived, closely spaced, and usually not preserved. The lower boundary of a flow may be a surface along which appreciable differential movement has taken place or a thick zone of distributed shear. Earth flows occur on moderate to gentle slopes and exhibit high moisture or ground water conditions.

Sediment Delivery from Deep-Seated Landslides

Sediment delivery to watercourses from deep-seated landslides (landslides typically $\geq$10 feet thick) can occur by several processes. Such processes can include sheet wash and erosion, shallow-or deep-seated movement of a portion of the landslide, or movement of the entire deep-seated landslide deposit.

The ground surface of a deep-seated landslide deposit, like any other hillside surface is subject to erosional processes such as rain drop impact, sheet wash (overland flow), and gully/rill erosion. Under these conditions the sediment delivery is, for all intents and purposes, the same as adjacent hillside slopes not underlain by landslide deposits. The earth materials within the landslide are disturbed and can be arguably somewhat weaker; however once a soil has developed the fact that the slope in question is underlain by a deep-seated landslide would make little difference regarding sediment delivery generated by erosion 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 on the exposed surfaces.

Clearly movement of a portion or all of a deep-seated landslide can result in delivery of sediment to a watercourse. However, movement would need to be on slopes immediate adjacent to or in close proximity to a watercourse and of sufficient magnitude to result in enough displacement of the toe of the slide for delivery to occur. 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, if anything to a watercourse. Also movement would need to be of sufficient magnitude to actually push the toe of the slide into the watercourse or result in over steepening of the toe to make it unstable enough to initiate failures at the toe and resulting sediment delivery.

Generally ground cracking at the head of a large deep-seated landslide does not equate to immediate sediment delivery at the toe of the landslide. Movement of large deep-seated slides creates some 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.

It is very import 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.

It is also important to realize that many times only a portion of a deep-seated slide may become reactivated, though the portion could be quite variable in size. Thus, though a slide may have a large reactivation does not necessarily mean that the entire slide mass is involved in the current episode of movement.

A large active slide over time could and can, deliver large volumes of sediment. Delivery generally occurs in a conveyer-belt like process with movement delivering earth materials to the creek bank or into the creek. These materials are then removed by fluvial processes resulting in increased sediment in the channel. Actual delivery can occur by over steepening of the toe of the slide and subsequent failure into the creek or the slide pushing out into the creek. Sediment delivery could also occur in a catastrophic manner. In such a situation large portions of slide 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.

METHODS

Landslide Inventory

The mass wasting assessment relies on a inventory of mass wasting features through the use of aerial photographs and field observations. John Coyle (John Coyle and Associates, Inc.) mapped shallow and deep-seated landslides in the Noyo WAU for Louisiana-Pacific Corporation using two sets of aerial photographs from 1978 (1:15,840) and 1996 (1:12,000). The exception to this is the MRC property in the Upper Noyo Planning Watershed where only aerial photograph interpretation was performed using photographs from 1996. The landslide mapping was originally done as part of a validation study on SHALSTAB (Dietrich et. al., 1998), the shallow-seated landslide slope stability model currently used by MRC. The objective of the SHALSTAB validation study did not require measurements or characteristics of the landslides be collected. MRC complimented the landslide inventory of Coyle by field confirmation, then collecting characteristics and measurements of the landslides identified by aerial photograph interpretation and field observations. Landslides post-1996 were not identified on aerial photographs; but were located in the field during field reconnaissance. It is likely that some post-1996 landslides have gone undetected.

Landslides identified from the field and aerial photograph observations are plotted on a landslide inventory map (Map A-1). Shallow seated landslides are represented as a point on the map, deep seated landslides are shown as a polygon representing the landslide deposit. Physical and geomorphic characteristics of landslides are categorized in a database including identification number, planning watershed, type of landslide, approximate failure date, slope gradient, length, width, depth, area, volume, sediment delivery, sediment routing, and associated land use (Table A-1). 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 (all field observed landslides would get this designation). 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.

A description of select parameters inventoried for each landslide observed in 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.

- I.D. Number: Each landslide is assigned a number in the inventory.
- Planning Watershed: Denotes the planning watershed in which the landslide is located.

  NN = North Fork Noyo
  NO = Olds Creek
  NR = Redwood Creek
  NH = Hayworth Creek
  NM = Middle Fork of the North Fork Noyo
  MC = McMullen Creek

- TSU – terrain stability unit in which landslide is located.
- Process/Type:
  - 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.
- Physical Characteristics: Include length, width, depth, area, and volume of individual slides.
- Sediment delivery and routing: Includes sediment delivered to streams (N - no sediment delivered; P - possible delivery, Y - sediment delivered), estimate of the percent of landslide mass delivered, the type of stream that sediment was delivered to (perennial or ephemeral/intermittent).
- Associate land use: Road, landing, skid trail or rock pit association.
- Min log (q/T) value, minimum value from SHALSTAB calculations for landslide site, from validation study (Dietrich et. al., 1998).

Landslide dimensions (length and width) for landslides not visited in the field were determined by measuring the mass wasting feature directly from aerial photographs. To extrapolate depth to shallow-seated landslides (debris slides, flows or torrents) not visited in the field, a comparison was done between the mean value slide depth and distribution of landslide depths as observed in the field (see Appendix A for plotted histograms). From this comparison it was determined that the use of two separate mean shallow-landslide depth values were representative of the sampled population. Mean depth of field observed shallow-landslides that were road associated received one depth (3.5 feet); mean depth of shallow-landslides non-road associated received another depth (3 feet). These mean depth values were 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 from topographic maps and aerial photograph interpretation were assigned 100% delivery. Landslides that were determined to deliver, but were not directly adjacent to a watercourse, were assigned the mean delivery percentage from landslides observed in the field.

Landslides were classified based on the likelihood that some land use practice was associated with the slope failure. In this analysis the effect of silvicultural techniques were not observed. Because almost all of the Noyo WAU has been managed, both currently and historically, for timber production it was determined that the effect of silvicultural practices was too difficult to confidently assign to landslides. 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, landings, or rock quarries. It was assumed that a landslide adjacent to a road, landing, rock pit or skid trail was triggered either directly or indirectly by that land use practice. Cutslope failures from roads, landings, rock pits or skid trails were only identified if the landslide mass was transported over the features' prism. If the cutslope failure did not cross the features' prism it was assumed that the failure would remain perched on the road, landing, skid trail or rock pit 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).

Accuracy in identifying landslides on aerial photographs was dependent on the size of the slide, 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. Less confidence is placed on landslides mapped in areas with thick canopy. 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, landslide surfaces 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.

The deep-seated landslides (rock slides and earth flows) received less attention in the landslide inventory than shallow-landslides. The deep-seated landslides will be treated on a site by site basis in the Noyo WAU, likely during timber harvest plan preparation and review. Only basic information on the deep-seated landslides such as location and surface area was collected.

Sediment Input from Shallow-landslides

The time period assumed for mass wasting interpretation and sediment budget analysis is forty years. This is assumed because of the use of 1996 and 1978 aerial photographs and field observations in 1998 (twenty year span) and because vegetative recovery on landslide surfaces makes it difficult to detect, with much certainty, landslides farther back than about twenty years from aerial photographs. Landslides, particularly small landslides, can re-vegetate much faster than 20 years in fact it can be difficult to observe a small landslide even ten years after failure. We acknowledge that we have likely missed some small mass wasting events by using a 20-year separation in 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 Noyo WAU, landslides greater than 300 cubic yards in size represented over 87% of the sediment delivery estimated. Landslides greater than 200 and 100 cubic yards in size represented approximately 92% and 97%, respectively of the sediment delivery estimated.

Small streamside mass wasting is difficult to quantify on aerial photographs due to their small size and dense stream-side canopy cover. In order to estimate sediment input for these areas, selected stretches of streamside topography were sampled. Mass wasting determined to have occurred in the last five years was measured and the sediment input rates of these sampled areas used to extrapolate sediment inputs from similar streamside areas throughout the watershed. It was assumed that this process would be constant for the forty year time period assessed in this report.

Sediment delivery estimates from mapped shallow-landslides combined with the small streamside mass wasting volumes were used to produce the total mass wasting sediment input. Sediment input to stream channels by mass wasting is quantified for two twenty-year time periods (1958-1978, 1978-1998). The Upper Noyo Planning Watershed only had sediment input quantified for the 1978-1998 time period due to lack of 1978 aerial photographs for that area.

Movement of deep-seated landslides has likely resulted in some sediment delivery in the Noyo WAU. Present sediment delivery from deep-seated landslides is judged to be difficult to determine. Factors such as rate of movement or depth of the deep-seated landslide are difficult to determine without in-depth geotechnical observations. Many of the deep-seated landslides mapped are dormant landforms. Only a couple of the mapped deep-seated landslides were observed to have recent movement associated with them. Thus the sediment delivery from deep-seated landslides is probably low. Some of the sediment delivery from shallow-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 delivered 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-landslides associated with deep-seated landslides are accounted for in the delivery estimates.

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 to stream channels. Terrain stability units were formerly called mass wasting map units (MWMU) in the December, 2000 version of this mass wasting report. A combination of aerial photograph interpretation, field investigation and SHALSTAB were utilized to delineate TSUs. The TSU designations for the Noyo 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 Noyo 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 is described based on the landform present, the mass wasting processes, sensitivity to forest practices, mass wasting hazard, delivery potential, hazard potential, and forest management related trigger mechanisms for shallow seated landslides. The landforms define the terrain found within the TSU. The mass wasting process section is a summary of 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. Delivery potential is based on proximity of TSU to watercourses and the likelihood of mass wasting in the unit to reach watercourses. The hazard potential is based on a combination of the mass wasting hazard and delivery potential (Table A-1). The trigger mechanisms are a list of forest management practices that may have the potential to create mass wasting in the TSU.

Table A-1. 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 was used to record attributes associated with each landslide and is located in the appendix. The spatial distribution and location of landslides is shown on Map A-1.

A total of 305 shallow-seated landslides (debris slides, torrents or flows) were identified and characterized in the Noyo WAU. A total of 157 deep-seated landslides (rock slides or earth flows) were mapped in the Noyo WAU. A considerable effort was made to field verify as many landslides as possible to insure greater confidence in the results. A total of 31% of the identified shallow-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 mean depth of road related shallow-landslides lead to the assignment of a 3.5 ft. depth for road associated landslides (see appendix for histogram). Non-road related shallow-landslides (see appendix for histogram) were assigned a depth of 3 ft. The mean sediment delivery percentage assigned to shallow-landslides determined to deliver sediment, but not visited in the field is 81%. Deep-seated landslides did not have depth or sediment delivery statistics calculated.
The temporal distribution of the 305 shallow-seated landslides observed in the Noyo WAU is listed in Table A-2. The spatial distribution by landslide process is shown in Table A-3.

Table A-2. Shallow-landslide Summary for the Noyo WAU Divided into Time Periods.

Planning Watershed	1958-1978 Landslides	1978-1998 Landslides
Olds Creek	10	41
Redwood Creek	7	7
North Fork Noyo	22	38
Hayworth Creek	44	42
Middle Fork North Fork Noyo	14	30
McMullen Creek	21	22
Upper Noyo	n/a*	7

* - 1978 aerial photographs were not available for this area.

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

Planning Watershed	Debris Slides	Debris Torrents	Debris Flows	Rock Slides	Earth Flows	**Total**	*Road Assoc.*
Olds Creek	48	3	0	15	0	**66**	*24*
Redwood Creek	12	2	0	6	0	**20**	*6*
North Fork Noyo	59	1	0	30	0	**90**	*13*
Hayworth Creek	78	5	3	37	0	**123**	*27*
Middle Fork North Fork Noyo	42	1	1	49	0	**93**	*13*
McMullen Creek	41	2	0	17	1	**61**	*13*
Upper Noyo	4	2	1	1	0	**8**	*4*

The majority of landslides observed in the Noyo WAU are debris slides and rock slides. Only a few of the rock slides are known to be active in the Noyo WAU, the remaining are judged to be dormant features. Of the 305 shallow-seated landslides in the Noyo, 100 are determined to be road related. This is approximately 1/3 of the total number of shallow seated landslides.

Twenty debris torrents and flows were observed in the Noyo WAU. This is approximately 6 percent of the total shallow-landslides observed in the Noyo WAU. Debris torrents or flows are not common in the Noyo WAU, but do occur and are processes that should be taken into account in relation to forest management practices.

All of the shallow-landslides inventoried were initiated on slopes greater than 60 percent with the exception of four landslides with slopes as low as 45 percent. Those landslides are attributed to road practices and shallow ground water. The majority of inventoried landslides originated in convergent topography where sub-surface 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. Such observations were, in part, the basis for the delineation of the Noyo WAU into terrain stability units.

Terrain Stability Units

The landscape was partitioned into five 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 into watercourses. The delineation for the TSUs was based on qualitative observations 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 observation. Hillslope and landslide morphology varies 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

Description:	Inner Gorge or Steep Slopes adjacent to Low Gradient Watercourses
Materials:	Shallow soils formed on weathered marine sedimentary rocks. May be composed of sediment from the toe of a deep-seated landslide deposit.
Landform:	Characterized by steep slopes or steep inner gorge topography along low gradient watercourses (typically less than 6-7%). An inner gorge is considered a geomorphic feature created from down cutting of the stream in response to tectonic uplift. Inner gorge slopes extend from either one side or both sides of the stream channel to the first break in slope. Inner gorge slope gradients typically exceed 70%. Slopes with lower inclination are locally present. Slopes commonly contain areas of multiple, coalescing shallow seated landslide scars of varying age. Steep slopes adjacent to low gradient streams are generally planar in form with slope gradients typically exceeding 70% and exhibit strong evidence of past landslide activity. The distinction between inner-gorge and steep streamside slopes is steep streamside slopes lack a distinct break in slope and has less active erosion from stream down cutting. The upper extent of the unit is variable. Where there is not a break in slope, the unit may exceed 150 feet upslope. Landslides in this unit generally deposit sediment directly into Class I and II watercourses.
Slope:	>70% to vertical, (mean slope of observed mass wasting events is 73%, range: 71%-76%)
Total Area:	920 ac.; 4.6 % of the total WAU area.
MW Processes:	*1 road-associated landslide* • 1 debris slides *4 non-road associated landslides* • 4 debris slides
Non Road-related Landslide Density:	0.03 landslides per acre for the past 40 years
Forest Practices Sensitivity:	High sensitivity to roading due to slopes adjacent to watercourses, bedrock underlying inner gorge slopes creates increased stability. High sensitivity to harvesting and forest management

practices due to steep slopes with localized colluvial or alluvial soil deposits next to watercourses. Bedrock underlying inner gorge slopes creates increased stability.

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

Delivery Potential: High

Delivery Criteria Used: Steep slopes adjacent to stream channels, all landslides delivered into perennial 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 can expose potential failure planes 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.
- Cut-slope of skid trails can remove support of slope creating debris slides, torrents 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.

Confidence: High, the inner gorge of the Noyo WAU is easily identified in the field. The near vertical slopes of the bedrock walls found in this unit are relatively stable, the overlying veneer of soils are moderately unstable.

TSU Number: 2

Description: Steep slopes or inner gorge topography adjacent to high gradient intermittent or ephemeral watercourses.

Materials: Shallow soils formed from weathered marine sedimentary rocks.

Landforms: Characterized by steep slopes or steep inner gorge topography along high gradient watercourses (typically greater than 7%). An inner gorge is considered a geomorphic feature created from down cutting of the stream in response to tectonic uplift. Inner gorge slopes extend from either one side or both sides of the stream channel to the first break in slope. Inner gorge slope gradients typically exceed 70%. Slopes with lower inclination are locally present. Slopes commonly contain areas of multiple, coalescing shallow seated landslide scars of varying age. Steep slopes adjacent to low gradient streams are generally planar in form with slope gradients typically exceeding 70% and exhibit strong evidence of past landslide activity. The distinction between inner-gorge and steep streamside slopes is steep streamside slopes lack a distinct break in slope and has less active erosion from stream down cutting. The upper extent of the unit is variable. Where there is not a break in slope, the unit may exceed 100 feet upslope. Landslides in this unit generally deposit sediment directly into Class II and III watercourses.

Slope: >70% (mean slope of observed mass wasting events is 77%, range: 68%-95%)

Total Area: 758 ac.; 4 % of total WAU area

MW Processes: *7 road-associated landslides*

- 7 Debris slides

26 non-road associated landslides

- 24 Debris slides
- 2 Debris torrent

Non Road-related Landslide Density: 0.04 landslides per acre for the past 40 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 may have an even higher sensitivity to forest practices.

Mass Wasting Potential: High, due to the steep converging topography of the slope in both unmanaged and managed conditions

Delivery Potential: High

Delivery Criteria Used: Steep slopes adjacent to stream channels, 87 percent of landslides observed in this unit delivered sediment to watercourses.

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.
- 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, torrents or flows in this unit.
- Cut-slope of roads can remove support of the toe or expose potential failure planes 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.
- Cut-slope of skid trails can remove support of the toe or expose potential failure planes of rock slides or earth 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 for susceptibility of unit to landslides and deliver sediment. Moderate confidence in placement of this unit. This unit is highly localized and exact boundaries are better determined from field observations. Within this unit there are areas of low gradient slopes that are less susceptible to mass wasting.

TSU Number: 3

Description: Dissected and convergent topography

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

Landforms: These areas have steep slopes (typically greater than 70%) that have been sculpted over geologic time by mass wasting events. The area is characterized primarily by strong evidence of past shallow landslide failures and 1) steep convergent and dissected topography located within steep gradient colluvial hollows or headwall swales and small high gradient watercourses, and 2) local very steep planar slopes. MRC intends this unit to represent areas of potentially high to moderately high hazard for shallow landslides that does not constitute a continuous streamside unit (otherwise 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 verification of landslide features.

Slope: >65%, (mean slope of observed mass wasting events is 73% range: 60 %-110%, 1 observation of 46% and 1 of 50%)

Total Area: 9358 ac., 47% of the total WAU

MW Processes: *74 road-associated landslides*

- 68 Debris slides
- 6 Debris torrents

132 non-road associated slides

- 123 Debris slides
- 5 Debris torrents
- 4 Debris flow

Non Road-related Landslide Density: 0.013 landslides per acre for the past 40 years

Forest Practices Sensitivity: Moderate to high sensitivity to road building, moderate to high sensitivity to harvesting and forest management practices due to moderately steep slopes within this unit. Localized areas of steeper slopes have an even higher sensitivity to forest practices

Mass Wasting Potential: High

Delivery Potential: Moderate

Delivery Criteria Used: The converging topography directs mass wasting down slopes toward watercourses. Headwater swales can torrent or flow down watercourses. Approximately 63% of landslides delivered sediment in this unit.

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 can over-steepen the slope creating debris slides, torrents or flows in this unit.
- Cut-slope of roads can remove support of the toe or expose potential failure planes 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.
- Cut-slope of skid trails can remove support of the toe or expose potential failure planes of rock slides or earth 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, 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 unusually adverse ground water conditions.

TSU Number: 4

Description: Non-dissected topography

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

Landforms: 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 is generally a midslope region of lesser slope gradient and more variable slope form than unit 3.

Slope: >35%, (mean slope of observed mass wasting events 77%, range: 51%-90%)

Total Area: 5070 ac., 25% of the total WAU

MW Processes: *11 road-associated landslides*

- 9 Debris slides
- 2 Debris torrents

19 non-road associated slides

- 17 Debris slides
- 1 Debris torrent
- 1 Debris flow

Non Road-related Landslide Density: 0.004 landslides per acre for the past 40 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 have and even higher sensitivity to forest practices

Mass Wasting Potential: Moderate to Low

Delivery Potential: Moderate

Delivery Criteria Used: Sediment delivery is localized in this unit to landslides which occur adjacent to watercourses, or have long run-outs to a watercourse. Approximate 57% of landslides delivered sediment in this unit.

Hazard-Potential Rating: **Moderate to Low**

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 can over-steepen the slope creating debris slides, torrents or flows in this unit.
- •Cut-slope of roads can remove support of the toe or expose potential failure planes 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.
- •Cut-slope of skid trails can remove support of the toe or expose potential failure planes of rock slides or earth 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, 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

Description: Low relief topography

Material: Moderately deep to deep soil, formed from weathered marine sedimentary rocks.

Landforms: 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 well developed terraces. Debris slides seldom occur and usually do not deliver sediment to stream channels. This unit can have some localized areas of moderately steep (>35%), concave topography which can be more prone to mass wasting processes.

Slope: <40% (mean slope of observed mass wasting events 86%)

Total Area: 3773 ac., 19% of WAU area

MW Processes: *3 road-associated landslides*

- 3 Debris slides

2 non-road associated landslides

- 2 Debris slides

Non Road-related Landslide Density: 0.0005 landslides pre acre for past 40 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: Sediment delivery in this unit is low. Delivery which occurs is associated with road failures adjacent to watercourses or moderately steep slopes adjacent to watercourses.

Hazard-Potential Rating: **Low**

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 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 in rock slides or earth flows in this unit or aid in initiation of debris slides, torrents or flows.

Confidence: High, except along TSU boundaries where the confidence level is moderate due to inexactness of boundary locations.

Sediment Input from Mass Wasting

Sediment delivery was estimated for landslides and small streamside mass wasting in the Noyo WAU. Landslides were determined to have either no sediment delivery or to deliver all or a percentage of their total volume. Of the shallow-landslides mapped by MRC in this watershed analysis, 68 percent of the landslides delivered sediment (Table A-4).

Table A-4. Total Shallow-seated Landslides Mapped for each Planning Watershed in the Noyo WAU. (Road Associated Landslides are Included).

Planning Watershed	Total Slides	Landslides with No Sediment Delivery	Landslides with Sediment Delivery
Olds Creek	51	20	31
Redwood Creek	14	8	6
North Fork Noyo	60	25	35
Hayworth Creek	86	23	63
Middle Fork North Fork	43	11	32
McMullen Creek	44	9	35
Upper Noyo	7	2	5
Sum	*305*	*98*	*207*
Percentage	*100%*	*32*	*68%*

Mass wasting was separated into two time periods for data analysis. The first time period is for mass wasting that occurred from 1958-1978, the second time period assessed is from 1978-1998. The cut-off dates from each of the time periods are based on the date of aerial photographs used to interpret landslides (1978 and 1996) and field observations (1998).

A total of 290,433 tons of mass wasting sediment delivery was estimated for the time period 1958-1998 in the Noyo WAU. This equates to 453 tons/sq. mi./yr. Of the total estimated amount 171,933 tons (59% of total) occurred in 1958-1978 and 118,501 (41% of total) occurred in the 1978-1998 time period (Table A-5).

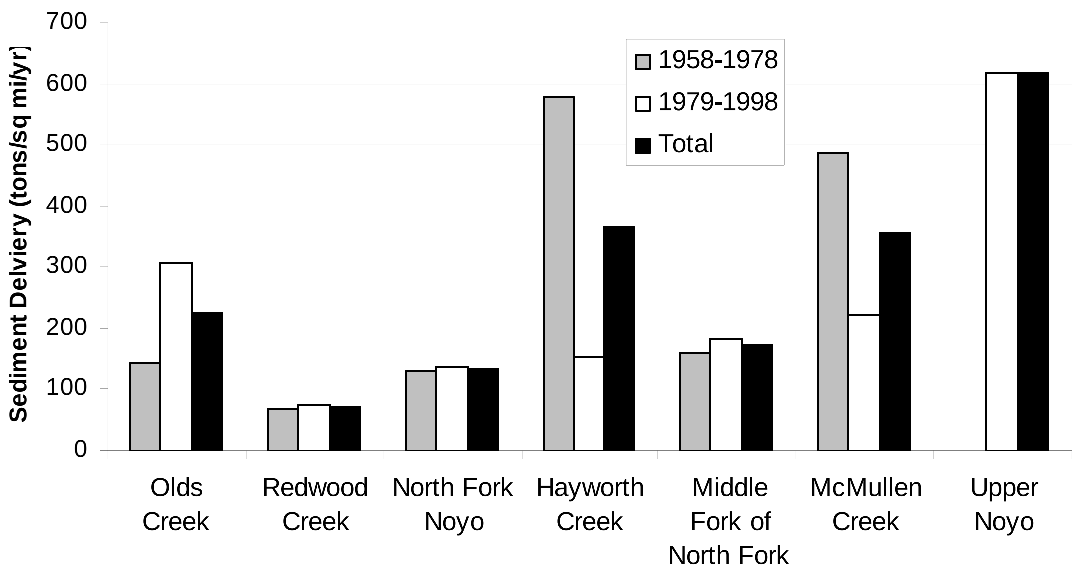
For North Fork Noyo, Hayworth Creek, Redwood Creek, and McMullen Creek planning watersheds, sediment input from mass wasting was highest during the 1958-1978 period (Table A-5)(Chart A-1). For Olds Creek and Middle Fork Noyo planning watersheds, sediment input from landslides was highest from 1978-1998.

The highest sediment input from mass wasting occurs in the Hayworth Creek and McMullen Creek planning watersheds. The higher sediment delivery appears to be due to a combination of extensive tractor yarding and intense forest management prior to forest practice rules, and a few very large landslides that contributed a high amount of the sediment in those planning watersheds. In contrast, Redwood Creek Planning Watershed has an extremely low mass wasting input. The low input for Redwood Creek, on Mendocino Redwood Company property may be attributable to a low number of mapped landslides (15), and a wide strath terrace bounding Redwood Creek. Most landslides in this planning watershed deposit sediment to this terrace and not to a watercourse.

Table A-5. Sediment Volume Input for MRC Ownership Listed by Planning Watershed. (data reported in tons of sediment delivered)

Planning Watershed	1958-1978	1978-1998
Olds Creek	10446	22350
Redwood Creek	2368	2596
North Fork Noyo	20137	21255
Hayworth Creek	87086	23086
Middle Fork North Fork	21077	24033
McMullen Creek	30818	14084
Upper Noyo	n/a	11097
Total	171933	118501

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



The twenty year look back periods used in this analysis are useful to provide a general idea of the magnitude of sediment delivery for the time periods analyzed. However, there is additional information available to better quantify the first ten years of each twenty year look back period by the use of data generated by the “Sediment Source Analysis and Preliminary Sediment Budget for the Noyo River” prepared by Matthews (1999). Analysis of the data presented in the Matthews study suggest that during the time periods 1957 to 1963 and 1963 to 1965 sediment delivery was 12 and 7 times respectively of that apparently delivered between 1965 to 1978 in the Headwaters Planning Area of the Noyo River (includes McMullen Creek, Redwood Creek, and Olds Creek).

In the North Fork Planning Area (Hayworth Creek and Middle Fork North Fork) of the Noyo River a similar review of delivered sediment was also attempted. This review showed that between the time periods 1957 to 1963 and 1963 to 1965 sediment delivery was about 1½ and one-half times respectively, that of the 1965 to 1978 sediment delivery. Likewise, the determined delivery rate for 1978 to 1988 was about 8½ times that determined for the 1988 to 1996 time period in the Hayworth Creek Planning Watershed. In the North Fork Planning watershed the 1978 to 1988 delivery rate was 10 times that determined for the 1988 to 1996 time period (Matthews, 1999).

Road associated mass wasting was found to contribute 53,635 tons (86 tons/sq. mi./yr) of sediment over the 40 years analyzed (1958-1998) in the Noyo WAU (Table A-6). This represents approximately 18% of the total mass wasting inputs for the Noyo WAU for 1958-1998. This is a relatively low percentage of the sediment delivery given that number of road associated landslides represented almost 1/3 of total shallow-landslides observed in the Noyo WAU. In some areas road associated sediment delivery was the dominant source (Upper Noyo Planning Watershed). However, in other areas road associated sediment delivery was low (Hayworth Creek, Middle Fork North Fork). The areas where road associated sediment is a low percentage is due to the fact that a few very large landslides and an abundance of small streamside mass wasting were contributing the majority of the estimated sediment. This mass wasting was not road associated.

Table A-6. Road Associated Sediment Delivery for Shallow Seated Landslides for the Noyo WAU by Planning Watershed, 1958-1978.

Planning Watershed	Road Associated Mass Wasting Sediment Delivery (tons)	Percent of Total Sediment Delivery
Olds Creek	14895	45%
Redwood Creek	1928	39%
North Fork Noyo	9186	22%
Hayworth Creek	5557	5%
Middle Fork North Fork	1797	4%
McMullen Creek	12500	28%
Upper Noyo	7772	70%
Total	**53635**	**18%**

Sediment Input by Terrain Stability Unit (TSU)

Total mass wasting sediment delivery for the Noyo WAU, from mass wasting estimates, was separated into respective terrain stability units. It should be noted that not all planning watersheds contain all five TSUs and that small streamside mass wasting data was added only to those TSUs in which small streamside mass wasting occurred.

The terrain stability unit with the highest sediment delivery is TSU 3 (Table A-7); which is estimated to deliver 148,833 tons of sediment over the last forty years, 51 percent of the total sediment input. Combining streamside units (TSU 1 and 2) yields 116,217 tons, 40 percent of the total sediment input. Combining all the streamside mass wasting provides close to half of the entire amount of sediment delivery. TSU 4 is estimated to have delivered a relatively low amount of sediment (22,276 tons) suggesting its moderate landslide hazard. TSU 5 delivered the lowest amount of sediment (3118 tons) due to the fact that it is a low hazard area and typically does not deliver landslide material except in extraordinary events.

Table A-7. Total Sediment Delivery by Terrain stability unit in the Noyo WAU (1958 to 1998).

	Terrain stability unit				
	1	**2**	**3**	**4**	**5**
Sediment (tons)	**91087**	**25130**	**148833**	**22276**	**3118**
% of Total	**31%**	**9%**	**51%**	**8%**	**1%**

CONCLUSIONS

In natural forest environments of the California Coast Range, mass wasting is a common occurrence. In the Noyo WAU this is due to relatively steep slopes, the condition of weathered marine sedimentary rock (inter-bedded sandstone and shale), locally thick colluvial soils and the occurrence of high intensity rainfall events. The discovery of numerous 1998 mass wasting features following the intense El Niño winter of 1997-1998 demonstrates that mass wasting events are episodic and many landslides may happen in a short time frame. Mass wasting features are observable throughout the Noyo WAU. Nearly all of the landslides visited in the field during this assessment occurred on slopes greater than 60%, in areas of convergent and or very steep planar topography.

Mass wasting sediment input is estimated to be at least 453 tons/sq. mi./ yr. over the 1958-1998 time period. Hayworth Creek and McMullen Creek had the highest sediment delivery in the Noyo. These areas were particularly high due to past harvest practices and the occurrence of a few very large landslides that significantly increased the sediment delivery amounts.
Overall in the Noyo WAU sediment delivery from mass wasting was highest in the 1958-1978 time period. The forest harvesting technique utilized in the 1950's and 1960's was tractor skidding of logs. This skidding was performed on steep slopes and often in streamside

environments and inner gorges, compacting and destabilizing the soil, increasing the frequency of mass wasting.

Approximately 1/3 of the number of shallow seated landslides are road associated in the Noyo WAU, though road related mass wasting only represented 18% of the sediment delivery in the Noyo WAU. However, in some areas it was as high as 70% of the mass wasting sediment delivery. A high number of road associated landslides are occurring in the Noyo WAU. The reason that the sediment delivery proportion was so low is because a few very large landslides and a high rate of small streamside mass wasting, that are not road associated, that significantly increased the sediment delivery amounts. Better road construction practices combined with design upgrades of old roads will lower this amount over time. This mitigation measure will need to be a focus of concern.

TSU 3 represented the greatest mass wasting sediment delivery for any one TSU, providing 51% of the sediment delivered from 1958-1998. Streamside mass wasting (combining TSU 1 and 2) yields 40% of the total mass wasting sediment input. Terrain stability units 1, 2 and 3 represent over 90% of the sediment inputs from mass wasting. Management activities in these areas will need special attention and evaluation.

LITERATURE CITED

Cruden, D.M. and D.J.Varnes. 1996. Landslide types and processes. In: Landslides Investigation and Mitigation, Transportation Research Board, Washington DC, Special Report 247: 36-75.

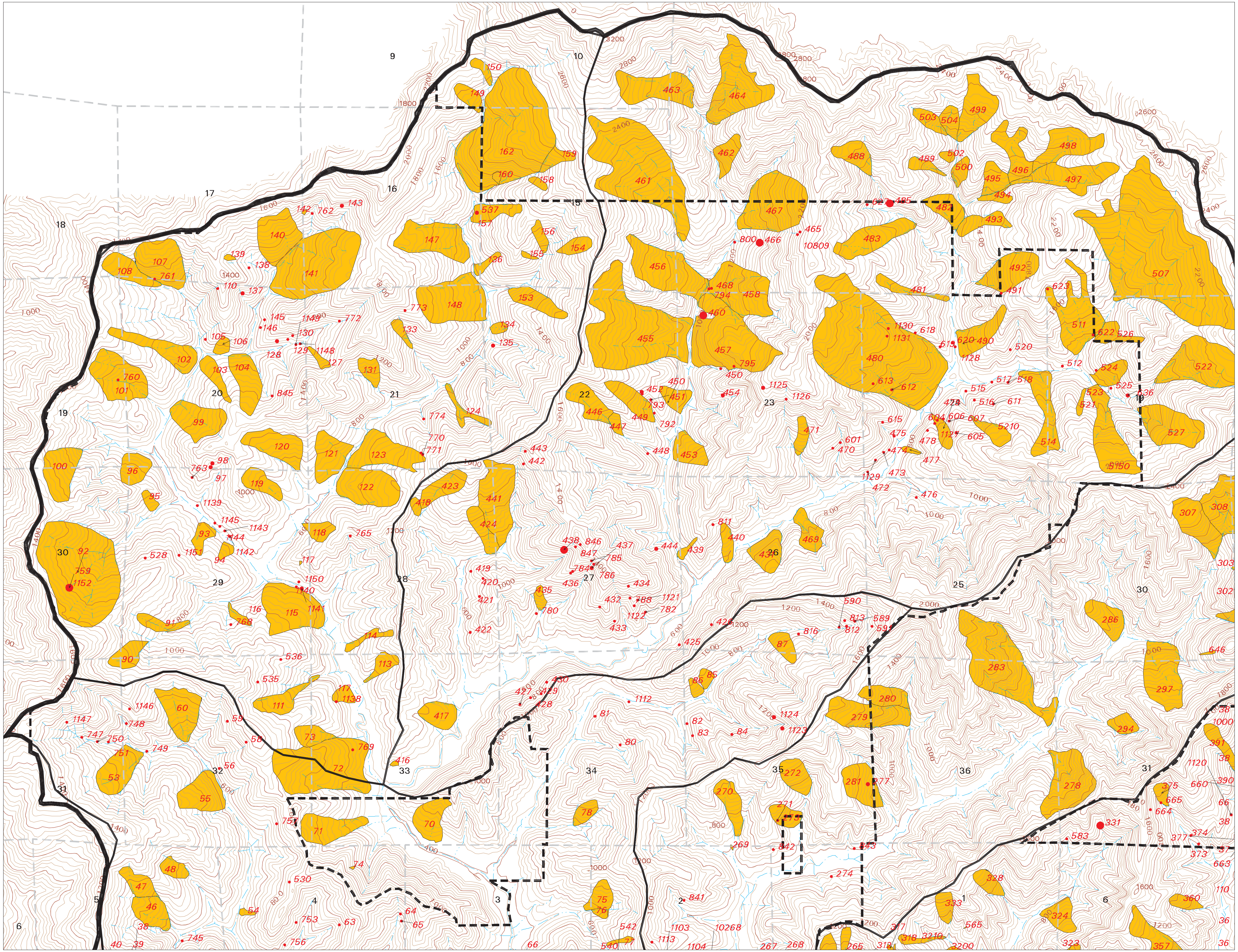
Dietrich, W.E. and Montgomery, D.R. SHALSTAB; a digital terrain model for mapping shallow-landslide potential, NCASI Technical Report, February 1998, 29 pp.

Dietrich, W.E., Real de Asua, R., Coyle, J., Orr, B., and Trso, M. 1998. A validation study of the shallow slope stability model, SHALSTAB, in forested lands of Northern California. Stillwater Sciences Internal Report, Berkeley, CA.

Matthews, G., Coyle., J. and J. Anderson 1999. Sediment source analysis and preliminary sediment budget for the Noyo River. Prepared for Tetra Tech, Inc.for the Uniteds States Envrionmental Protection Agency. Contract #68-C7-0018, work Assg. # 0-18. Graham Matthews and Assoc., Weaverville, CA.

Selby, M.J. 1993. Hillslope materials and processes. Second Edition. Oxford University Press. Oxford.

Washington Forest Practice Board. 1995. Standard methodology for conducting watershed analysis. Version 3.0. WA-DNR Seattle, WA.



Noyo River Watershed Analysis Unit

Map A-1
Mass Wasting Inventory

Large Deep-Seated Landslides

Shallow-Seated Landslides *

- < 500 cubic yards
- 500 - 5000 cubic yards
- > 5000 cubic yards

Flow Class

- Class I
- Class II
- Class III

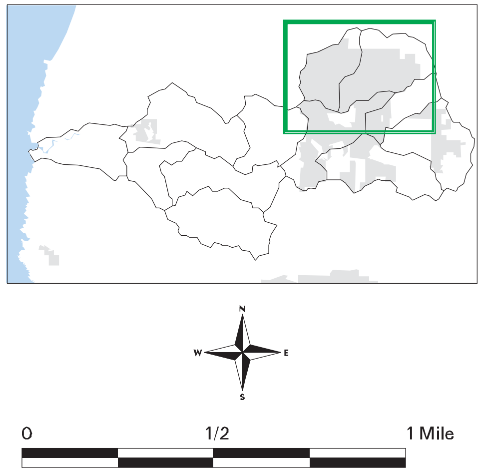
MRC Ownership

WWAA Boundary

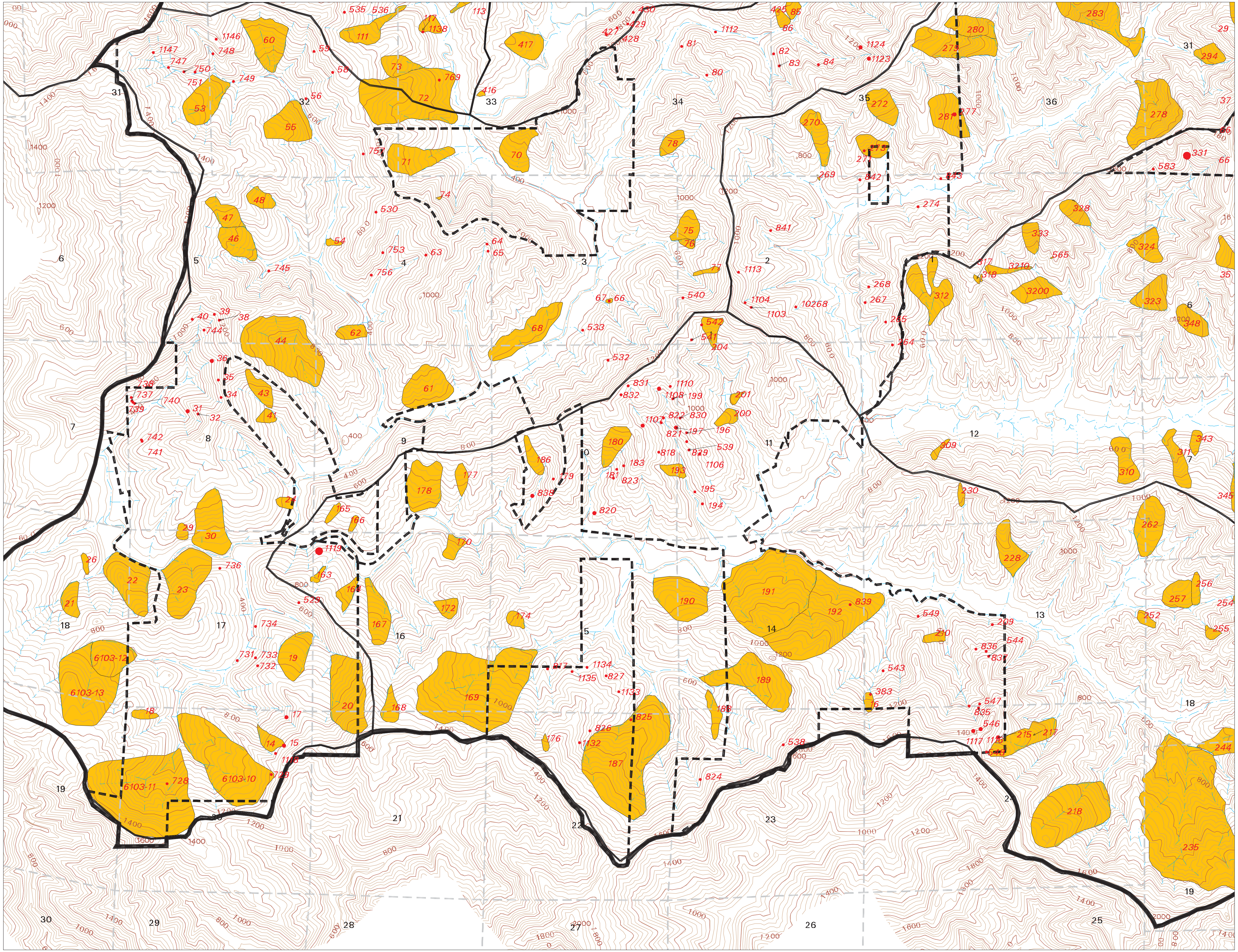
Planning Watershed Boundary

* only shown for MRC Ownership

Sheet 1



JULY 14, 2000



Noyo River Watershed Analysis Unit

Map A-1 Mass Wasting Inventory

Large Deep-Seated Landslides

Shallow-Seated Landslides *

- < 500 cubic yards
- 500 - 5000 cubic yards
- > 5000 cubic yards

Flow Class

- Class I
- Class II
- Class III

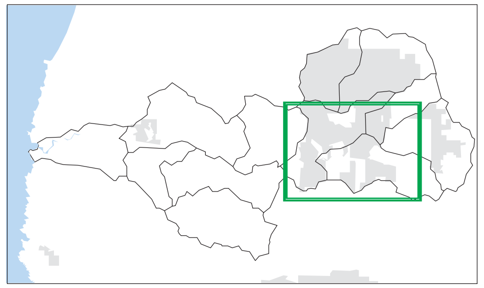
MRC Ownership

WWAA Boundary

Planning Watershed Boundary

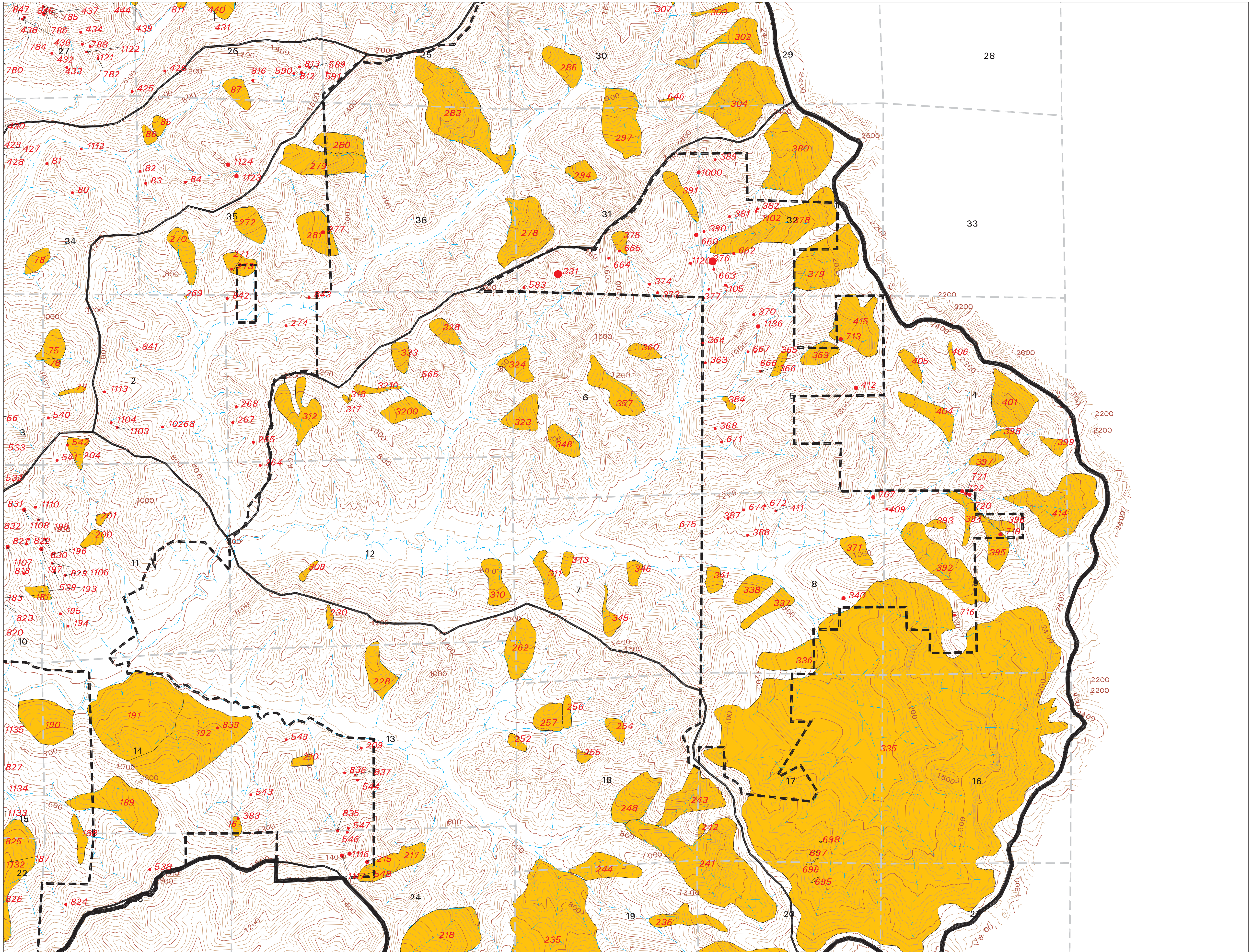
* only shown for MRC Ownership

Sheet 2



0 1/2 1 Mile

July 14, 2000



Noyo River Watershed Analysis Unit

Map A-1 Mass Wasting Inventory

Large Deep-Seated Landslides

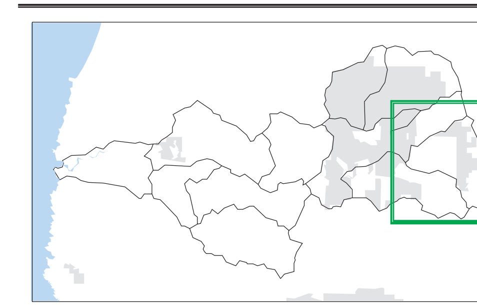
Shallow-Seated Landslides *
- < 500 cubic yards
- 500 - 5000 cubic yards
- > 5000 cubic yards

Flow Class
- Class I
- Class II
- Class III

- MRC Ownership
- WWAA Boundary
- Planning Watershed Boundary

* only shown for MRC Ownership

Sheet 3

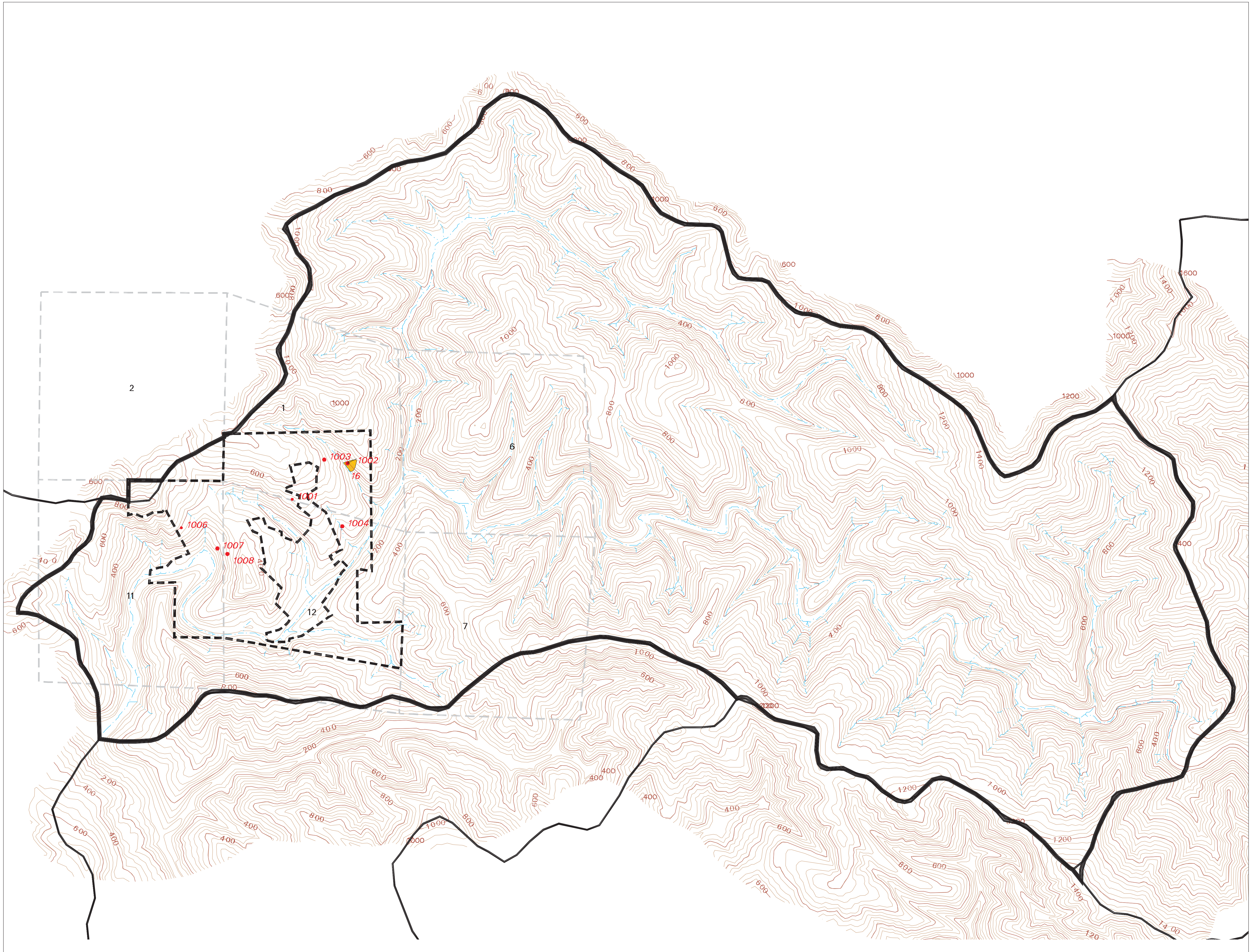


0 1/2 1 Mile

July 14, 2000

Noyo River Watershed Analysis Unit

Map A-1 Mass Wasting Inventory



Large Deep-Seated Landslides

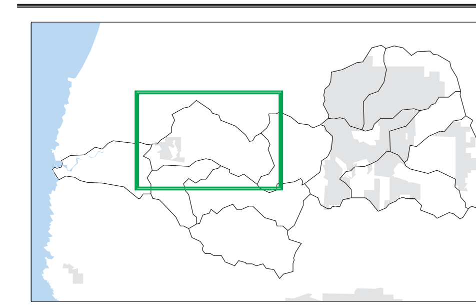
Shallow-Seated Landslides *
- < 500 cubic yards
- 500 - 5000 cubic yards
- > 5000 cubic yards

Flow Class
- Class I
- Class II
- Class III

- MRC Ownership
- WWAA Boundary
- Planning Watershed Boundary

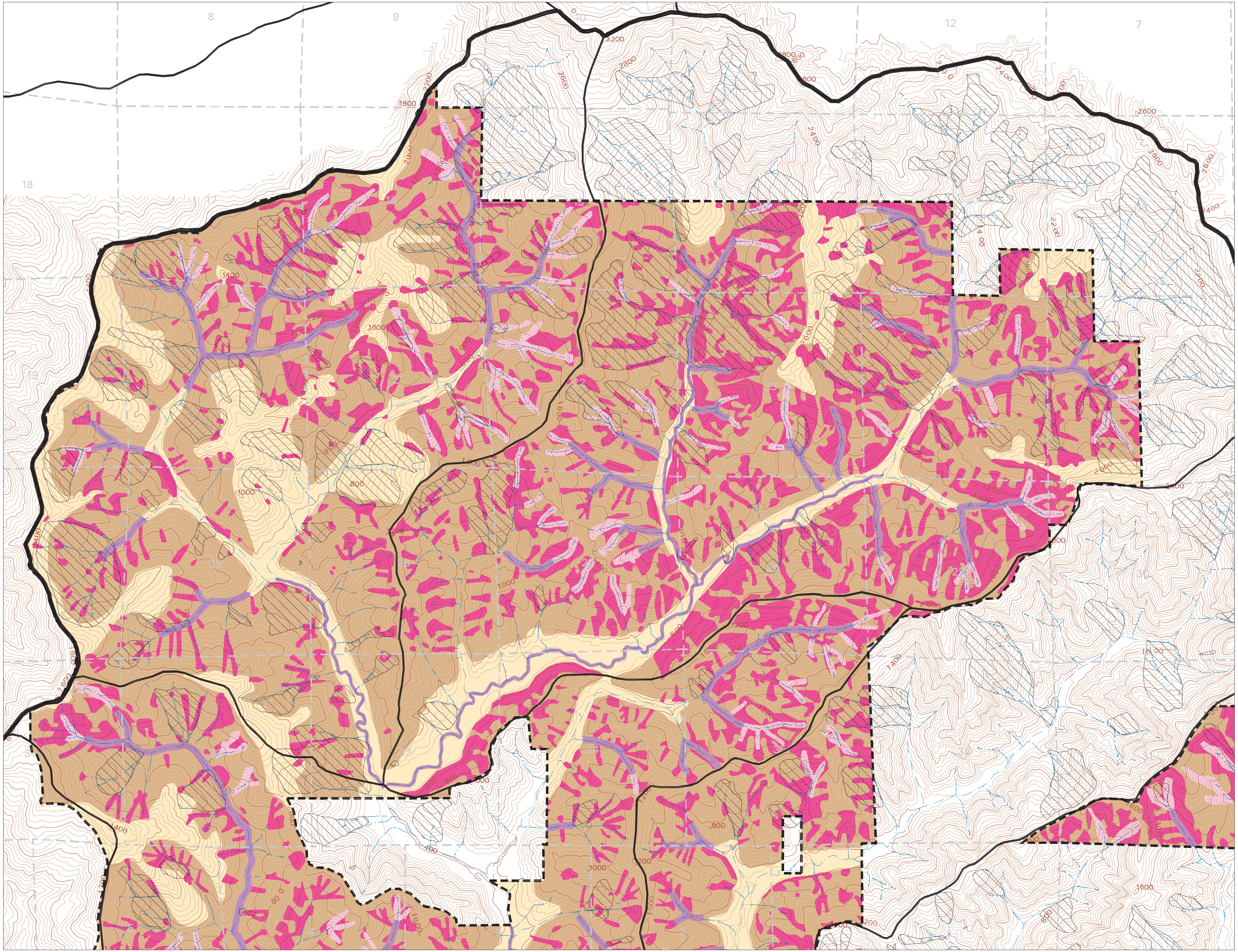
* only shown for MRC Ownership

Sheet 4



0 1/2 1 Mile

JULY 14, 2000



Noyo River Watershed Analysis Unit

Map A-2 Terrain Stability Units

Unit 1: Steep slopes or inner gorge along low gradient watercourses

Unit 2: Steep slopes or inner gorge adjacent to select intermittent or ephemeral streams

Unit 3: Steep, dissected topography

Unit 4: Non-dissected topography

Unit 5: Low relief topography

Deep Seated Landslides

Flow Class

Class I

Class II

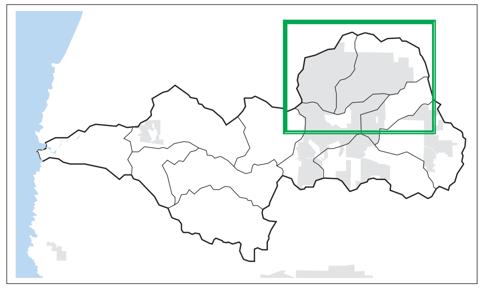
Class III

MRC Ownership

Planning Watershed Boundary

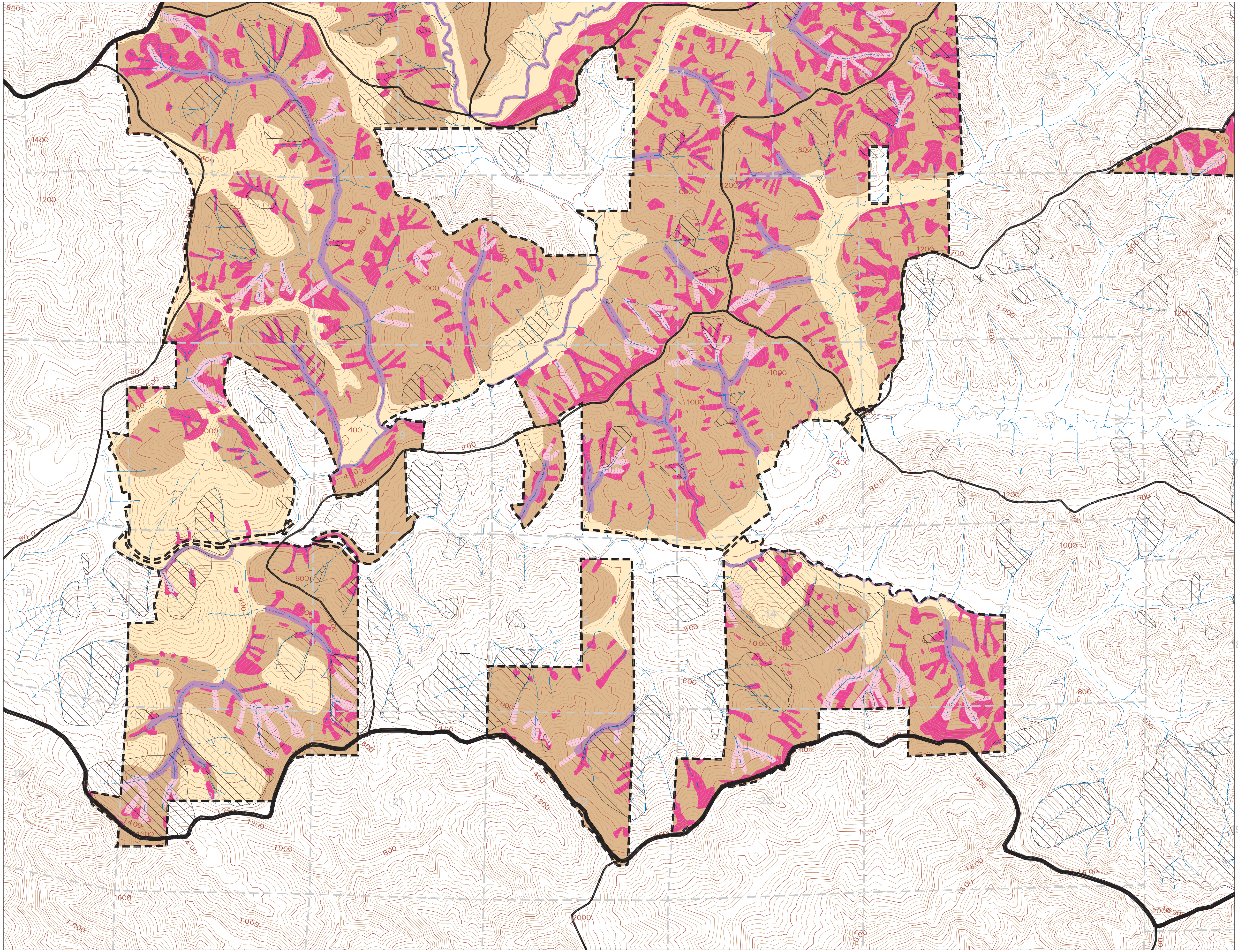
Basin Boundary

Sheet 1



0 1/2 1 Mile

March 2004



Noyo River Watershed Analysis Unit

Map A-2 Terrain Stability Units

Unit 1: Steep slopes or inner gorge along low gradient watercourses

Unit 2: Steep slopes or inner gorge adjacent to select intermittent or ephemeral streams

Unit 3: Steep, dissected topography

Unit 4: Non-dissected topography

Unit 5: Low relief topography

Deep Seated Landslides

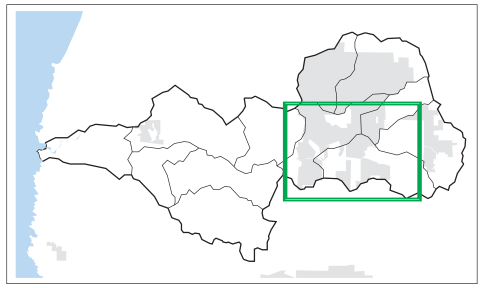
Flow Class
- Class I
- Class II
- Class III

MRC Ownership

Planning Watershed Boundary

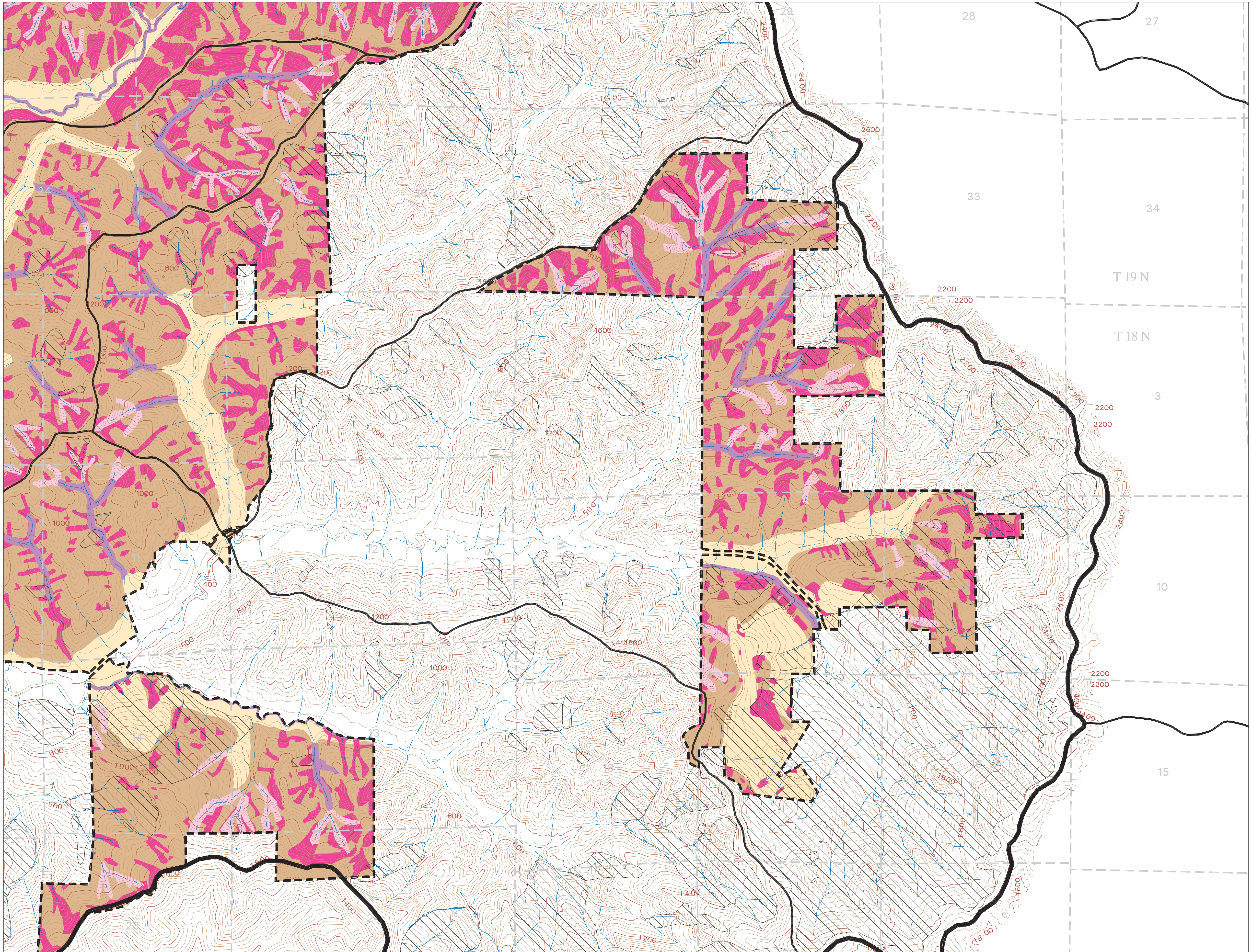
Basin Boundary

Sheet 2



0 1/2 1 Mile

March 2004



Noyo River Watershed Analysis Unit

Map A-2 Terrain Stability Units

Unit 1: Steep slopes or inner gorge along low gradient watercourses

Unit 2: Steep slopes or inner gorge adjacent to select intermittent or ephemeral streams

Unit 3: Steep, dissected topography

Unit 4: Non-dissected topography

Unit 5: Low relief topography

Deep Seated Landslides

Flow Class

Class I

Class II

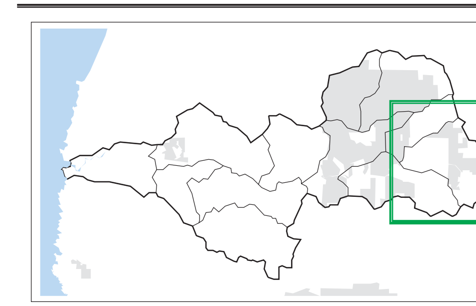
Class III

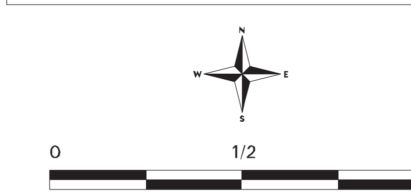
MRC Ownership

Planning Watershed Boundary

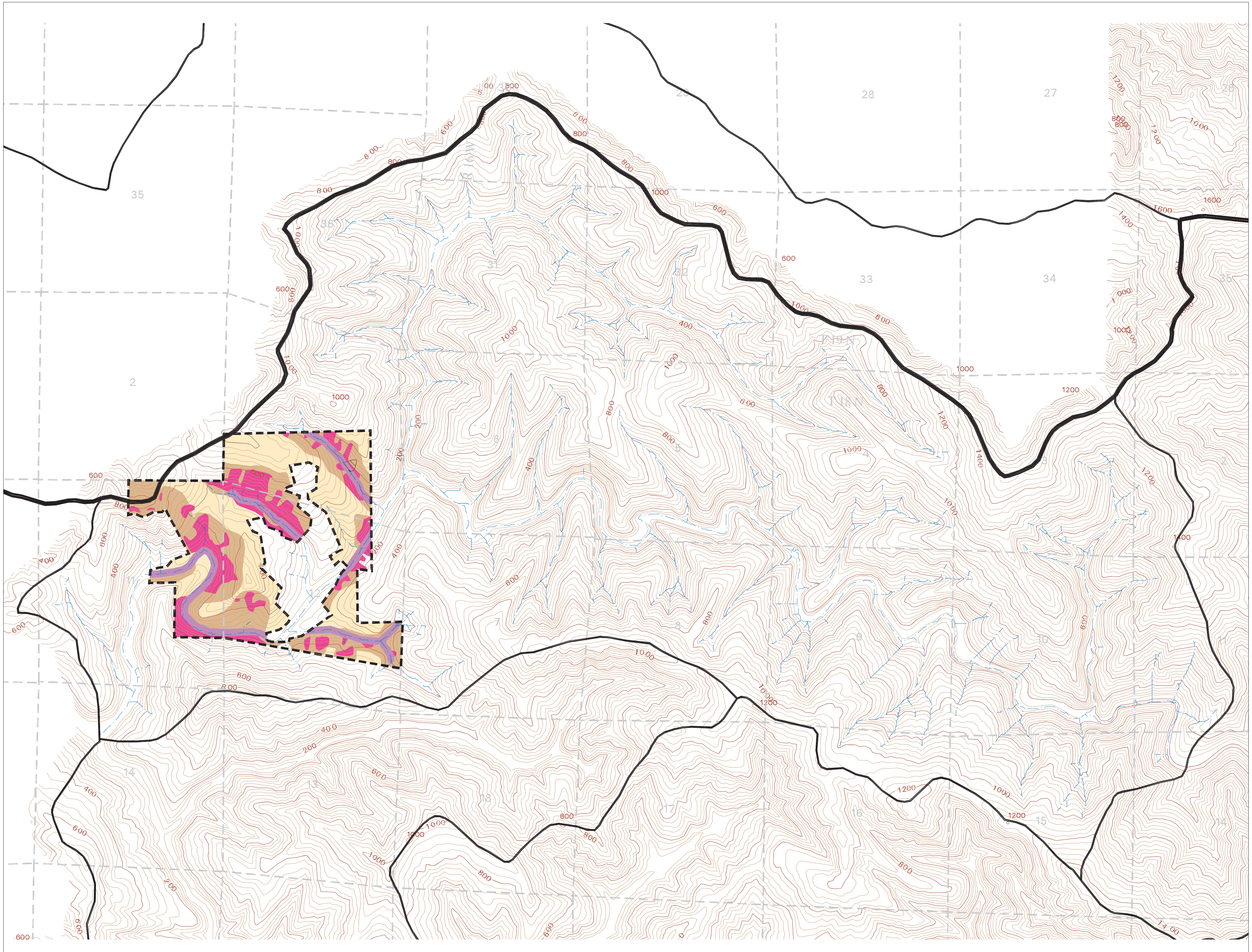
Basin Boundary

Sheet 3





March 2004



Noyo River Watershed Analysis Unit

Map A-2
Terrain Stability Units

Unit 1: Steep slopes or inner gorge along low gradient watercourses

Unit 2: Steep slopes or inner gorge adjacent to select intermittent or ephemeral streams

Unit 3: Steep, dissected topography

Unit 4: Non-dissected topography

Unit 5: Low relief topography

Deep Seated Landslides

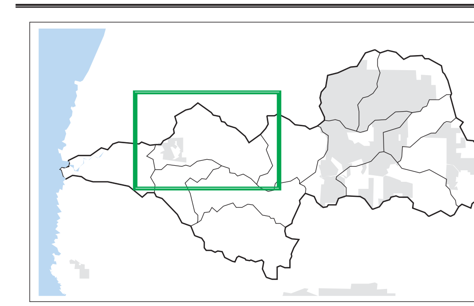
Flow Class
- Class I
- Class II
- Class III

MRC Ownership

Planning Watershed Boundary

Basin Boundary

Sheet 4



0 1/2 1 Mile

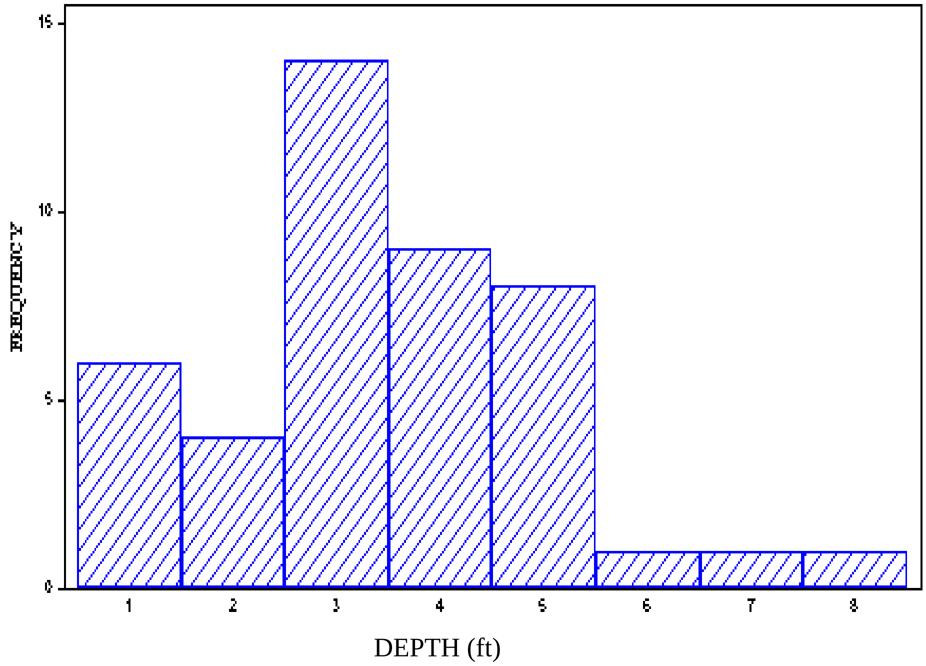
March 2004

Appendix A

Noyo WAU Mass Wasting Assessment

Histograms of Shallow-landslide depths, from field observed landslides.

a. Road Related Landslides (Mean =3.5 feet).



b. Non-Road Related Landslides (Mean = 3.0 feet).

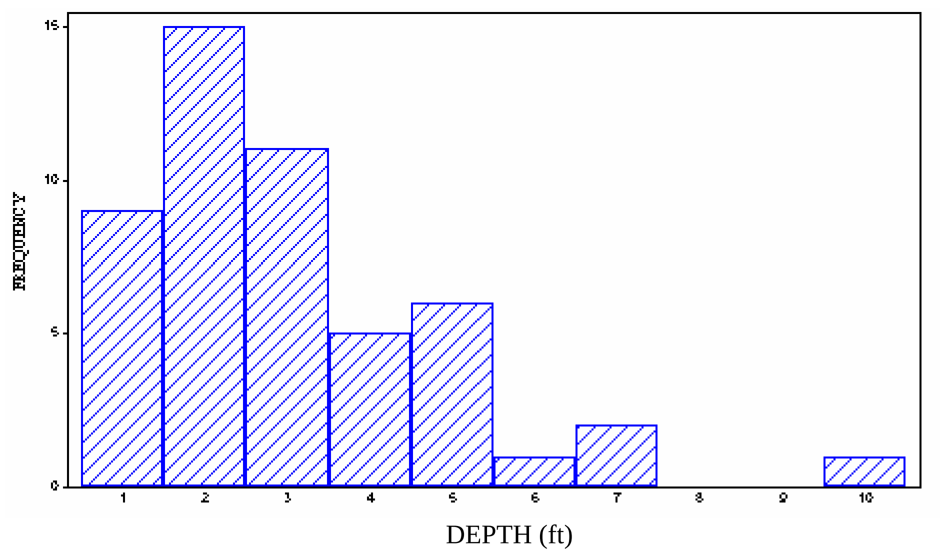


Table A-1. Landslide Inventory for the Noyo WAU.

I.D. No.	Planning Watershed	MWMU	Landslide Process and Certainty: Type	Landslide Process and Certainty: Certainty	Approx. Failure Date	Slope Gradient (%) (field)	Landslide Size (surface Area) (by photo date): Photo Yr. 78 L	W	Area	Photo Yr. 96 L	W	Area	Avg. Slide Depth (field)	Slide Volume (cu ft)	Sedmnt. Delvry.	Sedmnt. Delvry. (%)	Sedmnt. Delvry. vol (cu yds)	Sedmnt. Delvry. vol (tons)	Sediment Routing: Perrenial	Sediment Routing: Ephem./Int.	Assoc. Land Use	Min. LOG q/T	Comment
10	NN		RS	P																			
11	NN		RS	P																			
12	NN		RS	P																			
14	NN		RS	P																			
15	NN	3	DS	P	78		160	105	16800	160			3.5	58800	Y	81	1764	2381		X			
16	NO		RS	D	00																		active deep seated landslide
17	NN	2	DS	Q	78		100	100	10000	100			3.5	35000	Y	81	1050	1418		X	ROAD	-4.154	
18	NN		RS	P																			
19	NN		RS	P																			
20	NN		RS	P																			
23	NN		RS	P																			
24	NN		RS	P																			
29	NN		RS	P																			
30	NN		RS	P																			
31	NN	3	DS	D	78		66	132	8712	66			3	26136	Y	81	784	1059				-3.286	
32	NN	3	DS	Q	78		66	44	2904	66			3	8712	Y	81	261	353		X		-2.341	
34	NN	2	DS	D	78		44	110	4840	44			3	14520	Y	81	436	588	X			-2.617	INNER GORGE, MEANDER
35	NN	3	DS	Q	78		88	22	1936	88			3	5808	N	0	0	0				-2.644	
36	NN	3	DS	Q	78		132	44	5808	132			3	17424	Y	81	523	706		X		-3.667	
38	NN	3	DS	Q	78		44	22	968	44			3	2904	Y	81	87	118		X		-3.397	
39	NN	3	DS	Q	78		66	22	1452	66			3	4356	Y	81	131	176		X		-2.969	
40	NN	3	DS	Q	78		110	44	4840	110			3	14520	Y	81	436	588		X		-2.709	
44	NN		RS	P																			
46	NN		RS	P																			
47	NN		RS	P																			
48	NN		RS	P																			
53	NN		RS	P																			
54	NN		RS	P																			
55	NN		RS	P																			
56	NN	3	DS	Q	78		44	22	968	44			3	2904	Y	81	87	118	X			-3.319	OUTSIDE MEANDER
58	NN	3	DS	D	78	85	50	30	1500	50			2	3000	Y	81	90	122		X		-3.194	
59	NN	3	DS	D	78	70	40	30	1200	40			3	3600	N	0	0	0				-2.686	
60	NN		RS	P																			
61	NN		RS	P																			
62	NN		RS	P																			
63	NN	2	DS	Q	78		110	22	2420	110			3	7260	Y	81	218	294		X		-3.684	LOOKS LIKE ROAD ON PHOTO'S
64	NN	2	DS	D	78		66	44	2904	66			3	8712	Y	100	323	436		X		-3.563	
65	NN	3	DS	D	78		44	44	1936	44			3	5808	Y	81	174	235		X		-2.828	HEADWARD EROSION @ HEAD H2O
66	NN	4	DS	D	78		88	44	3872	88		0	3	11616	Y	100	430	581	X			-2.551	TERRACE DELIVERY BY PERENIAL
67	NN		RS	P																			
68	NN		RS	P																			
72	NM		RS	P																			
73	NM		RS	P																			
75	NN		RS	P																			
76	NN		RS	P																			
77	NN		RS	P																			
78	NN		RS	P																			
80	NN	3	DS	Q	78		44	22	968	44			3	2904	Y	100	108	145	X			-2.287	RIDGE LINE
81	NN	3	DS	D	78		110	60	6600	110			3.5	23100	N	0	0	0			ROAD	-3.006	CUT SLOPE
82	NN	3	DS	P	78		44	44	1936	44			3	5808	N	0	0	0				-2.592	
83	NN	3	DS	P	78		66	22	1452	66			3.5	8470	N	0	0	0			ROAD	-2.831	
84	NN	3	DS	D	78		110	44	4840	110			3	14520	N	0	0	0				-25000	MID SLOPE
85	NN		RS	P																			
86	NN		RS	P																			
87	NN		RS	P																			
90	NM		RS	P																			
91	NM		RS	P																			
92	NM		RS	P																			
93	NM		RS	P																			
94	NM		RS	P																			
95	NM		RS	P																			
96	NM		RS	P																			
97	NM	3	DS	Q	78		220	44	9680	220			3	29040	Y	81	871	1176		X		-3.375	SMALL DF ON DLS
98	NM	3	DS	Q	78		154	66	10164	154			3	30492	Y	81	915	1235	X			-2.411	
99	NM		RS	P																			
100	NM		RS	P																			
101	NM		RS	P																			
102	NM		RS	P																			
103	NM		RS	P																			
104	NM		RS	P																			
105	NM	3	DS	P	78		66	44	2904	66			3	8712	Y	100	323	436	X			-3.005	
106	NM		RS	P																			
107	NM		RS	P																			
108	NM		RS	P																			

<u>Table A-1.</u> Landslide Inventory for the Noyo WAU.

I.D. No.	Planning Watershed	MWMU	Landslide Process and Certainty: Type	Certainty	Approx. Failure Date	Slope Gradient (%) (field)	Landslide Size (surface Area) (by photo date): Photo Yr. 78 L	W	Area	Photo Yr. 96 L	W	Area	Avg. Slide Depth (field)	Slide Volume (cu ft)	Sedmnt. Delvry.	Sedmnt. Delvry. (%)	Sedmnt. Delvry. vol (cu yds)	Sedmnt. Delvry. vol (tons)	Sediment Routing: Perrenial	Ephem./Int.	Assoc. Land Use	Min. LOG q/T	Comment
110	NM	2	DS	Q	78		66	44	2904	66			3	8712	Y	100	323	436		X		-2.635	
111	NM		RS	P																			
113	NM		RS	P																			
114	NM		RS	P																			
115	NM		RS	P																			
116	NM		RS	P																			
117	NM		RS	P																			
117	NM		RS	P																			
118	NM		RS	P																			
119	NM		RS	P																			
120	NM		RS	P																			
121	NM		RS	P																			
122	NM		RS	P																			
123	NM		RS	P																			
124	NM		RS	P																			
127	NM		RS	P																			
128	NM	3	DS	Q	78		220	110	24200	220			3	72600	Y	100	2689	3630	X			-2.965	
129	NM	3	DF	D	50-60	83	75	50	3750	75			1	3750	Y	100	139	188		X		-3.339	NO SOIL, THIN LAYER 6" COLUVIUM
130	NM	3	DS	D	50-60	71	160	40	6400	160			2	12800	Y	100	474	640		X		-3.256	NO SOIL, THIN LAYER 6" COLUVIUM
131	NM		RS	P																			
133	NM		RS	P																			
134	NM		RS	P																			
135	NM	4	DS	D	78		154	44	6776	154		0	3	20328	Y	100	753	1016	X			-3.298	
135	NM		RS	P																			
137	NM	2	DS	D	78		154	110	16940	154			3	50820	Y	100	1882	2541		X		-3.466	
138	NM	3	DS	P	78		88	44	3872	88			3	11616	Y	100	430	581		X		-3.675	
139	NM		RS	P																			
140	NM		RS	P																			
141	NM		RS	P																			
142	NM		RS	P																			
143	NM	3	DS	D	78		166	150	24900	166			3	74700	Y	81	2241	3025		X			
145	NM	3	DS	D	78		66	22	1452	66			3	4356	Y	81	131	176	X			-25000	
146	NM	3	DS	D	78		44	22	968	44			3	2904	Y	81	87	118	X			-2.741	
147	NM		RS	P																			
148	NM		RS	P																			
153	NM		RS	P																			
154	NM		RS	P																			
155	NM		RS	P																			
156	NM		RS	P																			
157	NM		RS	P																			
162	NM		RS	P																			
163	NO		RS	P																			
164	NO		RS	P																			
169	NO		RS	P																			
176	NO		RS	P																			
179	NO	3	DS	Q	78		110	44	4840	110			3	14520	P	81	436	588	X			-3.441	
180	NO		RS	P																			
181	NO	3	DS	P	78		88	22	1936	88			3.5	6776	N	0	0	0			ROAD	-2.748	
183	NO	3	DS	Q	78		66	22	1452	66			3.5	5082	N	0	0	0			ROAD		
186	NO		RS	P																			
187	NO		RS	P																			
189	NO		RS	P																			
191	NO		RS	P																			
192	NO		RS	P																			
193	NO		RS	P																			
194	NO	3	DS	P	78		88	44	3872	88			3	11616	Y	81	348	470		X		-3.628	COULD NOT LOCATE IN FIELD
195	NO	3	DS	P	78		176	22	3872	176			3	11616	Y	81	348	470		X		-2.557	COULD NOT LOCATE IN FIELD
196	NO	3	DS	D	78	70	90	40	3600	90			5	18000	N	0	0	0				-2.401	
197	NO	3	DS	D	78	70	150	45	6750	150			4	27000	Y	100	1000	1350		X		-2.934	
199	NO	3	DS	Q	78		154	22	3388	154			3	10164	Y	84	316	427		X		-2.863	
200	NO		RS	P																			
201	NO		RS	P																			
204	NO		RS	P																			
209	NO	3	DS	Q	78		30	30	900	30			3	2700	Y	81	81	109		X		-2.814	COULD NOT LOCATE IN FIELD
210	NO		RS	P																			
215	NO	3	DS	P	78		233	100	23300	233			3	69900	Y	81	2097	2831		X		-3.119	
273	NR	3	DS	P	78		88	22	1936	88			3	5808	N	0	0	0				-3.599	OLD REVEGETADTED CLEAR CUT
274	NR	3	DS	D	78	110	60	70	4200	60			4	16800	N	0	0	0			ROAD	-2.171	OLD DEGRADED SCARP
277	NR	3	DS	D	78		242	44	10648	242			3.5	37268	Y	100	1380	1863	X		ROAD	-3.417	
279	NR		RS	P																			
280	NR		RS	P																			
281	NR		RS	P																			
331	NC	2	DT	D	78		600	140	84000	600			3	252000	Y	100	9333	12600		X		-25000	
335	NC		EF	D																			COMPLEX OF EARTHFLOWS WITH TOE ON MRC LAND

Table A-1. Landslide Inventory for the Noyo WAU.

I.D. No.	Planning Watershed	MWMU	Landslide Process and Certainty: Type	Certainty	Approx. Failure Date	Slope Gradient (%) (field)	Photo Yr. 78: L	W	Area	Photo Yr. 96: L	W	Area	Avg. Slide Depth (field)	Slide Volume (cu ft)	Sedmnt. Delvry.	Sedmnt. Delvry. (%)	Sedmnt. Delvry. vol (cu yds)	Sedmnt. Delvry. vol (tons)	Sediment Routing: Perrenial	Ephem./Int.	Assoc. Land Use	Min. LOG q/T	Comment
336	NC		RS	P																			
337	NC		RS	P																			
338	NC		RS	P																			
340	NC	5	DS	D	78		150	60	9000	150		0	3	27000	Y	81	810	1094		X			
341	NC		RS	P																			
363	NC	3	DT	D	78		30	88	2640	30			3.5	9240	Y	81	277	374			ROAD	-2.399	
364	NC	3	DS	Q	78		88	22	1936	88			3.5	6776	N	0	0	0			ROAD	-3.165	
365	NC		RS	P																			
366	NC	3	DS	D	78		66	44	2904	66			3.5	10164	Y	100	376	508	X		ROAD	-2.856	
368	NC	3	DS	D	78		110	44	4840	110			3	14520	Y	81	436	588		X		-3.309	
369	NC		RS	P																			
370	NC	3	DS	P	78		66	22	1452	66			3.5	5082	N	0	0	0			ROAD	-2.867	
371	NC		RS	P																			
373	NC	3	DS	P	78		66	22	1452	66			3	4356	Y	100	161	218	X			-2.522	ENTRENCHED MEANDER PATTERN
374	NC	1	DS	P	78		44	22	968	44			3	2904	Y	100	108	145	X			-2.74	ENTRENCHED MEANDER PATTERN
375	NC		RS	P																			
376	NC	3	DS	D	78		350	150	52500	350			3.5	183750	Y	81	5513	7442	X		ROAD		
377	NC	3	DS	Q	78		22	88	1936	22			3	5808	Y	81	174	235	X			-2.384	
378	NC		RS	P																			
379	NC		RS	P																			
381	NC	3	DS	P	78		66	22	1452	66			3	4356	Y	81	131	176		X		-3.315	
382	NC	3	DS	D	78		66	22	1452	66			3	4356	Y	81	131	176		X		-3.013	
383	NO	3	DS	D	99	68			0	175	72	12600	7	88200	Y	10	327	441		X	ROAD		INITIATED OFF OF DEEP SEATED SLIDE #16
384	NC		RS	P																			
387	NC	3	DS	D	78		110	44	4840	110			3	14520	P	81	436	588		X		-2.737	STEEP SLOPE
388	NC	3	DS	P	78	70	90	40	3600	90			3	10800	N	0	0	0				-2.403	
389	NC	3	DS	D	78		88	22	1936	88			3.5	6776	N	0	0	0			ROAD	-3.313	
390	NC	3	DS	Q	78		44	22	968	44			3.5	3388	Y	100	125	169		X	ROAD	-2.516	
391	NC		RS	P																			
392	NC		RS	P																			
393	NC		RS	P																			
394	NC		RS	P																			
395	NC		RS	P																			
409	NC	3	DS	P	78		110	22	2420	110			3.5	8470	N	0	0	0			ROAD	-2.51	
411	NC	4	DS	P	78	68	83	30	2490	83		0	4	9960	Y	100	369	498		X	ROAD	35000	
412	NC	2	DS	D	78		132	44	5808	132		0	3	17424	Y	100	645	871		X		-3.541	STEEP SLOPE
415	NC		RS	P																			
416	NH		RS	P																			
417	NH		RS	P																			
418	NH		RS	P																			
419	NH	3	DS	D	78		66	22	1452	66			3	4356	Y	100	161	218		X		-2.771	
420	NH	3	DS	D	78		44	22	968	44			3	2904	N	0	0	0				-3.074	
421	NH	3	DS	D	78		110	22	2420	110			3	7260	P	81	218	294	X			-3.628	STEEP WALL
422	NH	3	DS	P	78		44	22	968	44			3	2904	P	81	87	118	X			-3.284	STEEP WALL
423	NH		RS	P																			
424	NH		RS	P																			
425	NH	3	DS	P	78		44	44	1936	44			3	5808	N	0	0	0				-3.383	
426	NH	3	DS	D	78		110	44	4840	110			3	14520	N	0	0	0				-25000	
427	NH	3	DS	D	78		100	30	3000	100			3	9000	N	0	0	0				-3.452	STEEP CLIFF NEXT TO TERRACE
428	NH	3	DS	D	78		100	30	3000	100			3	9000	N	0	0	0				-3.358	STEEP CLIFF NEXT TO TERRACE
429	NH	3	DS	Q	78		330	66	21780	330			3	65340	N	0	0	0				-2.558	STEEP CLIFF NEXT TO TERRACE
430	NH	3	DS	P	78		88	44	3872	88			3	11616	N	0	0	0				-3.317	STEEP CLIFF NEXT TO TERRACE
431	NH		RS	P																			
432	NH	3	DF	D	78	90	150	25	3750	150			2	7500	N	0	0	0				-2.739	
433	NH	3	DS	D	78	90	90	25	2250	90			1	2250	N	0	0	0				-2.562	
434	NH	3	DS	P	78		330	22	7260	330		0	3	21780	N	0	0	0				-3.164	
435	NH		RS	P																			
436	NH	3	DS	D	78	77	125	12	1500	125			5	7500	Y	100	278	375		X		-25000	SEE SLIDE 784
437	NH	3	DS	P	78		132	44	5808	132		0	3	17424	Y	100	645	871		X		-3.988	
438	NH	3	DT	D	78	81	385	240	92400	385			7	646800	Y	100	23956	32340	X			-25000	RUNNOUT OVER VEGETATED
439	NH		RS	P																			
440	NH		RS	P																			
449	NH		RS	P																			
450	NH	1	DS	P	78					88	22	1936	3	5808	Y	100	215	290		X			
450	NH		RS	P																			
451	NH	2	DS	D	78				0	88	44	3872	3.5	13552	N	0	0	0			ROAD	-3.229	
452	NH	4	DS	P	78				0	176	88	15488	3	46464	Y	81	1394	1882		X		-3.296	
453	NH		RS	P																			
454	NH	3	DT	P	78		110	44	4840	110			3.5	16940	Y	81	508	686		X	ROAD	-4.309	POSIBLE DEBRIS TORRENT
455	NH		RS	P																			
456	NH		RS	P																			
457	NH		RS	P																			
458	NH		RS	P																			
460	NH	3	DT	D	78		500	250	125000	500			3	375000	Y	100	13889	18750	X			-25000	LONG PERSISTANT DEEP

Table A-1. Landslide Inventory for the Noyo WAU.

I.D. No.	Planning Watershed	MWMU	Landslide Process and Certainty: Type	Certainty	Approx. Failure Date	Slope Gradient (%) (field)	Landslide Size (surface Area) (by photo date) Photo Yr. 78: L	W	Area	Photo Yr. 96: L	W	Area	Avg. Slide Depth (field)	Slide Volume (cu ft)	Sedmnt. Delvry.	Sedmnt. Delvry. (%)	Sedmnt. Delvry. vol (cu yds)	Sedmnt. Delvry. vol (tons)	Sediment Routing: Perrenial	Ephem./Int.	Assoc. Land Use	Min. LOG q/T	Comment
461	NH		RS	P																			
465	NH	3	DS	P	78		88	22	1936	88			3	5808	Y	100	215	290		X		-25000	
466	NH	3	DS	P	78		488	110	53680	488		0	3	161040	Y	100	5964	8052		X		-25000	
467	NH		RS	P																			
468	NH	3	DS	P	78		44	22	968	44			3.5	3388	Y	100	125	169		X	ROAD	-3.264	
469	NH		RS	P																			
470	NH	3	DS	P	78		66	22	1452	66			3.5	5082	Y	81	152	206		X	ROAD	-2.929	
471	NH		RS	P																			
472	NH	1	DS	D	78	72	40	10	400	40			4	1600	Y	81	48	65		X		-3.032	COULD HAVE BEEN CONTROLABLE
473	NH	3	DS	P	78		66	22	1452	66			3.5	5082	Y	81	152	206		X	ROAD	-2.794	ROAD
474	NH	3	DS	P	78		66	22	1452	66			3.5	5082	Y	81	152	206		X	ROAD	-2.784	ROAD
475	NH	3	DS	P	78		22	22	484	22			3.5	1694	Y	100	63	85		X	ROAD	35000	ROAD
476	NH	3	DS	P	78		44	22	968	44			3.5	3388	P	81	102	137		X	ROAD	-2.505	
477	NH		RS	P																			
478	NH	3	DS	D	78	82	210	60	12600	210			3	37800	N	0	0	0	X			-25000	SHALSTAB RED
479	NH		RS	P																			
480	NH		RS	P																			
481	NH		RS	P																			
483	NH		RS	P																			
485	NH	3	DT	D	78		55	110	6050	55			3.5	21175	Y	81	635	858	X		ROAD	-3.044	
490	NH		RS	P																			
492	NH		RS	P																			
511	NH		RS	P																			
512	NH	4	DS	P	78		66	22	1452	66		0	3	4356	Y	100	161	218		X		-2.405	
514	NH		RS	P																			
515	NH	4	DS	P	78		66	22	1452	66		0	3.5	5082	P	81	152	206		X	ROAD	-2.224	
515	NH		RS	P																			
516	NH	3	DS	P	78		66	22	1452	66			3.5	5082	N	0	0	0			ROAD	-2.464	
517	NH	1	DS	P	78		44	22	968	44			3.5	3388	Y	100	125	169		X	ROAD	-5.933	
518	NH	3	DS	P	78		22	22	484	22			3.5	1694	Y	100	63	85		X	ROAD	-3.684	
520	NH	3	DS	P	78		88	22	1936	88			3.5	6776	Y	81	203	274		X	ROAD	-2.84	
520	NH		RS	P																			
521	NH		RS	P																			
523	NH		RS	P																			
524	NH	3	DS	P	78		66	22	1452	66			3	4356	Y	81	131	176		X		-2.754	
525	NH	2	DS	P	78		44	22	968	44		0	3	2904	Y	81	87	118		X		-3.595	
526	NH		RS	P																			
528	NM	3	DS	Q	96				0	90	48	4320	3.5	15120	N	0	0	0			ROAD	-3.145	
529	NN	3	DS	Q	96				0	33	48	1584	3	4752	N	0	0	0				-2.486	DELIVERY TO TERRACE
530	NN	3	DT	D	96				0	83	50	4150	3	12450	N	0	0	0				-2.149	POSSIBLE DEBRIS TORRENT
532	NN	3	DS	D	96				0	96	48	4608	3	13824	N	0	0	0				-2.661	
533	NN	3	DS	D	96				0	80	33	2640	3	7920	N	0	0	0				-3.605	DELIVERY TO TERRACE
535	NM	3	DS	D	96				0	83	66	5478	3	16434	N	0	0	0		X		-3.066	
536	NM	4	DS	Q	96				0	133	33	4389	3	13167	Y	81	395	533		X		-2.167	
537	NM	4	DS	D	96				0	224	80	17920	3	53760	Y	100	1991	2688	X			-2.98	
538	NO	3	DS	D	96	78			0	72	60	4320	3	12960	N	0	0	0			ROAD	-2.63	
539	NO	3	DS	D	96	90			0	65	40	2600	3	7800	N	0	0	0			ROAD	-3.07	BELOW ROAD
540	NN	3	DS	D	96				0	80	33	2640	3	7920	N	0	0	0				-2.186	
541	NO	4	DS	D	96	70			0	68	18	1224	2	2448	N	0	0	0				35000	
542	NO	3	DS	P	96	60			0	46	20	920	1	920	N	0	0	0				-2.695	SLOPE BREAK
543	NO	3	DS	D	96				0	80	33	2640	3	7920	Y	81	238	321		X		-2.309	STEEP TOPOGRAPHY
544	NO	3	DS	D	96	72			0	90	60	5400	3	16200	N	0	0	0			ROAD	-2.165	ROAD WASHED OUT
546	NO	3	DS	D	96	75			0	50	25	1250	7	8750	Y	81	263	354		X	ROAD	-2.664	
547	NO	3	DS	D	96	75			0	30	25	750	7	5250	N	0	0	0				-3.433	
548	NO	3	DS	P	96				0	67	33	2211	3	6633	N	0	0	0				-25000	
549	NO	3	DS	P	96				0	17	33	561	3	1683	N	0	0	0				-3.298	
583	NC	3	DS	D	96				0	67	33	2211	3.5	7738.5	Y	81	232	313		X		-3.876	
590	NN	1	DS	P	96					17	17	289	3	867	Y	100	32	44	x			-4.467	
612	NH	3	DS	D	96				0	50	16	800	3.5	2800	Y	81	84	113		X	ROAD	-3.327	COULD NOT LOCATE IN FIELD
613	NH	3	DS	P	96				0	50	16	800	3.5	2800	N	0	0	0			ROAD	-2.551	
615	NH	2	DS	D	96				0	17	67	1139	3	3417	Y	81	103	138		X		-25000	
618	NH	1	DS	Q	96					16	16	256	3	768	Y	81	23	31		X		-3.968	
619	NH	3	DS	P	96				0	16	16	256	3	768	Y	81	23	31		X		-2.454	COULD NOT LOCATE IN FIELD
620	NH	1	DS	D	96	98				60	25	1500	2	3000	Y	100	111	150	X			35000	INNER GORGE, LOG JAM
622	NH	3	DS	Q	96				0	32	16	512	3	1536	Y	100	57	77		X		-5.453	
623	NH	3	DS	QQ	96				0	32	16	512	3	1536	N	0	0	0				-3.362	
627	NH	4	DS	P	96				0	50	16	800	3	2400	Y	81	72	97		X		-25000	
636	NH	2	DS	D	96				0	96	50	4800	3	14400	Y	100	533	720		X		-5.192	
660	NC	3	DS	D	96				0	160	33	5280	3	15840	Y	100	587	792		X	ROAD	-25000	
662	NC	2	DS	D	96	95			0	40	60	2400	2	4800	N	0	0	0				-3.125	ROCKFALL AVALANCHE
663	NC	3	DS	Q-P	96	72			0	40	18	720	1	720	Y	100	27	36	X			-2.476	
664	NC	3	DS	D	96				0	66	33	2178	3	6534	Y	81	196	265		X		-3.405	HEAVILY LOGGED
665	NC	2	DS	D	96	75			0	40	68	2720	3	8160	Y	100	302	408	X			-3.705	HEAVILLY LOGGED, INNER GORGE
666	NC	4	DS	D	96	90			0	88	35	3080	3	9240	Y	100	342	462	X			-2.619	

Table A-1. Landslide Inventory for the Noyo WAU.

I.D. No.	Planning Watershed	MWMU	Landslide Process and Certainty: Type	Certainty	Approx. Failure Date	Slope Gradient (%) (field)	Landslide Size (surface Area) (by photo date): Photo Yr. 78 L	W	Area	Photo Yr. 96 L	W	Area	Avg. Slide Depth (field)	Slide Volume (cu ft)	Sedmnt. Delvry.	Sedmnt. Delvry. (%)	Sedmnt. Delvry. vol (cu yds)	Sedmnt. Delvry. vol (tons)	Sediment Routing: Perrenial	Ephem./Int.	Assoc. Land Use	Min. LOG q/T	Comment
667	NC	1	DS	D	96					33	33	1089	3	3267	Y	100	121	163	X			-4.785	
671	NC	4	DS	Q	96				0	16	16	256	3	768	Y	81	23	31	X			-2.389	
672	NC	3	DS	P	96	65			0	40	25	1000	2	2000	Y	100	74	100		X		-2.858	
674	NC	3	DS	P	96	68			0	32	15	480	3	1440	N	0	0	0				-2.333	
707	NC	3	DS	D	96				0	132	44	5808	3	17424	Y	100	645	871				-2.931	
713	NC	3	DS	D	96				0	183	66	12078	3.5	42273	Y	100	1566	2114		X	ROAD	-4.163	
716	NC	3	DS	P	96				0	66	16	1056	3.5	3696	N	0	0	0			ROAD	-25000	
719	NC	3	DS	P	96				0	133	60	7980	3	23940	Y	100	887	1197		X		-4.25	MAP CONVERSION
720	NC	3	DS	P	96				0	132	50	6600	3	19800	Y	100	733	990		X		-2.886	MAP CONVERSION
721	NC	3	DS	P	96				0	132	50	6600	3	19800	Y	100	733	990		X		-2.788	MAP CONVERSION
722	NC	3	DS	P	96				0	132	50	6600	3	19800	Y	100	733	990		X		-2.874	MAP CONVERSION
728	NN	4	DS	P	96				0	33	33	1089	3	3267	Y	81	98	132		X		35000	
729	NN	3	DS	D	96	72			0	50	30	1500	5	7500	N	0	0	0			ROAD	-2.289	
731	NN	4	DS	P	96				0	83	33	2739	3	8217	P	81	247	333	X			35000	COULD NOT LOCATE IN FIELD
732	NH	3	DS	D	96	62			0	42	18	756	2	1512	Y	100	56	76		X		-2.611	
733	NN	3	DS	D	96				0	33	16	528	3.5	1848	N	0	0	0			ROAD	-3.044	
734	NN	3	DS	P	96				0	83	33	2739	3.5	9586.5	P	81	288	388	X		ROAD	-2.503	
736	NN	1	DS	D	96					83	33	2739	3	8217	P	81	247	336	X			-2.517	MIDSLOPE
737	NN	3	DS	Q	96				0	16	16	256	3	768	N	0	0	0				-2.384	
738	NN	3	DS	Q	96				0	16	16	256	3	768	N	0	0	0				-3.007	
739	NN	3	DS	P	96				0	16	16	256	3	768	N	0	0	0				35000	
740	NN	3	DS	Q	96				0	16	16	256	3	768	N	0	0	0				35000	
741	NN	3	DS	P	96				0	33	16	528	3	1584	N	0	0	0				-2.583	
742	NN	3	DS	P	96				0	33	16	528	3	1584	N	0	0	0				-2.601	
744	NN	3	DS	P	96				0	16	16	256	3.5	896	N	0	0	0			ROAD	-3.755	
745	NN	2	DS	D	96				0	80	48	3840	3	11520	N	0	0	0				-2.557	
747	NN	2	DS	P	96	77			0	40	25	1000	3	3000	Y	100	111	150	X			-3.694	INNER GORGE
748	NN	1	DS	P	96					16	16	256	3	768	Y	100	28	39	X			-2.713	
749	NN	1	DS	P	96					16	16	256	3	768	Y	100	28	39	X			-2.422	INNER GORGE
750	NN	1	DS	D	96	75				60	35	2100	3	6300	Y	100	233	319	X			-25000	INNER GORGE
751	NN	1	DS	Q	96					33	16	528	3	1584	Y	100	59	80	X			-4.487	INNER GORGE
753	NN	3	DS	P	96				0	33	16	528	3	1584	P	81	48	64		X		-3.115	
756	NN	3	DS	P	96				0	33	33	1089	3	3267	Y	100	121	163		X		-2.958	
757	NN	3	DS	P	96				0	66	48	3168	3	9504	N	0	0	0				-3.124	
759	NM	3	DT	D	96	72			0	230	80	18400	10	184000	Y	100	6815	9200		X		-3.381	SHALSTAB RED
759a	NM									250	5	1250	5	6250	Y	100	231	313		X			RUNOUT FROM 759, SEE ALSO 1152
760	NM	3	DS	Q	96				0	16	16	256	3	768	Y	100	28	38		X		-2.848	
761	NM	1	DS	D	96					80	32	2560	3	7680	Y	100	284	384		X		-3.2	
762	NM	2	DS	Q	96				0	32	16	512	3.5	1792	Y	100	66	90		X	ROAD	-4.232	
763	NM	4	DS	Q	96				0	16	16	256	3.5	896	N	0	0	0			ROAD	-2.635	
765	NM	3	DS	P	96	65			0	35	30	1050	1	1050	Y	81	32	43		X	ROAD	-2.499	
768	NM	4	DS	Q	96				0	50	33	1650	3.5	5775	N	0	0	0			ROAD	35000	
769	NM	4	DS	Q	96				0	32	16	512	3	1536	N	0	0	0				35000	
770	NM	3	DS	Q	96				0	48	16	768	3	2304	N	0	0	0				-2.151	
771	NM	3	DS	Q	96				0	32	16	512	3	1536	N	0	0	0				-2.475	
772	NM	1	DS	P	96					33	16	528	3	1584	Y	100	59	79	X			-4.173	
773	NM	3	DS	D	78	0	154	110	16940	154	0	0	3	50820	Y	100	1882	2541		X			
774	NM	2	DS	Q	96				0	32	16	512	3	1536	Y	100	57	77	X			-3.501	
780	NH	3	DS	P	96				0	83	16	1328	3.5	4648	Y	81	139	188		X	ROAD	-2.566	
782	NH	3	DS	Q	96				0	32	32	1024	3.5	3584	Y	81	108	145		X	ROAD	-3.722	
784	NH	3	DS	D	96	77			0	80	50	4000	2	8000	Y	81	240	324		X		-2.437	SCARP MIGRATION OF SLIDE 436
785	NH	2	DS	D	96	75			0	38	25	950	2	1900	Y	100	70	95		X		-3.114	
786	NH	2	DS	P	96				0	33	33	1089	3	3267	Y	81	98	132		X		-3.09	COULD NOT LOCATE IN FIELD
787	NH	2	DS	P	96				0	17	33	561	3	1683	N	0	0	0				-2.26	
813	NN	3	DS	P	96				0	17	33	561	3	1683	P	100	62	84	x			35000	
816	NN	3	DS	P	96				0	83	33	2739	3.5	9586.5	Y	100	355	479	x		ROAD	-2.498	
817	NO	3	DS	Q	96				0	16	16	256	3	768	Y	81	23	31		X		-2.033	
818	NO	3	DS	D	96				0	33	16	528	3	1584	N	0	0	0				-3.384	
820	NO	4	DS	P	96				0	100	66	6600	3	19800	Y	81	594	802	X			-2.334	MAP CONVERSION
821	NO	1	DS	Q	96					16	16	256	3.5	896	Y	81	27	36		X	ROAD	35000	COULDN'T LOCATE IN FIELD
822	NO	1	DS	D	96	60				48	20	960	2	1920	Y	100	71	96		X		-2.641	VERY QUESTIONABLE
823	NO	2	DS	Q	96				0	16	16	256	3	768	Y	81	23	31		X		-2.918	CABLEYARD PARTIAL CUT
824	NO	3	DS	Q	96				0	16	16	256	3.5	896	Y	81	27	36		X	ROAD	-2.896	
825	NO	1	DS	Q	96					100	33	3300	3	9900	Y	81	297	401		X		-2.798	
826	NO	2	DS	D	96				0	50	16	800	3.5	2800	Y	81	84	113		X	ROAD	-3.134	
827	NO	3	DT	D	96				0	66	33	2178	3.5	7623	P	81	229	309		X	ROAD	35000	POSSIBLE DT
829	NO	3	DT	D	96				0	48	16	768	3	2304	N	0	0	0				-2.349	
830	NO	3	DT	D	96	90			0	24	40	960	3	2880	N	0	0	0			ROAD	-2.141	
830a	NO									160	16	2560	3	7680	Y	81	230	311		X			RUNOUT FROM 830
831	NO	3	DS	D	96	68			0	53	19	1007	1	1007	Y	81	30	41		X		-2.114	SLOPE BREAK
832	NO	4	DS	D	96	70			0	80	20	1600	3	4800	N	0	0	0				35000	
835	NO	2	DS	D	96				0	17	67	1139	3	3417	Y	100	127	171		X		-3.677	COULD NOT LOCATE IN FIELD
836	NO	3	DS	P	96				0	16	16	256	3	768	N	0	0	0				-2.947	STEEP TOPOGRAPHY
837	NO	3	DS	D	96	73			0	80	12	960	5	4800	Y	25	44	60		X		-2.987	HEADWARD EROSION 75% DEPO

Table A-1. Landslide Inventory for the Noyo WAU.

I.D. No.	Planning Watershed	MWMU	Landslide Process and Certainty: Type	Certainty	Approx. Failure Date	Slope Gradient (%) (field)	Landslide Size (surface Area) (by photo date) Photo Yr. 78: L	W	Area	Photo Yr. 96: L	W	Area	Avg. Slide Depth (field)	Slide Volume (cu ft)	Sedmnt. Delvry.	Sedmnt. Delvry. (%)	Sedmnt. Delvry. vol (cu yds)	Sedmnt. Delvry. vol (tons)	Sediment Routing: Perrenial	Ephem./Int.	Assoc. Land Use	Min. LOG q/T	Comment
838	NO	1	DS	P	96					100	66	6600	3	19800	Y	100	733	990	X			-2.508	MAP CONVERSION
839	NO	3	DS	D	96				0	48	16	768	3.5	2688	N	0	0	0			ROAD	35000	
841	NR	3	DS	Q	96				0	17	67	1139	3	3417	Y	81	103	138		X		-2.993	
842	NR	3	DS	p	96				0	17	50	850	3.5	2975	N	0	0	0			ROAD	-3.003	
843	NR	5	DS	P	96				0	17	50	850	3	2550	N	0	0	0				-2.251	
845	NM	3	DS	D	98				0	50	16	800	3.5	2800	Y	81	84	113		X	ROAD	-3.71	PARTIALLY REVEGETATED
846	NH	3	DS	P	96				0	33	16	528	3	1584	P	81	48	64		X		-2.29	COULD NOT LOCATE IN FIELD
847	NH	2	DS	P	96				0	16	16	256	3	768	P	81	23	31		X		-25000	COULD NOT LOCATE IN FIELD
1000	NC	3	DS	D	78		200	150	30000	200		0	3	90000	Y	100	3333	4500	X				STREAMSIDE
1001	NU	4	DF	Q	96				0	100	40	4000	3	12000	N		0	0					CONVERGENT
1002	NU	1	DS	P	96					120	80	9600	3.5	1244	Y	100	1244	1680	X		ROAD		
1003	NU	4	DT	Q	96				0	500	25	12500	3.5	43750	Y	81	1313	1772		X	ROAD		
1103a	NR									300	15	4500	3	13500	Y	100	500	675		X			
1004	NU	5	DS	P	96				0	100	80	8000	3.5	28000	Y	100	1037	1400		X	ROAD		
1104a	NR									200	32	6400	3	19200	Y	100	711	960		X			
1005	NU		RS	P	96									0									DORMANT
1006	NU	4	DS	Q	96				0	40	30	1200	3	3600	N		0	0					
1007	NU	3	DS	D	96				0	225	100	22500	3	2500	Y	100	93	125	X				INSIDE OF MEANDER BEND
1008	NU	4	DT	D	96				0	450	45	20250	3.5	70875	Y	81	2126	2870	X		ROAD		
1101	NH	3	DS	P	98				0	44	22	968	3	2904	Y	81	87	118		X		n/a	
1102	NC	3	DS	D	98				0	88	22	1936	3	5808	Y	81	174	235		X		n/a	
1103	NR	4	DT	D	98	77			0	52	45	2340	3	7020	Y	81	211	284		X		n/a	RUNNOUT 300x15x3', OVER ROAD
1104	NR	2	DT	D	98	75			0	300	45	13500	5	67500	Y	0	0	0		X		n/a	RUNNOUT 200x32x3', OVER ROAD
1105	NC	4	DS	D	98				0	33	16	528	3	1584	N	0	0	0				n/a	
1106	NO	3	DS	D	98	95			0	60	44	2640	3	7920	N	0	0	0			ROAD	n/a	
1107	NO	3	DS	D	98	75			0	150	60	9000	4	36000	Y	100	1333	1800		X	ROAD	n/a	
1108	NO	3	DS	D	98	82	90	68	6120	90		0	5	30600	Y	100	1133	1530		X	ROAD	n/a	
1110	NO	4	DS	D	98	65			0	90	50	4500	3	13500	N	0	0	0			ROAD	n/a	
1112	NN	5	DS	D	98	110			0	25	25	625	1	625	N	0	0	0			ROAD	n/a	MARGIONAL FOR INVENTORY
1113	NR	3	DS	D	98	85			0	135	80	10800	4	43200	N	0	0	0			ROAD	n/a	FILL SLOPE
1116	NO	3	DS	D	98				0	370	15	5550	5	27750	Y	75	771	1041		X	ROAD	n/a	25% DEPOSITION
1117	NO	3	DS	D	98	75			0	265	15	3975	5	19875	Y	100	736	994		X	ROAD	n/a	
1118	NN	2	DS	D	98	75			0	30	36	1080	2	2160	N	0	0	0			ROAD	n/a	
1119	NO	4	DS	D	98	72			0	90	270	24300	8	194400	Y	80	5760	7776	X		ROAD	n/a	COMPOUND SLUMP SCARPS
1120	NC	4	DS	D	98	90			0	63	30	1890	1	1890	Y	100	70	95	X		ROAD	n/a	
1121	NH	3	DF	D	98	70			0	300	30	9000	1	9000	Y	81	270	365		X		n/a	COBBLES FLOWING DOWNSLOPE
1122	NH	3	DF	D	98	72			0	40	23	920	1	920	Y	81	28	37		X		n/a	BOTH SHALSTAB RED (1121,1122)
1123	NN	3	DS	D	98	72			0	210	50	10500	6	63000	Y	100	2333	3150		X	ROAD	n/a	OVER ROAD
1124	NN	3	DS	D	98	82			0	187	98	18326	4	73304	Y	100	2715	3665		X	ROAD	n/a	OVER ROAD
1125	NH	3	DT	D	98	65			0	60	55	3300	5	16500	Y	100	611	825		X	ROAD	n/a	CULVERT FAILED
1125a	NH									350	5	1750	5	8750	Y	100	324	438		X			RUNNOUT FROM 1125
1126	NH	3	DS	D	98	76			0	165	50	8250	5	41250	N	0	0	0				n/a	REVEGETADTED >10 YRS OLD
1127	NH	3	DS	D	98	95			0	45	50	2250	1	2250	Y	50	42	56	X		ROAD	n/a	50% ONTO ROAD
1128	NH	1	DS	D	98	88				44	30	1320	3	3960	Y	100	147	198	X		ROAD	n/a	TRACTOR TRAIL FILL SLOPE
1129	NH	3	DS	D	98	77			0	50	54	2700	3	8100	N	0	0	0				n/a	
1130	NH	3	DS	D	98	85			0	40	65	2600	2	5200	N	0	0	0			ROAD	n/a	OVER ROAD
1131	NH	4	DS	D	98	89			0	50	110	5500	4	22000	N	0	0	0			ROAD	n/a	
1132	NO	2	DS	D	98	68			0	50	100	5000	3	15000	Y	20	111	150		X	ROAD	n/a	FURURE FAILURE LIKELY
1133	NO	4	DS	D	98	80			0	110	120	13200	4	52800	N	0	0	0	X		ROAD	n/a	
1134	NO	3	DS	D	98	75			0	50	90	4500	6	27000	Y	20	200	270		X	ROAD	n/a	
1143	NM	3	DS	D	98	56			0	40	36	1440	3	4320	Y	100	160	216	X		ROAD	n/a	CONCAVE TOPOGRAPHY
1144	NM	3	DS	D	98	54			0	80	60	4800	3	14400	Y	50	267	360	X		ROAD	n/a	T, 50% DEPOSITION ON ROAD
1145	NM	3	DS	D	98	50			0	30	30	900	3	2700	Y	100	100	135	X		ROAD	n/a	
1146	NN	3	DS	D	98	69			0	38	42	1596	3	4788	N	0	0	0			ROAD	n/a	
1147	NN	2	DS	D	98	63			0	100	50	5000	4	20000	Y	50	370	500		X		n/a	SHALSTAB (RED?), 50% DEPO
1148	NM	1	DS	D	98	76				36	50	1800	2	3600	Y	100	133	180	X			n/a	
1149	NM	1	DS	D	98	78				30	50	1500	2	3000	Y	100	111	150		X		n/a	INNER GORGE BANK EROSION
1150	NM	1	DS	D	98	76				40	36	1440	3	4320	Y	100	160	216	X		ROAD	n/a	INNER GORGE BANK EROSION
1151	NM	3	DS	D	98	46			0	35	20	700	3	2100	N	0	0	0				n/a	
1152	NM	3	DS	D	98	72			0	40	30	1200	3	3600	N	0	0	0				n/a	RECENT SSL IN MIDDLE OF 759
10268	NR	3	DS	P	96				0	17	33	561	3.5	1963.5	Y	100	73	98		X		-3.307	
10809	NH	3	DS	D	96				0	160	16	2560	3	7680	Y	100	284	384		X		n/a	