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Geotechnical Report for Rayonier's Forest Practices Application for Unit 29.437 in the North Fork Calawah Watershed

14 September 2016

Prepared by: Julie J. Dieu
Geomorphologist
Rayonier, Pacific Forest Resources

The purpose of this report is to describe and evaluate the possible responses of potentially unstable landforms within and near Unit 29.437 to timber harvest and road construction. Unit 29.437 covers portions of Sections 17, 20 and 21 of Township 29 North, Range 11 West, W.M. (see the attached RFR Harvest Exhibit), in the North Fork Calawah Calawah watershed administrative unit (WAU).

This FPA was submitted for SEPA review with a geotechnical report for three reasons: 1) Many of the mass wasting prescriptions in the North Fork Calawah Watershed Analysis have been deemed "non-specific;" 2) We are proposing to reconstruct road across potentially unstable slopes; and 3) This proposal requires yarding corridors across potentially unstable slopes.

Introduction

Unit 29.437 lies on land owned and managed by Rayonier Washington Timber Company (RWTC) of Rayonier Inc. Until a Notice of Transfer of Approved Forest Practice Application/Notification is submitted to the Washington Department of Natural Resources (WADNR), RWTC shall be considered the operator. No FPA number is available at this time.

Location

Unit 29.437 lies within Clallam County. The unit is bordered to the east and west by additional RWTC ownership (within the green ownership lines on the attached RFR Harvest Exhibit), to the northeast in Section 16 by WADNR ownership and to the south by the United States Forest Service. Elevation within Unit 29.437 ranges from approximately 850 feet at the downstream end of the North Fork Calawah River to approximately 1840 feet at the top of the unit. Hillslope gradient ranges from nearly level floodplain and terrace surfaces to 120%, and there are nearly vertical rock bluffs.

Unit 29.437 lies approximately 12 miles east by northeast of the City of Forks. The unit can be viewed on the Deadman's Hill 7 ½' topographic quadrangle. The high ridge along the eastern edge of the unit is the watershed divide between the mainstem North Fork Calawah River and its tributary Short Creek. The continuation of the ridge towards the southwest separates the mainstem from its tributary Albion Creek. The unit is accessed from Highway 101 by the Cooper Ranch County Road, to the USFS 29 Road, also locally called the A-Line Road, and then by the USFS 2922 which comes due south through a topographic feature called Bonidu Flats. Finally, turn west onto the USFS 2922.015 Road just before crossing the Canyon Creek Bridge over the North Fork Calawah River, do cross the Short Creek Bridge over the North Fork Calawah River, park where the actual Short Creek crossing on WADNR is out and continue hiking up the USFS 2922.015 Road to the edge of the unit.

Timber stands proposed for harvest are dominated by Douglas-fir of late 1950's and early 1960's origin; red alder occurs along the mainstem and in narrow bands down many of the small tributaries within the unit.

Qualifications and Evaluation

I am a licensed engineering geologist in Washington State with twenty-one years of experience in slope stability work in the forested environment, and I am accepted on the "qualified expert" list maintained by the WADNR. In addition, I was a co-lead on the Sedimentation Module for the North Fork Calawah Watershed Analysis, and, in fact, did the mass wasting inventory and drafted the GMU map for the western two-thirds of the WAU, including the area of this proposal.

In my assessment of Unit 29.437, I have reviewed historic and recent aerial photography (1953, 1964, 1977, 1990, 2003 and 2013), topographic maps, and the Soil Survey of Clallam County Area, Washington (Halloin, 1987). The geologic map of the Forks 1:100,000 Quadrangle (Gerstel and Lingley, 2000) was reviewed, as was the Geologic Map of the Olympic Peninsula (Tabor and Cady, 1978). New LiDAR data, 2015 by WADNR, are available for this area – these produced the contours on the RFR Harvest Exhibit. I also utilized information from the North Fork Calawah Watershed Analysis Sedimentation Module (Dieu and Shelmerdine, 1997) and the draft Module K – 2014 Mass Wasting Prescription Reanalysis Level 2 (Dieu, 2015).

I reviewed cutting boundaries around unstable slopes, evaluated delivery potential, reviewed the channel migration zone delineation and walked the road projects, both abandonment and reconstruction, on February 9th, 17th, 25th, March 3rd and March 10th, 2016. On each day, I was accompanied by one or more Pacific Forest Management employee(s).

Overview

Geology/Soils

The underlying geology of Unit 29.437 and adjacent hillslopes has been mapped as OEm on the Cape Flattery 1:100,000 Quadrangle by Schasse (2003). It is contiguous with the same unit mapped immediately south of the unit on the Forks 1:100,000 Quadrangle by Gerstel and Lingley (2000). Numerous measurements on the two quadrangles show strike as due west-east or slightly northwest-southeast from west-east, and dips to the north or northeast at 50 to 90 degrees. This geologic unit is comprised of thick- and thin-bedded sandstone with lesser, thin-bedded siltstone, shale, and slate, and traces of coal. These are interpreted as deep-marine deposits of the late Oligocene to Early Eocene. Descriptions of this geologic unit are consistent with my field observations of rock outcrops in the cutslope of the 2922.015 Road and the many bedrock exposures within the unit. There is a distinct band of massive sandstone across the entire unit, intersecting in the zone of 1000-1200 feet of elevation. It causes forested slopes of 110% and cliffs, and several routes from the USFS 2922.015 Road to the high ridge are unpleasant even for the North Fork Calawah WAU; the best way to see the top of the unit is to climb up to the ridge near the southern property line and then there is a well-developed trail along the whole length of the ridge because there is both elk and salal-picker traffic.

Schasse (2003) and Tabor and Cady (1978) recognized a narrow floodplain of Quaternary alluvium (Qa) along the North Fork Calawah River, and mapped intermittent terraces of Quaternary glacial materials along the margins of the floodplain. Schasse (2003) specifically identified these as Qgo, glacial outwash of undifferentiated Pleistocene age. These units are

consistent with my observations in the North Fork Calawah WAU, and consistent with the base of Unit 29.437. However, the Qgo "terrace" within and adjacent to Unit 29.437 is almost entirely buried under debris/alluvial fan deposits and its 10-45% gradients and variable topography mask the terrace.

Halloin (1987) mapped Solleks very gravelly loam, 60 to 90 percent slopes on hillslopes within and adjacent to Unit 29.437. It is a well drained soil of moderate permeability formed in residuum and colluvium derived from sandstone and conglomerate (Halloin, 1987). It ranges in depth from 20 to 40 inches and the "hazard of water erosion is severe" (which probably has more to do with the extreme hillslope gradients than with actual properties of the soil, a point Halloin fails to illuminate). This basic soil type is described as Solleks very gravelly loam, cool, 60 to 90 percent slopes where it occurs above 1600' elevation; this elevation distinction occurs within Unit 29.437.

Halloin (1987) mapped Queets silt loam along the floodplain and low river terraces of the North Fork Calawah River; this soil is adjacent to Unit 29.437 where Rayonier has delineated a riparian management zone along intermittent areas of low floodplain that are identified as channel migration zone and appropriately removed from the unit (see the Alternate Plan attached to this FPA for more information about the CMZ). It is described as a very deep, well-drained soil formed in silty alluvium.

Halloin (1987) mapped a few higher terraces, principally glacial outwash terraces, as Solduc very gravelly sandy loam. This soil is formed in glacial outwash that has loess and volcanic ash in the upper soil column, and Halloin describes the soil as very deep and somewhat excessively drained. In my experience, this is typical of outwash terraces in the North Fork Calawah WAU. He did not map this loam where the glacial terrace exists, but arguably the soil of the terrace is derived from the local bedrock and not from the glacial deposit because of the fans.

Landslide History

No landslides were mapped in or adjacent to Unit 29.437 for the North Fork Calawah Watershed (Map A-1, Sedimentation Module, North Fork Calawah Watershed Analysis). From the 1953 aerial photography, several surface erosion events associated with inner gorges and the USFS 2922.015 Road fillslope were mapped.

A brief review of some of the available aerial photography, listed in Table 1, revealed little additional information. In 1953, the area is devoid of living vegetation with just a few standing, burned tree trunks visible after the 1951 Forks Fire. There are a couple of small events, either surface erosion or debris slides, up high in Creek 7, and some sidecast has been shed off the 2922.015 Road. A cutslope failure has occurred between Creeks 4 and 4a as is described below in Point 43. As noted on Map A-1, there is an area of surface erosion on the south aspect of the Creek 4 inner gorge.

In 1964, some vegetation has grown. The south aspect of the Creek 4 inner gorge shows worsening erosion which may be a combination of surface erosion and small debris slides. And the cutslope between Creeks 4 and 4a now has narrow debris slides that extend above the original failure.

The subsequent photo years reveal a landscape in recovery. In 1977, there are some areas of sparse trees. By 1990, there is complete canopy closure everywhere except the south aspect of the lower part of Creek 4, which is noted as a bare rock cliff in Point 42 below. No new landslides were observed after the 1964 aerial photography. And consistent with the original landslide inventory, only small events which may be a combination of surface erosion and debris slide processes occurred in response to the Forks Fire.

Table 1: Aerial Photography Reviewed for Unit 29.437

Type and Year of Aerial Photography	Air Photo Numbers
Stereo B&W 1953	CL 53-6 to -8
Stereo B&W 1964	OLY-64 30B-4 and -5
Stereo B&W 1977	OL-77 31F-6 and -7
Stereo B&W 1990	OL90 4 31-141 and -142
Stereo Color 2003	OL-C-03 30-31-156 and -157
Orth photography 2013	NA

North Fork Calawah Watershed Analysis Overview

The hillslope of Unit 29.437 is mapped as Geomorphic Map Unit (GMU) 53, sedimentary highly dissected >65% slopes (Map A-2, Sedimentation Module, North Fork Calawah Watershed Analysis). Mass wasting hazard in GMU 53 is generally moderate because within these extended hillslopes there are isolated polygons of high hazard called bedrock hollows and debris flow tracks, and other areas that lack failure history are low hazard. This area is correctly mapped as GMU 53 – bedrock hollows and debris flow tracks/inner gorges are present. However, the Creek 4 drainage could have been mapped as GMU 77, convergent headwalls. GMU 77 delineates steep (>70%) teardrop landforms that are broadly convergent and are comprised of numerous bedrock hollows and first-order channels that converge into a single channel which is capable of debris flow transport. GMU 77 is a high hazard landform because of the concentration of bedrock hollows and inner gorges; convex and planar hillslopes within the GMU are considered low hazard as they are in GMU 53. GMU 53 in this area of the North Fork Calawah WAU is subject to the Mass Wasting Hazard #3 and #4 Prescription. (If remapped as GMU 77, Creek 4 would be subject to the Mass Wasting Hazard #1 Prescription.)

The Mass Wasting Hazard #3 and #4 Prescription applies to GMU 53 where the Rule Call of *Prevent and Avoid* was established for certain channel types. In this area, it is Segments 7 and 8 of the North Fork Calawah River which are believed to be highly sensitive to excess sediment inputs (Map E-1, Stream Channel Module, North Fork Calawah Watershed Analysis – attached to the Alternate Plan Proposal). This prescription requires that a geotechnical expert review cutting boundaries to verify that landforms are correctly identified and delineated, and help implement recommendations related to road design and water management. (The Mass Wasting Hazard #1 Prescription applies to GMU 77 regardless of location in the WAU. This prescription has the same requirements for geotechnical review, but generally lacks detailed recommendations for road design and water management so it better to follow the Mass Wasting Hazard #3 and #4 Prescription.)

In the past year, a reanalysis of the mass wasting module has been conducted (Dieu, 2015 in draft form). Mass Wasting Map Units (MWMU) was drawn for the entire watershed, replacing the existing GMU layer. GMU 77 is now called MWMU #3; the headwaters of the Creek 4 basin were remapped as a convergent headwall, MWMU #3. Individual inner gorges and bedrock hollows are delineated as MWMU #1 and #2. The outer meander bend landform has been delineated as MWMU #4. The Sections 20 and 21 Redlining Maps are attached to this report.

Fault Gouge/Breccia Implications for Road Building

The Calawah Thrust Fault crosses Bigler Mountain and the headwaters of Devil's Creek where we have constructed or reconstructed many miles of road in the fault gouge/breccia. The common road building issue in this material is cutslope failures which have taken a variety of forms including oozing slumps where there is surface water present, head cutting debris slides on very steep, dry slopes, and one ½-acre deep-seated translational slide. This issue is not further discussed in this report because the USFS 2922.015 Road has a cutslope that exposes predominately massive sandstone such that fault gouge/breccia does not appear to be present and because the .0151 and .0152 spurs lie on the fans that have buried the glacial terrace.

Qualifying Terms

Table 2 below provides definitions for qualifying adjectives and adverbs.

Table 2: Definitions for qualifying words used in Unit 29.437 Geotechnical Report.

Highly as in "highly dissected"	Two of the hillslope geomorphic map units in the North Fork Calawah Watershed Analysis, Sedimentation Module (Dieu and Shelmerdine, 1997), were differentiated only on the degree of dissection by streams or swales. GMU 52 is moderately dissected; GMU 53 is highly dissected. These terms were not quantitatively described in the WA, although it is apparent on Map A-2 that GMU 52 has a lower stream density. By the phrase "highly dissected" I mean that streams and swales, and the related unstable landforms, are spaced every 200-500 feet across the hillslope.
Subtly, Moderately and Deeply as they described a concave feature, either a historic failure scar or a bedrock hollow	Concave features that are set back into the extended hillslope a short horizontal distance are "subtly concave." The actual horizontal distance is difficult to measure, and the perception varies with width of the feature. If a historic failure scar or bedrock hollow is 20-50 feet wide, then it is only inset into the extended hillslope by a few feet. When a bedrock hollow is 150-feet wide, then it may be inset as much as 20

	feet. Generally, the inset is <20% of the width for "subtly," while "moderately" means an average appearance of concavity, and "deeply" refers to those, usually >200-feet-wide features, that are many 10's of feet deep into the hillslope.
Narrow as it describes a landform	A narrow landform is <50-feet wide.
Broadly as it describes a landform	This adverb is used to modify "concave", "planar" and "convex." It means that at the full scale of the landform, it is a particular slope form. A ridge may be "broadly convex" but may have smaller features such as wind throw pits on it.
Well, Moderately and Sparsely as they modify "stocked" in reference to the density of tree stems present on a landform	"Well stocked" means an average tree spacing of 16 feet or less; "moderately stocked" means an average tree spacing of approximately 16-30 feet; "sparsely stocked" means there are few trees in the feature, and they may be >30' apart or they may be clumped with open patches between the clumps.
Dense and Sparse as they modify understory vegetation	Dense understory vegetation means that the leaf coverage (when the plants have leaves as some are deciduous) is 80% or greater. Sparse understory means that the leaf coverage is less than 20%.
Historical as it refers to landslides	I use historical as an anthropologist does – to mean "in the era of recorded history" which in Washington State means Euro-American occupation at approximately 1860.

Unstable Landforms and Other Features Within or Adjacent to Unit 29.437

Below, I describe in more careful detail those potentially unstable landforms that we have removed from the proposed harvest as well as some of the relatively stable hillslope features, the specific locations where the logging operations will require yarding corridors through unstable slopes buffers, and those individual features that broadly meet unstable slopes definitions but that I have deemed to be stable and harvestable or that appear to lack delivery potential. Landforms below ridgetop and draining into Short or Albion creeks are also described because they lie adjacent to the proposed harvest. Mapping is done on LiDAR, from aerial photography, with reference to road stationing and visual observation of width; it is intended to help the reviewer locate the landforms described in the report and is not intended to be of survey-quality precision.

Observation Points for Creeks 7 and 8

Point 1: Adjacent to the property line, which is painted on the ridge just north of this feature, there is a 60-feet-wide, 85-90% bedrock hollow with mossy rock exposures across the top and along the margins. In the center, there is a 100-feet-long, 40-feet-wide canopy opening. Above and below this opening, the feature is well stocked with conifer, old growth stumps are present, and salal and sword fern are the understory species.

Point 2: The northern bedrock hollow in the headwaters of Creek 7 is 100-feet-wide, moderately concave, and measures 85% in its center axis. There are rocky exposures along its northern edge. It is well stocked with conifer, old growth stumps are present, and salal, sword fern and Oregon grape comprise a sparse understory.

Point 3: The bedrock hollow south of the one described in Point 2 is 150-feet-wide and deeply concave. The center axis from ridgetop is 85%; the side slopes measure 100-105% and have rock exposures. The hillslope south of this bedrock hollow is a 200-feet-wide, 80-85% planar hillslope with a small bench at its base approximately 200 feet downhill. Both the planar slope and the hollow are well stocked with conifer and have abundant sword fern. If the adjacent bedrock hollows were being buffered from the harvest unit, this slope still would be included in the proposed harvest. However, this feature, the bedrock hollow to the north (Point 2) and the associated inner gorge have not been removed from Unit 29.437 because Creek 7 does not route or deliver to the channel network (see Profile 4, which shows low gradient alluvial fan and terrace for 600 feet beyond the end of channelized flow, and the calculations provided in the Delivery Discussion Section).

Point 4: The debris fan of Creek 7 extends 200 feet uphill from the 2922.015 Road with a gradient of 35%. Creek 7 crosses the 2922.015 Road on an oblique angle towards the north; it creates a 10-feet-deep inner gorge into the fan for 75 feet below the road; this is not protected in a buffer because Creek 7 does not route to the mainstem.

Point 5: At this location, Profile 4 crosses the old grade (2922.0152 Road). Creek 7 from the unbuffered bedrock hollows described in Points 2-3 causes a small area of wash on the old grade. The canopy is mixed, with dense sword fern.

Observation Points for Creek 5

Point 6: The northern corner of this headwater area of Creek 5 is a 100-feet-wide bedrock hollow. It measures 85% with limited rocky exposures, is subtly concave, and extends to within 40 feet of ridgetop. It supports a moderate stocking of conifer with dense salal and lesser sword fern. It has been appropriately removed from the proposed harvest.

Point 7: Lower on the hillslope, there is 75-feet-wide, 80%, subtly concave bedrock hollow that connects to the lower inner gorge of Creek 5. This feature is well stocked with conifer, old growth stumps are abundant, and sword fern and salal comprise the understory. It has been appropriately removed to the upper extent of concavity; the hillslope is planar and remains 80% above the feature.

Point 8: This bedrock hollow extends downslope and its 64% swale (which has not been buffered) joins the inner gorge on Creek 5. The hollow is at least 150-feet-wide, slopes within it measure 75-85%, and it supports a moderate stocking of conifer with an understory of dense salal and lesser sword fern and Oregon grape. Old growth stumps are present throughout. The southern corner extends further uphill right into the rocky ridge edge; the northern edge becomes convex into the ridge shoulder at a lower elevation. The feature has been appropriately removed from Unit 29.437.

Point 9: This isolated buffer protects three bedrock hollows. The upper extent of the center feature is 100% and rocky where it extends up into a knob on the ridge; this hollow is moderately concave and 60-feet-wide at the top. Most other slopes within the buffer are 75-80%, and the ridge between the center and northern hollows is included in the buffer. The area is well stocked with conifer, a few alder trees are present, and sword fern with lesser Oregon grape provides abundant understory. The hollows have been appropriately removed from the harvest unit; their coalesced swale of 40% is proposed for harvest.

Point 10: In this area, a 30-feet-wide concave feature is protected nearly to ridgetop. Just east of this feature, the planar slope is proposed for harvest. The planar slope is 100% and has rocky exposures just below the ridge, but the lower slope where a full coverage of colluvium exists is 75-78%. It is well stocked with conifer, old growth stumps are present, and sword fern, salal and Oregon grape comprise the understory.

Point 11: The cutting boundary above Creek 5 dips downhill so that convex side ridges are included in the proposed harvest and then extends uphill to buffer concave and >70% features. The main ridge varies from nearly flat to 60%, and its shoulders are convex in the vertical and average 40-feet-high and 80%. Where concave features extend towards ridgetop, the cutting boundary is placed on the break-in-slope across the top of the concave feature such that the ridge shoulder is proposed for harvest.

Point 12: Further down the ridge described in Point 11, the cutting boundaries on the two inner gorges pinch together. The ridge is 6-feet-wide. The hillslope off the south side is 120% with unvegetated raveling surfaces and the hillslope off the north side is a 100%, 60-feet-wide bedrock hollow that extends up into the ridge from the Creek 5 inner gorge. The bedrock hollow is moderately stocked with conifer, and the understory is comprised of salal, Oregon grape and sword fern, all in approximately 6 inches of soil in the oversteepened band of rock described above in the Overview – Geology/Soils Section.

Point 13: The front face of the ridge between Creeks 5 and 4 that falls down to the 2922.015 Road, is planar and a uniform 80% in the vertical plane between the top of the cutslope and the rock knob 300 feet up the slope. Between ridges against the inner gorges of Creeks 5 and 4, the feature is subtly concave in the horizontal plane. It is well stocked with conifer, old growth stumps are present, and sword fern in the dominant understory species. This feature appears to be a bedrock hollow, but there is a low gradient surface just 30-feet below the 2922.015 Road so delivery is precluded by the road itself and by the lower hillslope.

Point 14: Below the feature described in Point 13, there is a 60%, strongly convex surface for 300 feet before Creek 5 where delivery across the road and down this surface is unlikely.

Point 15: This isolated buffer protects a 90% concave fillslope segment that falls towards the stream; sidecast pullback will be done during the proposed abandonment.

Point 16: Where Creek 5 crosses the 2922.015 Road, the broadly concave inner gorge side slopes measure 80+%. Alder and big leaf maple are present in the center axis, and conifer and old growth stumps are present 50-feet higher. Sword fern is the dominant understory species, with salmonberry present among the alder and maple. The edges of the inner gorge have been painted on the distinct break-in-slopes where the fall lines change from into-the-inner-gorge to straight-down-the-hill-towards-the-road.

Point 17: Below the 2922.015 Road, Creek 5 is cut into debris fan deposits. The fan supports alder with scattered big leaf maple and sword fern and salmonberry comprising the understory. Profile 3 was measured down this fan (see attached).

Point 18: The northern distributary of Creek 5 just reaches the old grade and has created a 60-feet-wide fan that crosses 40-feet across the old grade; it appears to be 3- to 4-feet-deep at the fan apex.

Point 19: The southern distributary of Creek 5 carries more water than the northern one, and has created a larger fan on the old grade. Just above the road, there are discrete, 10- to 12-feet-high lobes that appear to be debris flow deposits. The fan is predominately alluvial below the old grade and extends to the mainstem.

Point 20: Creek 5 has a 15-feet-high inner gorge near the confluence with the mainstem. The inner gorge walls support salmonberry and sword fern with limited big leaf maple and vine maple. The slopes are 70-80% and do not display overt signs of active erosion such as bare, raveled areas. The lower inner gorge has been appropriately protected; the creek lacks an inner gorge between this point and the upper inner gorge described in Point 115.

Observation Points for Creek 4

Point 21: At this location, the cutting boundary dips down the hill on a side ridge of 88% that is well stocked with conifer and supports salal and sword fern. Approximately 150 feet lower, the hillslope gradient slacks to a lower gradient above the break-in-slope into the inner gorge.

Point 22: The cutting boundary above Creek 4 dips downhill so that convex side ridges are included in the proposed harvest and then extends uphill to buffer concave and >70% features. The main ridge varies from nearly flat to 60%, and its shoulders are convex in the vertical and average 40-feet-high and 80%. Where concave features extend towards ridgetop, the cutting boundary is placed on the break-in-slope across the top of the concave feature such that the ridge shoulder is proposed for harvest.

Point 23: The cutting boundary protects a 150-feet-wide bedrock hollow. In the upper area, it is moderately concave, measures 72%, and has Oregon grape and salal in the understory. Lower, it

becomes steeper and sword fern becomes the dominant understory species. All of the hollow is well stocked with conifer and old growth stumps are present throughout. It has been appropriately removed from the harvest unit; the ridge between it and the next bedrock hollow to the south is proposed for harvest.

Point 24: The cutting boundary dips 100-feet below the main ridge to include the upper, 65% portion of a bedrock hollow. The cutting boundary is painted on a distinct break-in-slope where the hollow becomes >80%. The upper hollow proposed for harvest is well stocked with conifer and has an understory dominated by sword fern. The lower hollow is moderately stocked with conifer with denser sword fern.

Point 25: The next adjacent bedrock hollow to the south is 60-feet-wide and measures 80%. It is well stocked with conifer, old growth stumps are present, and sword fern are the dominant understory species and are dense in the lower hollow. The unstable landform has been appropriately removed from the proposed harvest. The ridge to the south is wider and extends further into the convergent headwall than other ridges, and we are proposing to harvest it for 200 feet downslope.

Point 26: South of the long ridge described in Point 25, the buffer extends back uphill around a 100-feet-wide bedrock hollow that measures 85%. It is well stocked with conifer, old growth stumps are present, and the understory species in the upper hollow include salal, Oregon grape and sword fern; just sword fern is present in the lower hollow. To the south of its uppermost extent, a small ridge has been included in the area of proposed harvest.

Point 27: The bedrock hollow to the north of the center hollow described in Point 28 is moderately concave, 100-feet-wide, 76%, and supports well stocked conifer with dense salal. Old growth stumps are present. This feature has been removed from the proposed harvest.

Point 28: The center bedrock hollow in the convergent headwall in the headwaters of Creek 4 is 200-feet-wide and deeply concave. It is well stocked with conifer with an understory of sparse sword fern. There is a smaller hollow off to the southern edge of the center feature. Both hollows and the narrow ridge between them have been appropriately removed from Unit 29.437.

Point 29: The bedrock hollow just south of the one described in Point 28 is subtly concave, 75-feet-wide, and measures 72%. This hollow is well stocked with conifer, old growth stumps are present, salal and Oregon grape exist near ridgetop and sword fern is the dominant understory species lower in the feature.

Point 30: The southern bedrock hollow in the convergent headwall in the headwaters of Creek 4 and its tributary Creek 4d is 200-feet-wide and measures 85%. It is well stocked with conifer, and the understory is dominated by salal across the top and by sword fern lower in the feature.

Point 31: The cutting boundary extends down the ridge between Creeks 4d and 4c. It is 40- to 70-feet-wide, and averages 80% but is steeper and gentler in pitches of 20- to 30 feet. It is well stocked with conifer, old growth stumps are present, and below the fringe of dense salal in the upper 100 feet, sword fern and Oregon grape are the dominant understory species. The southern

cutting boundary is painted on the top of the exposed bedrock described in Point 35, and then drops off the ridge shoulder to protect the lower inner gorge of Creek 4c.

Point 32: Approximately half way down the ridge described in Point 31, the area of proposed harvest narrows because an 80% concave feature extends uphill from Creek 4d. The bedrock hollow is 50-feet-wide and subtly concave, and it supports a moderate stocking of conifer and sword fern.

Point 33: This isolated buffer protects a 100-feet-wide, moderately concave bedrock hollow. The main feature measures 85%, and is moderately stocked with conifer and supports a sword fern understory. The upper cutting boundary has been painted along the upper margin of significant soil; above this, there is a 95%, 25-feet-high rocky area created by wind throw – it is part of the ridge and has not been protected. Below the lower cutting boundary, the swale is 60% and it has not been protected. The bedrock hollow has been appropriately removed from Unit 29.437.

Point 34: The lower inner gorges of Creeks 4d and 4c are 75-80% and the lower, unbuffered ridge is 40%. Where the ridge steepens into a face above Creek 4, the ridge has been protected as part of Creek 4's inner gorge.

Point 35: The bedrock hollow in the headwaters of Creek 4c is 75-feet-wide and moderately concave. Approximately 75-feet down within the feature, there is a 3-feet-high scarp indicating that a historical failure has occurred (not observed in the aerial photo review). Above this scarp, the feature measures 85-90% and supports well stocked conifer with salal and Oregon grape. Below the scarp, the hollow and inner gorge exceed 100% and little is growing except moss where the debris flow scoured to bedrock. The hollow and its inner gorge has been appropriately removed from the proposed harvest.

Point 36: The eastern bedrock hollow in the headwaters of Creek 4b is 250-feet-wide and deeply concave. It measures 90+% and is particularly steep on the rocky side margin along the northern edge. In fact, the ridge between this feature and the bedrock hollow described in Point 35 is <30 feet wide with cliffs along both edges. The hollow is well stocked with conifer, old growth stumps are present, and sword fern is the dominant understory plant. The hollow and the adjacent ridge to the north have been buffered from Unit 29.437.

Point 37: This deeply concave bedrock hollow in the southeast corner of the headwaters of Creek 4b is 75- to 100-feet-wide. It measures 80% in the center axis for 200+ feet downhill. It is moderately stocked with conifer and sword fern is the dominant understory species. One tree on the upper edge of the cutting boundary has been labeled "cut"; otherwise, the feature is fully protected.

Point 38: Along the western margin of the inner gorge on Creek 4b, the cutting boundary extends nearly to ridgetop around a 50-feet-wide, 75-80% bedrock hollow. The bedrock hollow is well stocked with conifer and the understory is comprised of sword fern. Further north, the cutting boundary dips down an 80% ridge that is well stocked with conifer with two, >6-feet, old growth stumps.

Point 39: At this location, the buffer protects a subtly concave bedrock hollow of 80-85%. It supports a canopy of mixed conifer and alder, and sword fern and Oregon grape are present in the understory.

Point 40: The inner gorge buffer on Creek 4 has been extended uphill to protect a 60-feet-wide, 115% bedrock hollow. Adjacent to this feature, the inner gorge buffer protects >80% hillslope with an alder-dominated canopy. The cutting boundary is painted on a break-in-slope and above the buffer is a 70-80% hillslope that is moderately stocked with conifer and scattered alder with an understory of sword fern; old growth stumps are present.

Point 41: Just above the 2922.015 Road, the inner gorge on Creek 4 averages 80-85%. The hillslope is irregular and the upper 6 to 10 feet is steeper with bedrock exposures. The inner gorge supports alder, with vine maple, salmonberry and sword fern. The inner gorge has been appropriately removed from the proposed harvest.

Point 42: The northern side slope of Creek 4 above the 2922.015 Road is 120+% because it is a mossy bedrock exposure the supports a few conifer trees and scattered sword fern. More broadly, the inner gorge above the road is a distinctly bowl-shaped feature of 200-feet-width and other slopes within the bowl are 80-100%. Alder and big leaf maple are the dominant tree species with some conifer trees on the higher slopes. Sword fern is abundant where soil is present, and salmonberry exists near the creek.

Point 43: The steep face between Creeks 4 and 4a that falls towards the 2922.015 Road has a 150-feet-wide bedrock hollow which has experienced a historical failure. The hollow averages 80% with a steeper rocky area along the top margin. It supports alder, vine maple and a few conifer trees, and the sword fern are dense. The feature has direct delivery across the road towards the confluence of the two creeks, so it has been protected in a buffer that is contiguous with the adjacent inner gorge buffers.

Point 44: Along the northern buffer of the inner gorge on Creek 4a, a subtly concave, 40- to 50-feet-wide bedrock hollow is protected where its lower extent measures 75-85%. The feature supports a moderate stocking of conifer with sword fern and Oregon grape. The upper area of the bedrock hollow measures 65-70% but there are not overt signs of instability and this area has not been protected.

Point 45: At this location, the cutting boundary has been painted on a convex break-in-slope between >80% inner gorge and a broadly convex hillslope of 80%. Along one segment, the cutting boundary is painted higher than the break-in-slope because there are no trees right on the break; one >24" tree on the boundary has "cut" painted on it so that it can be harvested.

Point 46: Further south, the next bedrock hollow is 75-feet-wide, measures 71%, is well stocked with conifer and has sword fern and Oregon grape in the understory. For no obvious reason, such as evidence of a historical failure, the hollow has no old growth stumps in the center axis. The hollow has been appropriately removed from the harvest unit.

Point 47: At this location, a bedrock hollow extends above the Creek 4a inner gorge. It is subtly concave, 40- to 50-feet-wide, and measures 85%. It is well stocked with conifer, old growth stumps are present, and the understory is dominated by sword fern and Oregon grape. It has been appropriately removed from Unit 29.437, and the narrow ridge between it and next bedrock hollow has also been included in the buffer.

Point 48: The bedrock hollow that forms the headwaters of Creek 4aa is deeply concave and 200- to 225-feet-wide. It measures a uniform 85% across its width. It is well stocked with conifer trees with alder down low in the throat and an alder patch along the western margin. Some old growth stumps are present and sword fern grow throughout. It has been appropriately protected.

Point 49: In the headwaters of Creek 4a, there are two 100-feet-wide bedrock hollows. The eastern one extends right into the shoulder of the ridge while the top of the western one can be delineated on a convex hillslope 30 feet below ridgeline. These are well stocked with conifer, old growth stumps are present, Oregon grape is present along the upper margins and on the ridge, and sword fern is present throughout. Below the coalescence of the two hollows, the canopy is dominated by alder. The hollows and most of the ridge between them have been removed from the harvest unit.

Point 50: The inner gorge downstream of the 2922.015 Road on Creeks 4 and 4a is 100+% out past the fillslope on the northern side – nearly a cliff like the slope above the road. It supports alder, big leaf maple and sword fern. Towards the south, the fillslope and valley surfaces are 60-80% and support alder, salmonberry and sword fern. There is a small ridge from the road down towards the confluence of the two streams and it supports Oregon grape too. The total buffered area here includes hillslope <70% and ridge and is in excess of both unstable slope protection and the Type Np buffer required on Creek 4.

Point 51: The debris deposits from Creek 4 extend 75 feet beyond the old grade. The stream is incised through the old grade and the 6 to 15-feet-high debris lobes, creating a small inner gorge with oversteepened and unvegetated walls. The end of fish habitat has been identified at the bottom of the debris fan where there is a significant gradient break, and the Type F buffer is wider than the inner gorge such that the unstable slopes well protected.

Point 52: The inner gorge slopes along Creek 4 are 15- to 20-feet-high and measure 80+% near its confluence with the mainstem. There are bare areas of ravel along the inner gorge, evidence of active erosion, and few trees are actually rooted on the inner gorge walls. The inner gorge is well protected within the Type F RMZ.

Observation Points for Southern Portion of Unit 29.437

Point 53: At this location, there is a 100-feet-wide bedrock hollow with a center axis of 90% and a northern margin of 70% in the fall line of the hollow. This feature is moderately concave, well stocked with conifer, old growth stumps are present, and sword fern is the dominant understory species. Our original delineation can be observed in the chipped out blazes; this feature is unlikely to deliver and has been included in the proposed harvest. (Point 68, R-ND)

Point 54: Downhill of the bedrock hollow described in Point 53, the swale is <70%. The cutslope is 90-100% and appears to have been a small borrow pit, perhaps to provide fill for the Creek 4 crossing. Below the road, the hillslope is 75% and planar, and then slacks to progressively lower gradients for almost 1000 feet before reaching the cutting boundary on the mainstem river (see Profile 3).

Point 55: The debris fan below the bedrock hollow described in Point 53 ends 60 feet above the old grade. There are no distributary channels, the ditch of the old grade is 8-feet-wide and 3-feet-deep, and it slopes south away from Creek 4 so no delivery is possible.

Point 56: At this location, there is a 125-feet-wide bedrock hollow. It is 100% at the rocky top just below a rock knob and 80-85% lower down. The feature is fairly planar onto itself, with distinct ridges on each edge. The lower swale to the 2922.015 Road is 75%. The feature is well stocked with conifer, old growth stumps are present, and the understory is comprised of sword fern and Oregon grape. This feature is unlikely to deliver and has been included in the proposed harvest.

Point 57: Across the 2922.015 Road from the bedrock hollow described in Point 56, the hillslope is a 70% convex surface that foots into the lower gradient surface below.

Point 58: The side slope along this edge of the bedrock hollow described in Point 59 is 90%. The cutting boundary has been placed on a distinct break-in-slope where the fall line is down the 65-70% ridge and not into the hollow.

Point 59: This bedrock hollow is 250-feet-wide and measures 80%. It is well stocked with conifer, old growth stumps are present, and the understory includes sword fern, salal and Oregon grape. This hollow remains concave right to the base of the cliff off the edge of the ridge, and the cutting boundary has been painted at the top of the cliff.

Point 60: Below the 2922.015 Road from the feature described in Points 58-59, there is no swale or inner gorge, just fillslope. Nothing has been buffered below the road.

Point 61: This ridge becomes 90-100% but still supports a moderate stocking of conifer, old growth stumps are present, and sword ferns are dense. The proposed harvest does not include the lower ridge where the gradient is lower (e.g., 80%) but where the trees are non-merchantable. A yarding corridor from the 2922.0152 Road will cross this lower, buffered ridge which is not an unstable slope but is mentioned because of the corridor.

Point 62: This bedrock hollow is almost 200-feet-wide and measures 80-90%. The canopy is moderately stocked with conifer up high in the feature, and alder and salmonberry down the hill. The uppermost edge is irregular, subtly concave and <80%, so this feature has been protected to ridgetop.

Point 63: This bedrock hollow measures 90% in the center axis and is 150-feet-wide. It has been protected up to a break-in-slope where the gradient drops to 85% and the hillslope becomes convex in the horizontal plane. The hollow supports conifer up high and alder lower in the throat,

and sword ferns are present throughout. The northeast corner of this feature is planar, 80%, supports alder and vine maple, and has been included in the buffer. A yarding corridor from the 2922.0152 Road, to harvest the timber on the ridge between this buffer and the next one to the southwest, will just touch the upper southern edge of this hollow.

Point 64: Below the 2922.015 Road from the feature described in Points 61-63, there is no swale or inner gorge, just fillslope. Nothing has been buffered below the road.

Point 65: The bedrock hollows described in Points 58-59 and 61-63 form a fan below the 2922.015 Road. It measures 35+% above the old grade (2922.0152 Road) where it is a debris fan and 25% below the road where it is probably more, but not exclusively, alluvial in nature. The 25% fan surface extends to the steep bank against the mainstem river – clear evidence of delivery potential (see Profile 2).

Point 66: This bedrock hollow coalesces with the one described in Point 68. It is 75-80%, 100-feet-wide, and supports a mixed conifer and alder canopy with sword ferns. Old growth stumps are present. Like the hollow described in Point 63, in the northeast corner of this buffer there is an 80% planar slope with 3-feet-high, indistinct tension cracks which has been protected because it displays signs of instability and lies within the fall line of the bedrock hollow. The yarding corridor described in Point 63 will also just touch the edge of this feature.

Point 67: The cutting boundary dips down an 80% ridge to include a few conifer trees in the proposed harvest, but cuts off where the ridge exceeds 80% and the trees are alder.

Point 68: The lower extent of this bedrock hollow, just above the cutslope of the 2922.015 Road, is 70% and 150-feet-wide. This area supports alder trees. The top 50 feet of the hollow measures 80% and supports few trees – it is brushy with devil's club and vine maple and obviously wet as evidenced by macro-pores. Pit-and-mound topography with conifer trees in or just above the bedrock hollow make identification of the top difficult – the cutting boundary has been painted so that 2 tree widths of the conifer stand are included in the buffer and the southern part of this lies against the property line. A yarding corridor from the 2922.0152 Road to the little patch of timber described in Point 67 will be needed along the southwest edge of this hollow.

Point 69: Below the 2922.015 Road from the feature described in Points 66-68, there is a 75% swale. It supports alder, salmonberry and sword fern, and has been buffered to the ridge on each side and to where the hillslope becomes <70%. Profile 1 shows moderate gradients extending most of the way to the mainstem river and suggesting that delivery is possible.

Point 70: The southern edge of Unit 29.437 above the 2922.015 Road is broadly convex in both planes and averages 80%. Near the buffer described in Points 66-68, there is a 40-feet-wide, subtly concave feature. It has a 6-feet diameter old growth cedar stump in the center, and creep below the stump is creating some of the concave appearance. The presence of vine maple suggests poor growing conditions and that ravel may have been an active process after the last era of harvest. The feature extends nearly to the property line and approximately 200-feet above the road. It is unclear whether this is a potentially unstable landform; if it should fail, delivery

across the road and all the way to the North Fork Calawah seems unlikely because the failure volume this feature could produce would be small.

Point 71: At this location below the 2922.015 Road there is broadly concave surface of 70-75% with one 50-feet-wide ridge with 25- to 30-inch hemlock trees in a strip down the hill. Otherwise, it supports mostly alder with salmonberry and sword fern. This surface foots into the flat below. It has not been protected because failure seems unlikely and delivery across the flat below is also unlikely.

Point 72: In this area, the old grade drops off a fan edge towards a terrace surface. The bulge in the mainstem buffer protects a tributary with a short segment of Type F water. The tributary lies within a small inner gorge where it drops off the terrace – the inner gorge is well protected within the Type F riparian buffer. The isolated buffer protects another small segment of inner gorge that measures 100% and supports a few alder trees and salmonberry.

Point 73: West of the area described in Point 71, the hillslope is broadly concave across 800 feet. Each 200-feet-width of the hillslope looks planar onto itself such that there are no discretely concave landforms suggesting failure history (i.e., neither historical failure scars nor bedrock hollows). Gradients vary from 55% lower on the hillslope to 75% higher on the hillslope and there are small irregularities of a 20-feet scale created by wind throw. The canopy is mixed conifer and alder with concentrated pockets of each; sword fern are present throughout and salmonberry are scattered. This hillslope has not been protected because it appears to lack failure potential.

Point 74: This sliver of a buffer on the edge Unit 29.437 protects a 70-75% swale up to the property line. The swale is only 75-feet-wide, and its other side was protected when Unit 29.475 was engineered and harvested.

Observation Points for Mainstem Floodplain/Channel Migration Zone

Point 75: Along this segment of the North Fork Calawah River, there is a 25- to 50-feet-high bank of unconsolidated materials that the river is eroding. This bank is completely protected, usually within the 86-feet-wide no-cut area that includes the 36-feet erosion hazard area (EHA) described in the Alternate Plan Proposal and the 50-feet core zone of the RMZ, and where this is insufficient the buffer is painted on the break-in-slope to delineate the outer meander bend landform.

Point 76: In this area, the historic migration zone (HMZ) is delineated on a subtle 1-foot step from the low floodplain that shows evidence of this winter's flooding (e.g., small areas washed free of leaves) to the next surface. The next surface is certainly within the floodplain, but I did not find silt in the lowest moss growing on trees and bushes, the alder trees are larger than they are on the lower surface, and this higher surface has a low density of 5- to 6-feet-diameter spruce stumps. In sight of the Type F riparian management zone on Creek 4, there are four 30- to 50-inch (diameter at breast height) spruce trees along the edge of the mainstem where HMZ is present on the west side of the river. The no-cut buffer along this segment protects the HMZ where it exists, another 36 feet for the EHA, and 50 feet for the core zone of the RMZ in the alder conversion.

Point 77: Along this segment of the river, the HMZ, similar to that described in Point 76, is intermittent along the eastern edge of the mainstem. The next surface is 4-feet above the channel, and a 2- to 3-feet step above the HMZ. As on the south side of Creek 4, there is a 36-feet-wide EHA on the HMZ and a 50-feet-wide core zone of the RMZ.

Point 78: Along this segment of the river, the historic CMZ is very low and has been strongly flooded this past winter with new, overbank deposition on the surface. The next surface is 15-feet higher and supports well stocked conifer. The HMZ is protected by a 36-feet-wide EHA and a standard 105-feet-wide Type F RMZ.

Observation Points for Adjacent Features Draining to Short and Albion Creeks

Point 79: Near the property line and east of the main ridge, there is a 65% bedrock hollow below the cliff. It is well stocked with conifer, old growth stumps are present, and the understory is limited. The cutting boundary is painted above this feature.

Point 80: At this location, the hillslope is 65% and concave into the shoulder of the ridge. Along the northern edge, below a break-in-slope from a convex knob, the hollow is 80%; where this occurs, the unit cutting boundary is painted 1-3 tree widths above the hollow.

Point 81: South of the bedrock hollow described in Point 80, there is a 150-feet-wide bedrock hollow that measures 75%. The feature is well stocked with conifer and supports sparse sword fern. The cutting boundary has been painted just off the edge of the ridgetop, above this feature.

Point 82: South of the bedrock hollow described in Point 81, there is a 60-feet-wide bedrock hollow that measures 80% and is moderately stocked with conifer. The cutting boundary is painted 1-2 tree widths above this feature.

Point 83: At this location, the cutting boundary is 1-2 tree widths above a 175-feet-wide, 75% bedrock hollow that is well stocked with conifer and supports sparse sword fern.

Point 84: The inner gorge below the bedrock hollow described in Point 85 parallels the main ridge and the unit cutting boundary. The cutting boundary is painted right on the break-in-slope at the top of the inner gorge for just a couple of trees and then pulls away as the break-in-slope drops away from the ridge. The inner gorge averages 80%, is well stocked with conifer, and sword fern are present.

Point 85: This bedrock hollow is 150-feet-wide and measures 80%. It is well stocked with conifer and sword fern are present. Its upper edge is 70 feet below the rocky knob, so the unit cutting boundary lies 3-4 tree widths above the break-in-slope at the top of the hollow.

Point 86: This bedrock hollow is 50-feet-wide and measures 74%. It is subtly concave. It is well stocked with conifer, old growth stumps are present and salal is the dominant understory species. The unit cutting boundary is painted 1-2 tree widths above the feature.

Point 87: This bedrock hollow off the southern edge of the high ridge is 100-feet-wide, moderately concave, and 75-80%. It is well stocked with conifer, old growth stumps are present, and the salal is dense. The unit cutting boundary is painted on or just above the upper edge of the landform.

Point 88: Off the eastern edge of the high ridge, there is a 100-feet-wide bedrock hollow. Near the top, it is subtly concave, measures 72%, is well stocked with conifer of <6" diameter, and has dense salal. Seventy-five feet lower, it is more deeply concave and steeper. The cutting boundary is painted 1-2 lines of trees above this feature.

Point 89: This bedrock hollow below the southeastern ridge edge is approximately 200-feet-wide. It measures 90% in the center axis, is moderately stocked with conifer, and the salal is dense. The top of the landform where the hillslope first becomes concave is 70 feet below ridgeline such that the unit cutting boundary is 3-4 lines of trees above the landform.

Point 90: West of the bedrock hollow described in Point 89, the next bedrock hollow is approximately 150-feet-wide. It is subtly concave and 75% near the top, and is deeper and steeper down into the throat. It is well stocked with conifer and the salal is dense. The cutting boundary is painted along its upper margin.

Point 91: West of the bedrock hollow described in Point 90, the next bedrock hollow is 175- to 200-feet-wide. It measures 90+% and extends nearly to ridgetop. It supports a moderate stocking of conifer and some old growth stumps are visible above the dense salal. The northern corner lies against a mossy rock knob. The cutting boundary lies on the upper edge of the ridge, above this feature.

Point 92: South of Point 48, off the back side of the main ridge, there is a 100-feet-wide, moderately concave, bedrock hollow of 70-72%. It is well stocked with conifer, and the salal understory is very dense on this aspect. The cutting boundary has been painted just off the eastern edge of the ridge, 1-2 lines of trees above this bedrock hollow.

Point 93: At this location, there is a 175-feet-wide bedrock hollow of 80% gradient. It is moderately concave. It is well stocked with conifer, with dense salal and lesser Oregon grape. Old growth stumps are present. The unit cutting boundary is painted on or above the edge of this hollow.

Point 94: Below ridgeline southeast of the unit, there are two bedrock hollows that coalesce. Each is 75- to 100-feet-wide, measures 70-75%, and is well stocked with conifer with dense salal up high. The unit cutting boundary lies 2-3 tree widths above the hollows.

Delivery Discussion

Harvest is proposed on bedrock hollows of >70% at Points 1, 2, 3, 13, 53, 56 and 70 because delivery of failures from these features is precluded by the 2922.015 road prism and/or by the nature of the hillslope below the 2922.015 Road. Validation of this field interpretation can be modeled by run-out calculations on fan surfaces.

Prochaska et al. (2008) provide a succinct overview of the available models and their limitations, and then provide a simple topographic model which utilizes parameters that can be measured without estimating initiation point, initiation volume or the down-valley bulk-up process; this model shows some promise, but only applies to debris flows that reach the fan apex. The model predicates on determining the elevation of the highest point in the drainage and the elevation of the apex of the fan – this is h, the vertical height of the drainage above the fan apex. The half-height, that elevation that is ½ way between the first elevations, is located on the stream. β is the angle, in degrees, between the half height and the fan apex; it is calculated by measuring the stream distance to the fan apex. α equals 0.88 times β where α is the angle in degrees from 0.5 times height to the end of the run-out. Using α to project the run-out down the fan surface requires knowing the fan gradient. Prochaska et al. (2008) do not present a final formula and do not show any of their calculations, nor do they provide sufficient data to check any of their calculations. Pete Waldrip of Rayonier, who is a licensed professional engineer, helped me create a user-friendly formula where β can be calculated in % and the fan gradient measured in %; the calculation then requires arc tan to convert β to degrees before multiplying by 0.88, and then tan to convert the α value back to %. α does not actually appear in the formula – it is present as [(arc tan (β%))*(0.88)].

$$\text{Run-out} = 0.5\ h\ [(\beta\%-f\%)/((\tan[(\text{arc tan}\ (\beta\%))*(0.88)\ ] - f\%)\ -1$$

Where:
h = elevation of highest point of the drainage – elevation of fan apex
β% = 0.5 h / stream length between the midpoint of elevation and the fan apex (this value is a decimal %, not a degree)
f% = average gradient of the fan in decimal %

I have applied this model to Creek 7 and to the feature described in Point 53 and present the data used and the results below in Table 3. (Note: Fan gradients are a field measurement taken as a broad average of the fan slope below the 2922.015 Road and are not directly reflected on the profiles.)

Table 3: Data and Results for Run-Out Calculations

Drainage	Max H (ft)	Apex H (ft)	β%	f%	Run-out (ft)
Creek 7	1480	1000	.60	.35	126
Point 53	1550	1040	.85	.25	75

Calculations for these two examples are provided because these two features extended further up the hill than the other bedrock hollows. The other features extend only 200-300 feet above the 2922.015 Road and will have shorter or equivalent run-out distances. This is because β% and f% have fairly narrow ranges in this setting and are approximately represented by the provided examples; this means that 0.5h is the significantly changing factor such that shorter features will have shorter run-out and also cannot deliver. These results support the field interpretations for no delivery for specific, smaller unstable slopes at Points 1, 2, 3, 13, 53, 56 and 70.

Yarding Corridor Discussion

Using Rayonier's LiDAR data in the North Fork Calawah WAU and adjoining ownership, Pacific Forest Management does a detailed yarding analysis of each harvest unit after the cutting boundaries are established. The software is "Terrain 3D with Cable" from Softtree Technical Systems Inc.; it is a product related to RoadEng, a Softtree program that facilitates road design. Hard copies of these yarding profiles are available at the Forks Rayonier Office. Pacific Forest Management personnel help me interpret the yarding analysis (e.g., identifying where a corridor might need to be cut). Where corridors are needed, the area to be harvested by the corridor is shown in yellow highlighter. Some of the high ridges have insufficient lift to utilize corridors; these areas are shown in orange highlighter and are only suitable for helicopter logging. A completely different yarding option for Unit 29.437, to place the tower across the North Fork Calawah River on an existing landing up the B1500 Road, was analyzed and Mike Dilley of Dilley & Solomon was consulted. It was determined that this scenario is just too far to cable yard, even if the logs were dropped onto the 2922.0152 Road.

Furthermore, 10.7 acres have been designated as "Helicopter" on the RFR Harvest Exhibit. Although isolated pockets of this timber could be downhill yarded with barely adequate lift, most of it cannot be cable yarded. This timber will not be cable yarded; it may be removed by helicopter.

Each geotechnical report represents worst case scenario of possible tree cutting for the utilization of yarding corridors. The actual practice of loggers with the technology to log in steep ground around numerous buffers is to test a corridor by drawing the carriage through the buffers slowly the first couple of turns. This may break limbs and tops off of the trees in the corridor, but seldom results in trees being cut (pers. corr. Dave Dilley, 2014). Furthermore, estimated carriage clearance is model-derived assuming strict safety defaults and does not account for intermediate supports. By tightening the lines and utilizing intermediate supports, loggers may achieve additional carriage clearance and lessen impacts.

In addition to site-specific recommendations provided in Table 4, the following recommendations apply to all corridors: 1) Use a 90-100' yarder tube; 2) Utilize elevated tail hold trees; 3) Make all cut yarding corridors as narrow as possible (standard forest practices); and 4) Fell and leave all trees in all yarding corridors side slope within the feature to limit the debris slide initiations that could evolve into debris flows.

A summary of yarding corridor impacts is provided in (a) and a full list of mitigations for those impacts in (c) of the Summary below.

Table 4: Yarding Corridor Expected Tree Cutting and Recommendations

Point Number	Expected Tree Cutting (Impact)	Recommendations
61	This corridor will lie on the ridge that is included in the buffer because the trees are non-merchantable. There is 65' of	No recommendations.

	carriage clearance at the top of the buffer and 100' down lower. One or more danger trees may have to be cut (trees are quite sparse, so this won't be a "cut" corridor).	
63, 66	A corridor will just touch the upper edges of the features described in Points 63 and 66. There is 40' of carriage clearance at the top of the bedrock hollow described at Point 63, and 60' of clearance along the edge of the Point 66 feature. One or more danger trees may need to be cut at each location.	Full suspension is requested – this may mean lighter-than-normal payloads and/or 40' logs instead of tree-length yarding. If it cannot be achieved, then single end suspension is required AND yarding scars must be covered with slash.
68	One corridor is needed across the feature described in Point 68. It will have 40-70 feet of carriage clearance and a corridor may have to be cut.	Clearance should be improved by obtaining at tail hold permit on USFS. Full suspension is requested – this may mean lighter-than-normal payloads and/or 40' logs instead of tree-length yarding. If it cannot be achieved, then single end suspension is required AND yarding scars must be covered with slash.

Road Discussion and Recommendations

The 2922.015 Road was open and drivable when the North Fork Calawah Watershed Analysis was conducted (1996-97), although the pipe at the Short Creek crossing was filled with gravel and the crossing was a drivable ford over the top of the pipe. Just a few years later, Short Creek experienced a dam break flood event that destroyed what remained of the crossing. However, the rest of the road across WADNR and across Rayonier is in fairly good shape and most of the work that needs to be performed could be categorized as road maintenance (e.g., replacing pipes, adding additional cross-drain culverts, cleaning the ditch and spreading topping rock). The only reconstruction effort to affect a potentially unstable slope is the pipe replacement at Station 101+45 on Creek 7. Creek 7 is an untyped water that does not deliver to the mainstem, and a rusty but functioning shallow pipe of 18" diameter is being replaced with a 36", so this site has little failure risk and no delivery risk.

After timber harvest has occurred, the 2922.015 Road will be abandoned from the southern Rayonier property line to Station 105+30. A waterbar will be installed every 100 feet; some of these will occur as cross-drain culverts and stream crossing pipes are removed and the rest will be dug across the road and anchored into the cutslope so that water cannot continue down the ditchline. The mass wasting segments (MW-1365, 1366 and 1367) listed in Rayonier's East Clallam Road Maintenance and Abandonment Plan (RMAP) will be accomplished as the Creek 4 and 5 crossings are removed and as sidecast pullback is done between Stations 114+60 and

115+40, the southern edge of the Creek 4 crossing that will not be part of the stream crossing fill removal. In addition, the perched sidecast along the southern edge of the Station 109+90 Landing will be removed when the landing is reconstructed.

The 2922.0151 Road is part construction on an existing road prism and part new construction. It lies on low gradient hillslope and terrace and does not cross nor lie near any potentially unstable slopes.

The 2922.0152 Road is an old grade that will be reconstructed to Station 28+60. It lies on moderate gradient (25-45%) debris and alluvial fans. The crossing at Station 14+45 will be rebuilt across the small inner gorge where Creek 4 has down cut into its fan (see Point 51 above) – this is the only location where the 2922.0152 Road crosses or lies near a potentially unstable slope. This crossing occurs where the channel gradient is 15% and approximately 75 feet above the end of the longest debris lobes. The low channel gradient and the mid-fan position of this site means that this fill is unlikely to fail as a debris flow, but it can be fluvially eroded if the pipe plugs. It is at some risk of being destroyed if a debris flow were to travel down Creek 4, although the debris flow should be losing momentum and depositing as it comes through this part of the fan. We are proposing to install a 60" pipe on a 5-feet-wide, non-fish-bearing stream, the outlet end of the pipe will be covered with 6-feet of fill, and the inlet and outlet edges will be armored with rock. These specifications should prevent the pipe from plugging during normal fluvial transport and should prevent the crossing from being destroyed by a debris flow.

The 2922.015 Road lies in GMU 53. If it were an orphaned road proposed for reconstruction, the design would call for a cross-drain culvert approximately every 300 feet. As mentioned above, this road was drivable until the complete failure of the Short Creek crossing, and it only requires basic maintenance and some culvert replacements to be usable. Installing several new cross-drains in a road that has been stable without them, and then digging them back out within 1-2 years as we abandon the road back to Station 105+30 is unwarranted. (Note: It is Rayonier's current plan to abandon the 2922.105 Road back to Station 109+90 before logging and then to complete the abandonment after logging – we are not promising to follow this plan, but it is likely to occur this way.) The 2922.0151 and .0152 roads lie on GMU 73, debris and alluvial fans and are not subject to Mass Wasting #3 and #4 Prescription but only to standard forest practices. Cross-drain culverts are being added to these roads, but not to the 300' spacing requirements.

Waste Areas Discussion and Recommendations

There are 3 waste areas proposed in this FPA, each along the 2922.015 Road. (Note: WA 1 labeled on the RFR Harvest Exhibit is located on WADNR ownership under a separate FPA; it will be used for material excavated during the Short Creek bridge installation.) Waste Area 2 is being permitted for 9,000 cubic yards and is the primary waste area for the abandonment project. Waste Area 3 is being permitted for 1,000 cubic yards. Each is located on fan deposits and poses no unstable slope hazard. Waste Area 4 is located on the landing at Station 109+90. It is being permitted for 400 cubic yards which will be placed on the surface of the existing landing after the sidecast pullback along the southern edge of the landing is accomplished (see above).

Discussion of North Fork Calawah Mass Wasting Prescriptions
All Mass Wasting Hazard Prescriptions begin by specifying that a geotechnical evaluation be conducted by appropriate personnel and that a letter or small report detailing, among other things, the potentially unstable landforms and specific recommendations of the geotechnical personnel, be submitted with the FPA. This requirement has been met.

Of timber harvest, Mass Wasting Hazard #1 Prescription for GMU 77 – Convergent Headwalls – says:

> *No broadcast burning or aerial spraying within GMU 77.*
>
> *Although harvest will usually be restricted to convex areas, under recommendation of the specialist selective harvest may be possible in concave areas and small inner gorges if sufficient vegetative canopy and root strength are retained to limit failure potential. It is the intent of this prescription that levels of selective harvest be mathematically justified.*
>
> *Wherever possible, full suspension should be accomplished. This is particularly important in the concave areas with shallow (<18 inches deep) soils and across sharp slope breaks. When full suspension is not possible, use leading-edge suspension.*

For the area in the headwaters of Creek 4 now mapped as MWMU #3, the original GMU 77, we are absolutely following Mass Wasting Hazard #1 Prescription by only proposing harvest on convex surfaces. No yarding corridors are possible within or near MWMU #3 because there is insufficient lift; the convex surfaces will have to be helicopter logged.

Mass Wasting Hazard #3 and #4 Prescription for GMU 53 for timber harvest has generally been followed in that unstable landforms meeting definitions for bedrock hollows and debris flow tracks have been identified and buffered from the proposed harvest. Some prescriptions apply to selective or experimental harvest, which are not proposed here. One prescription encourages the leaving of pre-existing downed wood; this routinely occurs and, in fact, downed wood is fairly abundant after logging on steep ground because many smaller trees are not worth cable yarding to the landing.

Mass Wasting Hazard #3 and #4 Prescription for GMU 53 for road construction and reconstruction has several elements. Those that do apply are quoted below:

> *Road construction across GMU 78 and bedrock hollows should be avoided where reasonable alternatives exist (e.g., building on ridgetop). If the construction of a riedgetop road is not possible, the next best alternative it to place the road above the heads of bedrock hollows.*
>
> *Culverts in channels within Mass Wasting Hazard Units 3 and 4 shall be no smaller than 36-inch metal or 24-inch smooth plastic. If a seep develops from a bedrock hollow exposed in a cutslope, a 24-inch smooth plastic culvert shall be installed to carry this water and cutslope ravel. All culverts within Mass Wasting Hazard Units 3 and 4 shall be placed on no less than 5 percent gradient.*

All roads in GMU 36, 52, 53, 54, and 71 where the hazard in moderate shall be full-bench roads wherever slopes are greater than 55 percent.

Landings must be constructed in GMU 36, 52, 53, 54, and 71 where the hazard is moderate to avoid placement in Mass Wasting Hazard #4. (This means avoiding the bedrock hollows and debris flow tracks.)

Excess rock and soil shall be end-hauled out of GMU 36, 52, 53, 54, and 71 where the hazard is moderate or, upon geotechnical advice, may be deposited on a large convex surface within these GMU if delivery to fish-bearing waters by mass wasting or surface erosion processes is unlikely to occur.

As much ditchline as possible should be cross-drained onto convex landforms within GMU 36, 52, 53, 54, and 71 where the hazard is moderate, and frequent cross-drains (300 to 400 ft) to disperse the water should be used. In places, outsloped roads may aid water control.

We have met most of the Mass Wasting Hazard #3 and #4 Road Prescriptions – culverts are appropriately sized and will be placed on >5% gradients, landings avoid the hazard landforms within GMU 53, excess rock and soil are being placed on an existing landing or removed to a stable GMU (WA #2 and #3 do not lie in GMU 53), and ditchlines are drained onto convex surfaces. Our cross-drain spacing does not meet the 300-400' recommendation for reasons discussed above in the Road Discussion and Recommendations Section.

Summary

The following are responses addressing WAC 222-10-30 (1) (a, b, c).

(1) In order to determine whether such forest practices are likely to have a probable significant adverse impact, and therefore require an environmental impact statement, the applicant much submit the following additional information, prepared by a qualified expert. The expert must describe the potentially unstable landforms in and around the application site and analyze:

(a) The likelihood that the proposed forest practices will cause movement on the potentially unstable slopes or landforms, or contribute to further movement of a potential unstable slope or landform;

Response: There is a low likelihood that this proposal will cause movement on potentially unstable slopes or landforms with delivery potential. All landforms meeting bedrock hollow and inner gorge definitions in both the North Fork Calawah Watershed Analysis and Standard Forest Practices with delivery potential have been removed from the proposed harvest. Several bedrock hollows and other, broadly concave features of >70% are proposed for harvest because they are unlikely to fail or unlikely to deliver, and a limited number of necessary yarding corridors are not expected to increase failure risk due to a small loss of rooting strength.

Harvest is proposed on bedrock hollows of >70% at Points 1, 2, 3, 13, 53, 56 and 70 because delivery of failures from these features is precluded by the 2922.015 road prism and/or by the nature of the hillslope below the 2922.015 Road. Validation by modeling of this interpretation has been provided above in the Delivery Discussion Section. The areas of hillslope described as broadly concave in Points 71 and 73 appear to have a low likelihood of failure. The single tree labeled "cut" at the top of the bedrock hollow described in Point 37 is well above the lower center axis where rooting strength is most critical in a hollow. And the upper portion of the bedrock hollow described in Point 44 is 65-70% with a distinct break-in-slope to 75-85% into the lower hollow – the upper portion of the hollow just barely meets the criteria for potentially unstable slopes and has not been protected because the lower hollow is where a failure is more likely to initiate.

To summarize Table 4, there is one location (i.e., an intersection of a yarding corridor and a discrete unstable landform) where a yarding corridor may have to be cut (Point 68). This should be as narrow as possible and full suspension is requested. To achieve the greatest suspension, I have encouraged the use of elevated tail hold trees and intermediate supports and I have specified that lighter-than-normal payloads and 40' logs may be necessary. At this site, a tail hold on ridgetop on USFS would increase lift and I have suggested this. There are two sites where one or more danger trees may have to be cut to facilitate yarding (Points 63 and 66). There is one location where a corridor is needed on a convex surface that has been included in a buffer (Point 61).

Where just one or more danger trees need to be cut, such as at Points 63 and 66, all of the other trees on these potentially unstable landforms will maintain the root reinforcement of the soil mantle provided by their intertwining root systems (Gray and Megahan 1981; Sidle et al. 1985). The cutting of narrow corridors also has a limited and short-term effect on rooting strength, particularly where the potentially unstable slope is well-stocked with conifer so that the remaining trees will react by increasing their growth rate for a period of years as they do after commercial thinning (e.g., Curtis and Marshall, 2009 who report higher-than-unthinned growth rates and a slight gain or no net loss of total wood volume at 17 years). The feature described in Point 68 is poorly stocked, but the actual corridor will lie on its southern edge and not in the center axis, limiting expected impacts. The corridor that lies on a buffered convex surface at Point 61 is not expected to elevate landslide rates.

Helicopter logging, proposed on the high ridge, is a delicate operation because the lifted trees must clear standing timber to avoid snagging and potentially crashing the helicopter. This means that no buffer impacts are expected.

It is the general belief, upon which are predicated the Forest Practices Rules, that avoidance of unstable landforms such as inner gorges and bedrock hollows by appropriately buffering them from harvested areas is a strategy that will limit landslide occurrences to a frequency and magnitude within the range of natural processes (Forests & Fish Report, Appendix C). I believe that we have met this standard by the nearly complete removal of those landforms that meet forest practices definitions of bedrock hollows and inner gorges and that have clear delivery

potential. Furthermore, I believe that we have met the standards of Mass Wasting Hazard Prescription #1, and #3 and #4, for the North Fork Calawah Watershed Analysis.

Finally, abandonment of a segment of the 2922.015 Road, including removal of two large fills with failing culverts, sidecast pullback and closely spaced waterbars will reduce the landslide risk this road currently represents.

(b) The likelihood of delivery of sediment or debris to any public resources, or in a manner that would threaten public safety; and

Response: In Unit 29.437, 47.3 acres of potentially unstable slopes have been removed from the steeper portions of the proposed harvest. Proposed for harvest are 62 acres of steeper hillslope. (Note: To avoid including riparian buffers in the first number and fan surfaces in the second number, the values provided are the cable ground and buffers within it as portrayed on the RFR Harvest Exhibit.) This means that 43% of the steep hillslope where potentially unstable slopes could exist has been removed from the proposed harvest. Except for the trees that must be cut to accommodate yarding corridors, there is nearly complete buffering of potentially unstable slopes with delivery potential. Seven sites where trees will be harvested on potentially unstable slopes each have limited to no delivery potential. These limited operations on unstable slopes do not increase landslide risk at the scale of the harvest unit, although immediately local landslide risk may be temporarily increased.

There is no possibility that public safety will be threaten by this proposal – Unit 29.437 is miles from any public or private infrastructure.

(c) Any possible mitigation for the identified hazards and risks.

Response: Mitigation occurs through the careful engineering of this harvest unit and road construction, through the leaving of additional trees in numerous locations and through the recommendations made for the yarding corridors. Numerous potentially unstable slopes have been removed from the harvest unit with the cutting boundaries placed on the trees rooted in breaks-in-slopes or where the slope forms change. The entirety of almost all of the features have been appropriately removed from the proposed harvest – 47.3 acres of buffer which is 43% of the steep ground.

Additional trees that increase wind firmness and provide barrier trees between bedrock hollows or between a bedrock hollow and its associated debris flow track have been left throughout Unit 29.437. The following Observation Points catalog the locations of these extra trees: Points 9, 28, 36, 45, 47, 49, 50, 59, 61, and 67.

The following recommendations for the yarding corridors provide mitigation: 1) Utilize elevated tail hold trees and intermediate (midspan) supports; 2) Make all cut yarding corridors as narrow as possible (standard forest practices); and 3) Fell all trees in all yarding corridors side slope within the feature to limit the debris slide initiations that could evolve into debris flows.

Finally, the abandonment of a segment of the 2922.015 Road is a form of mitigation that will reduce existing landslide risk.

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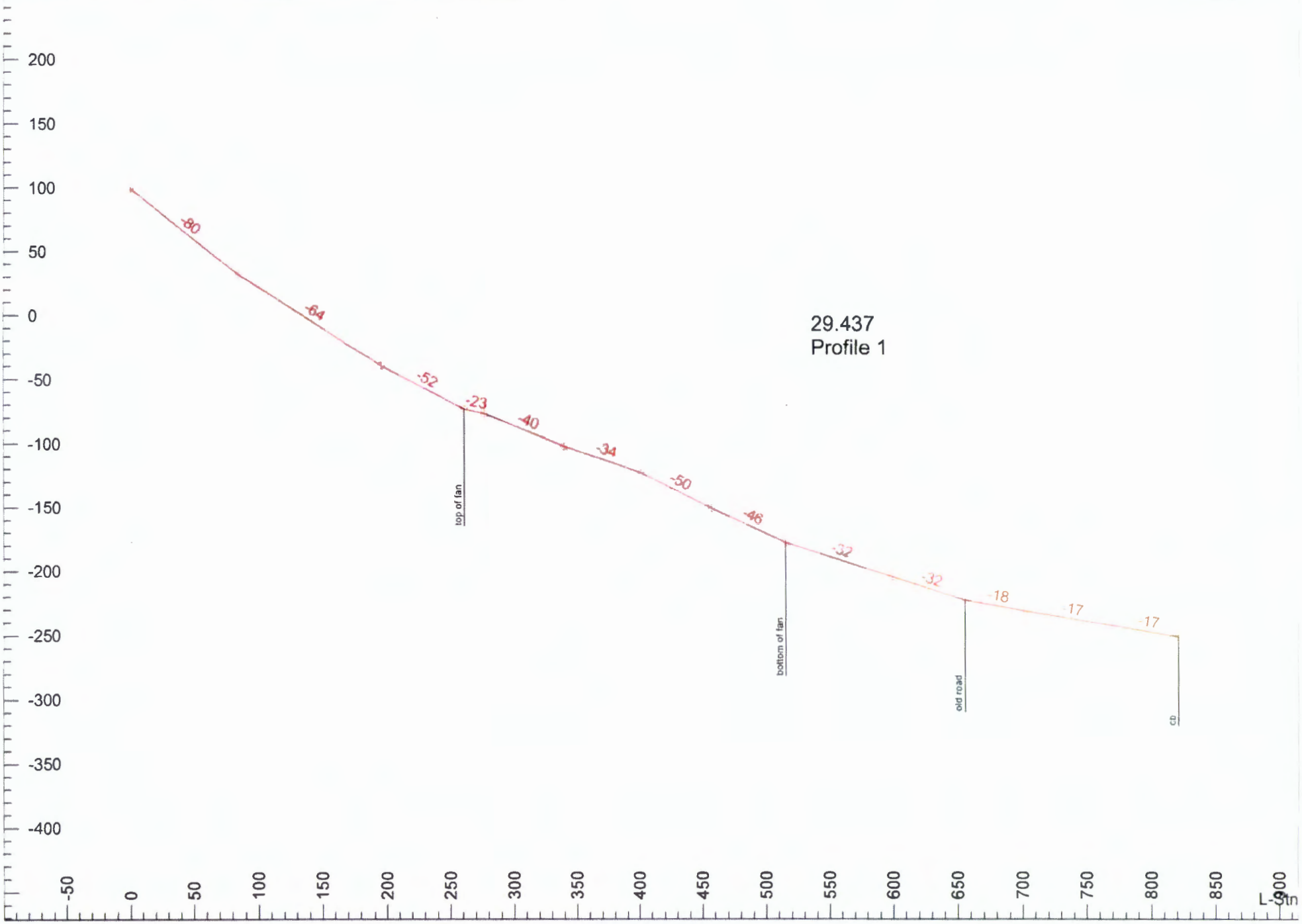

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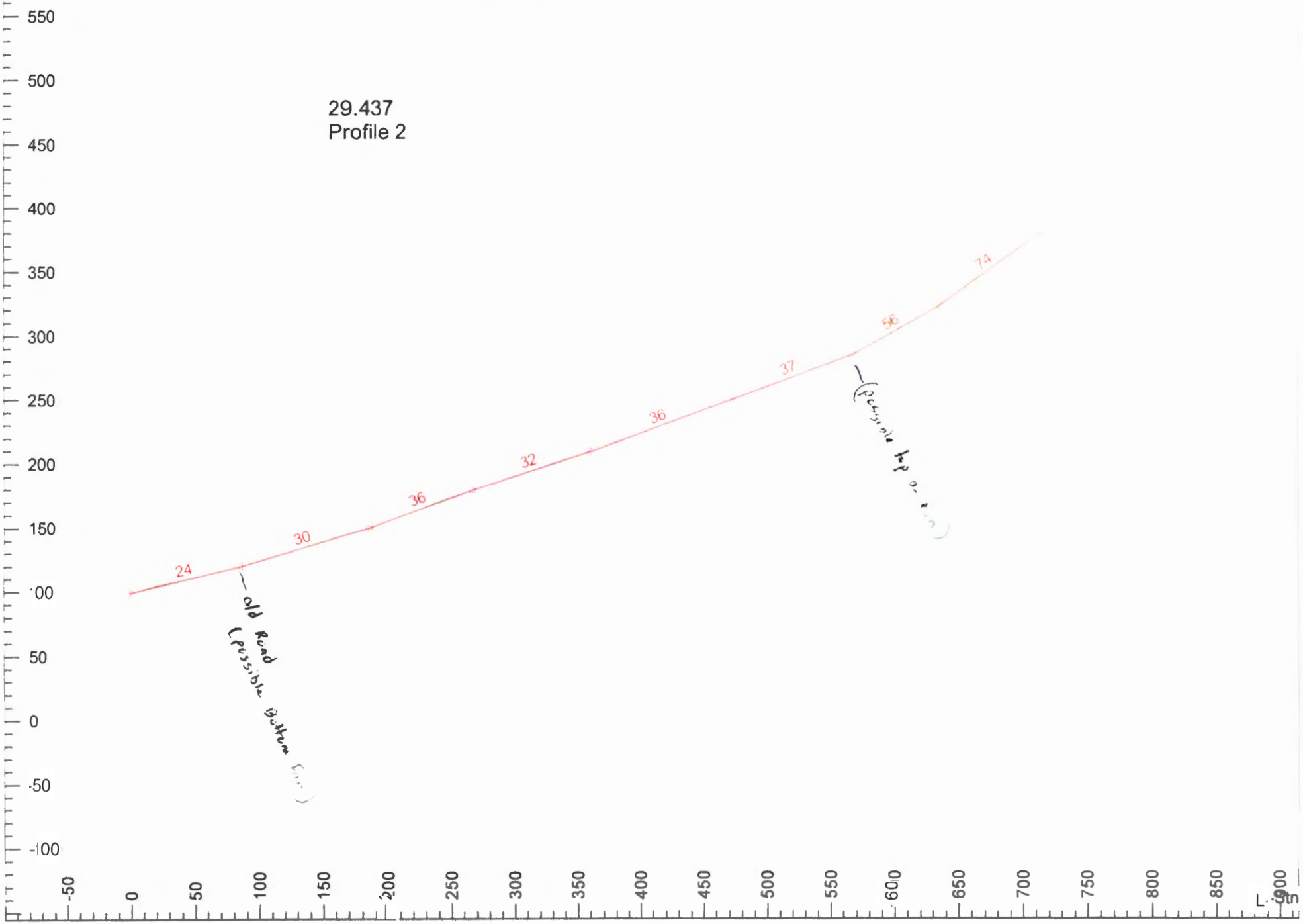

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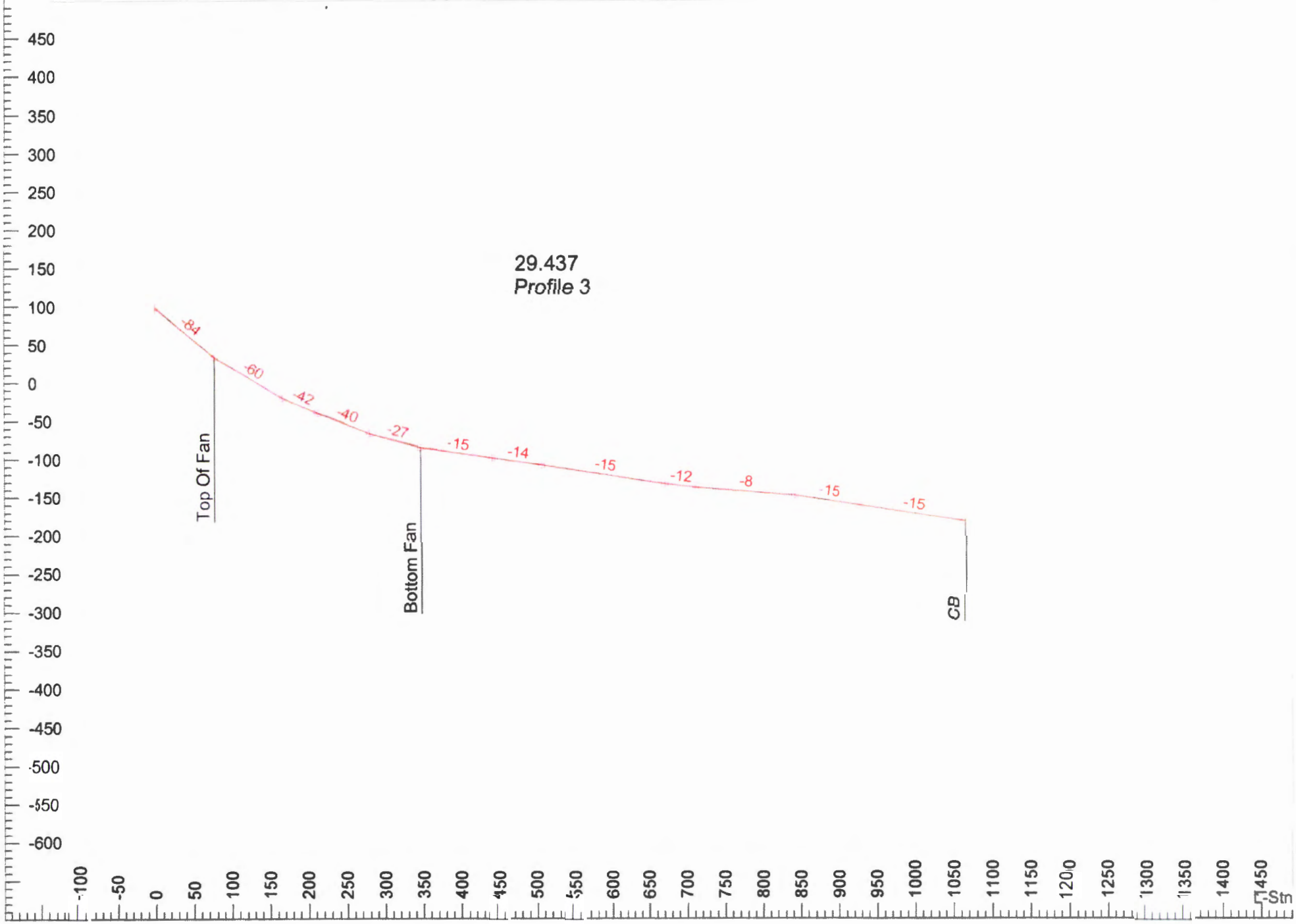

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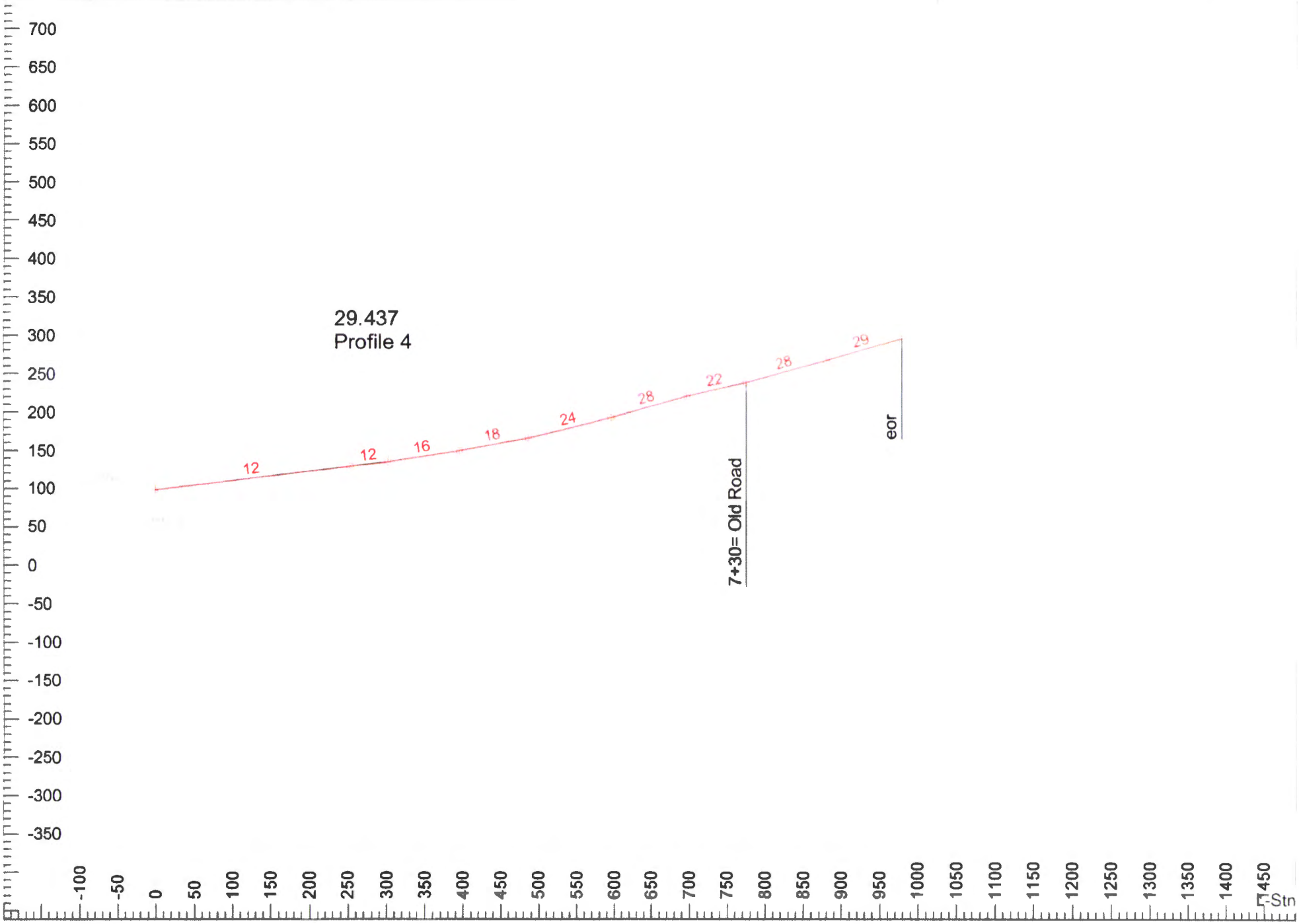

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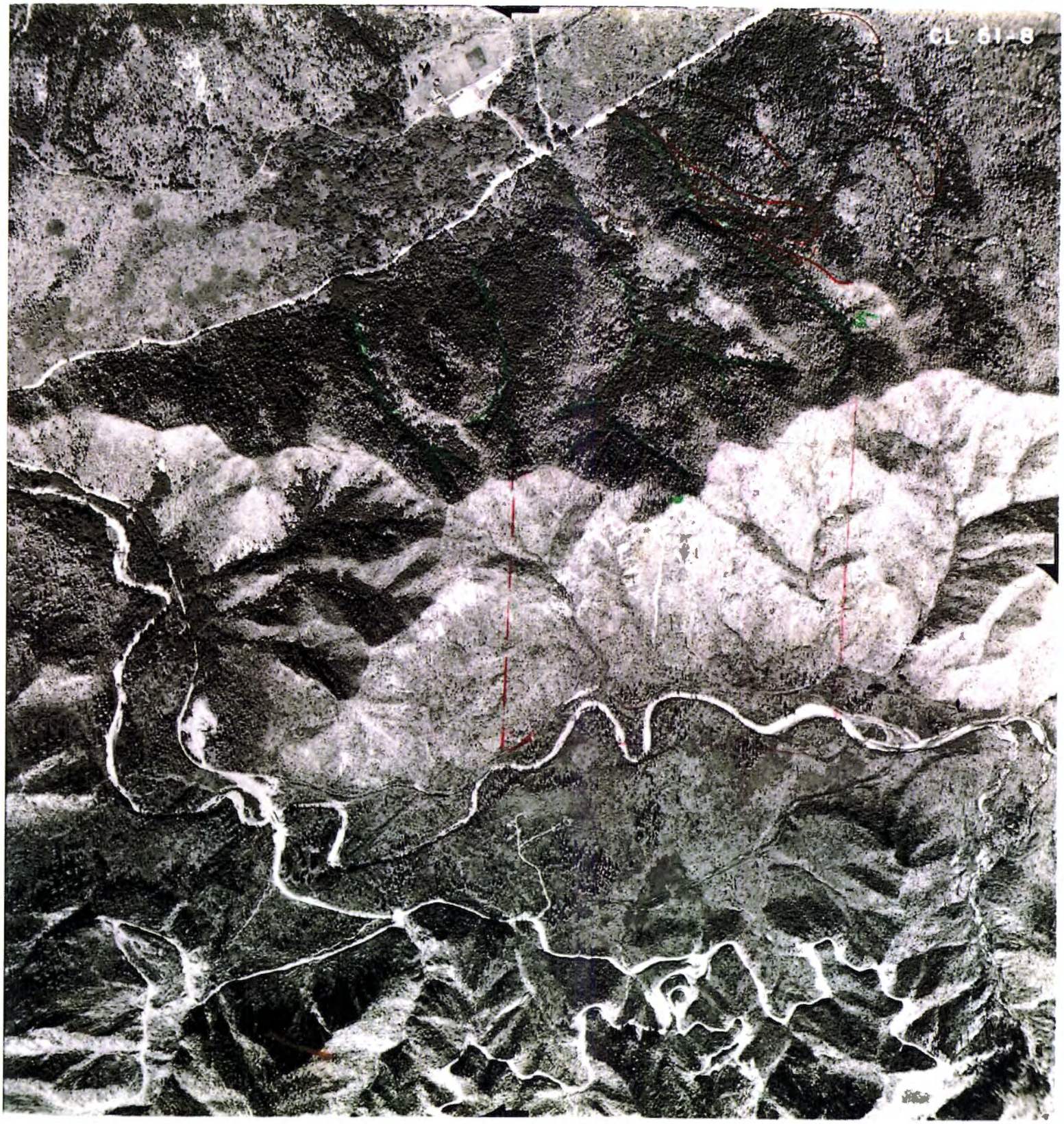

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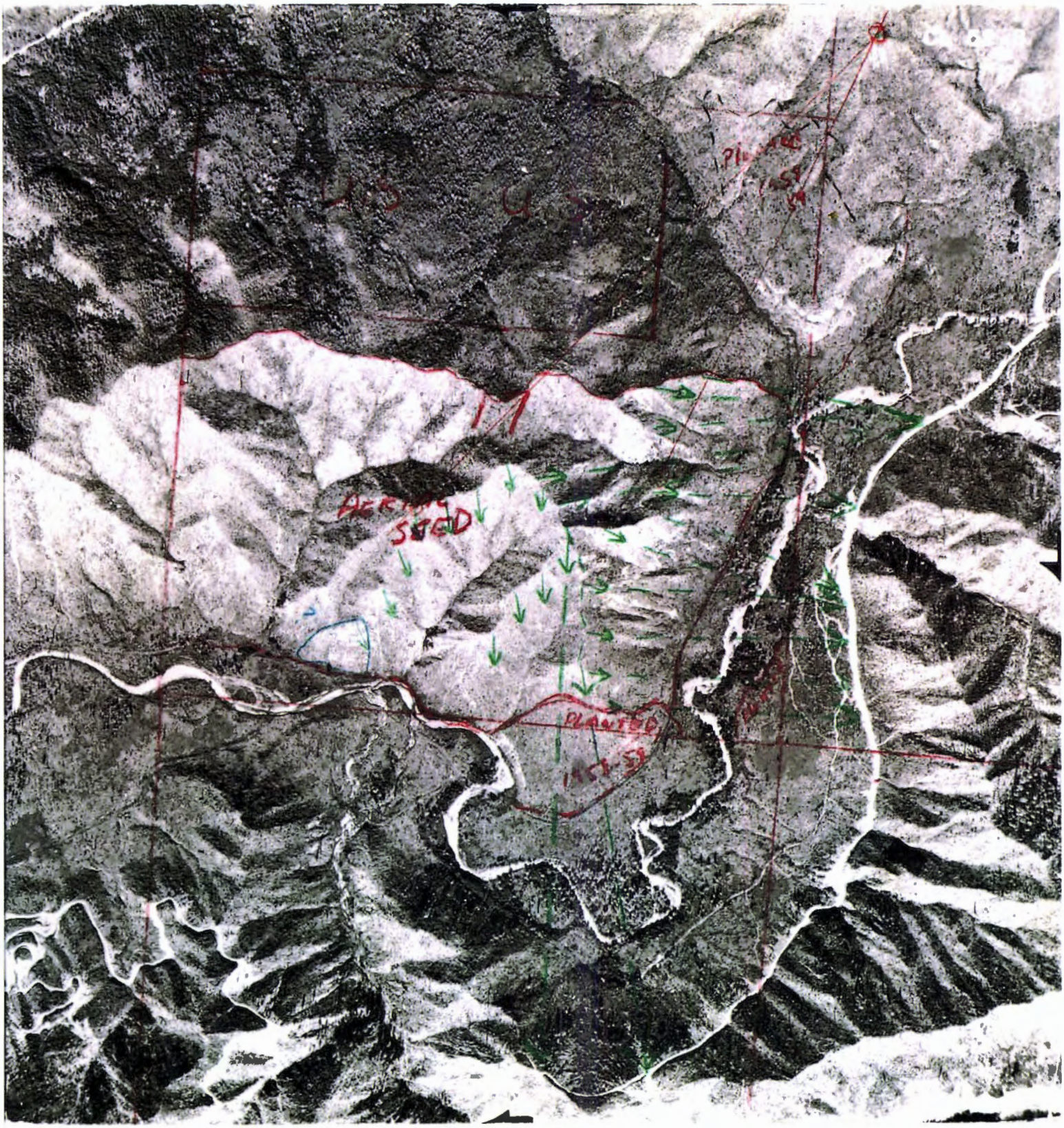

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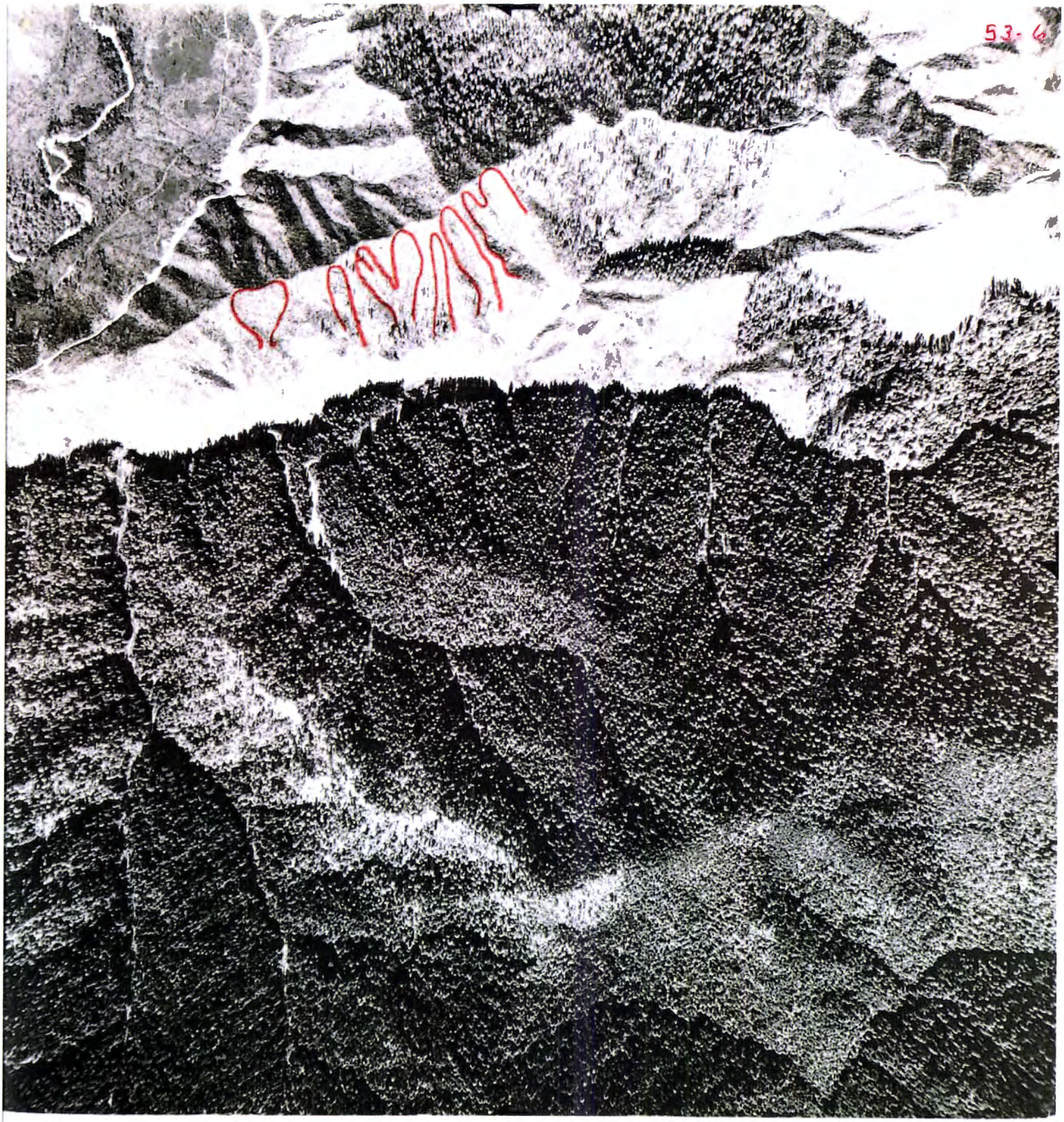

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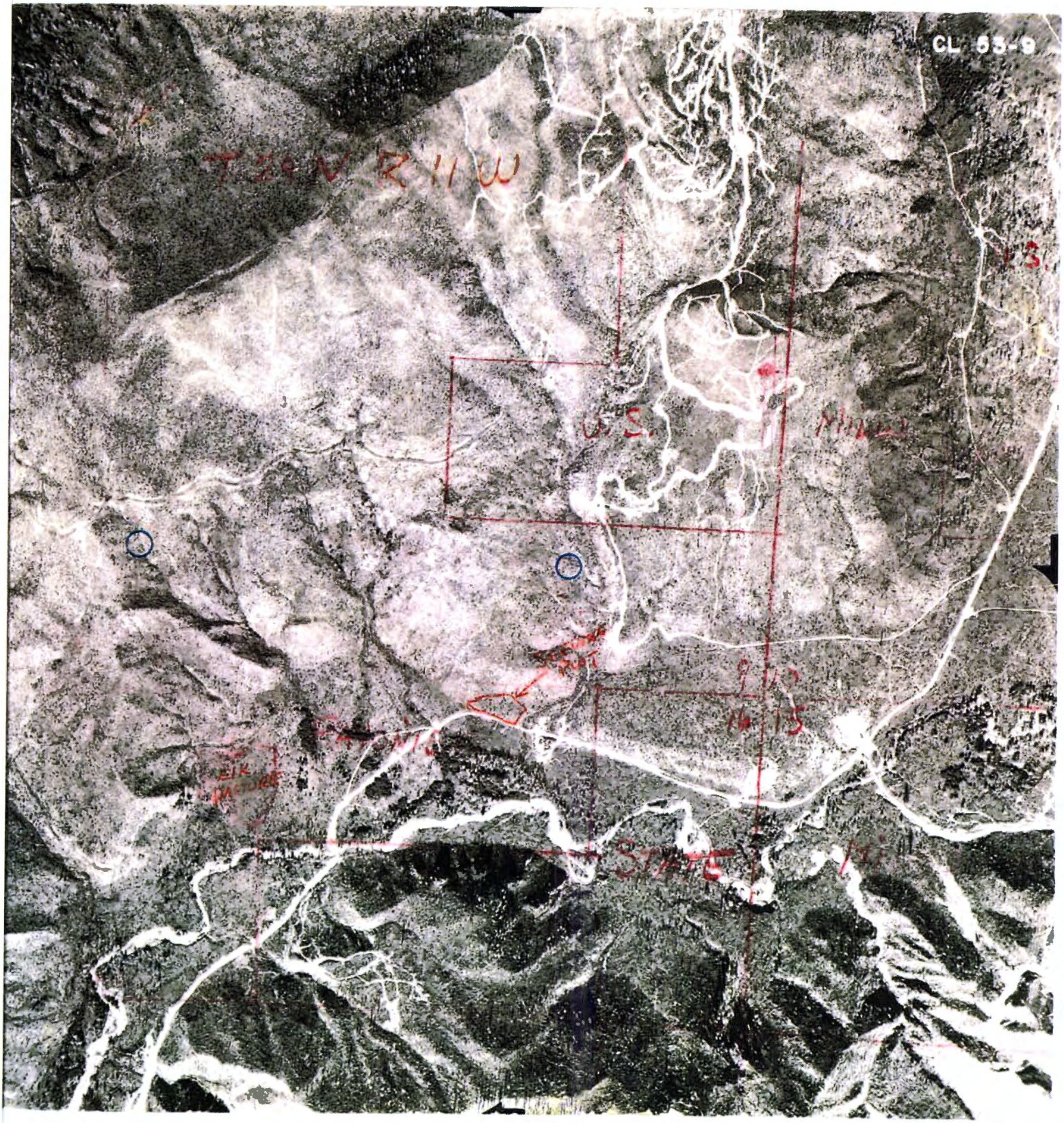

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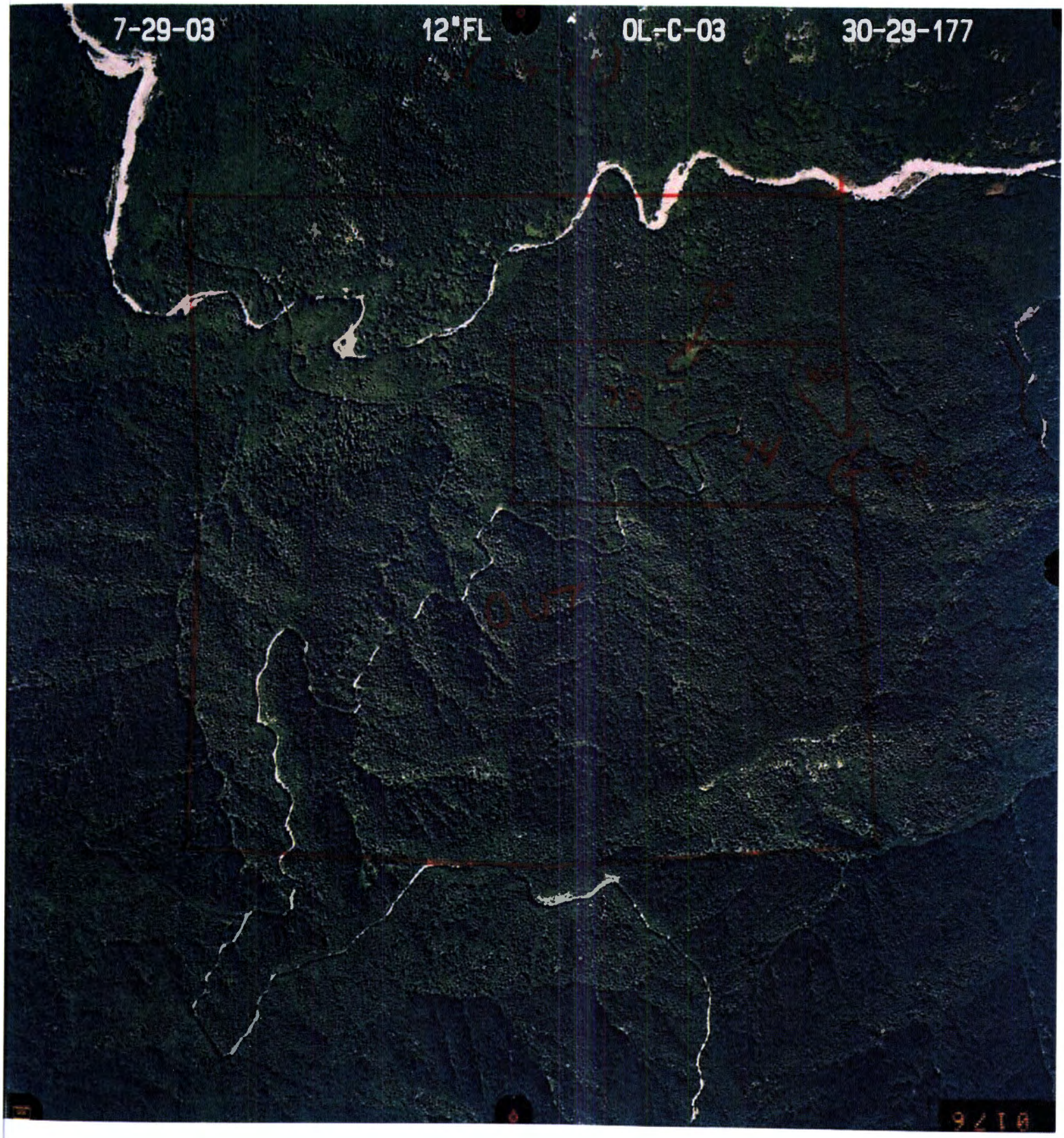

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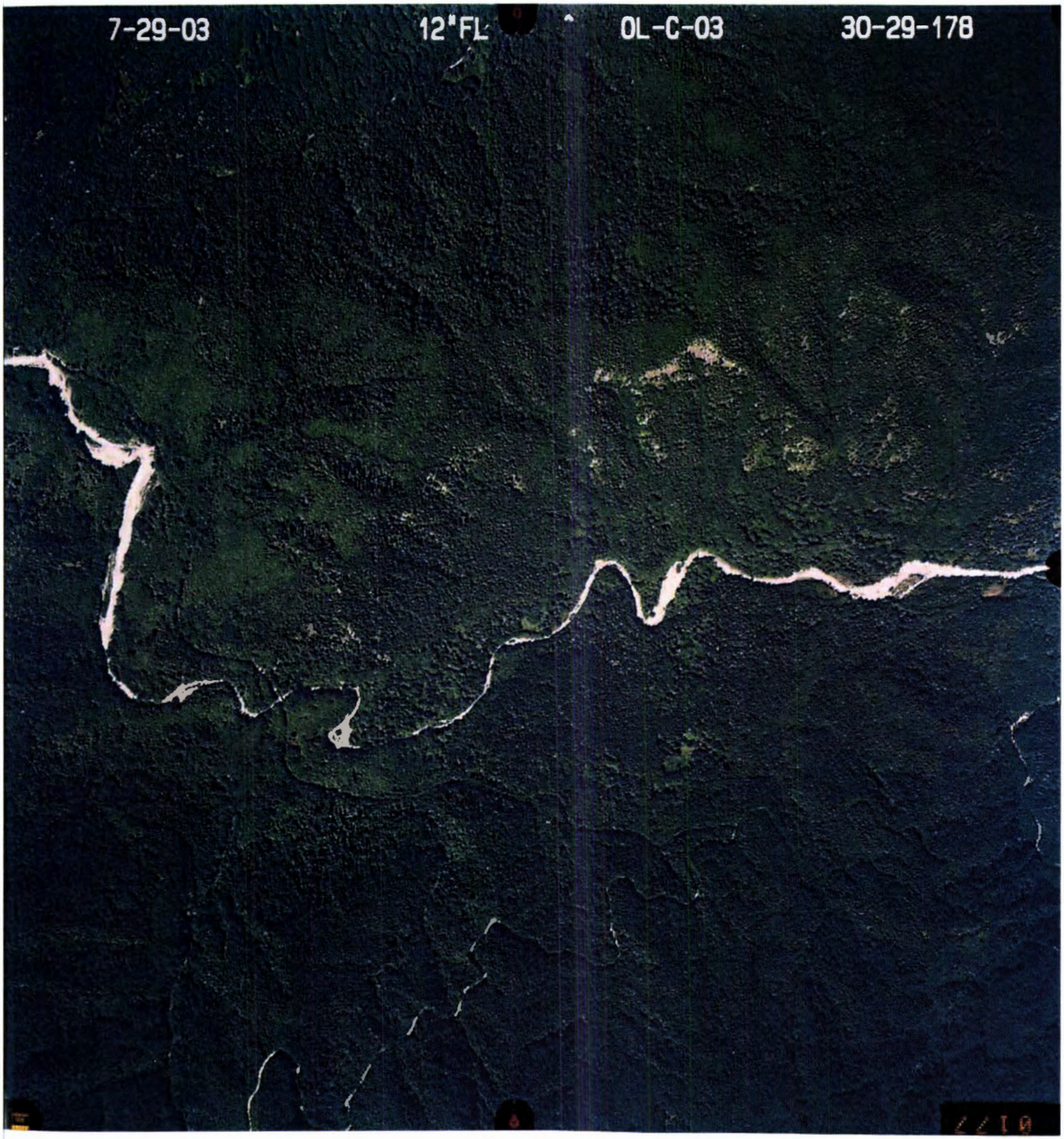

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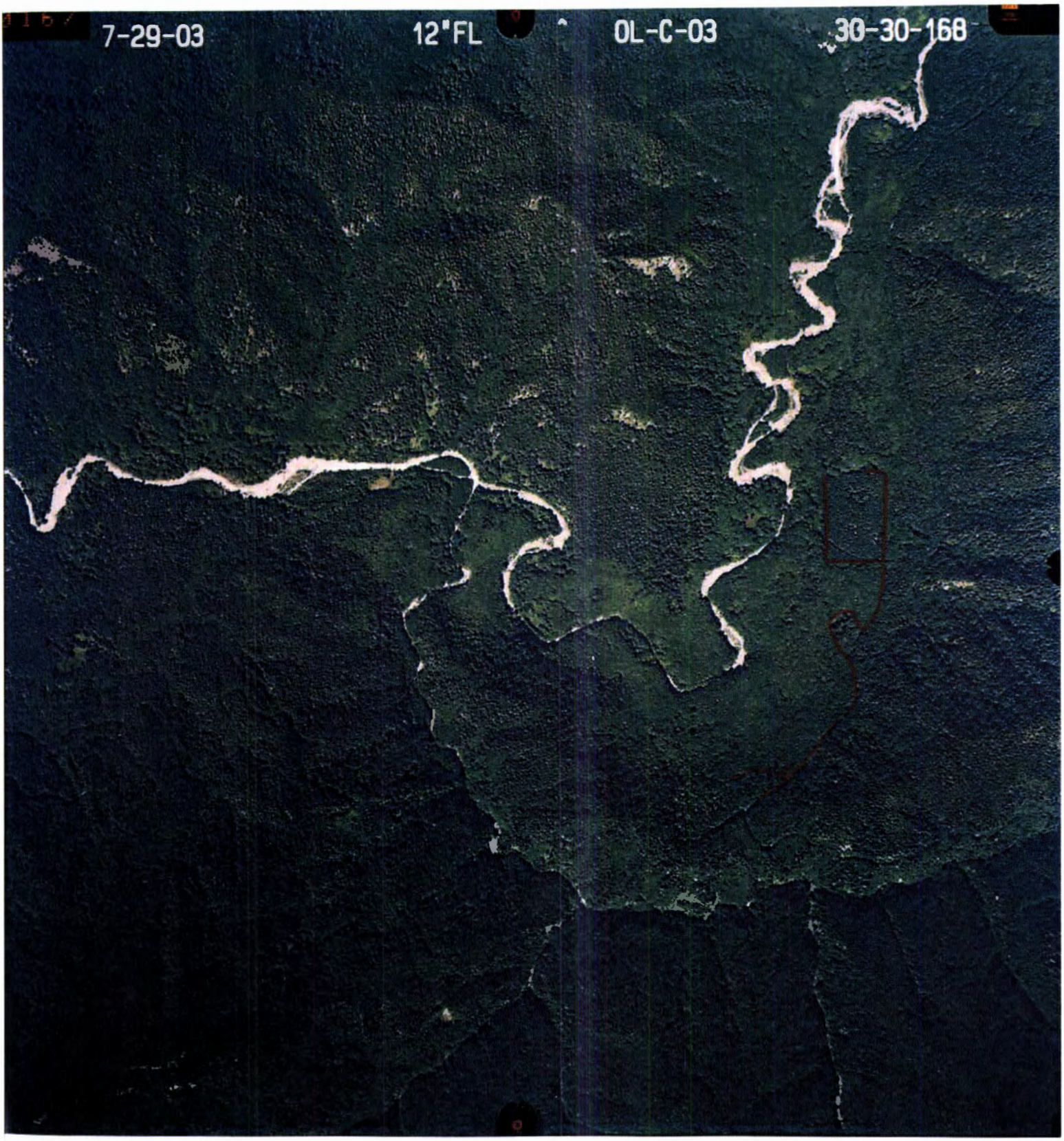

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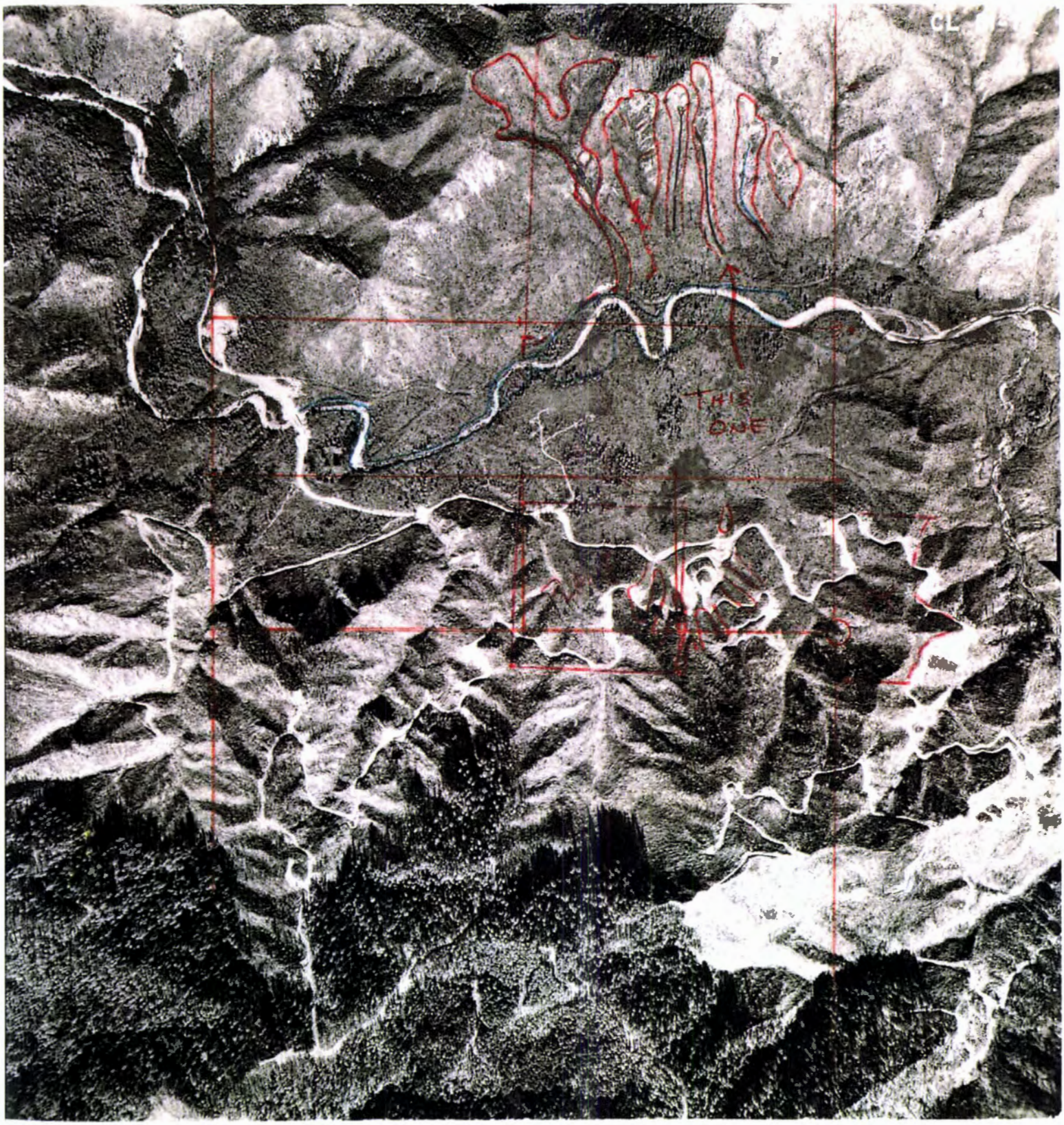

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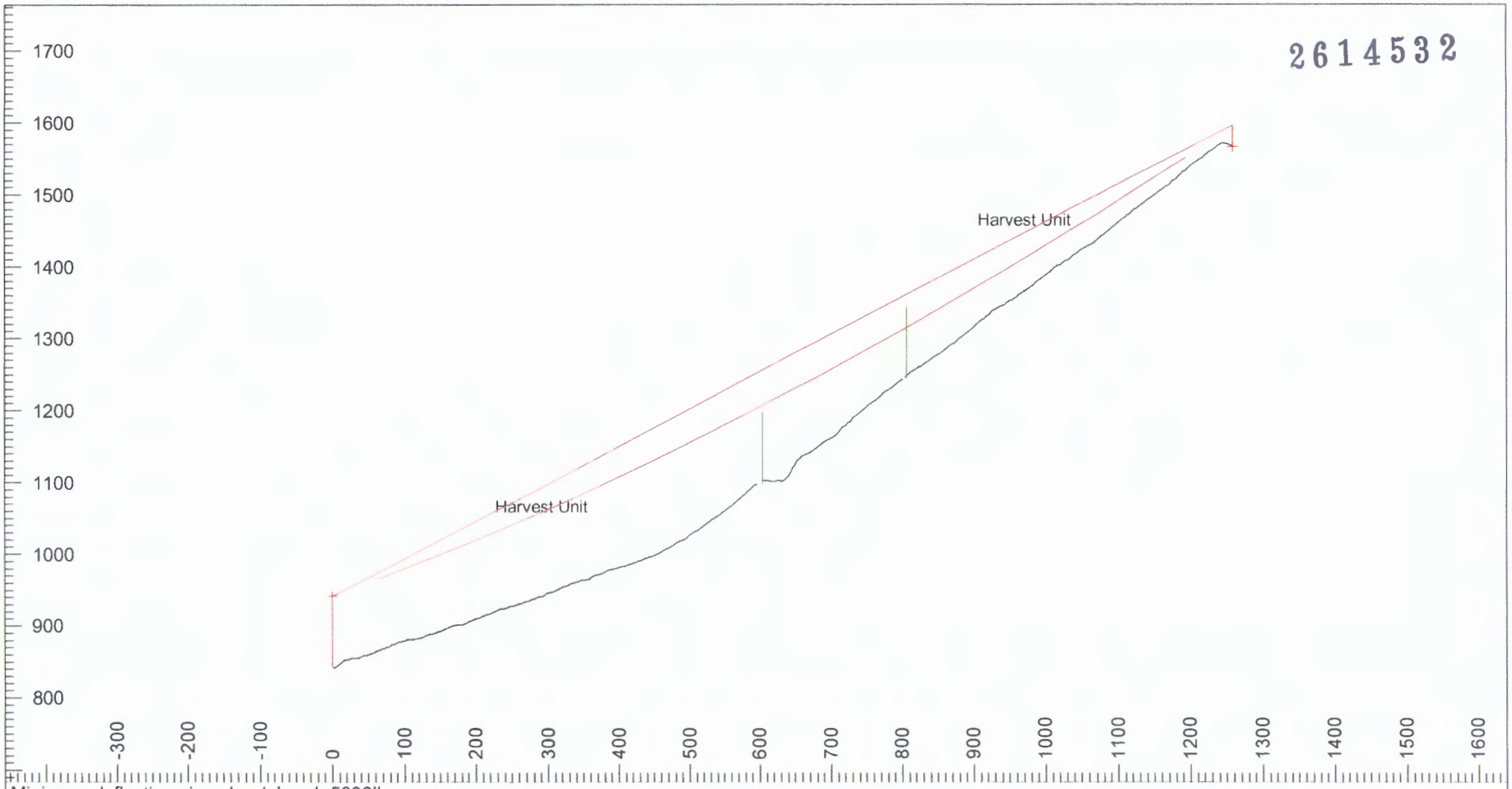

Minimum deflection given load, Load=5000lbs
Slackline, SL, ML, HB, Butt. Rigg., Car Wt.=300lbs

Station (ft.)	64.2	189.7	315.3	440.8	566.3	691.9	817.4	942.9	1068.5	1194.0
Car Clear (ft.)	99.2	109.2	117.1	131.1	114.4	94.8	64.6	47.8	35.7	16.9
Load (lbs)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

29.437 Landing 4 Profile 1

STA 24+00

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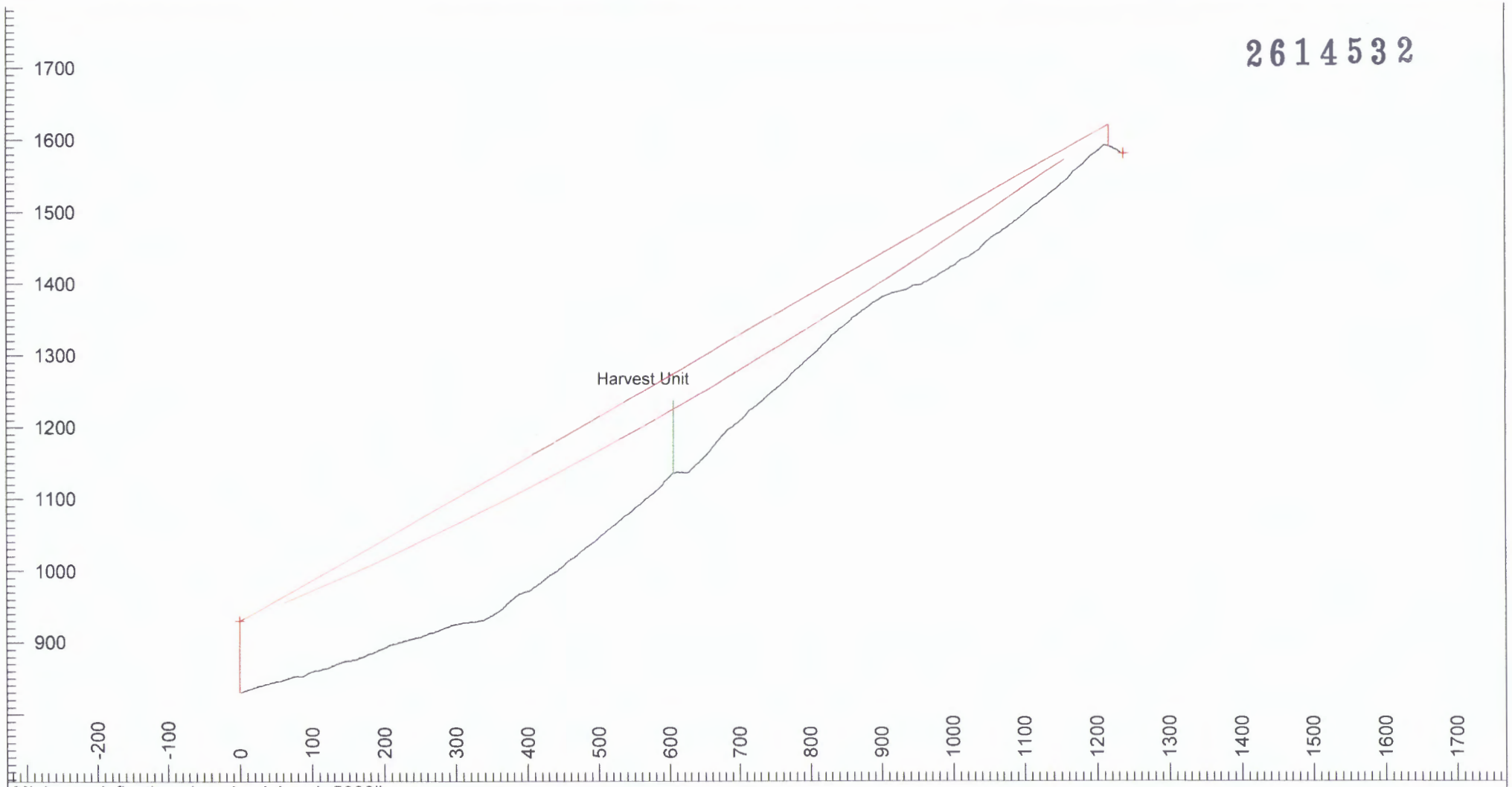

Minimum deflection given load, Load=5000lbs

Slackline, SL, ML, HB, Butt. Rigg., Car Wt.=300lbs

Station (ft.)	62.1	183.5	305.0	426.5	548.0	669.4	790.9	912.4	1033.9	1155.3
Car Clear (ft.)	107.2	123.6	140.0	137.2	108.7	79.6	43.5	24.2	44.6	31.0
Load (lbs)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

29.437 Landing 5 Profile 1

STA 27+00

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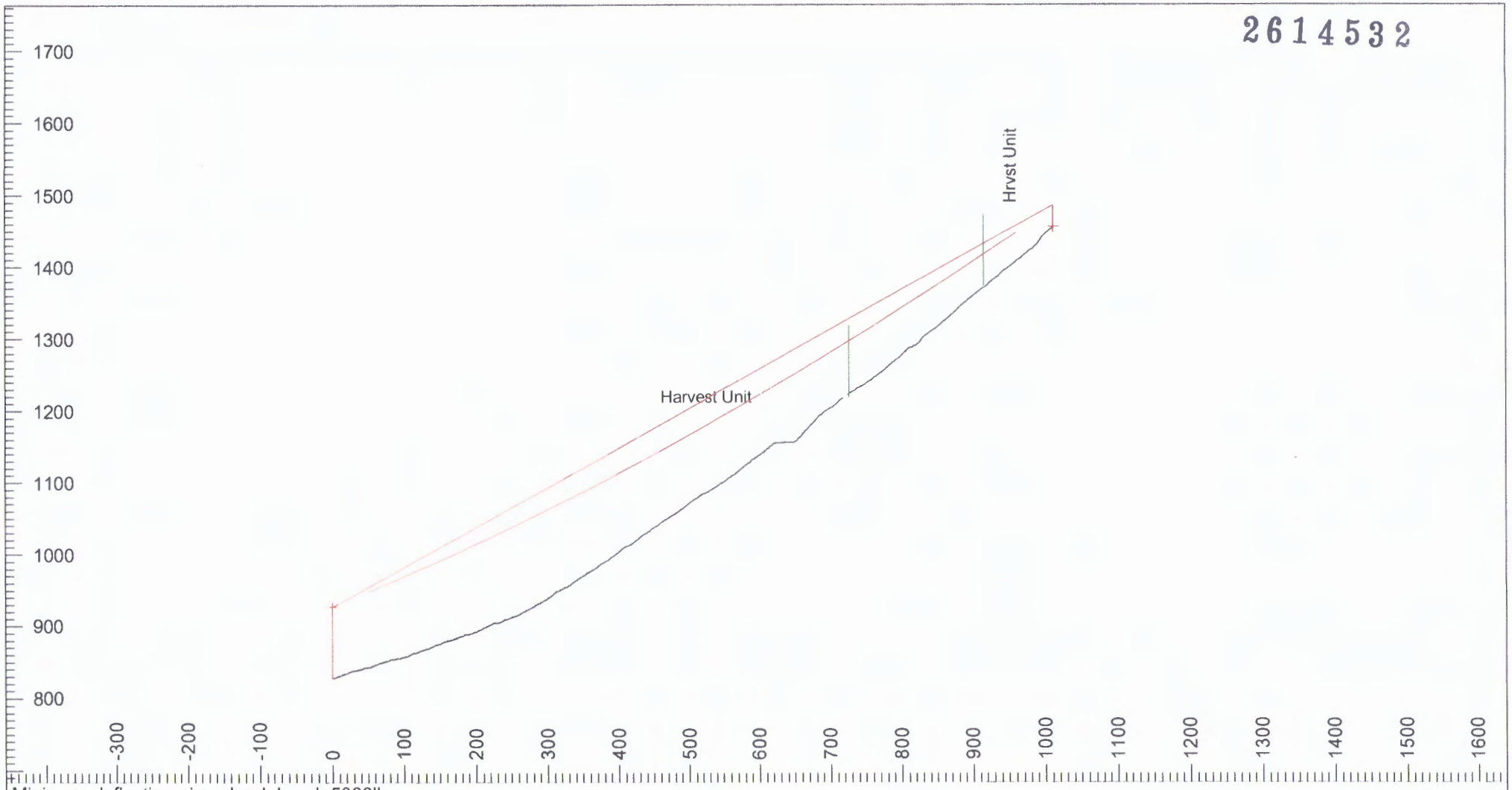

Minimum deflection given load, Load=5000lbs
Slackline, SL, ML, HB, Butt. Rigg., Car Wt.=300lbs

Station (ft.)	51.6	152.5	253.4	354.2	455.1	556.0	656.9	757.7	858.6	959.5
Car Clear (ft.)	105.7	115.6	125.5	115.5	100.7	91.6	91.3	72.3	56.3	39.0
Load (lbs)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

29.437 Landing 6 Profile 1

STA 28+80

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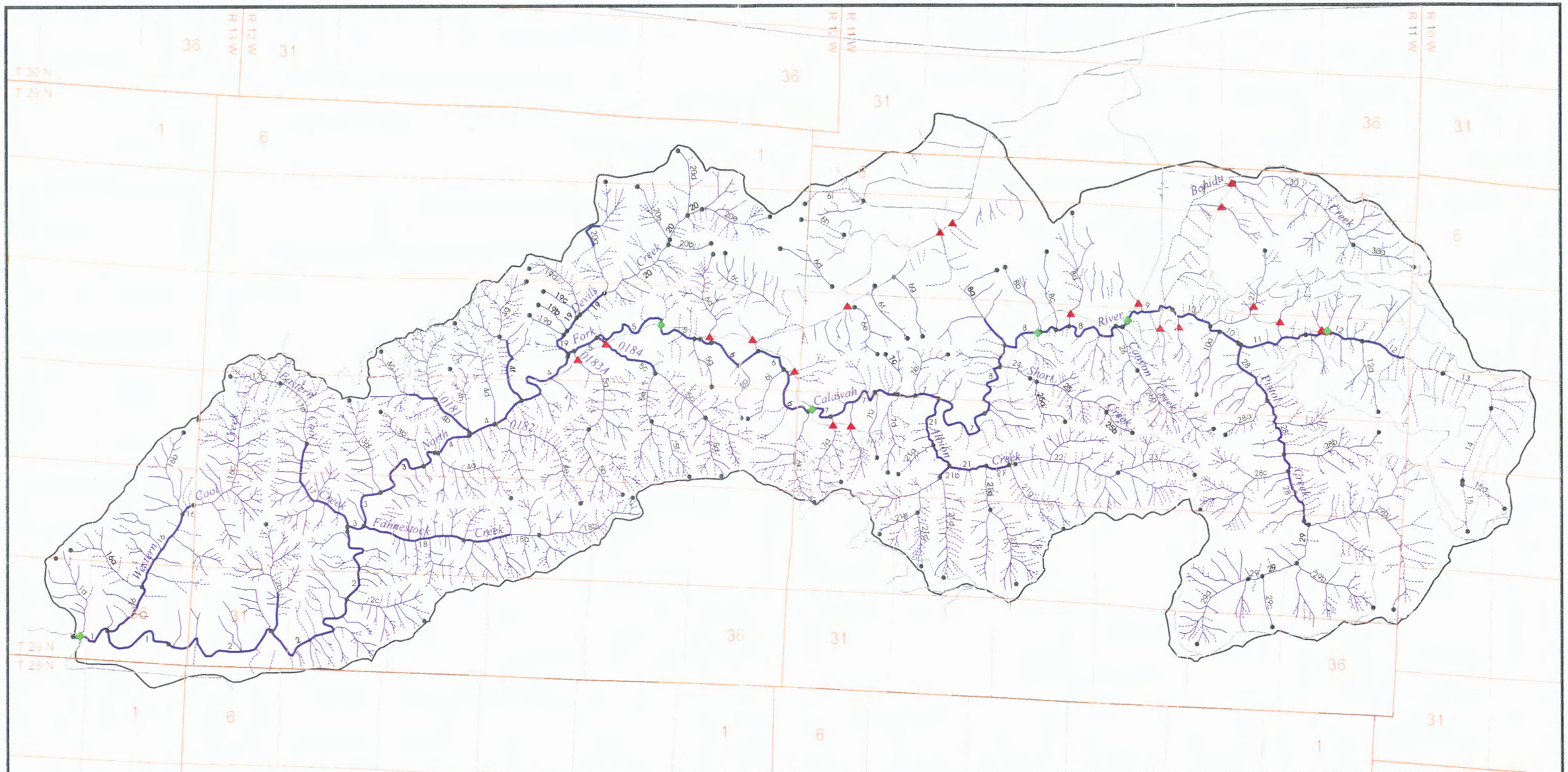

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Rayonier

EcoLogic

The Watershed Analysis Team cannot assure the reliability or suitability of this information for a particular purpose. Original data elements were compiled from various sources. Spatial information may not meet National Mapping Accuracy Standards. This information may be updated, corrected or otherwise modified without notification. For additional information about this data, contact the Olympic National Forest or Rayonier.

Scale 1:63,360 (1 inch = 1 mile)

0 1 2 3
Statute Miles

Map projection: State Plane Washington North
Created on September 23, 1996

LEGEND

- Culvert
- Bridge
- Road
- Type 1 - 3 stream
- Type 4 - 5 stream
- Unknown stream type
- Channel segment number and break points

North Fork Calawah River Watershed Analysis

Map E-1 Channel segments and public works.

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2922.015 Road Decommission

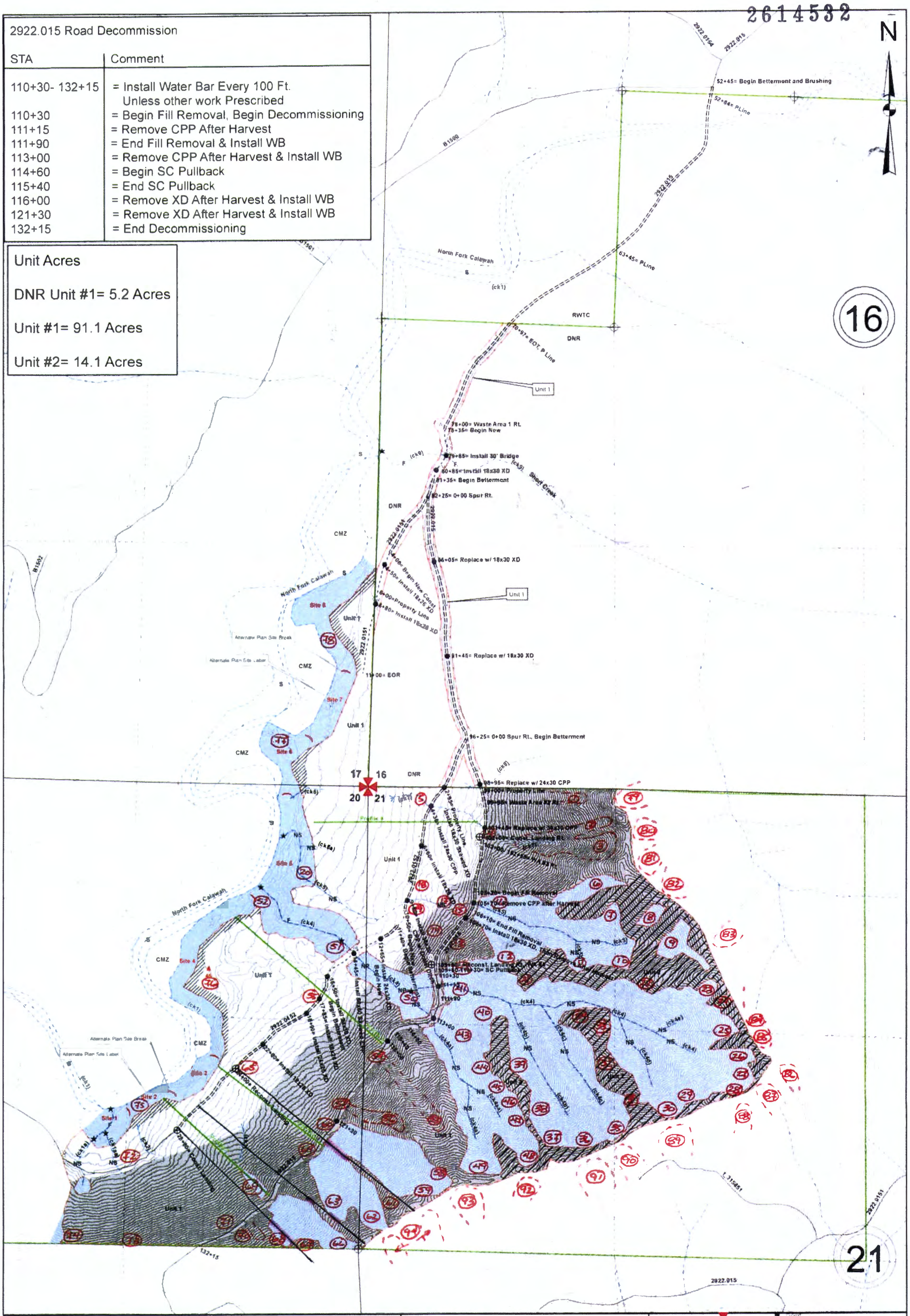
STA	Comment
110+30- 132+15	= Install Water Bar Every 100 Ft. Unless other work Prescribed
110+30	= Begin Fill Removal, Begin Decommissioning
111+15	= Remove CPP After Harvest
111+90	= End Fill Removal & Install WB
113+00	= Remove CPP After Harvest & Install WB
114+60	= Begin SC Pullback
115+40	= End SC Pullback
116+00	= Remove XD After Harvest & Install WB
121+30	= Remove XD After Harvest & Install WB
132+15	= End Decommissioning

Unit Acres

DNR Unit #1= 5.2 Acres

Unit #1= 91.1 Acres

Unit #2= 14.1 Acres



PFM	Engineering & Surveys		Logging	
RFR Harvest Exhibit Block: 29.437 Legal: 17, 20, 21(29-11W) Scale: 1 inch = 500 feet Date: 9/2/2016 Lat/Long: 48.008/-124.136	Field Book: Digital	Field Book:	110.4	Unit Acres Yarding Corridor
	Field Book:	Roads Marked: Y	0	Orange Ringed Leave Trees
	Field Book:	C/L Marked: Y	0	Cut Trees Marked w/ Orange "C"
	Obs. Points			PROFILES