LAND USE HISTORY OF THE

GUALALA WATERSHED

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PREPARED IN COOPERATION WITH THE CALIFORNIA RESOURCES AGENCY'S NORTH COAST WATERSHED ASSESSMENT PROGRAM

DECEMBER 15, 2002

APPENDIX 3: LAND USE HISTORY OF THE GUALALA WATERSHED

Photo Inset On Title Page: A road following the streambed, November 21, 1955, forcing the creek to flow under the road (center) and then across the road sidecast (right).

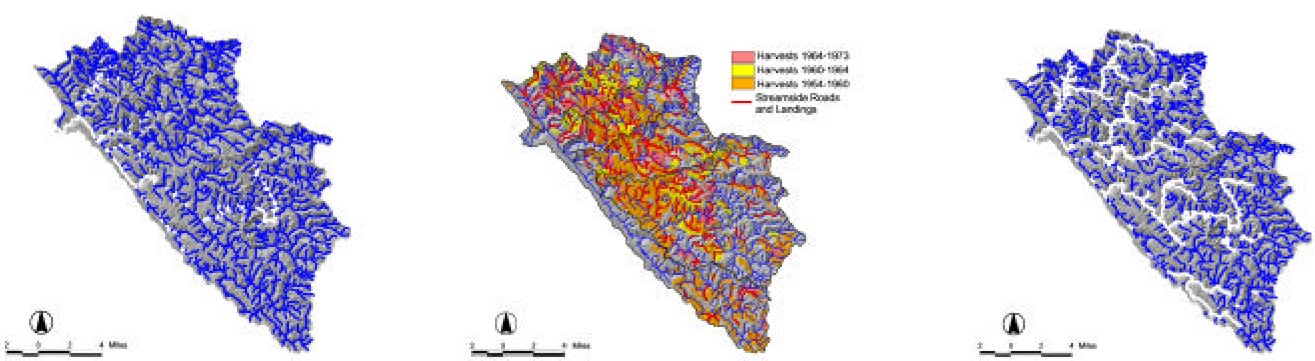
I. HISTORICAL TREND OVERVIEW

Located immediately north of the Bay Area, the Gualala Watershed has one of the longest spans of historical uses compared to other North Coast Watersheds. The watershed has been subject to three eras of active land use: (1) old growth redwood harvesting throughout lower alluvial basin areas between 1868 to 1911, (2) tractor harvesting of remaining old growth conifer stands in the central reaches of the watershed between 1952 to 1968, and (3), cable/ tractor harvesting of second growth coniferous stands throughout the lower basin areas again, often in excess of 50% of the land area in individual planning watersheds between 1990 to present. Historic land use patterns have interfaced with anadromous habitat conditions. However, these intrusions have been separated by variable recovery functions thru time and space.

II. RELATION OF LAND USE IMPACTS TO RIPARIAN CANOPY COVER

Since 1868, overstory stream canopy cover has been dependent on a particular stage of an economic cycle which drives intensive historic land use practices clearing riparian areas. These episodic events have been separated by equally long periods of inactivity and overstory riparian canopy recovery. The extent of riparian canopy cover has shifted rapidly throughout time and geographical location in response to three logging era boom and bust cycles. The earliest 1900 photos show riparian areas cleared of old growth redwood by oxen/ steam donkey yarding methods. In contrast, the 1942 aerial photos showed riparian canopy cover of mature second growth in the lower basin reaches following the Great Depression. During the post war housing boom, heavy tractors cleared riparian vegetation throughout the central basin reaches between 1952 and 1968. Current forest practice rules now ban these procedures. Overstory riparian canopy has now mostly recovered in the higher stream reaches. Lower stream reaches will take longer to recover being wider.

Canopy cover was complete in most tributaries as of 1942 indicating advanced regeneration from original old growth logging along the South Fork and lower to mid reaches of the North Fork. The remainder of the watershed in 1942 consisted of undisturbed old growth conifer timberland in the central reaches, and natural grassland oak woodlands in upland areas. The earliest photos dating back to 1936 and 1942 generally show baseline riparian overstory conditions of the watershed with which to compare broad scale habitat changes by successive land use impacts. Only the larger downstream stream reaches were naturally aggraded and wide and thereby exposed (Figure 1a). Large scale block clearance projects in the mid century (Figure 1b) eliminated overstory shade canopy over most primary anadromous spawning grounds by 1968 (Figure 1c). Timber operations and ranchland conversions removed riparian canopy cover, changing streambank exposure from about five percent in 1942 to a range of 40 to 70 percent bank exposure in the Gualala River Watershed by 1968. Interestingly, the earliest stream surveys in 1964 and 1971 show consistent coho observations and older/ larger steelhead. These consistent observations of Coho and larger steelhead date back to a time when most shade canopy had been removed. Canopy removal can implicate stream warming, although there are no historic stream temperature measurements that can be traced back to this time.



(a) 1942 Stream Exposure (80% Old Growth Conditions) (b) 1952 to 1968 Tractor Operations (c) 1968 Stream Exposure (white)

Figure 1: Overstory riparian shade canopy elimination throughout the Gualala Watershed by 1968

In the mixed conifer –oak woodland areas in the north east and east areas of the watershed, a large portion of the original conifered tract had been harvested by 1968. These had occupied north slopes and riparian areas on private ranch parcels. Prolonged cattle grazing in these areas after harvest prevented timely reestablishment of canopy cover over fish bearing watercourses. This presumably elevated stream temperatures.

As of 2001, canopy cover measurements taken during habitat typing surveys show improving canopy closure, reflecting riparian vegetative in-growth since 1968. and infrequent timber harvesting until the late 1980s. Aerial photos from 1999 substantiate these findings, with bank exposure reduced to approximately 25% averaged throughout the watershed (Figure 2, below). Streamside canopy now consist primarily of 40 year old pole to mid sized sized conifers/ mixed conifer hardwood stands in the middle to upper basin reaches. This represents an overall gradual improvement in stream cover from 1968 conditions when anadromous bearing streams were entirely exposed without cover. There has been active timber harvesting in the 1990s throughout the lower sub-basin reaches. However, the requirement of minimal entry WLPZ corridors over streams appears to have provided adequate mitigation. In addition, riparian corridor widths and leave tree density standards have been gradually expanded since 1995. These corridors are now managed as minimal to no entry zones as future late seral habitat areas. Despite these trends, contemporary stream surveys now generally show predominantly young of the year steelhead and absence of coho.

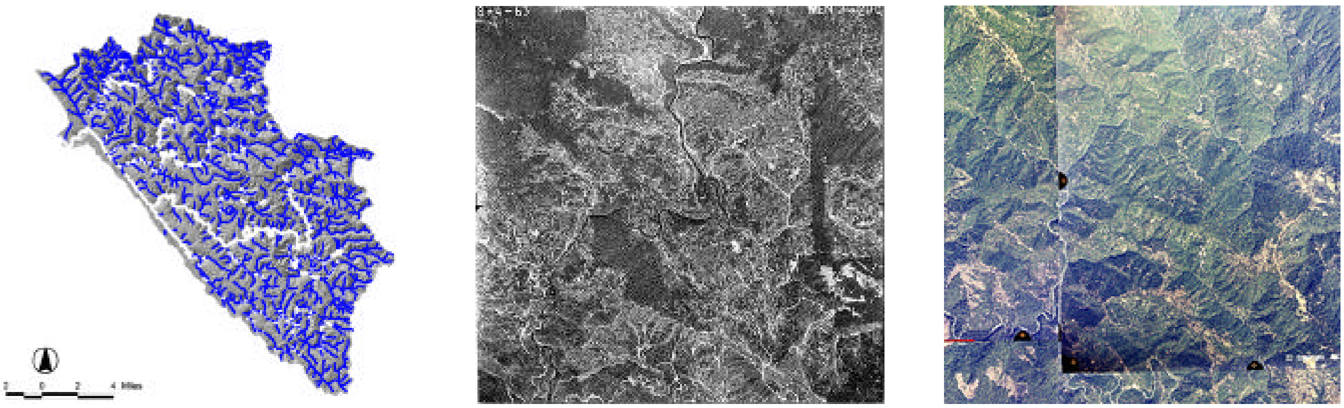


Figure 2: (a) 1999/ 2000 stream exposure (white) (b) Central Rockpile Subbasin 1963 (c) Central Rockpile Subbasin 1999

III. RELATION OF LAND USE IMPACTS TO STREAM CHANNEL CONDITIONS

Land use activities have influenced stream channel structure by (a) accelerated sedimentation inputs, (b) channel grading and simplification, and (c) depletion of LWD. However, the study found overall interrelationships to be very complex, and expressed differently in the watershed through time. The sub basin summaries in the forward report attempt to enumerate complex interactions, which compare differently basin to basin. This indicates varying implications to salmonid viability.

1868 to 1911

Stream Channel Simplification

The original old growth redwood logging was limited to the main stem South Fork and the bottom alluvial basins of the major tributaries. Old growth redwood harvesting extended up into the middle reaches of the North Fork. Stream channels in these areas made efficient and economical log transport networks by oxen teams/ steam donkeys between 1868 and 1911. Watercourses were frequently used as skid paths to move logs downslope. Natural pool structure was removed during construction and use of watercourses as skid ramps. Log planking of the streambed eased frictional constraints. Construction of splash dams represented a significant alteration of stream channel morphology.

Figure 3: Left: Steam donkey cable yarding to a lateral rail line. Right: chowtime in a creekbottom, North Fork Gualala

By 1900, a rail network extended along most of the South Fork. Lateral raillines, however, did not extend far up either the Wheatfield, Buckeye, or Rockpile basins. The North Fork had the most extensive lateral network extending through the low lying alluvial basins (1) in the Little North Fork, and (2) the main stem North Fork up to Dry Creek approximately. To keep the rail-line positioned on a level grade, most of the fill ballast closely followed the stream channel. The railline had to be built on a low elevation rise following an even sideslope contour. In some areas of tight turns and other areas of engineering constraints, massive cut and fill excavation operations were carried out by a mobile train mounted steam shovel. These worked at the endpoint of the newly constructed railline. Large amounts of dirt fill were hauled in to level the rail grade. Fill ballast was frequently built up along the edge of major streams. Although wood trestles were built over larger watercourses, smaller watercourses were crossed by wood and earth fill. This frequently dammed the watercourse over time, and failed altogether. Many sections of the lateral raillines continue to be used today as part of the current permanent and seasonal road network with watercourse crossings upgraded and repaired.

The introduction of the stream donkey by the turn of the century reduced ground impacts by cable pulling large logs from fixed locations. Elaborate pully systems enabled cable winching over larger distances. These operations did not disturb the ground to the extent of more recent tractor operations characterized by large scale slideslope excavations and skid trail networks.

LWD

Natural LWD distributions were undoubtedly altered by the in-stream skidding practices. LWD evaluation is limited by few photos at the time and these are often difficult to reference to an actual site. In some areas, whole trees were felled into the stream, leaving more woody debris after yarding than undisturbed conditions. In other situations, natural LWD was removed to make the in stream log skid ramps.

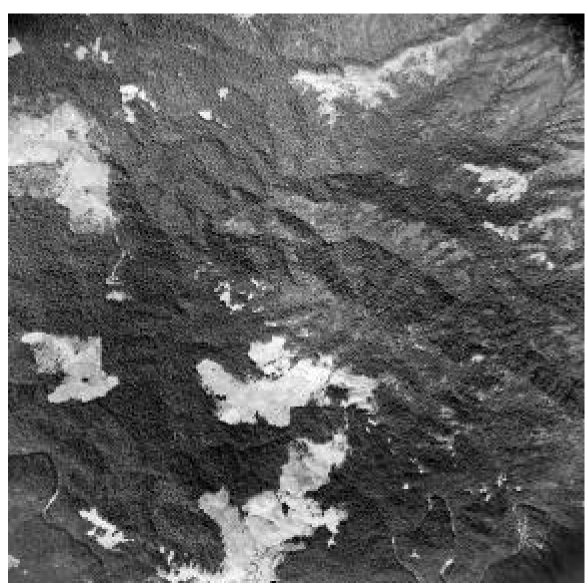
SEDIMENTATION INPUTS

These activities undoubtedly left the lower alluvial areas of the watershed vulnerable to major erosional impacts by infrequent large storm events. In addition, precipitation records from Fort Ross, dating back to 1876 show that between 1891 and 1925 rainfall was above average and has been below average as a general comparative trend since.

Historic sediment terraces exist along low order tributary channels in nearly every watershed that has experienced intensive pre-1973 logging practices. This includes the Garcia, Albion, Big River, and Elk Creek watersheds. Many of the historic terraces have been dated to the turn of the century old growth railroad logging era. Historic terraces developed from early century stream channel aggradations that buried the original channel over bedrock. These aggradations accumulated in the lower gradient response reaches. Subsequent storms eroded down the central channel, leaving terraces on one or both sides of the stream. More detailed analysis of the Noyo Watershed study and implications for the Gualala Watershed are provided in the "Stream Gradients" Section, pgs 28-36.

After logging, the cleared areas were frequently burned and used as pastureland. Other larger areas were generally abandoned. The 1936 photos show the Gualala Watershed long dormant during the Great Depression. The mid sized second growth stands shown in these photos indicate that old growth logging by steam donkey had ceased shortly after the turn of the century. There are no interior logging roads away from the coast. The old railline network was unused and abandoned during the Great Depression. This can indicate a prolonged period of channel stabilization, and a gradual wash out of remaining bedload fines. However, there are no field accounts dating back to this time to verify this.

Figure 4: Old growth conifer tracts, Fuller Creek, 1942. The main stem Wheatfield Fork is at bottom center.



<u>Tractor Era (1952 thru 1968)</u>
Stream Channel Simplification

Increased demand for lumber products during the 1950s coincided with the widespread deployment of D-8 and D-10 sized heavy tractors throughout the watershed. By 1952, an ample timber supply of old growth conifer timber occupied the Rockpile, Buckeye, and Wheatfield sub-basins. Old growth conifer timber occupied the central reaches of the North Fork, and inland areas of the Upper South Fork on north slopes.

Between 1952 and 1960, tractor method harvesting extended in a broad sweep from the upper reaches of the North Fork, east through the central and upper reaches of Rockpile and Buckeye Creeks, and throughout lower and middle reaches of Wheatfield Fk. By 1968, tractor harvesting had continued at an active pace to comprise a majority and in some areas, most of the timbered areas in the west and central reaches of the watershed. The use of crawler tractors was characterized by large-scale sideslope excavations and skid trail networks. Harvest operations followed straight parcel lines irregardless of watercourse condition or difficult terrain. Roads often followed the stream channel to enable downslope skidding. Many roads had steep gradients designed to access all positions of the sideslope. In addition, skid trails frequently followed or crossed ephemeral stream channels. Across steep terrain, skid trials cut deep into the sideslope, creating a terraced effect (Figures 9 and 13).

Located along an even gradient, stream channels were once again the most efficient and economical log transportation routes to build roads during this era. In short time, this engineering methodology became highly ordered and well organized. At first, ROW fallers clear cut the riparian zone. Then the D-8 tractor entered the creek to grade the stream channel flat to one side. These heavy tractors pushed dirt fill over the natural streambank into the creek to even the road grade along the outside edge. Road grading along the creek smoothed over natural pool structure and complexity, forcing the stream channel to run in a lineal pattern bounded by road fill to one side. Streamside road building pushed large amounts of sidecast over the streambank, frequently burying the stream channel. This forced the stream to reform towards the outer streambank as a simplified trench (see photo on Title page).

The mid century road networks followed streams up the narrow valleys and inner gorger canyons of the central North Fork, middle Rockpile PWS, and higher reaches of Fuller Creek. Heavy tractors cut into the steep sidebanks at the base of the streams, making the near vertical cut banks along the roads prone to failure during winter storms. Tractors graded the streambed flat to one side, simplifying channel complexity and structure. These operations pushed large volumes of dirt debris into the streams as road fill sidecast. Entire burial of the stream channel was more common in steep terrain. In narrow and deeply incised inner gorge canyons, tractors had to work along the streambed to grade the road. In addition, CGS mapping found that the mid century road networks crossed a high density of debris slides and debris flows in steep topography [Plate 1: CDMG Map of Landslides and Geomorphic Features Related to Landsliding].

The deeply incised channel topography tended to concentrate flows during storm events. The steep topography and high stream density probably caused intense, flashy runoff, that (1) challenged and often removed the primitive log/ dirt road stream crossings and instream landings (Figure 11) , and (2) undermined the streamside roads collapsing road segments into the streams (Figure 9, 17, 20, 21, 23, 28, 66, and 67). CGS and CDF mapping found a high density of road debris slide failures from the streamside road concentrated in the central basin reaches in steep terrain (See Synthesis Appendix 6A).

The in-stream landing was particularly destructive to salmonid habitat. Frequently located at the confluence point of several streams, the entire stream channel was often buried to construct large flat log strorage decks and loading facilities. To build these, D-8 tractors pushed log chunks into stream pools to allow water percolation under the landing. Then the D-8 pushed dirt fill over the chunks prior to grading even the landing surface. In steep basins, for example, the Fuller Creek tributary to Wheatfield Fork, deeply incised inner gorges were impractical to build an in stream landing. The solution was to build large complex landings at the base of the inner gorge canyons where alluvial washout created more or a moderate slope gradient. Often, these in stream complex landings exceeded two to three acres in size. In addition to Fuller Creek, complex landings were particularly located in the central reaches of the North Fork and Rockpile sub-basins.

Built between 1952 and 1968, streamside/ in-stream road and landing networks spanned the entire natural fluvial drainage system of the north and central regions of the watershed. These roads dominated stream channel structure throughout the lower and middle reaches of the North Fork, Rockpile, Buckeye and Wheatfield sub-basins (see Figure 5 below). Approximately 95 miles of in-stream/streamside roads simplified the stream channel complexity and structure in the watershed. These roads represent a significant proportion of stored sediment deposits that are episodically released into streams by reactivated bank erosion during present day storm events.

Table 1: In Stream/ Streamside Road Networks by Sub-Basin

Subbasin	In Stream/ Streamside Roads (miles) 1952 – 1968
North Fork	18
Rockpile	16
Buckeye	27
Wheatfield	19
South Fork	15

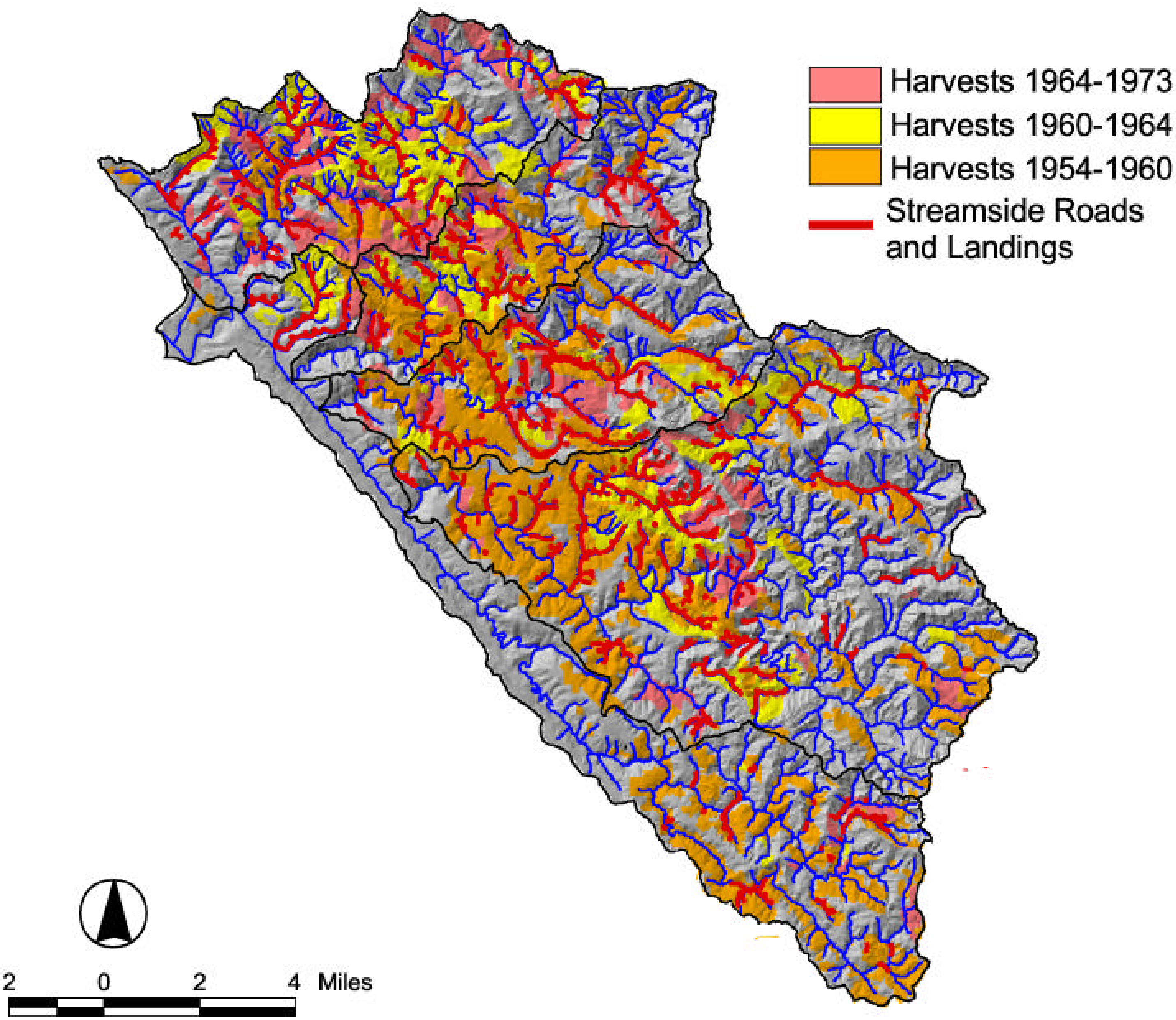


Figure 5: Streamside Roads and Landings 1968. Red lines show where the road or landing (circles) are built either in or immediately adjacent to the stream channel. Road fill has been pushed over the streambank into the watercourse at these locations.

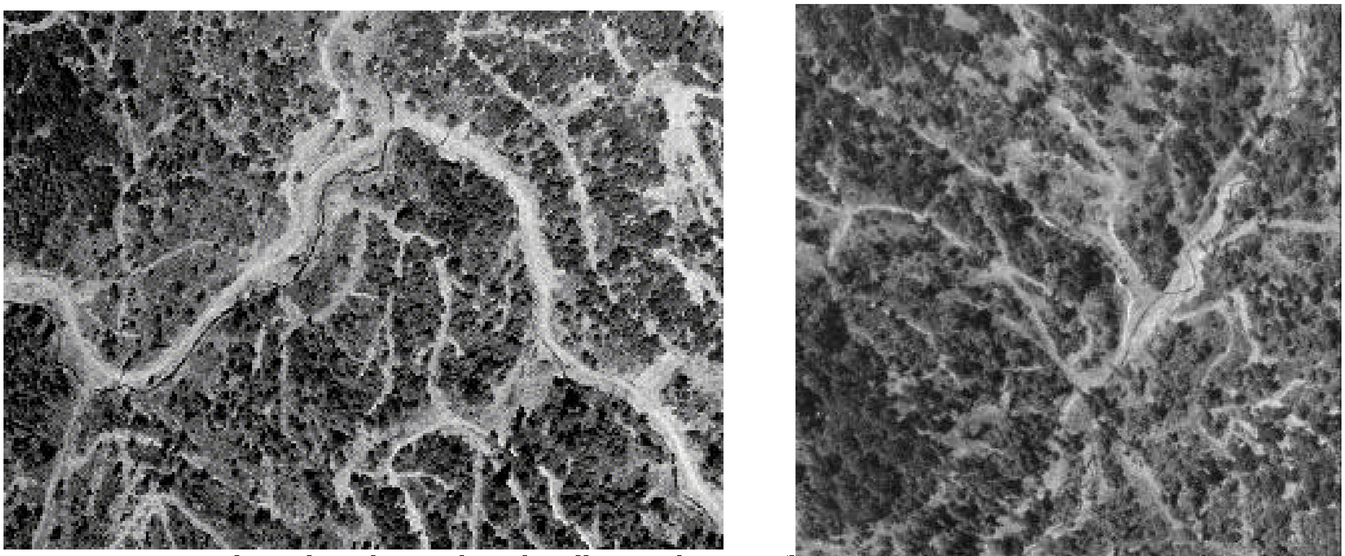


Figure 6: Streamside roads in the North Fork Fuller Creek ravine (left) , and in stream roads in an unnamed tributary to the lower Wheatfield Fork basin at Annapolis Fire station (right), 1965.

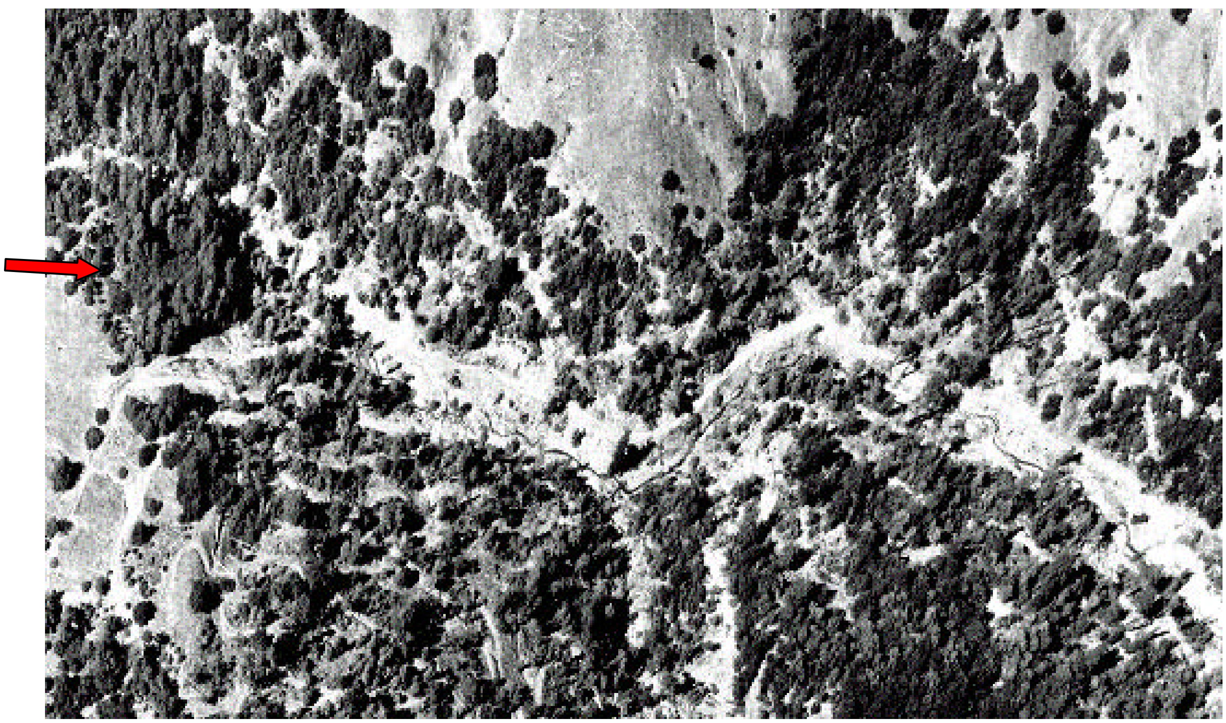


Figure 7: Streamside road along Elk Creek, 1965, Wheatfield Fork. Initial Right Of Way (ROW) clearance is complete along the road and riparian area, and logging operations are active to clear downslope coniferous stands (red arrow).

LWD

1961, 1963, and 1965 aerial photos show long sections of riparian zones cleared of all vegetation from old growth tractor logging operations. Streambanks were largely cleared of LWD, especially where roads were built along the creek to one side. In the channel zone, trees were felled in all directions, including across watercourses. This left tree trunks spanning the channel in multiple locations (Figures 36 and 62). Considerable logging debris was left in the channel. However, aerial photos immediately post operations show long portions of the channel generally removed of logs and in channel LWD (Figures 18, 29, 31, 34, and 63). GRWC and 2001 DF&G field surveys confirm low LWD counts in survey locations. Pre-harvest inspection reports document generally higher LWD counts in upper tributary watercourses.

In east areas of the watershed where ranching has been the dominant use, conversion of forested riparian zones to pastureland also removed in stream LWD. Review of 1961 and 1965 aerial photos showed long reaches of riparian areas cleared of all vegetation. This was more pronounced than the timber operations in the central reaches of the watershed.

Sedimentation Inputs and Transport

Natural geologic instabilities interact with major rainstorm events to define geofluvial conditions. Anadroumous fisheries have adapted to these conditions. Timber management and ranching activities have accelerated these processes. The California Geological Survey documents this process throughout the Gualala Assessment Report. Heavy rainfall and high river flow are responsible for activating many landslides and washing out roads. Storm damage occurs with or without land use. However, poor landuse practices can increase the erosion and sediment load.

Most of the documentation in the land use section of the NCWAP Gualala River Watershed Report shows that roads have been the dominant source of land use induced sediment loads, past and present. 1965 aerial photo coverage shows the impacts of poor road construction practices with large storm events. By 1964, 47% of the North Fork, 61% of the Rockpile, 65% of the Buckeye, and 30% of the Wheatfield sub-basins had been tractor logged. Streamside and instream roads/ landings dominated the road network at this time. In upslope areas, there was indiscriminate constructions of roads across steep and unstable terrain. Approximately 95 miles of instream/streamside roads simplified the stream channel complexity and structure throughout the watershed between 1952 and 1968.

The lack of any erosion control facilities installed throughout large areas of the watershed, coupled with the uncontrolled installation of fills and failure to remove fills adjacent to watercourses, left the entire watershed particularly vulnerable to large storm events. Major flood events in 1962, 1964 and 1966 caused massive erosion downcutting, slides, and washing of soil and debris into watercourses. The residual effects can still be observed in some areas today.

1965 Cal Trans photos taken at 1 to 1200 scale show the extent of the storm damage from a moderate sized storm in December, 1964. These show either (1) channel meandering through wide, flat areas of sediment fans in low gradient steps (see Figures 8, 9, 16, 24, 26, 27, 28, 29, and 30), (2) stream deflections around fresh debris slides (see Figures 14, 17, 20, 54, 56, and 60). Roads following the stream channel repeatedly collapsed as fill sidecast washed out during peak flows, undermining the road. Debris slides above and below roads were frequent. Blow outs through landings built over channel are numerous throughout the 1965 photos (Figures 14, 31, 32, and 33). There were frequent watercourse diversions onto roads and skid trails (Figures 12, 20, 57, and 61). The 1966, 1962, and 1970 storms rank 2, 3, and 5 on peak discharge flows, respectively. The highest flood event occurred on December 22, 1955, but only approximately 15% of the watershed had been tractor logged by this time. Although the 1964 flood event caused record rainfall along the northcoast, most of the force of the rains was north of the Gualala, leaving this storm comparable to other storm events in the mid century.

The 1965 air photo coverage shows two trends from the impacts of the mid century tractor operations (1) heavy initial impacts from fresh road and landing construction near streams, and (2) long term residual impacts as a sediment source that can span many decades. As an immediate impact, log debris can block road crossings, causing diversion and failure of the structure. For example, logged between 1963 and 1964, the 1965 photos of Grasshopper Creek (Figure 11) and Wolf Creek (Figure 13) show that large amounts of wood debris washed down during the 1964 flood, blocking primitive log bridge crossings. These wood jams blocked the creek, causing diversions onto the road. Mid century logging operations frequently felled trees directly over streams leaving considerable debris in or along the stream channel (Figure 62) The Forest Practice Rules require trees to be felled in a direction leading away from streams. This avoids in stream debris build-up that can potentially move downstream and clog culvert inlets.

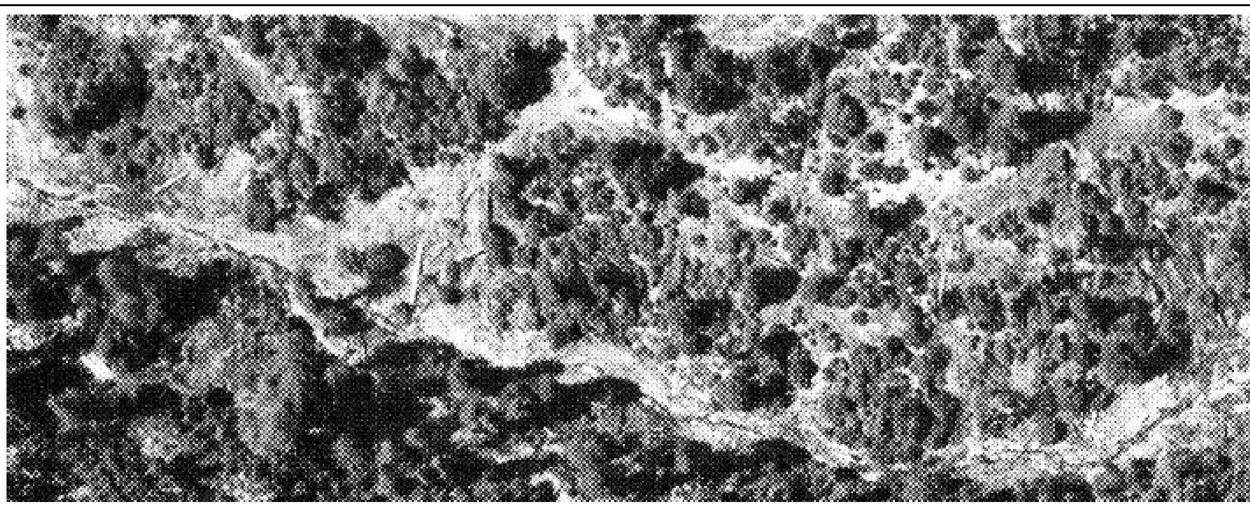


Figure 8: The in stream road in a tributary stream to Grasshopper Creek eliminated natural channel structure. The 1964 storms washed soil debris onto the stream channel already impacted by the in stream road construction. This caused the stream channel to meander through the logging debris, finding a new course (1965).

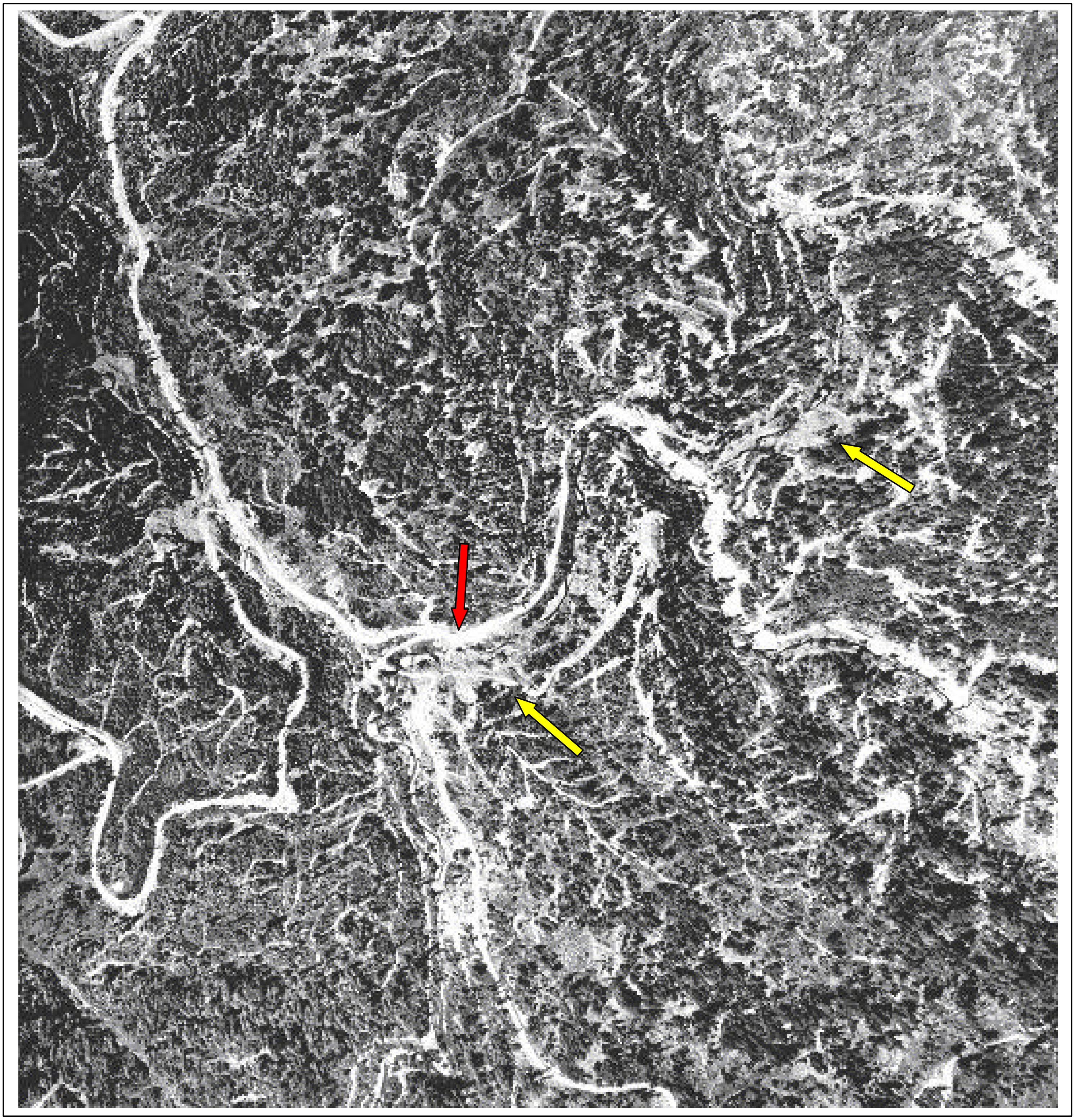


Figure 9: Central Landing Complex Built Over The Main Stem Fuller Creek, and Streamside Roads, June,1965. High storm flows during the 1964 flood event incised the landing complex (lower left, yellow arrow) and undercut the lower North Fork Fuller Creek road (upper right, yellow arrow), collapsing a one quarter section of the road into the creek.. Note meandering stream flow patterns over filled channel substrate (red arrow) By 1984, most of this debris had washed downstream, and Fuller Creek flowed straight through the original V-shaped stream channel bordering the landing. The 1996 storms washed remaining debris out to expose the graveled substrate seen today

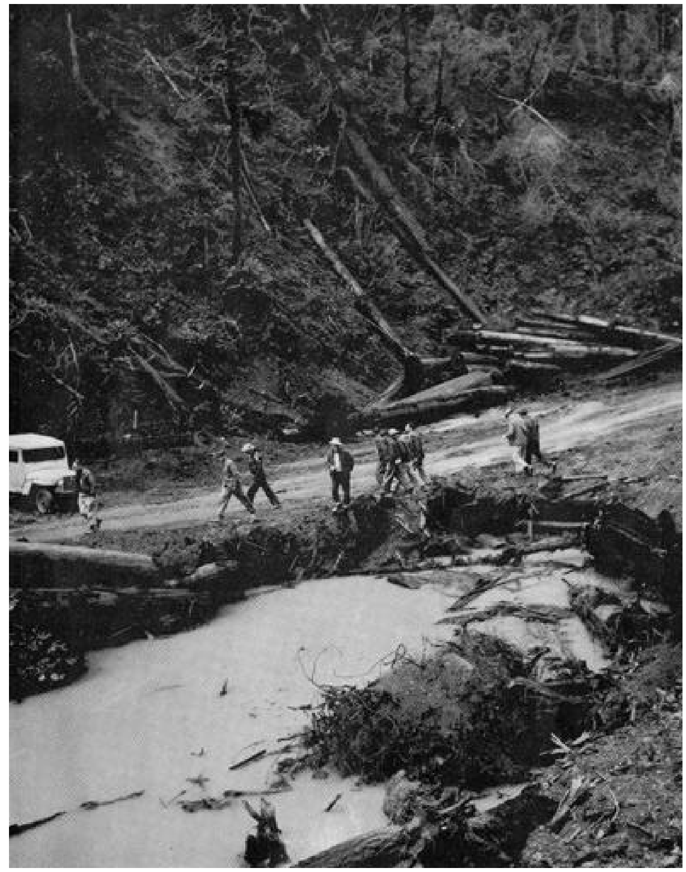
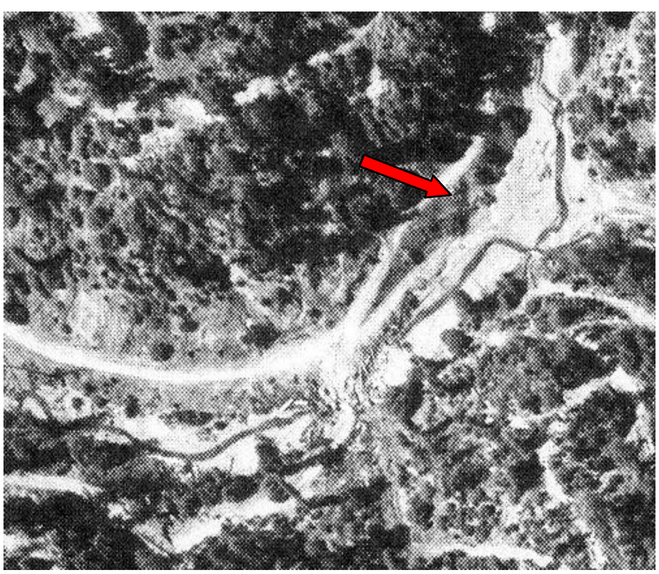


Figure 10: Left: Logging debris sidecast from the main streamside road in Grasshopper Creek, left, November 21, 1955. This road is now abandoned and vegetated.
Right: A primitive log chunk road crossing in Grasshopper Creek, right, November 21, 1955. The stream flows through the logs and debris pushed into Grasshopper Creek to make the road bed. These substandard road crossings generally failed during large storm events (lower right).



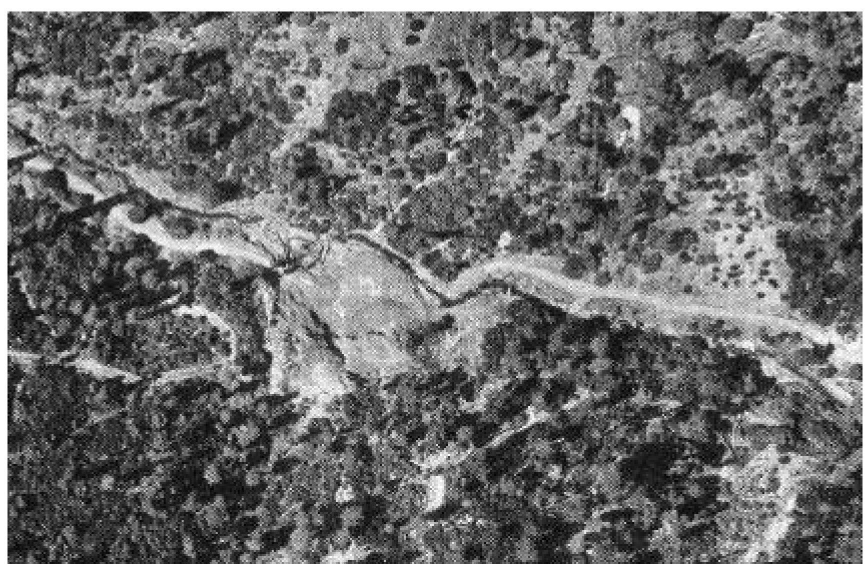


Figure 11: Left: Log debris blocked the inlet of a primitive log dirt crossing of Grasshopper Creek (left) from the 1964 flood, causing the creek to divert onto the south road approach, then route back to the main channel through a debris slide. The abrupt turn in the creek (red arrow) follows a long term geologic terrace per 1942 photos.

Right: One half mile downstream, Grasshopper Creek washed out a primitive log debris road crossing (June, 1965).

Figure 12: Watercourse diversion down the main road (left) discharged down several skid trails to the lower in stream road. This is a tributary creek to the North Fork Wheatfield, June, 1965.

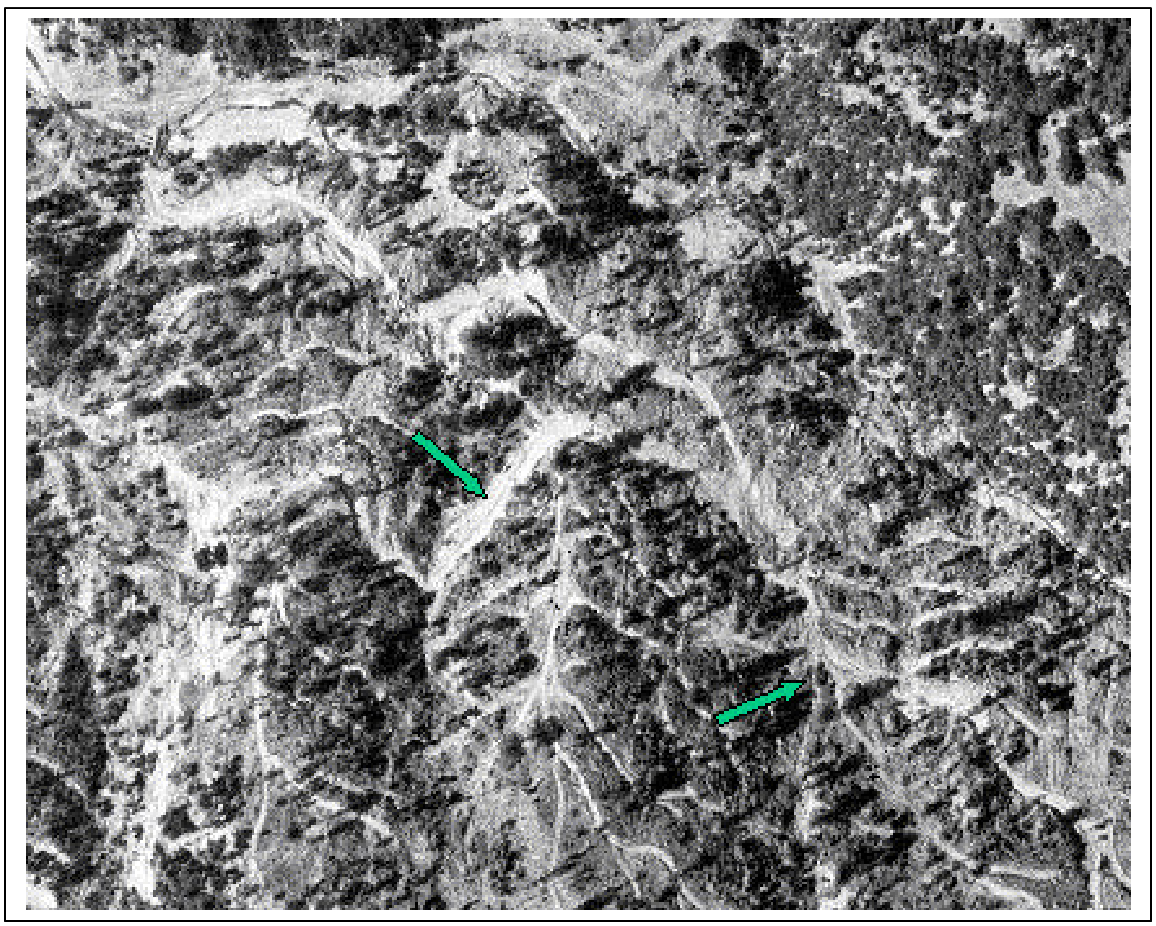


Figure 13: Road and skid trail terraced network on steep north facing sideslopes in Wolfe Creek, east Wheatfield basin. Green arrows show gullying down the roads.

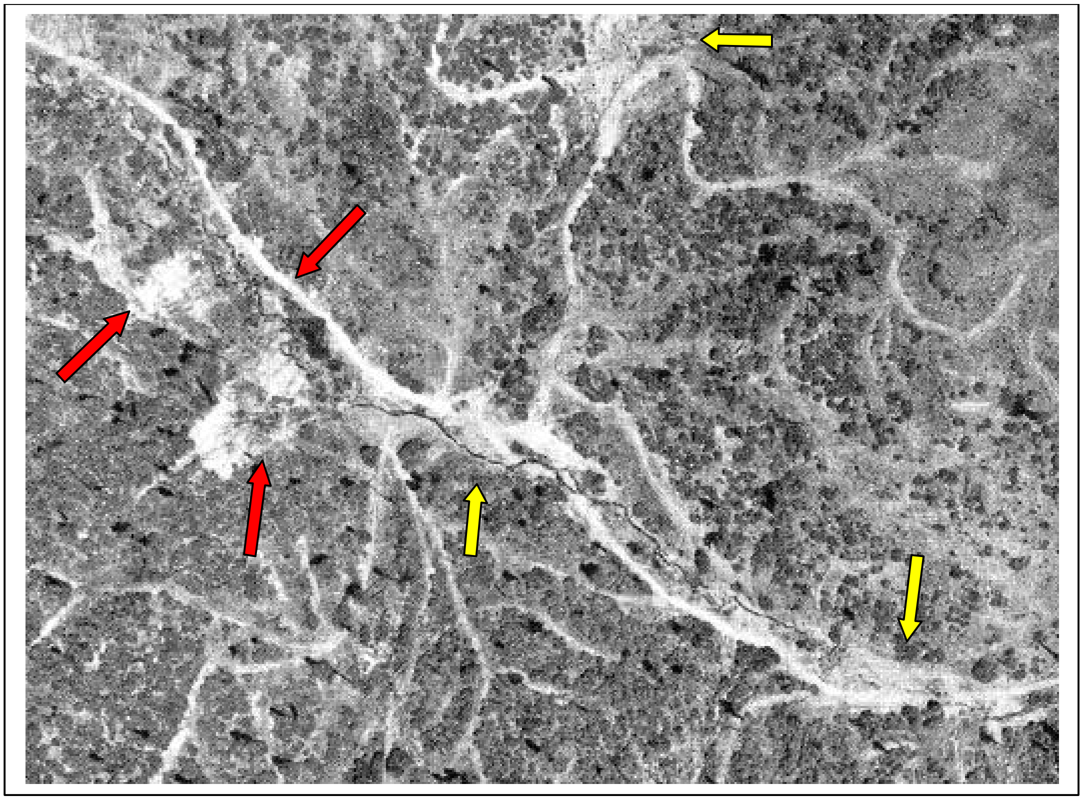


Figure 14: Multiple road debris slides accessing Tobacco Creek (red arrows). Three instream landings (yellow arrows) consist of wood chunks pushed into the stream channel and topped over with dirt fill. These are located at the confluence of several streams. The left landing (center) and top landing have incised down while the right landing shows overflow patterns.

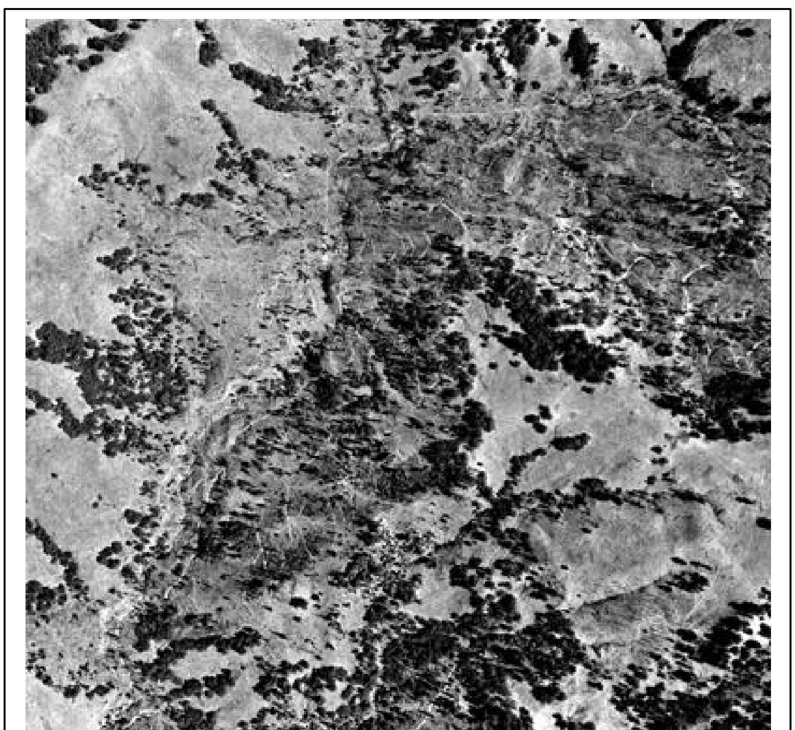


Figure 15: Canopy removal in a tributary to Marshall Creek , 1965. The road was constructed down a steep ravine making numerous switchback turns.to the streamside road following the central channel.

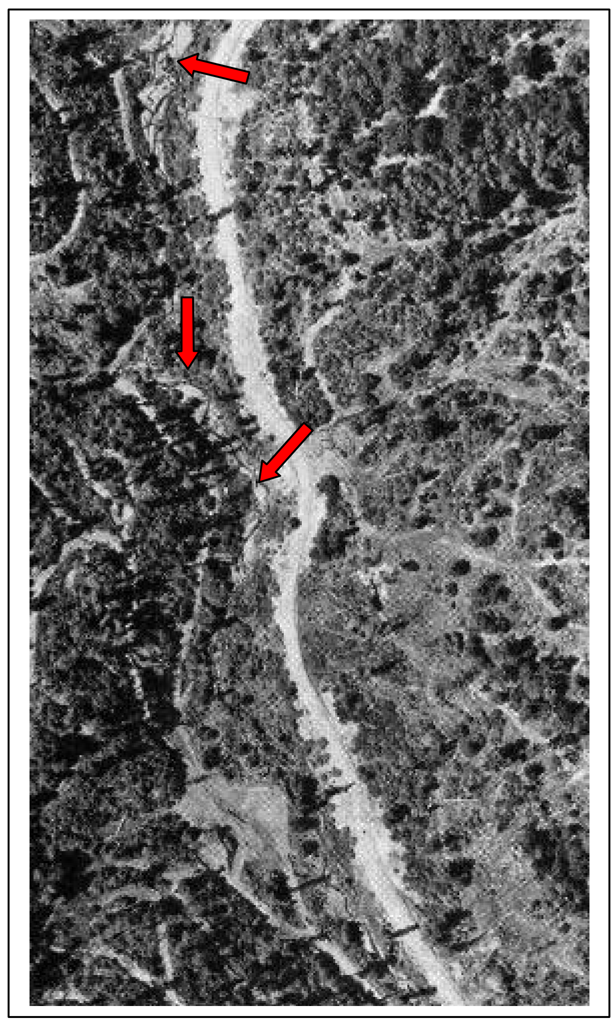


Figure 16: Braided channel patterns and sediment step fans, Fuller Creek

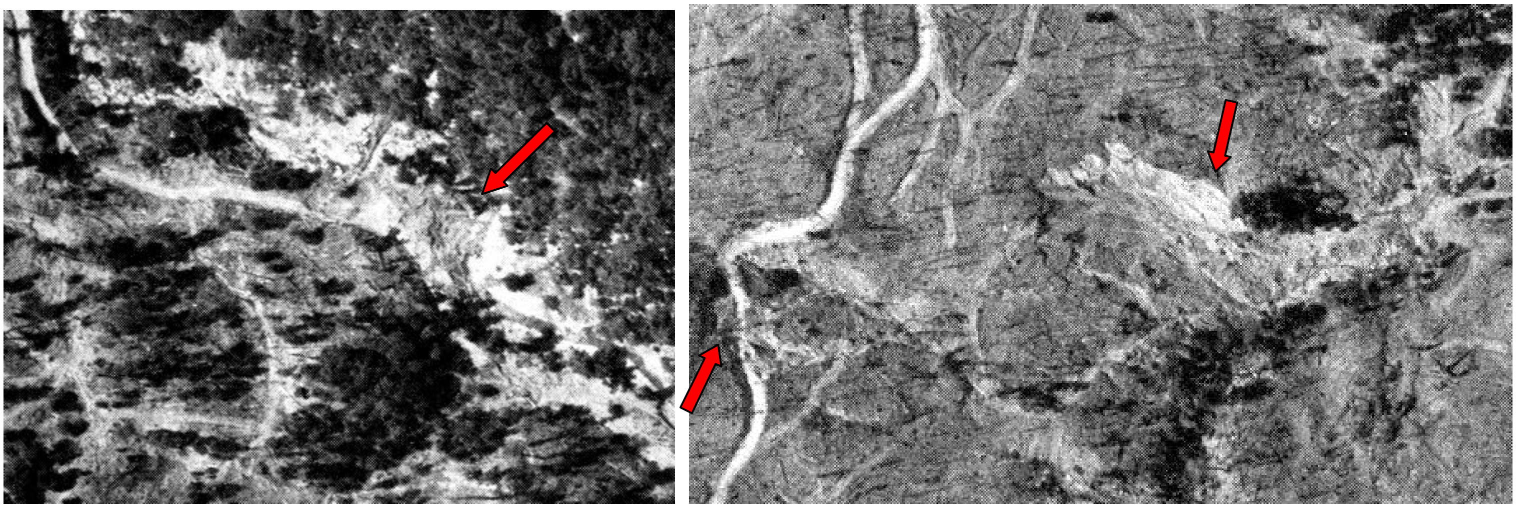


Figure 17: Left: The 1964 flood event undermined the streamside road, causing a massive debris slide into Wolfe Creek. Note meandering angular channel patterns through the slide debris (red arrow) 1965. Right: Debris slides and debris flows in an operations area in the Danfield Creek tributary subbasin

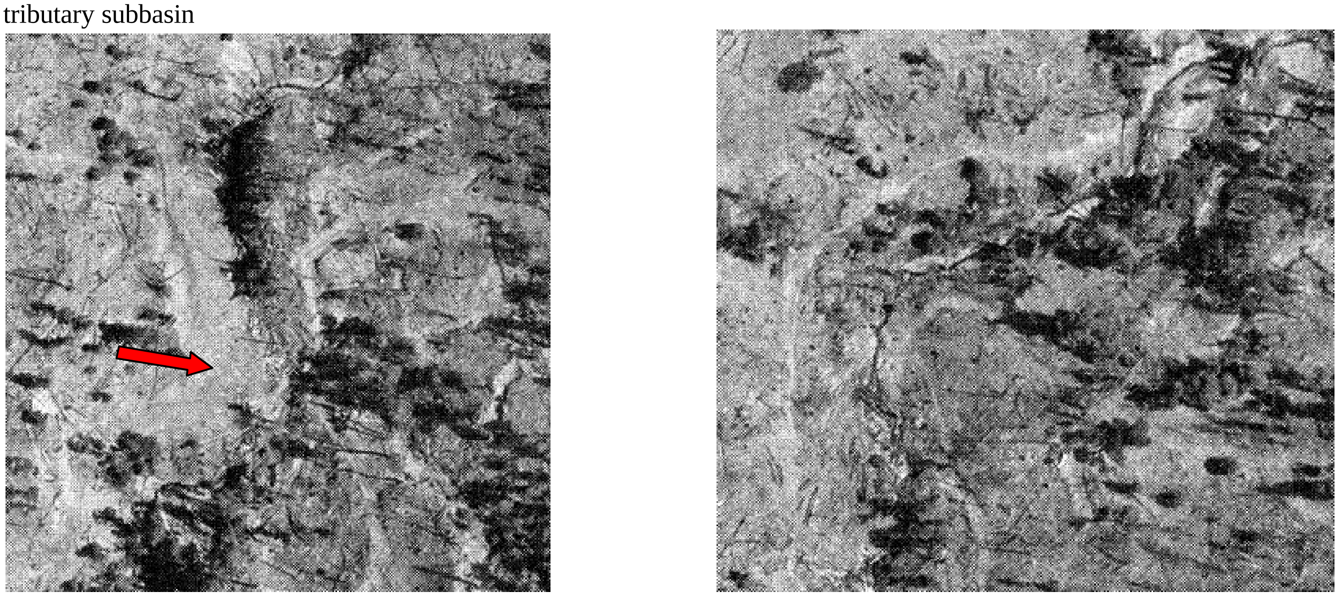


Figure 18 A log chunk-dirt fill road crossing (red arrow) and riparian clearance in a canyon in a tributary to Marshall Creek.

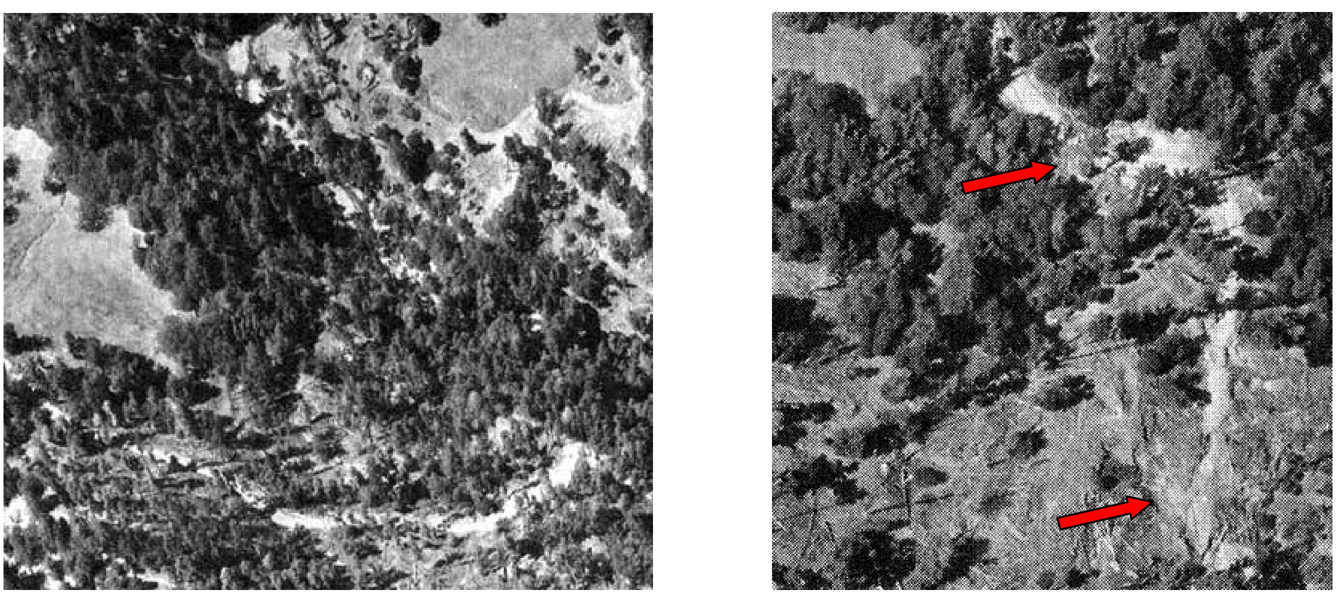


Figure 19: Left: Original old growth coniferous stream cover over upper Rockpile Creek during initial logging   Right: Road washouts along a ranch road in the Upper Rockpile PWS, ~300 ft. upslope of Rockpile Creek, 1965.

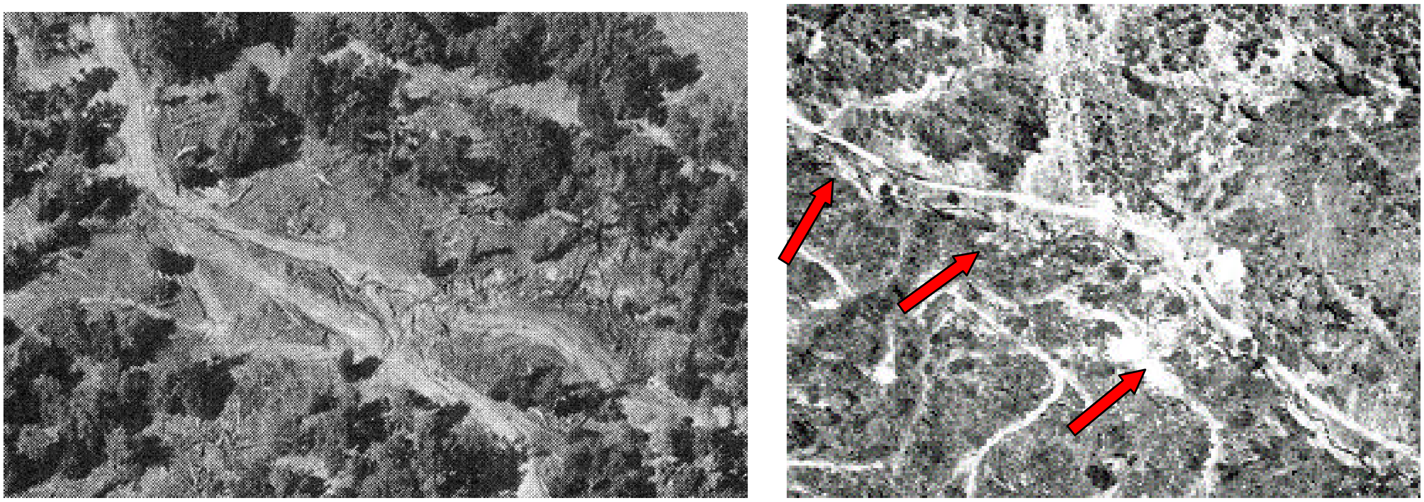


Figure 20: Left: Stream diversion onto a ranch road in the Upper Rockpile PWS, 1965. Rockpile Creek is ~500 feet north. Right: Multiple road debris slides accessing Tobacco Creek.

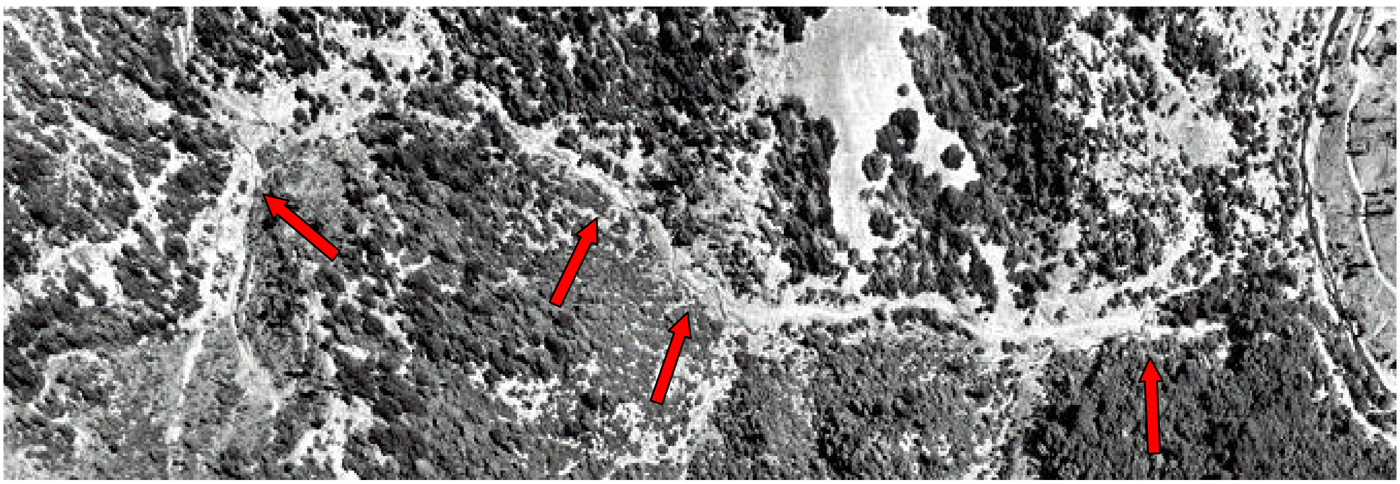


Figure 21: Stream diversions and washouts of a streamside road following a tributary stream to lower House Creek, 1965.

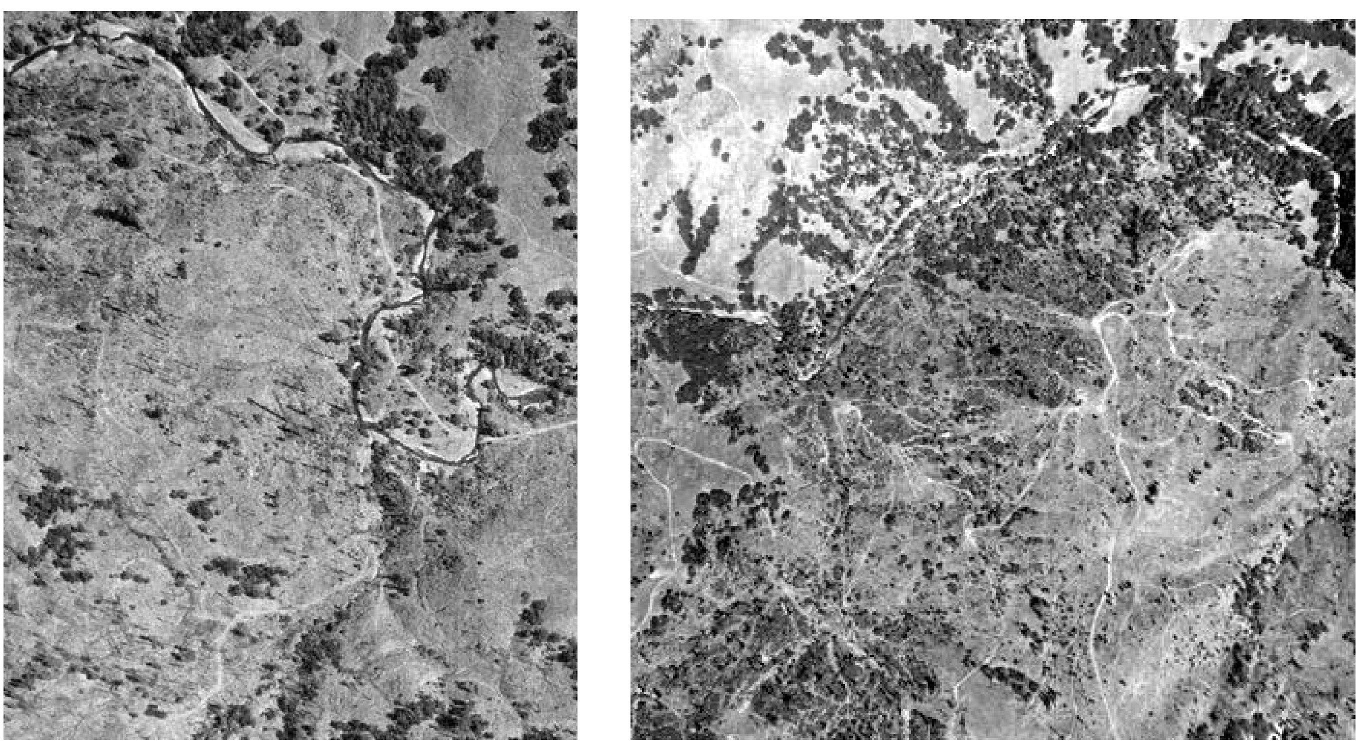


Figure 22: Ranchland conversions along Marshall Creek, tributary to the Upper South Fork, 1965

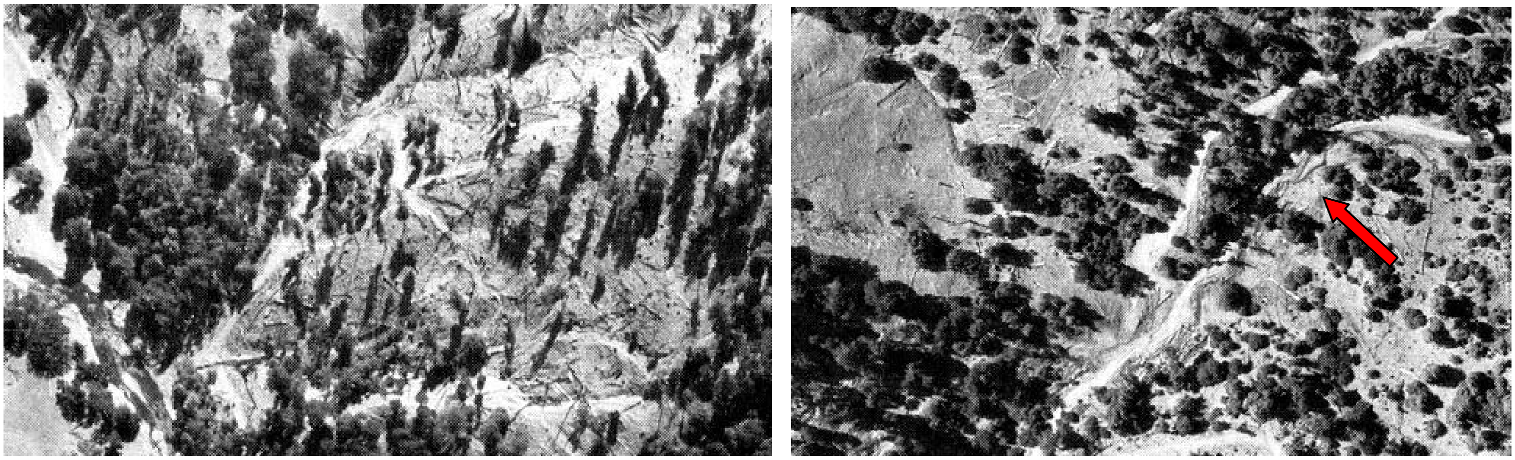


Figure 23: Left: Streamside road along an unnamed tributary to the main stem Wheatfield Fork   Right: Road washout slightly upstream.

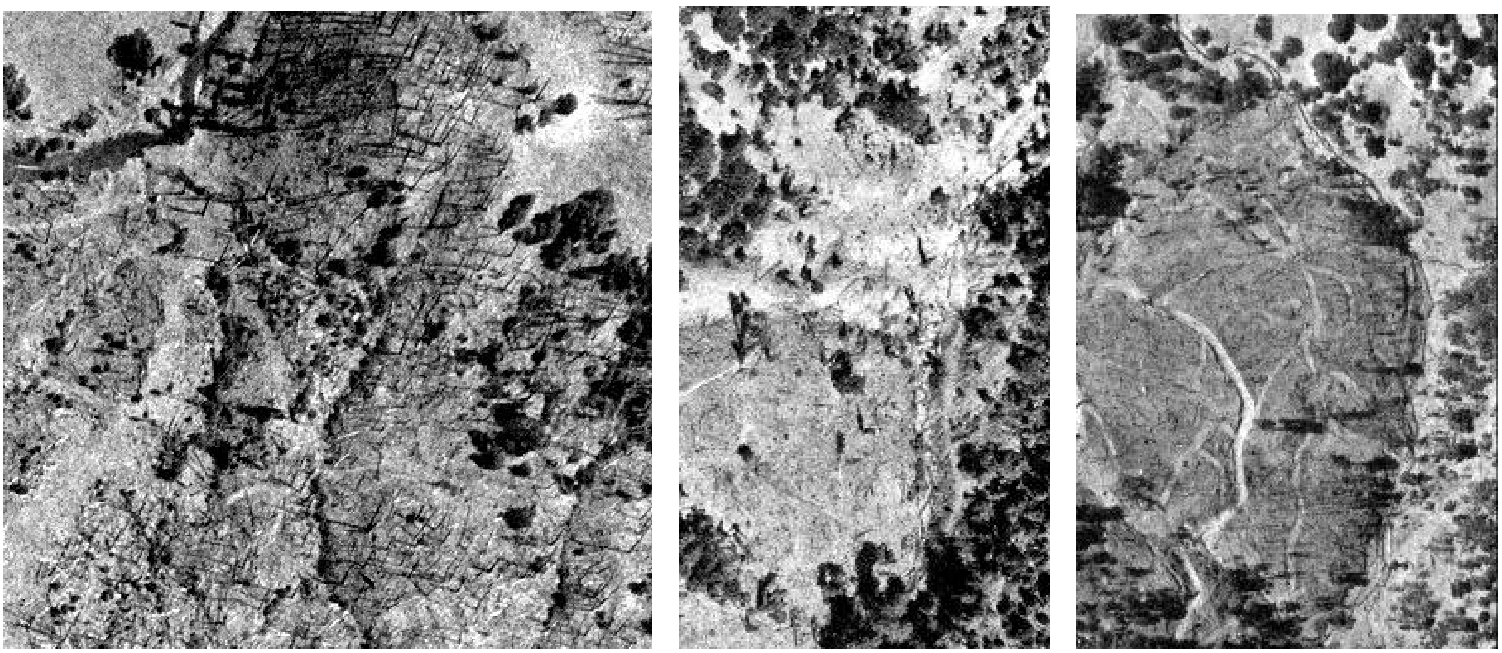


Figure 24: Riparian canopy removal and streamside road networks along the North Fork McKenzie Creek (center) and in the Danfield Creek. tributary subbasin (left and right)

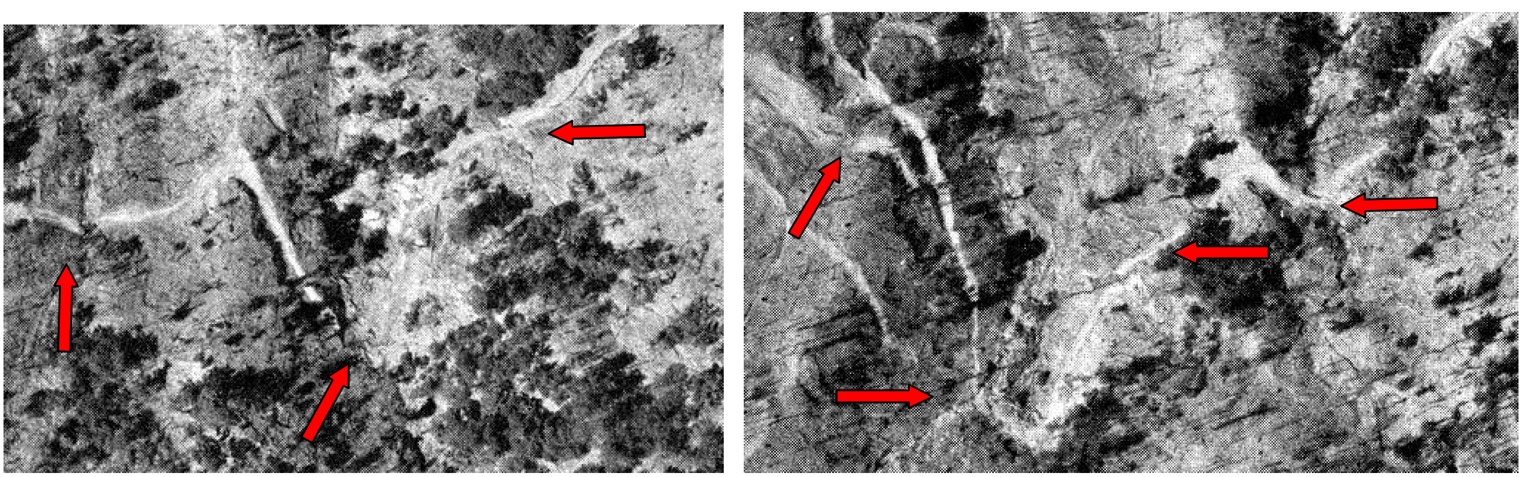


Figure 25: Road debris slides and road crossing failures in the Danfield Creek tributary subbasin. Most of the road crossings in this area show signs of failure.

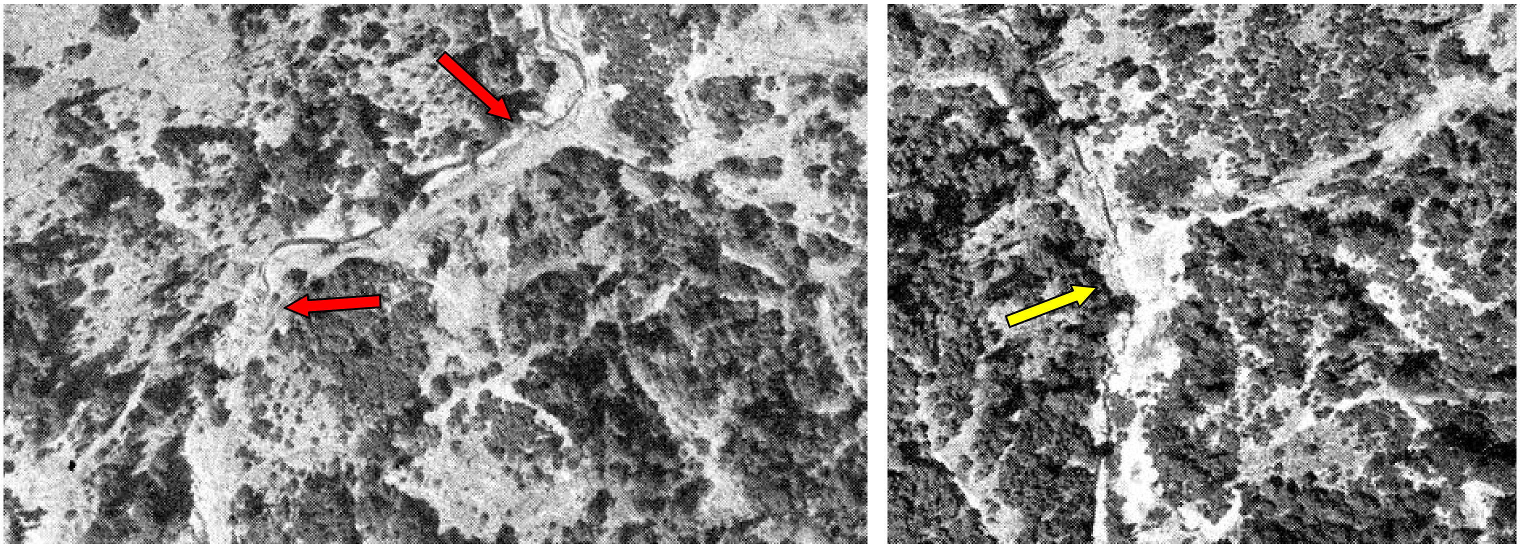
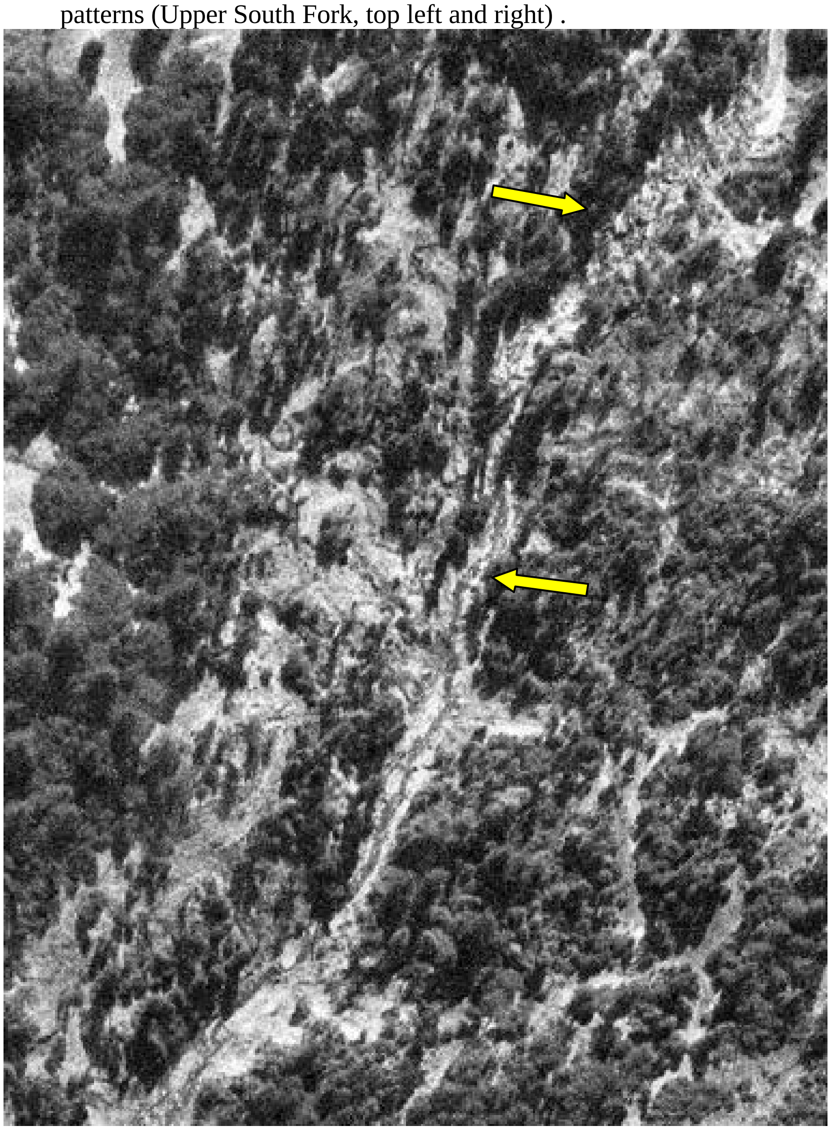
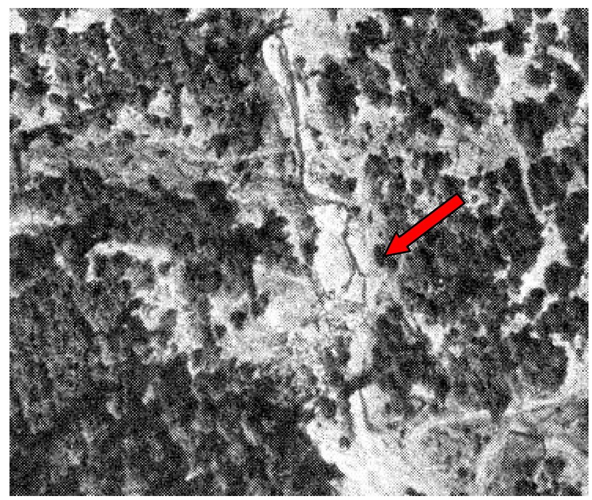


Figure 26: In inner gorge canyons, road building was often confined to the streambed by the steep inner canyon walls. Tractors graded the channel zone flat to one side, often burying the watercourse with fill sidecast. This forced the stream to meander through the road fill, finding a new course offset from the original channel. The 1965 photos show a disrupted channel pattern in these areas, characterized by frequent channel braiding, (red arrows) and abrupt turns in the channel (yellow arrows). Upstream of the disturbance, the channel typically shows a well defined central channel. Turns in the channel are comparatively gradual. In disrupted channel areas, the channel narrows down as the stream spreads through the debris and disturbed ground in angular, dissected patterns (Upper South Fork, top left and right) .





Tributary to the Upper South Fork

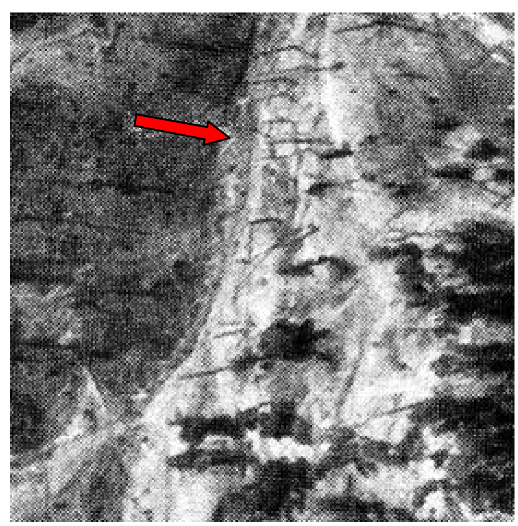


Figure 27: Disrupted channel patterns from in stream tractor operations, House Creek.

Tributary to House Creek

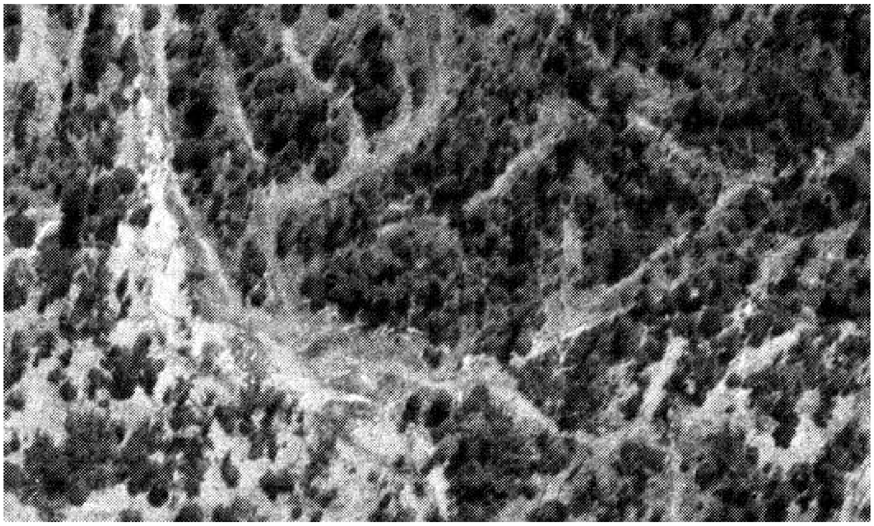


Figure 28: Top: A large in stream landing complex offset from a braided channel pattern in a tributary to the Upper South Fork.

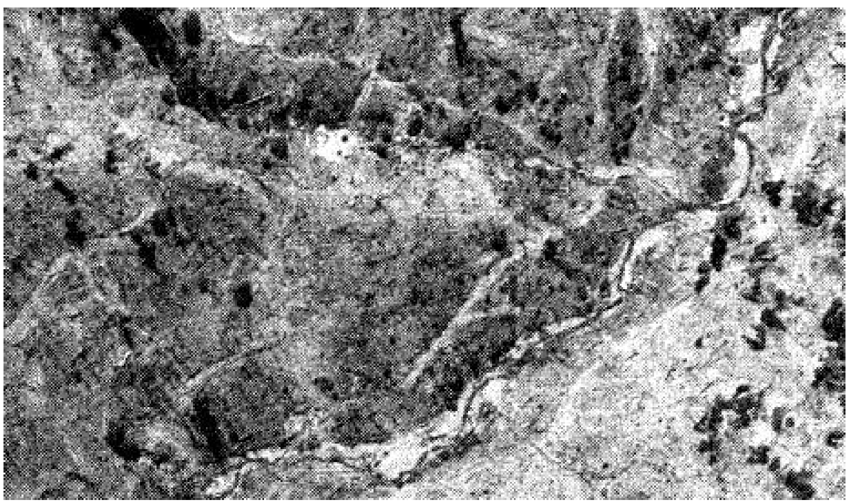


Figure 29: Tributary in the Upper House Creek subbasin

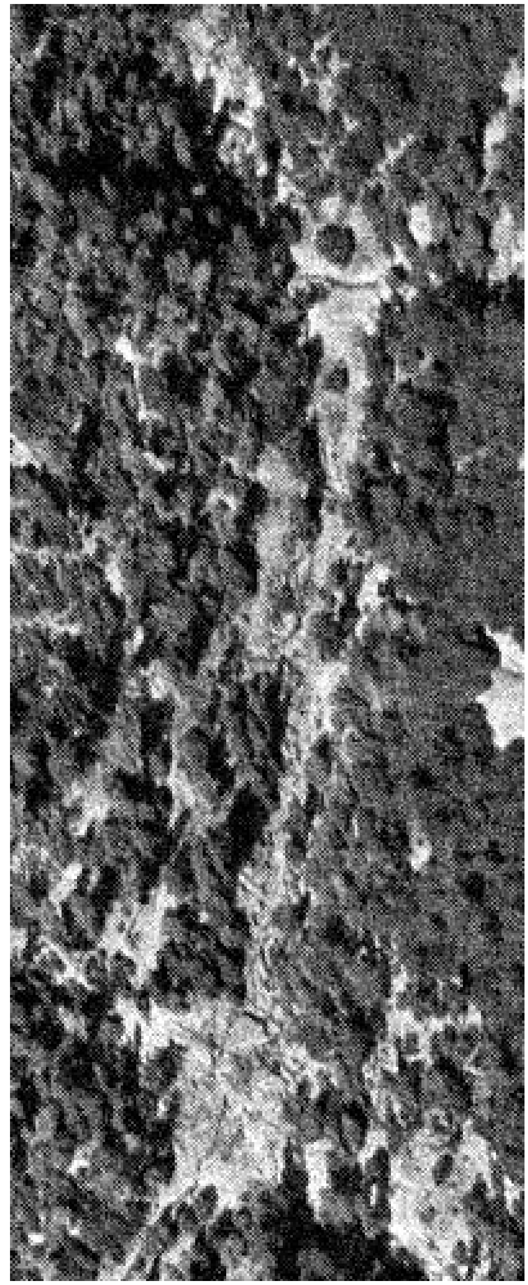
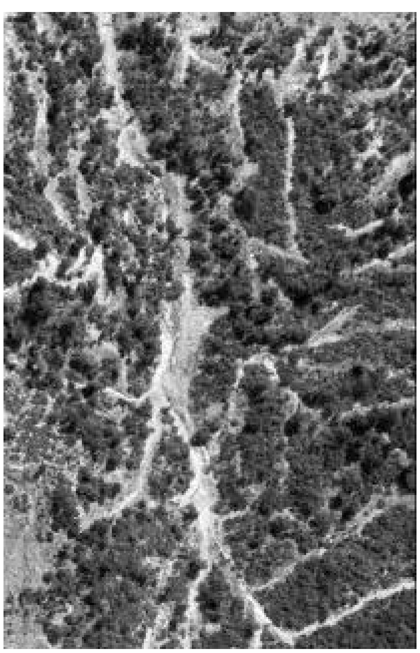
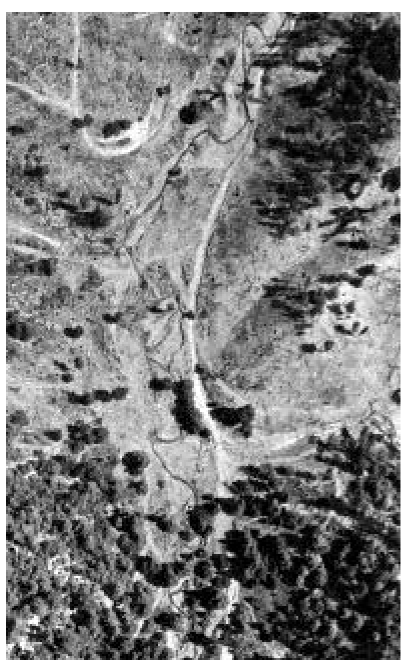
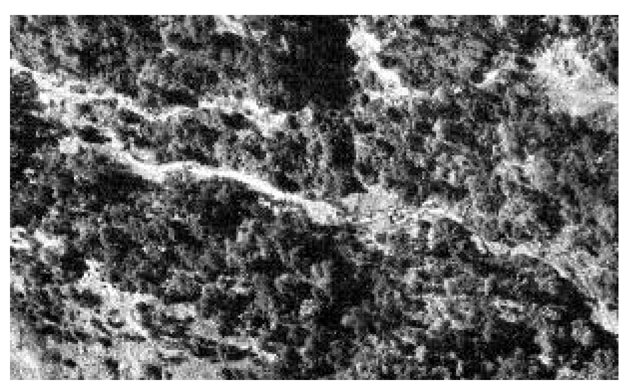


Figure 30: Tractor yarding throughout the stream leaves a disrupted channel with angular and diffused channel patterns post operations (top and bottom right).

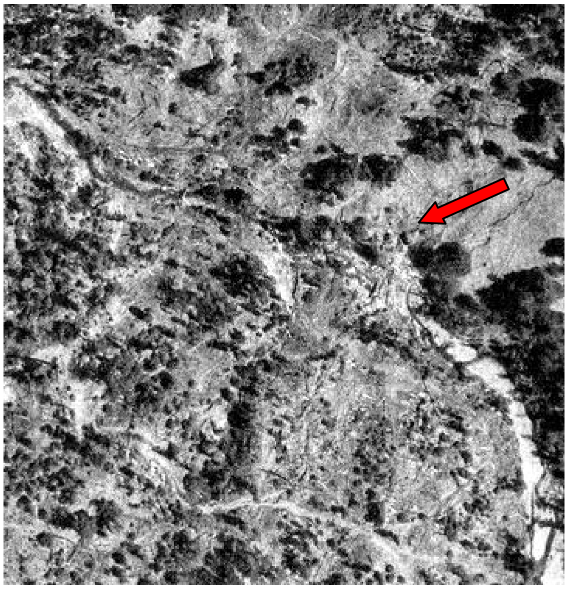






Tributary Upper South Fork

House Creek



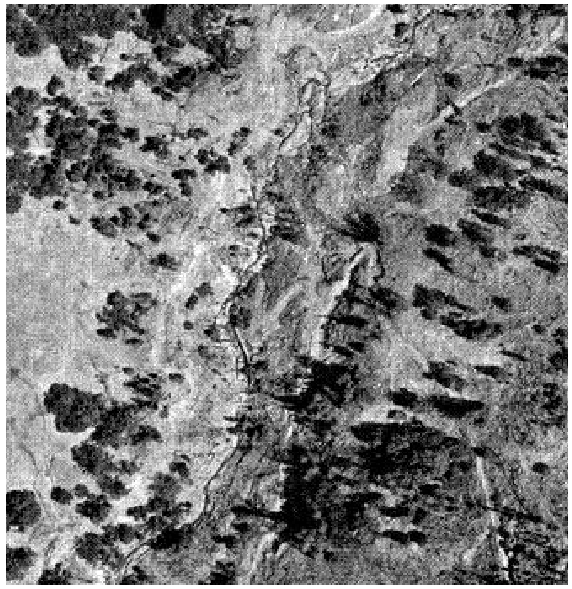
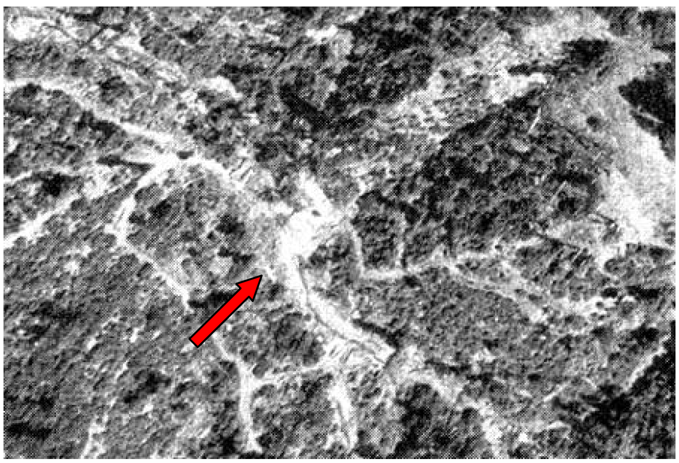


Figure 31: Left: Mid century logging operations frequently used primitive stream crossing structures. Log chunks were pushed into the stream channel and topped with dirt fill. Large storm events (1964 storms in this case) often overflowed onto to these crossings, creating a disrupted meandering channel pattern through these structures (red arrow).
Right: Riparian stream clearance and streamside road networks in a tributary to Marshall Creek.

Figure 32 Riparian stream clearance removed coniferous cover in a lower tributary stream to House Creek. These stream crossings (red arrows) also used log chunks pushed into the channel and were topped with dirt fill. The meandering stream channel patterns at the crossings shows the depth of these structures where the stream makes abrupt switchback turns.



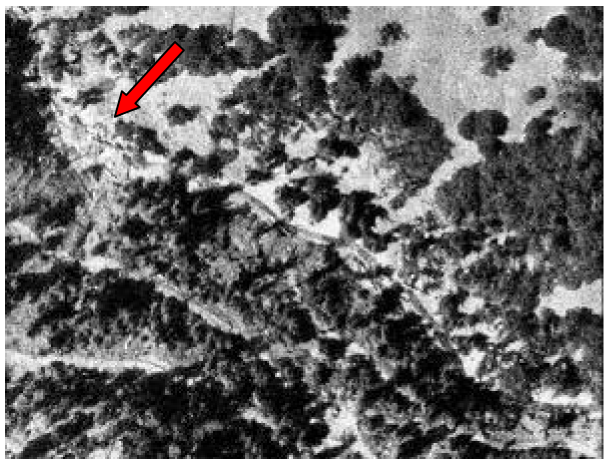


Figure 33: Left: A landing complex was built directly into a stream in a tributary to Marshall Creek, using log chunks and dirt fill. The creek flows under the landing complex at the red arrow. Right: An in stream landing disrupts channel flows along Wolf Creek, tributary to Wheatfield Fork (red arrow).

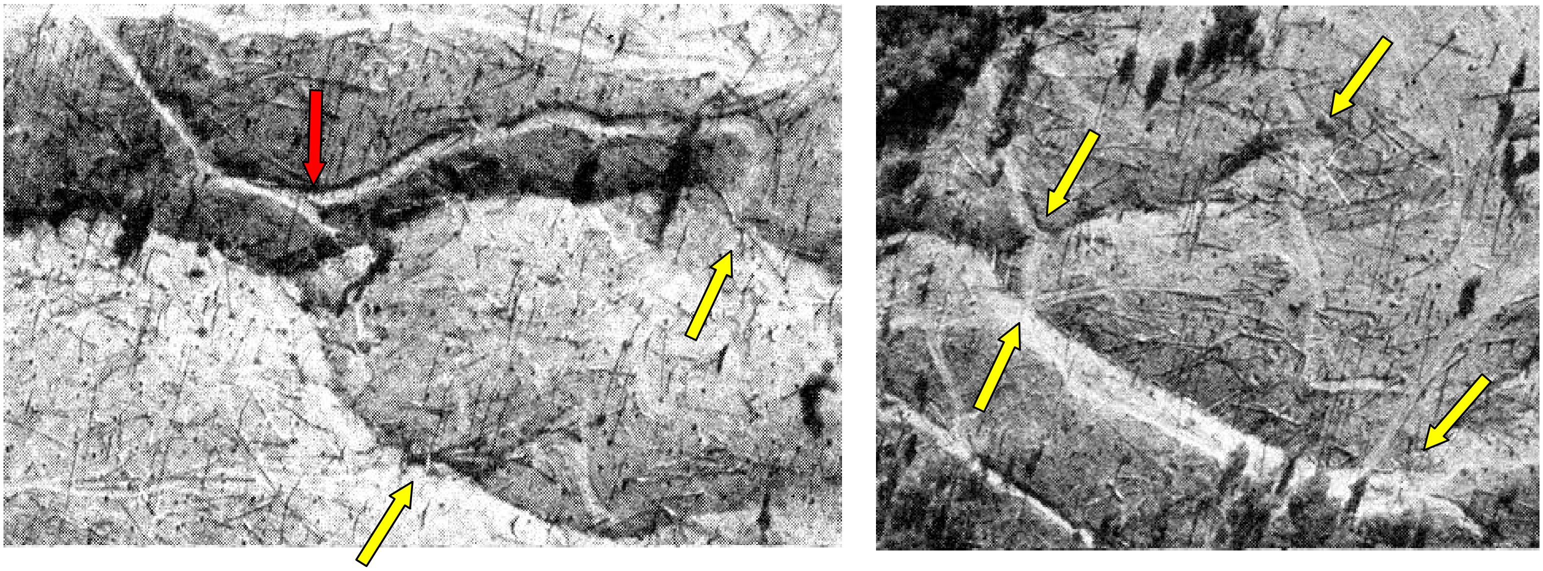


Figure 34: Reentry of the mid century tractor areas under a Timber Harvest Plan typically requires the repair of legacy impacts that continue to represent present day sediment sources. In this case above, the THP could require installation of cross ditches along the abandoned seasonal roads. This would disperse runoff away from the low point in the road and resulting debris slide covering the creek where flows had concentrated. (red arrow). Timber Harvest Plans frequently require removal and stabilization of failing stream crossings left abandoned (yellow arrows). Typical procedures include (1) removing of the decaying log chunks and soil debris from the channel crossing point, (2) grading back the road approaches and (3) applying grass seed and mulch to the exposed ground. Similar repairs have been effected throughout the watershed where covered under a Timber Harvest Plan, substantially reducing sediment point sources and contributing to improving channel sediment conditions noted in the CGS geofluvial analysis.

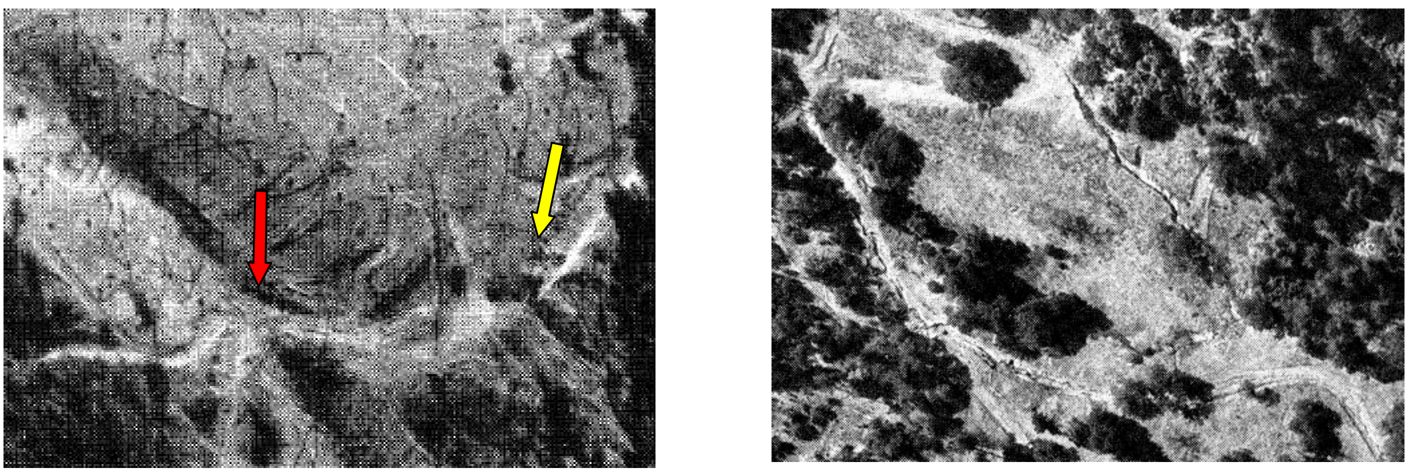


Figure 35:Left: In higher tributary watercourses that exhibited low flows in the summer, tractors pushed dirt straight into the stream to make the road crossing. The red arrow shows where a switchback turn in the road was made in the center of the creek The yellow arrow shows were the fill slope failed as a debris slide at a second dirt fill road crossing of a stream. If such an area were subject to a THP, culverts sized to a 100 year storm event would be required today. Or the stream crossings must be pulled back and stabilized with grass seed and mulch prior to the winter rains. Right: Repair of gully erosion down abandoned roads dating to the mid century is typically repaired in areas subject to THPs. This includes installation of cross ditches, upgrading culverts and regrading inside ditches.

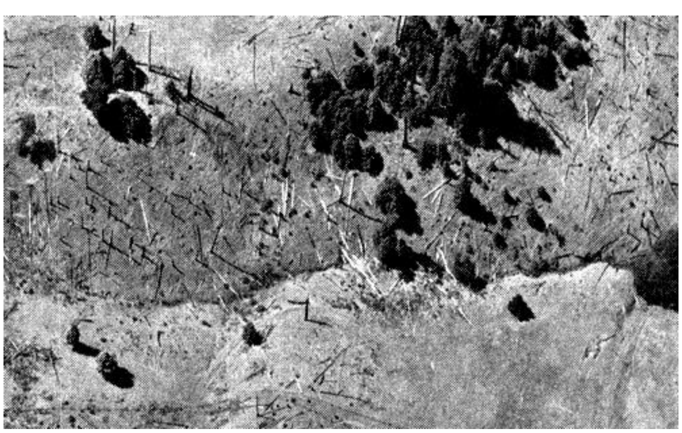


Figure 36: The Gualala NCWAP Team frequently recommended tree planting of former riparian areas that had been converted to pastureland during the mid century. The 1965 photo (left) of a tributary to the lower reaches of House Creek shows conifer extraction from the stream leaving oak and madrone upslope. surrounded by existing grasslands. Such procedures were common in the east and upslope basin reaches. Artificial regeneration can be difficult. These areas are often highly compacted from decades of prolonged cattle grazing. Several planting seasons are usually required to overcome high seedling mortality rates.

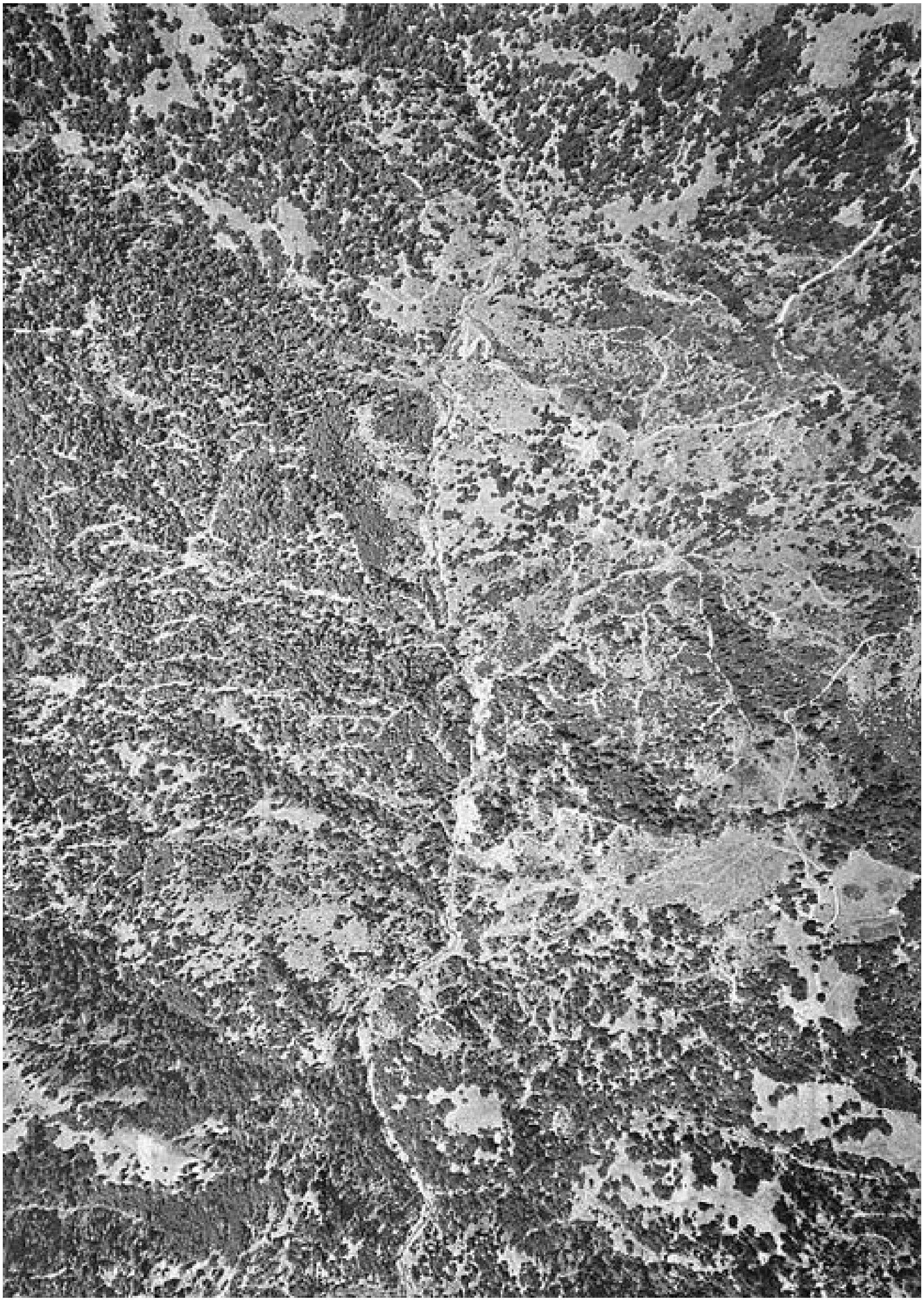


Figure 37: Long term residual effects of streamside/ in stream road construction, June, 1965. A tributary to the Upper South Fork was logged in the mid 1950s. This 1965 photo shows vegetation returning on the clear cuts indicating approximately 7 to 10 winter storm runoff periods on these roads. The in-stream road network (center) incised deeper over time, trenching down the road. There had been large storm events in 1962 and 1964 affecting this area. Numerous debris slides and debris torrent slides have been found in this photo.

In addition, new streamside roads pushed fresh road fill towards the creek over the streambank. This sidecast is especially prone to failure during high flows. Historic road related debris slide failures accessing streams have been identified as a major source of land use induced sediment sources. Major storm events can trigger multiple road debris slide failures accessing streams (Figures 9, 14, 17, and 20).

In the long term, legacy road networks can continue to release sediment. For example, wood debris placed to support the roadbed along the creek deteriorate, and collapsing the road. Subsequent peak flow events can continue to downcut instream landings collapsing dirt fill into streams. After several decades, road and skid trail gullies may have incised down to rock or hard clay. CGS generally found fewer stream channel disturbances in 1999/ 2000 compared to 1984. This can indicate increasing stabilization from legacy impacts over time .

Mid Century Stream Aggradation and Subsequent Channel Recovery Patterns

The 1965 photos show that most of the point source sediment discharges consist of road debris slides accessing streams activated during large storm events. Figures 9, 14, and 20 show multiple road debris slides accessing watercourse over relatively short sections of the stream. Fresh debris slides fanned out over the channel, forcing the stream to meander around the slide mass. These meandering stream channel patterns in Fuller Creek returned to a more lineal pattern in observed in mid 1984 photos, and again with 1999 photos (see Figure 39, below). Meandering channel patterns in Sullivan and Grasshopper Creeks also returned to a more lineal pattern thru 1984 and more so by 1999. In Fuller and Sullivan Creeks, a graveled stream substrate can be found today in contrast with a silt and sand dominated substrate indicated in the 1965 photos. The Fuller Creek basin has been particularly targeted by the Gualala River Restoration Council for rehabilitation work. Stabilizing sediment sources has apparently allowed residual in-stream sediment loads to be washed downstream, reexposing the graveled substrate seen today. 1965 air photo coverage is only available in the east portion of the watershed.

In addition, abandoned streamside roads and landings can continue to discharge sediment during present day storm events. These mid century roads lining the stream channel can release sediment into streams by streambank erosion activated during present day storms. For example, in the Buckeye subbasin, stream channels in Grasshopper Creek in 1993 surveys contained dams of stored sediment behind jams of large woody debris. The channel continued to downcut to pre-logging levels. This indicates long residency time of mid century generated debris still deposited in streams in the middle basin reaches. Stewart Creek in the North Fork shows similar long term channel aggradation in low gradient channel steps In stream landings are still down cutting to pre-logging levels. In the steep central Rockpile PWS where in stream roads were built up and down most of the major streams, sediment continues to be lodged behind in channel wood debris pushed into the watercourse.

Stream channel morphology shows the following evolution over the last half century: (1) a high density of debris flow mounds in the active channel triggered by mid century storm events, (2) progressive abatement of the frequency of these point sources over successive decades, and (3), apparent recovery of in stream channel substrate between 1984 and 1999/ 2000 as evidenced by a reduction in the percentage of channel length that is affected by excess sediment storage or sediment sources. The comprehensive CGS fluvial geomorphic mapping of stream conditions documents that the channel has improved from 1984 to 1999/ 2000 throughout the watershed.

The CGS watershed wide geofluvial mapping compared stored sediment channel characteristics between 1984 and 1999/ 2000. This comparison basically shows stream channel sediment residency movement thru time. The 1984 mapping spans 16 years after the end of the tractor logging era by 1968. The fluvial geomorphic mapping of stream conditions documents that the channel has improved from 1984 to 2000 throughout the watershed. The CGS method of evaluation provides information on both hillslope sediment sources and channel disturbance. The time-series mapping of all channel sediment characteristics allows for determining the trend of channel conditions by identifying patterns in channel geomorphic conditions and sediment storage over the time period.

The map of all channel features often reveals that a greater length of the channel has been affected by sediment input and storage than just the areas directly associated with sediment sources. This reflects the general condition of the watershed where sediment has migrated downstream from its source. With time, sediment from one source mixes downstream with sediment from other sources making it difficult to associate these dispersed sediments with their individual sources. Comparing the same portion of the stream channel between 1984 ad 1999/ 2000 often elucidates the source. As documented in Appendix 2, most of the stream segments in the Gualala watershed show a reduction in the percentage of channel length that is affected by excess sediment storage or sediment sources. 47% of the disturbed channels throughout the entire watershed showed improvement from 1984 to 2000. The largest improvement (57%) occurred in the Buckeye Creek Subbasin. Improvements ranged from 38% to 47% for the other four subbasins. This period includes recent active timber harvesting in the north portion of the watershed.

The mapping of mid century in-stream and near-stream roads across the watershed was compared with the landslide and fluvial geomorphic mapping. A strong correlation was found between those roads and braided and or aggraded stream reaches in 1984. In general, sediment levels decreased in the watershed. Sediment loads appeared further downstream in the later photos indicating that net sediment transport exceeded net sediment delivery over the period. Much of the coarser fraction of the streambed consists of well-rounded gravels and cobbles that likely have occupied those channels for many decades.

Slope instabilities and landslides are the primary long term source of the sediment load in the Gualala River system. Geologic sediment accumulations represent most of the total volume of sediment deposited throughout the fluvial system. Geologic, or pre-historic sediment terraces typically line low order tributary channels in large volumes. This includes aggraded and braided channel patterns. Historic terraces typically line the geologic terraces inset of the stream channel. Although these post 1900 sediment depositions form a fractional part of the total sediment load, stream bank erosion activated during storm events releases sediment stored in the historic terrace formations that line the inner stream channel (See Figures 45 – 48). Areas that contain large amounts of historic sediment stored in the active channel and or/ historic terrace depositions are likely large contributors of the suspended sediment during present day high discharge events.

Synthesis Of Historic Roads and Geofluvial Analysis
In 1984, 145 historic landings were spatially associated with stream aggradation or braiding.
In 2000, 8 historic landings were spatially associated with stream aggradation or braiding.

In 1984, 174 km of historic in-stream roads were spatially associated with stream braiding and aggradation.
In 2000, 67 km of historic in-stream roads were spatially associated with stream braiding and aggradation.

Of those reaches that were aggraded in both 1984 and 2000, 8 out of 9 were spatially associated with a historic in-stream road or landing.
Of those reaches that were braided in both 1984 and 2000, 11 out of 20 were spatially associated with a historic in-stream road or landing.

***Conclusion* :**
1. Historic streamside/ instream roads and landings are responsible for most of the disturbed channel patterns observed in the 1984 imagery.
2. There has been a significant shift in the location of modern roads to ridgelines and mid slope benches, leaving most of the historic streamside roads and landings abandoned and vegetated. Some portions of the historic streamside roads continue to be used today.
3. There has been recovery with stream braiding and aggradation patterns between 1984 and 1999/ 2000. There is declining linkage between historic streamside/ instream road networks with stream aggradation patterns between 1984 and 2000. Proper repair and abandonment procedures applied to these roads will speed up this process.

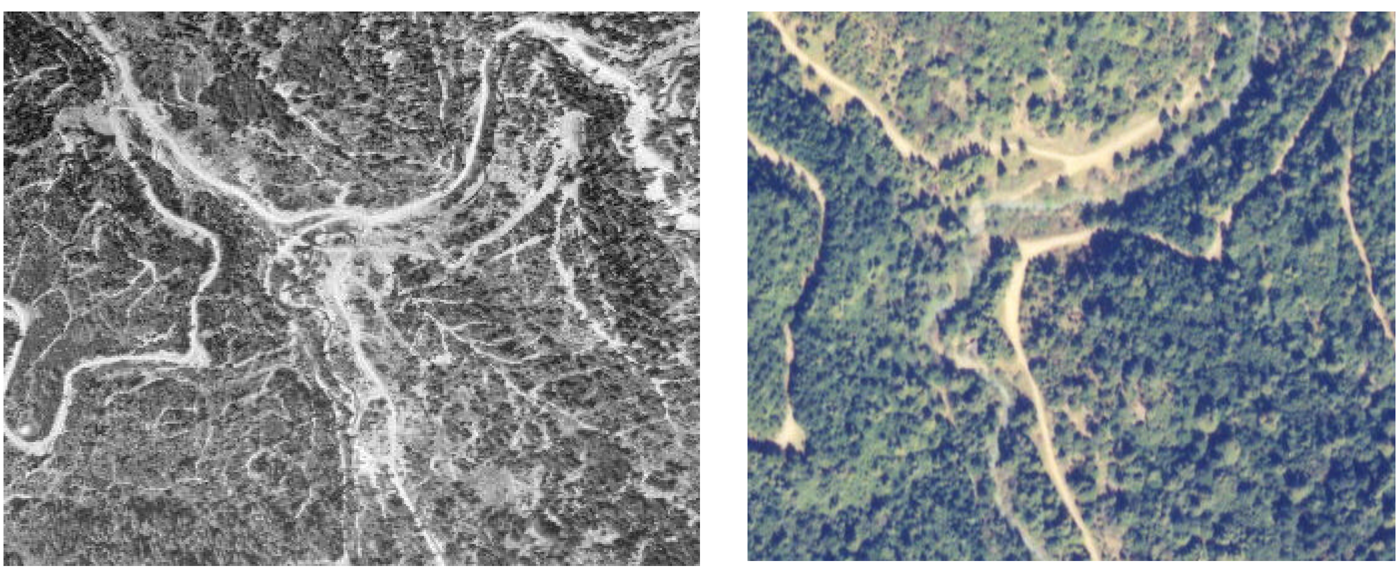


Figure 38: Fuller Creek landing complex, June, 1965 (left), and 1999 (right). Fuller Creek meanders around debris depositions in 1965 in contrast to a more lineal pattern today.

1990 to 2001

Stream Channel Simplification

After a period of relative inactivity during the 1970s and early 1980s, substantial changes in land use patterns are shown in the air photo coverage with logging operations becoming more active in the watershed by the late 1980s. Rather than following straight parcel lines over large areas characteristic of the 1950s and 1960s, harvest units are smaller, but can be more numerous in years of favorable market conditions. Non operation buffer zones around watercourses become more apparent since the mid 1990s, as larger dimensional second growth conifers are retained post harvest for riparian habitat corridors. These riparian buffer strips become incrementally wider and denser by 2001. This contrasts to the 1950s and 1960s, when tractor yarding operations were particularly concentrated in riparian areas containing the largest and highest valued trees, leaving roads, skid trails, and uncontrolled fills adjacent to watercourses. New road construction shifts to ridgelines and mid slope benches. Landings are built distant from watercourses. Seasonal roads and landings built in the 50s and 60s following watercourses are either abandoned, decommissioned, or left vegetated. Cable yarding methods appear during the 1990s, to become the dominant yarding method on steep terrain by 2000. Tractor yarding is limited to upslope locations of near level to moderate terrain. As a regulatory requirement on Timber Harvest Plans, road watercourse crossing standards have been incrementally upgraded to accommodate greater peak flow events. By 1998, the 100 year storm event was implemented as the minimum sizing standard. Bridges become the industry standard for road crossings of fish bearing waters.

Recovery of in channel geofluvial conditions as mapped between 1984 and 1999/2000 can be attributable, in part, to the Forest Practice Rules prohibiting heavy equipment entry into channel zones. Simplified stream channel structure dating back to mid century tractor grading of the stream channel appears to be generally stabilizing during the last several decades. In addition, there has been further protection provided in recent times by non operations buffer zones now typically retained as habitat corridors around larger order streams.

Figure 39: 1999 air photo of clearcut units between Rockpile Creek (top) and Buckeye Creek (center).

Table 10: Comparison of Tractor and Cable Yarding Methods, Timber Harvest Plans 1991 - 2001

Subbasin	Percent Cable Yarding	% Tractor Logged
North Fork	43	57
Rockpile	44	56
Buckeye	42	58
Wheatfield	30	70
South Fork	32	68

LWD

Removal of merchantable chunks from streams occurred up to the mid 1990s. This practice has now been phased out to leave WLPZ stream corridors basically intact as non operations areas.

Distributions of larger dimensional trees as recruitment of LWD depends on current riparian timber inventory. This is generally low in areas subject to 1950s and 1960s era old growth harvesting. Vegetation in growth is fairly young in these areas. These consist of pole sized conifers intermixed by mid sized tan-oak and madrone. In addition, the common practice of harvesting larger dimensional trees next to streams continued well into contemporary times. Only very recently have riparian zones been essentially excluded from timber operations.

Sedimentation Inputs and Transport

Successive aerial photo overlays show that road construction shifted from streambed locations during the mid century to mid slope benches and ridgeline locations during the last two decades. Of 1,300 miles of road in the watershed, only approximately 10 miles are located within 50 ft. of blue line streams. This compares with approximately 95 miles of mid century in stream/ streamside roads that followed watercourses along the streambed

The redirection of active roads to ridgelines and mid slope benches during the last two decades has allowed the streamside legacy roads and landings to vegetate and increasingly stabilize. Debris slides from these roads have tapered off over time. Storm generated gullying down mid century roads and skid trails incises deeper to bedrock or hard clay. Comparison of aerial photos taken in 1984 with those taken in 1999/2000 show a general decrease in sediment accumulations that were interpreted as indicative of channel disturbance in the transport reaches, while the response reaches showed little change. This suggests that movement of sediment in the transport reaches exceeded re-supply over this period. However, in some areas the trend was reversed.

Table 2: Comparison of Historic In-Stream Roads with Modern Roads within 50 Feet of Blue Line Streams

Subbasin	In Stream/ Streamside Roads (miles) 1952 – 1968	Modern Roads (miles) Within 50 Feet of Streams/ Total Road Length in Subbasin
North Fork	18	2.5 / 291
Rockpile	16	1.5 / 168
Buckeye	27	1.5 / 229
Wheatfield	19	3.0 / 444
South Fork	15	1.5 / 116

Timber and ranchland roads crossing steep slopes, historically active landslides, debris slide slopes or inner gorges can be sources of excess sediment to stream channels through erosion, fill failures and landsliding. Roads with undersized culverts and improper drainage design are vulnerable to stream crossing blowouts and debris slide failures during large storm events. Such roads can impact streams and delay or reverse recovery process downstream. In addition, abandoned streamside roads and landings can continue to discharge sediment during these storms.

The current road network shows less overall coincidence of debris slides and stream crossing failures compared to historic times. Proximity to streams and steep slopes, however, continues to be associated with most of the contemporary road failures. Timber Harvest Plan records generally indicate that road failures triggered by storm events represent a major proportion of contemporary sediment pulses in the watershed. The largest storm events in the last decade were in 1986 and 1996. Undersized culverts and substandard road crossings were particularly vulnerable to failure during these storms.

Modern roads cross streams at a perpendicular rather than following the stream to one side. This makes modern road sediment inputs more related to the immediate road watercourse crossing sites and road approaches to streams. Historic roads following the creek are prone to failure where streambanks underlaying the road collapse during storms as a function of fluvial velocity, steepness, and geologic instabilities (see Figure 5).

CDF's studies of the implementation and effectiveness of the Forest Practice Rules indicate that mass wasting failures associated with current timber operations have been mostly related to roads. Roads produced the highest sediment delivery to watercourse channels when compared to other erosion processes (Monitoring Study Group 1999). The majority of the road related mass failures were associated with fill slope problems, indicating that proper road construction techniques are critical for protecting in-stream resources.

As a regulatory requirement, road watercourse crossing standards have been enlarged to accommodate greater peak flow events. By 1998, the 100 year storm event was implemented as the minimum culvert sizing standard in areas under approved Timber Harvest Plans. Bridges become the industry standard for road crossings of fish bearing waters.

Figure 40: Culvert failure of contemporary road networks

Cumulative Effects of Multiple Timber Harvest Plans

The consequence of active timber harvesting conducted in the watershed since 1990 indicates that contemporary timber operations did not preclude recovery in both fluvial geomorphic stream channel characteristics and riparian canopy cover. Between 1991 to 2001, 45,070 acres or 24% of the watershed has been subject to Timber Harvest Plans. THPs have been particularly concentrated in the North Fork, Rockpile, and Buckeye subbasins. Between 1991 and 2001, 38% of the North Fork subbasin has been subject to Timber Harvest Plan activities, 63.3% in the Rockpile subbasin, and 32.2% in the Buckeye subbasin. Timber harvest operations include road building, use, and maintenance associated with the active Timber Harvest Plans. These operations have taken place during the period where CGS NCWAP mapping documents a 30 to 40 per cent improvement in detrimental sediment storage or source attributes between 1984 and 1999/ 2000. Similarly, riparian canopy cover continued to improve from the mid century bank to bank clearance operations. By the end of the tractor era in 1968, a range of 40 to 70 percent bank exposure gradually improved to approximately 25% by 1999/ 2000.

The study documented long term trends in overall watershed conditions. None of the improving trendlines have been reversed by any concentration of Timber Harvest Plan activities between 1991 and 2001. This contradicts certain projections of recent land use for cumulative effects by which a high density of Timber Harvest Plans may trigger adverse cumulative impacts in excess of the individual potential contributions from each project alone. No such cumulative processes from any collection of Timber Harvest Plans were realized in the Gualala watershed.

Only the mid century tractor operations caused a heavy concentration of multiple impacts as documented with this study. These can be inferred to be cumulative, and in excess of individual contributions. The mid century storms generated the greatest collective impacts discharged from the large block areas cleared by tractors using the streamside road networks. Harvest operations comprised a total of 47% of the North Fork, 61% of the Rockpile, 65% of the Buckeye, and 30% of the Wheatfield by 1964. The resulting extreme channel aggradation directly impaired anadromous habitat as a cumulative effect from the large scale land use operations upslope. This contrasts with more dispersed land use patterns in 1942, indicated by photo sets dating to this time. Tractor operations were just starting, limited to small scattered block removals along the lower Wheatfield. Few debris slides were noted, and in channel conditions appeared undisturbed.

However, analysis for cumulative effects is extremely limited by the inherent variability of cause and effect relationships thru time and space. The large storm events are responsible for most of the watershed damage. When these occur is a function of unpredictable weather conditions, rather than any threshold triggered by cumulative land use. This study shows that basic assumptions underlining cumulative effects need to be reevaluated in the context of longer term watershed trends interrupted by broad scale disturbances, including storm events and earthquakes, and how improper land use practices may accelerate the effects of unpredictable, broad scale natural disturbances.

Figure 41: Current permanent and seasonal road network of the Gualala Watershed

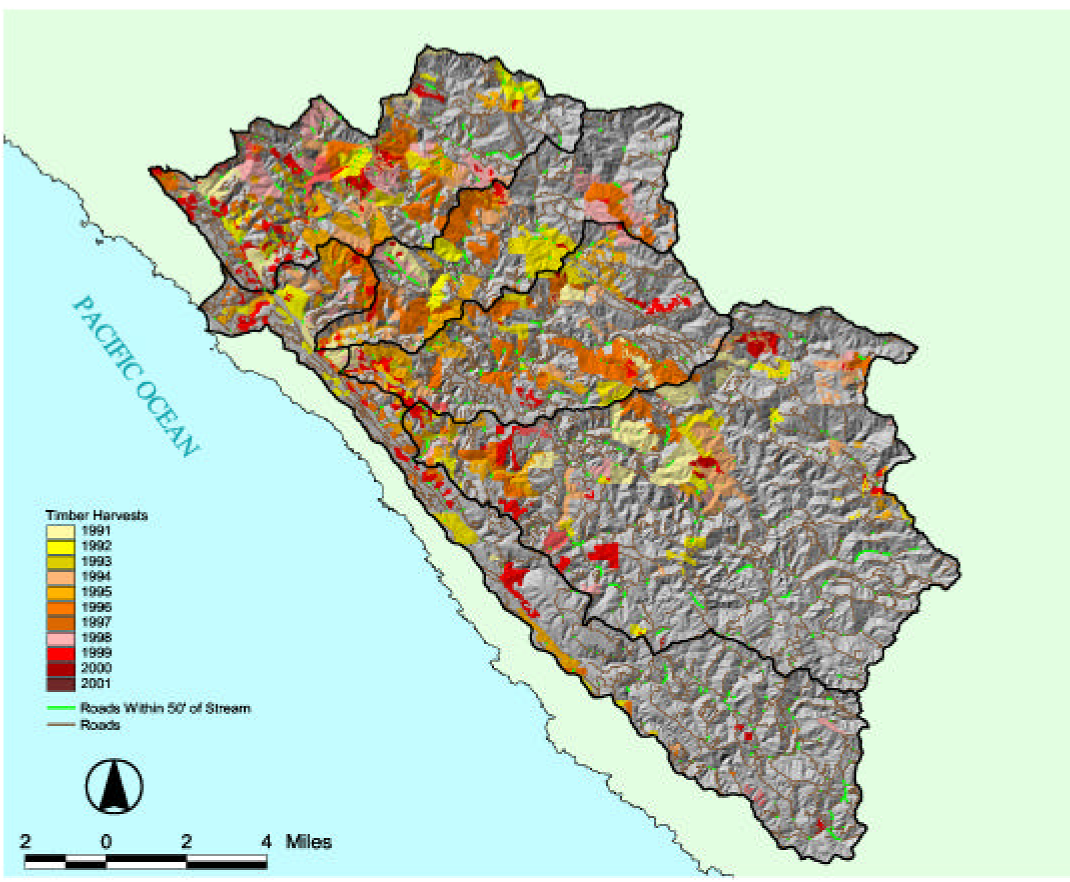


Figure 42: ICE roads located within 50 ft. of a watercourse (green), with 1991 to 2001 THPs.

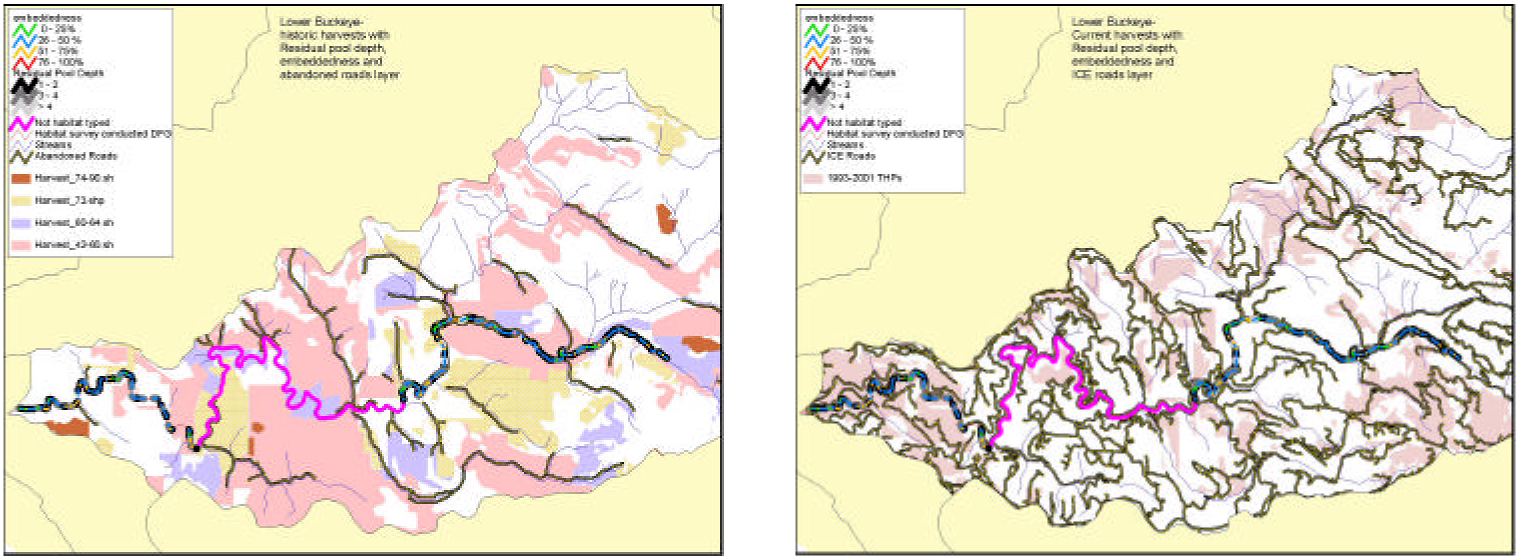


Figure 43: Buckeye streamside roads with pre 1973 stand replacement areas left), and the modern road network (right) with 1991 to 2001 THPs.

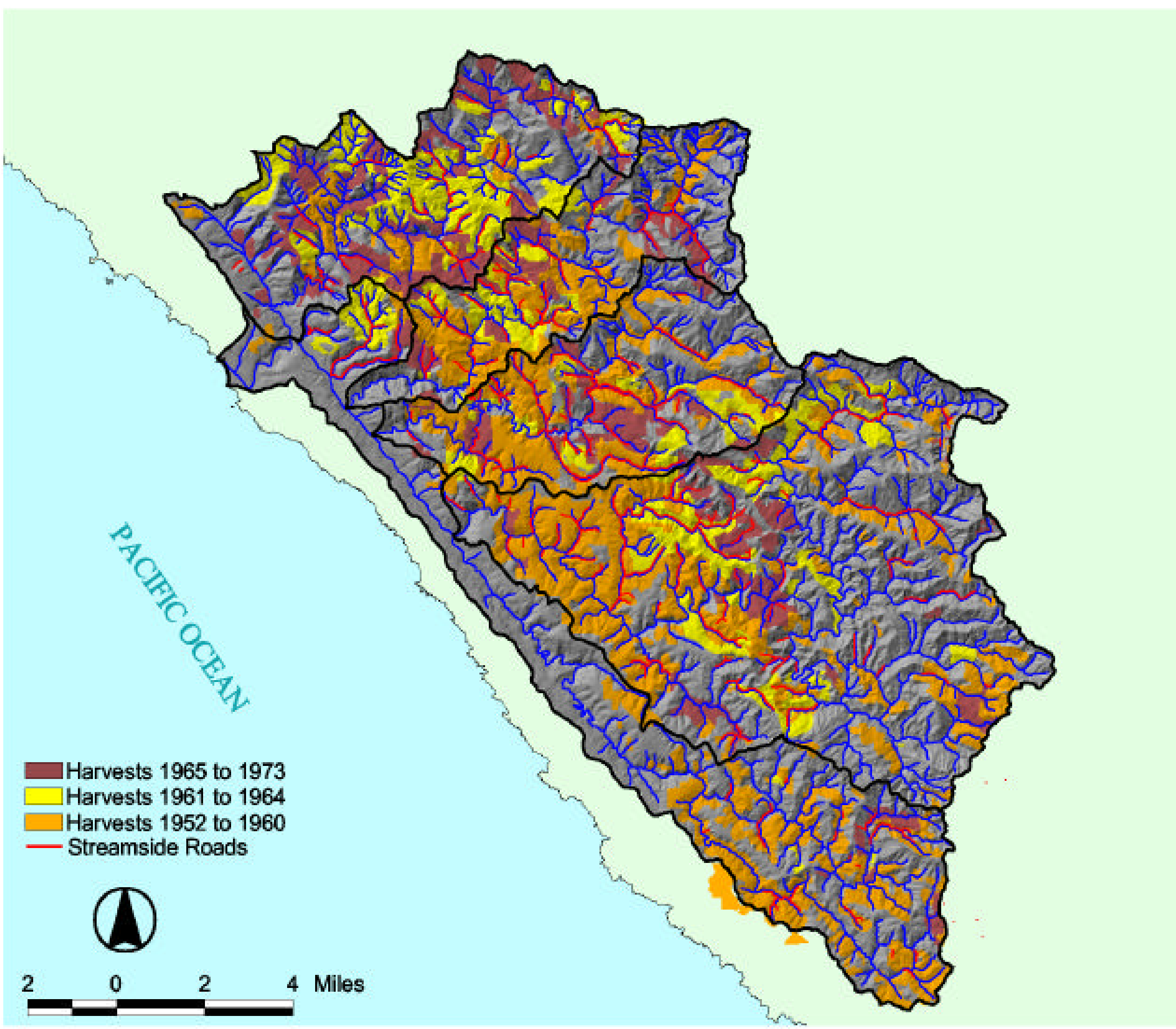


Figure 44: Mid century streamside/ instream roads and landings. Pre-1973 harvests are shown in three separate time strata.

IV STREAM GRADIENTS

The above sections characterized sediment discharges into streams through time Stream gradients determine sediment transport through the watershed. Sediment routes quickly through upper watershed reaches because of the steep gradient but moves slowly through lower river areas and storage reaches. The Gualala River persists in transporting and storing sediment at elevated loads. The residence time of excess sediment accumulated in transport reaches is relatively short and some recovery is apparent over decades. However, excess sediment accumulated in lower depositional reaches is hard to quantify and may remain much longer with only vaque evidence of recovery. This substantiates the more detailed long term channel surveys in Redwood Creek which show that the 1964 flood sediment inputs discharged in the higher reaches are still stored in the middle and lower reaches (Okazaki and Jones, 1998)

Residual stream channel aggradation from historic pre-1973 land use impacts have been recently studied in detail on Jackson State Forest in the South Fork Noyo River watershed. Detailed channel mapping in the South Fork Noyo River watershed (2001) reported significant amounts of stored historic sediment in the lower basin reaches of the SFNR. This consisted of (1) in channel depositions and (2) channel terraces accumulated during the last 100 years from two logging periods (1) old growth harvesting (1904-1937) and second growth tractor logging during the mid century (1940s to 1973).

This study found that most of the historic sediment debris terraces formed adjacent to long tern geologic aggregation depositions in the channel zone. These land use induced sediment sources lined the geologic terraces inset of the current stream channel (see Figures 45-48). Historic terraces developed from early century stream channel aggradations that buried the original channel over bedrock. These aggradations predominantly accumulated in the lower gradient response reaches. Subsequent storms eroded down the central channel, leaving terraces on one or both sides of the stream. Historic terraces can also form from eddying of sediment deposits along the edge of the streambank during high flows. Historic terraces were identified by logging remnants lodged or buried within the terraced sediment. Old growth stumps showed the base of the natural geologic terraces. No logging debris were located within the identified geologic terraces. However, the study was unable to differentiate the historic terraces associated with the second growth logging from the historic terraces associated with the old growth logging. Many of the historic terraces in the SFNR watershed have large alder trees that are probably 30 to 40 years old. From this, it is inferred that the historic terraces observed in the channels of the SFNR were deposited following logging at various locations within the SFNR watershed prior to 1973. No new terraced structures were found. This indicates that post 1973 regulatory implementation caused less sediment to discharge into streams. This reduces the potential for sediment aggragation build-up in the stream channel to then downcut to form streamside terraces.

More of the stored historic sediment depositions in the SFNR consisted of sediment stored in the active channel (158,000 cubic yards) vs. 68,000 yrds. stored in historic terraces (about a 2 to 1 ratio). By analysis of six channel cross sections, it is speculated that approximately 43 to 72 per cent of the historic sediment that once existed in the SFNR watershed has eroded and transported downstream (see Figure 46). Sediment generated by pre-1973 logging is being transported through the system but has not yet flushed out of the system. Similar to the Redwood Creek study, it is speculated that it will take tens to hundreds of years for the historic sediment to flush through the watershed mouth.

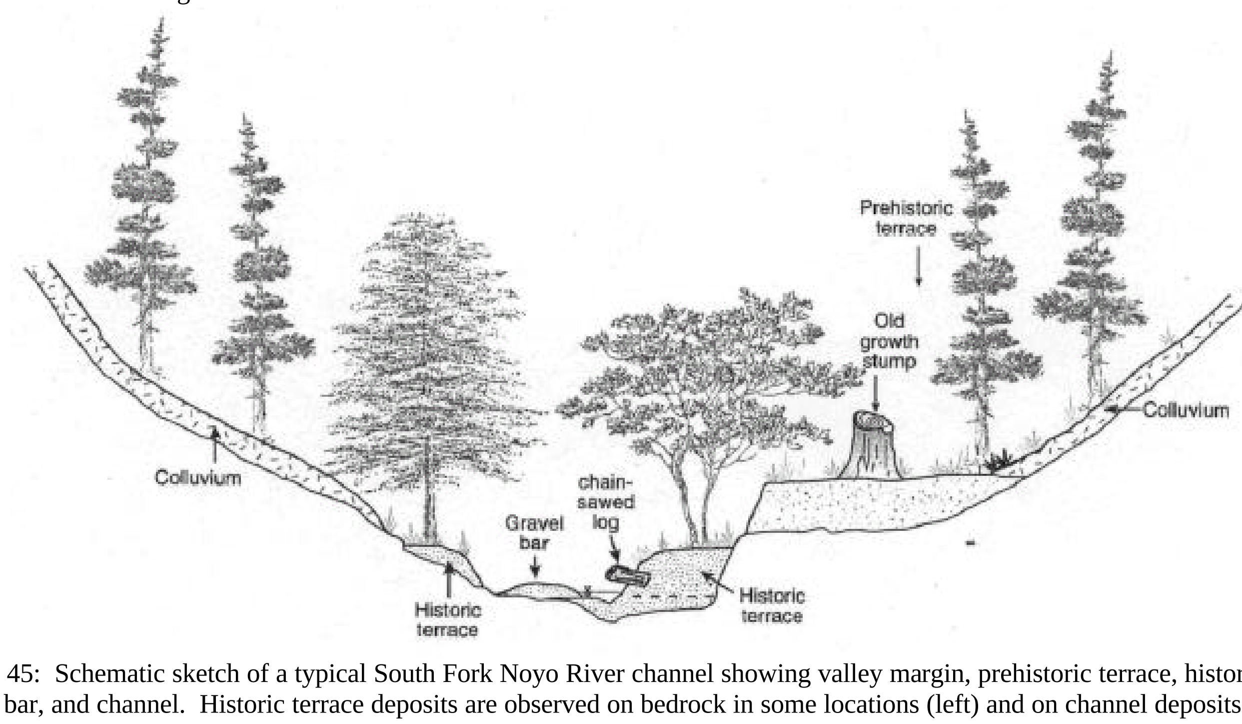


Figure 45: Schematic sketch of a typical South Fork Noyo River channel showing valley margin, prehistoric terrace, historic terraces, gravel bar, and channel. Historic terrace deposits are observed on bedrock in some locations (left) and on channel deposits in other locations (right). Old growth redwood stumps are diagnostic of prehistoric deposits and embedded chain-sawed logs are diagnostic of historic deposits. Prehistoric terraces support second growth redwood trees and ferns, historic terraces typically support alder trees and grasses.

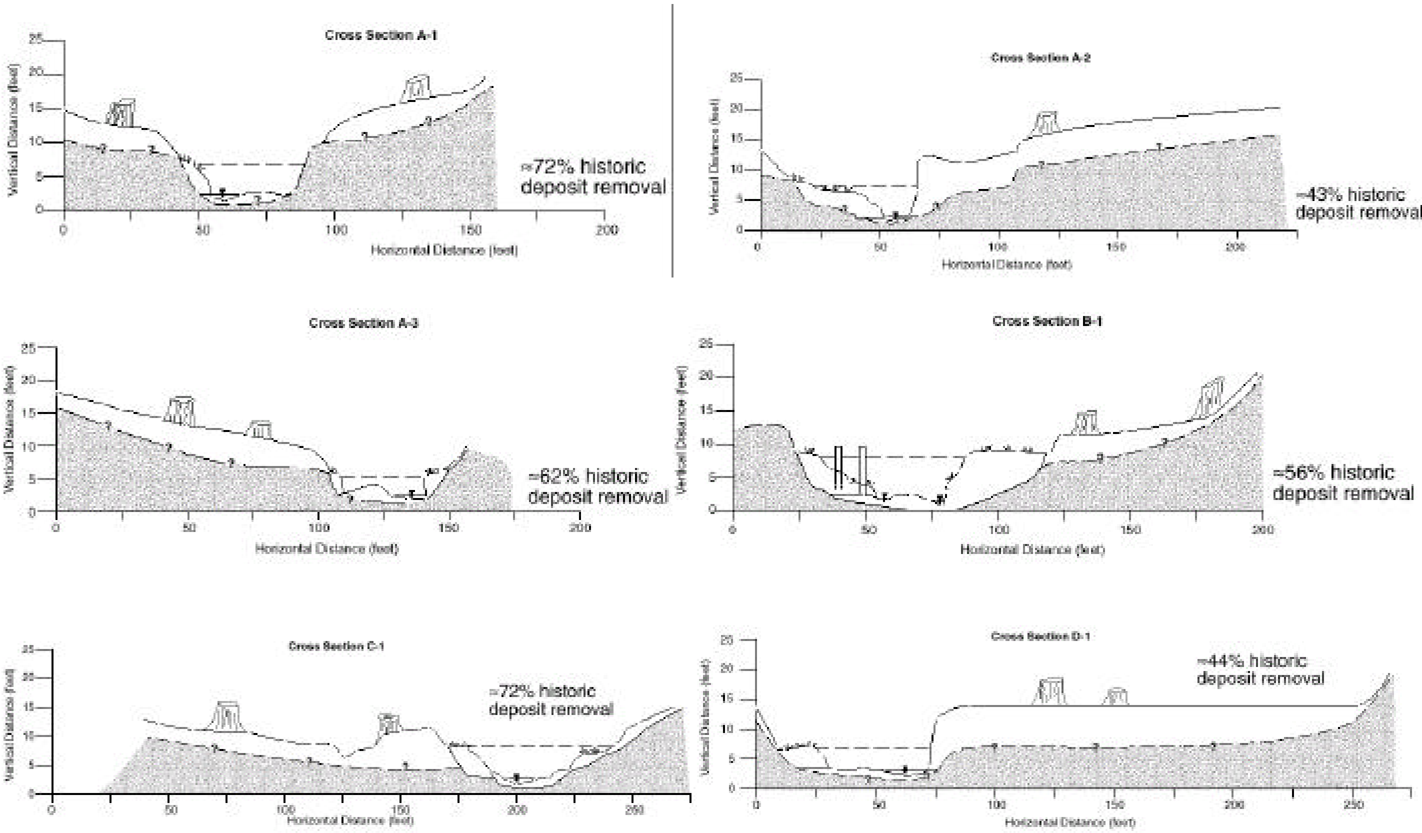


Figure 46: Six survey cross sections. Dashed lines represent probable maximum thickness of historic aggradation used to estimate amount of material removed since time of terrace depostion.

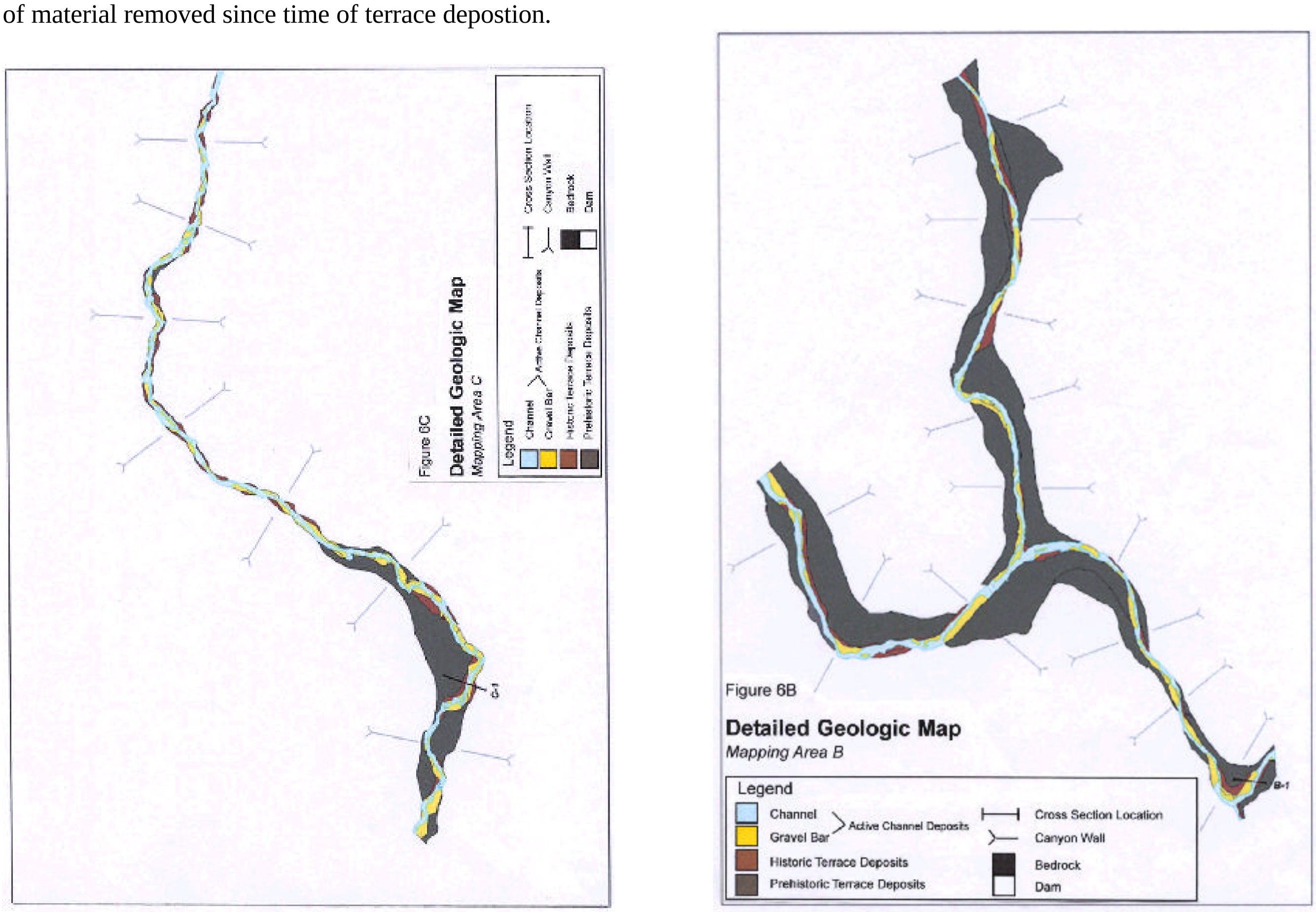
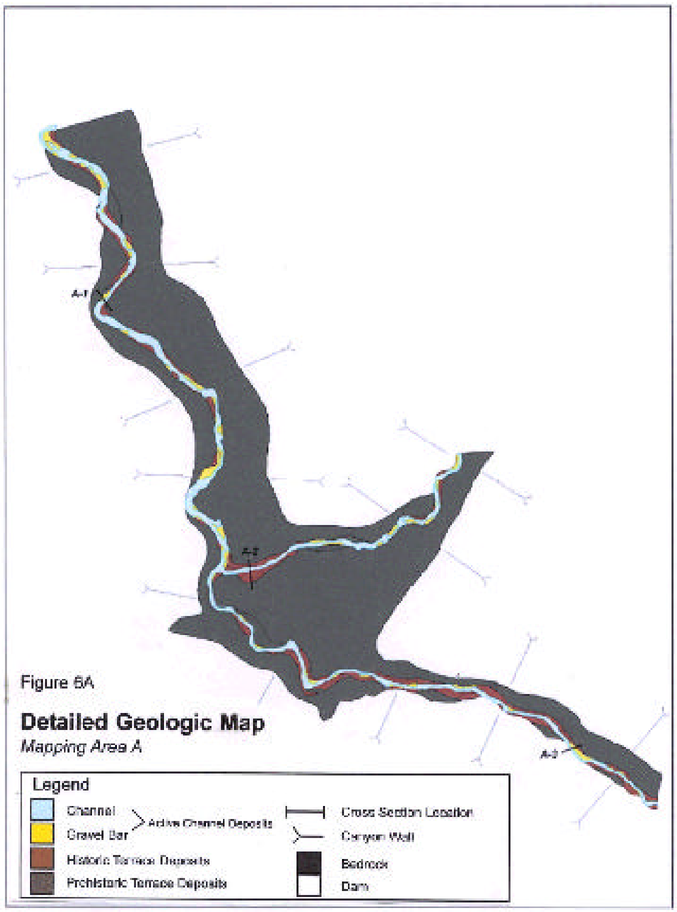


Figure 47: Stream channel maps showing active channel deposits, historic and pre-historic deposits, and bedrock in the South Fork Noyo River Watershed, Brown = historic terrace, Grey = geologic, or pre-historic terrace, Yellow = gravel bar.



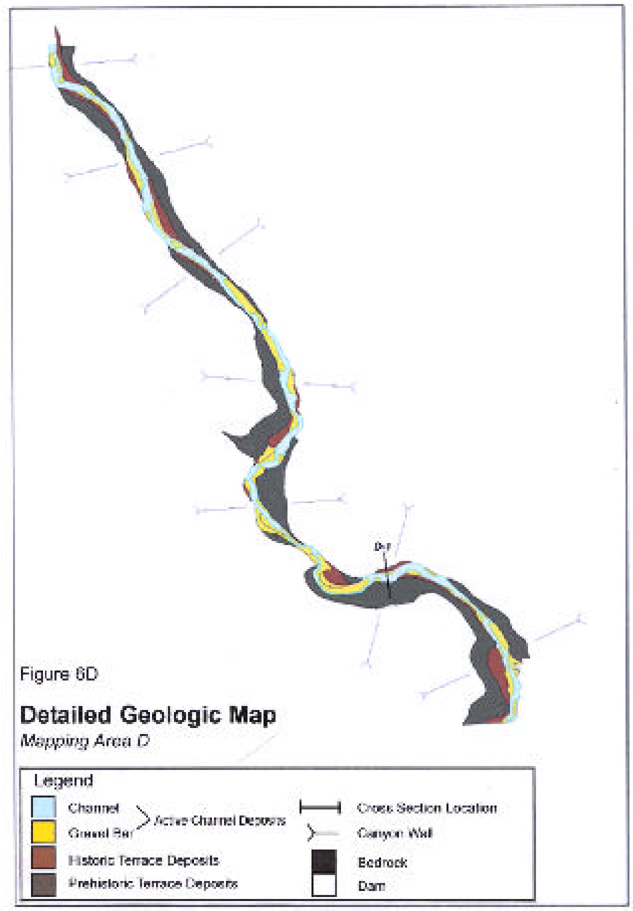


Figure 48: Additional stream channel maps showing active channel deposits, historic and pre-historic deposits, and bedrock in the South Fork Noyo Watershed. Brown = historic terrace, Grey = geologic, or pre-historic terrace, Yellow = gravel bar.

Areas that contain large amounts of historic sediment stored in the active channel and / or historic terrace depositions are likely large contributors of the suspended sediment during present day high discharge events. The majority of the historic terraces and active channel deposits were originally introduced into the fluvial system by logging practices used prior to 1973. The study shows that the suspended sediment eroded from long term channel storage locations significantly increases suspended sediment loads over the short term. By not addressing long term sediment storage and relying solely on present day sediment sampling, suspended sediment load entering the watercourse by modern management practices can be substantially over estimated.

Historic terraces exist along low-order tributary channels in nearly every watershed that has experienced intensive pre-1973 logging where investigated. This includes the Garcia, Albion, Big River, and Elk Creek watersheds in Mendocino County. These have been found in the Maple Creek watershed in central Humboldt County (collaborated by this author). The Maple Creek watershed was railroad harvested during the 1930s. These indicate extensive, and wide spread channel aggregations caused by pre 1973 timber operations. Such aggregations and resulting historic terraced formations are also evident in the Gualala watershed. The 1965 photos confined to the east basin reaches show mid century stream channel aggradations in Grasshopper (Figures 8 and 11), Fuller (Figures 6, 9, and 16), Sullivan (Figure 88, Wheatfield Subbasin), Tobacco (Figures14), and McKenzie Creeks (Figures 24 and 40). These areas consist of steep terrain interfaced by dense mid century in stream/ streamside road networks. As documented in these areas, such impacts activated multiple debris slides and debris flows over relatively short distances of the stream. The meandering, angular, and diffuse channel patterns (pgs 8 – 19) indicate channel aggradation in many portions of the central channel. Actual ground verification of historic sediment terrace structures in these and other lower tributary reaches can provide quantitative estimates of future potential sediment discharge during subsequent storm events. In addition, the 95 miles of in stream/streamside roads in the Gualala Watershed represent a substantial sediment source during present day storm events by activated channel bank erosion. These proportionate contributions can be large when estimating sediment budgets for the watershed.

In addition, the Noyo study found larger amounts of historic in channel and terraced sediment deposits in more recent pre 1973 areas. Old growth areas logged in the 1920s and 1930s contained higher sediment loads compared to turn of the century areas. This indicates that earlier logged areas have had more time for deposits to wash downstream and out of the watershed. In the

Gualala Watershed, the central reaches of the watershed were tractor logged between 1952 and 1968. This substantiates field observations of considerable historic pre-1973 stream channel sediment deposits still lodged in or adjacent to the central North Fork, Rockpile, Buckeye, and Wheatfield subbasins. The lower reaches likely contain high amounts of historic sediment accumulations stored in the form of in channel depositions and historic terraces. Future ground surveys need to quantify these depositions.

This section summarizes sediment inputs by sub-basin over the last century as a function of land use disturbance for the Gualala Watershed. Subbasin gradient maps provide a spacial indication as to where sediment has moved over time. The SFNR study found that a significant portion of the historic sediment is currently stored in the lower SFNR channel between its confluence with the North Fork of the SFNR and the mouth of the SFNR. This sediment is stored in the channel in the dry season and is transported downstream in high discharge events. Stream gradient maps can provide an indication as to where historic sediment may be currently stored in the Gualala watershed. Future field reconnaissance will provide quantitative comparisons. Sediment storage reaches are shown in yellow for each of the subbasin maps.

NORTH FORK

The sub basin has been subject to two eras of historic land use; (1) redwood old growth redwood harvesting in the lower alluvial basin reaches between 1868 to 1911, and (2) tractor harvesting in the central reaches between 1942 to 1968. The sub-basin contains steep, deeply incised terrain and overall high stream densities. This can cause intense flashy runoff, and frequent debris flows that challenge streamside roads and landings, and poorly engineered stream crossings.

The 1868 to 1911 old growth logging era used heavy cut and fill practices to build the rail network on an even grade through the lower redwood alluvial basin reaches. Although resulting channel aggredations can be expected from these practices, about 100 years has passed since the end of this period, allowing substantial time for the logging debnis to be washed downstream and out of the watershed. When logging resumed in the central basin reaches during during the 1950s and 1960s, streamside roads and landings were densely concentrated along Dry Creek, Robinson Creek, McGann Gulch, and Stewart Creek. 18 miles of historic roads built in or along the streambed simplified pool structure and complexity throughout the major tributary streams. Large storm events were particularly concentrated during the mid century. 1981 photos show a high density of road and landing failures discharging into the major streams with these roads. Only 40 years has elapsed since the end of the tractor era, indicating considerable mid century sediment storage in the lower to central basin stream reaches. There were road failures and debris slides accessing streams with the 1996 storm events, but less frequent overall compared to mid century discharges. Between 1990 and 2000, cable/ tractor harvesting has been conducted throughout the lower to central basin reaches in excess of 50% of the land area between 1990 to present, much of which by even-aged management practices.

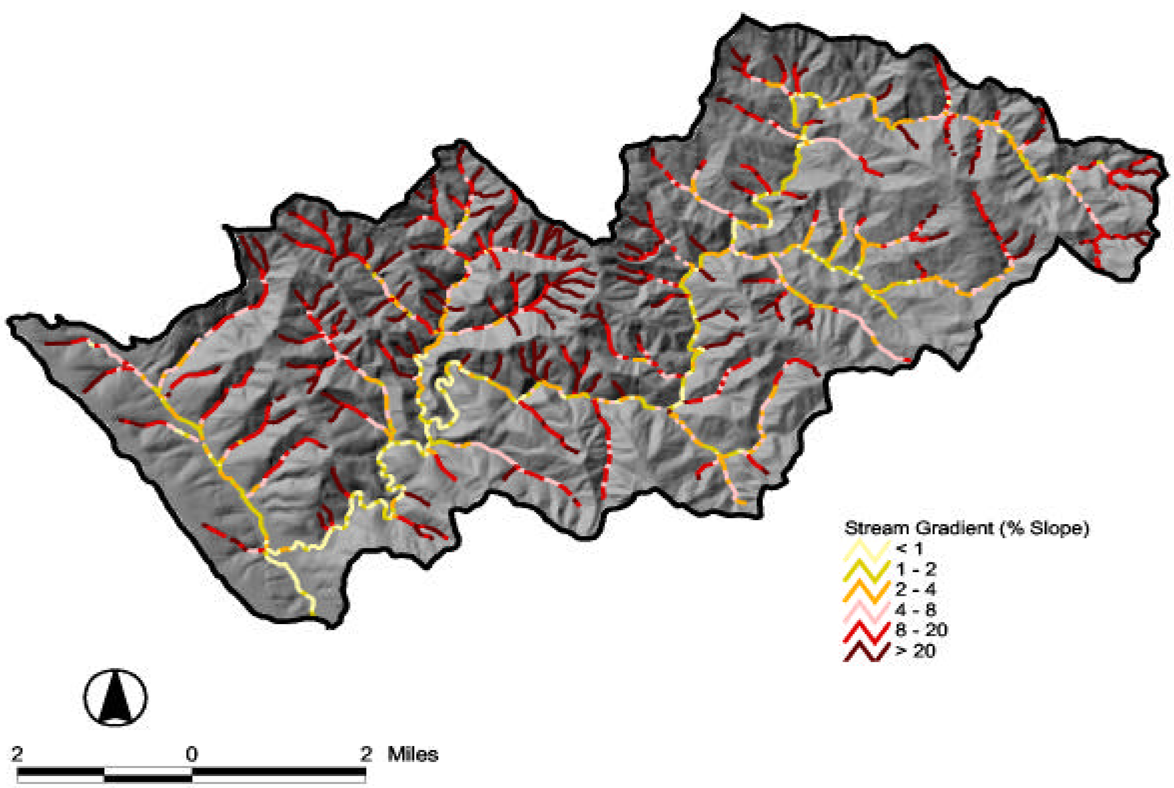


Figure 49: North Fork Stream Gradients

Despite three land use waves in the North Fork sub-basin spanning 150 years, the study found comparatively moderate degrees of residual sedimentation in the subbasin (See North Fork Sub-basin synthesis in Gualala Report). The sharp contrast between steeper gradients in the upper NF reaches, and near level to moderate gradients along lower NF reaches shows a high potential for sediment transport to the alluvial floor of the basin. The steepest topography and broadest tributary valleys are found in the North Fork basin. Steep, V-shaped, narrow, rectilinear, fault controlled valleys characterize the upper reaches of the basin. In the lower reaches of the basin, streams generally meander through alleviated valleys. Streams in this area are characterized by sinuous low level relief and well developed flood plains built by the river. Historic terraces may be located along the (1) Little North Fork, and (2) at the base of Robinson and Dry Creeks as low gradient response reaches.

Table 5: North Fork Stream Gradients	% stream length
< 1% (Response Reach)	**9.2%**
1-4% (Response Reach)	**22.1%**
4-20% (Transport Reach)	**39.8%**
>20% (Source Reach)	**29.0%**

ROCKPILE

Mid century pre-1973 tractor method harvesting has been the dominant land use period in the Rockpile basin, removing most of the old growth conifer dominated stands throughout the lower and central reaches of the basin in a comparatively narrow time frame between 1952 and 1968. The original turn of the century operations were limited to the lowest reaches of the basin due to limited rail access from the South Fork. Between 1952 and 1964, 65% of the area had been subject to tractor harvest operations prior to the 1964 storms with no erosion control facilities installed. The middle reaches were nearly entirely tractor logged within a narrow timeframe between the late 1950s and 1964 By the end of the first logging era in 1968, 73.5% of the basin had been harvested. A total of 16 miles of roads were built along streams with sidecast covering the streambank leading to the creek. Streamside roads and landings were densely concentrated at the base of steep ravines. CGS mapping found more numerous debris slides and debris flows compared to other sub-basins. Many of the streamside roads crossed erosion prone areas. The residual effects of sedimentation and accumulation of debris in channel from this time period are documented in various THP records. The 1986 and 1996 storms form contemporary land use induced sedimentation pulses from (1) failures of undersized road crossing structures facilities, and (2) road washouts on steep slopes, and near channel locations. Cable/ tractor harvesting throughout the lower basin reaches occurred in excess of 50% of the land area between 1990 to present.

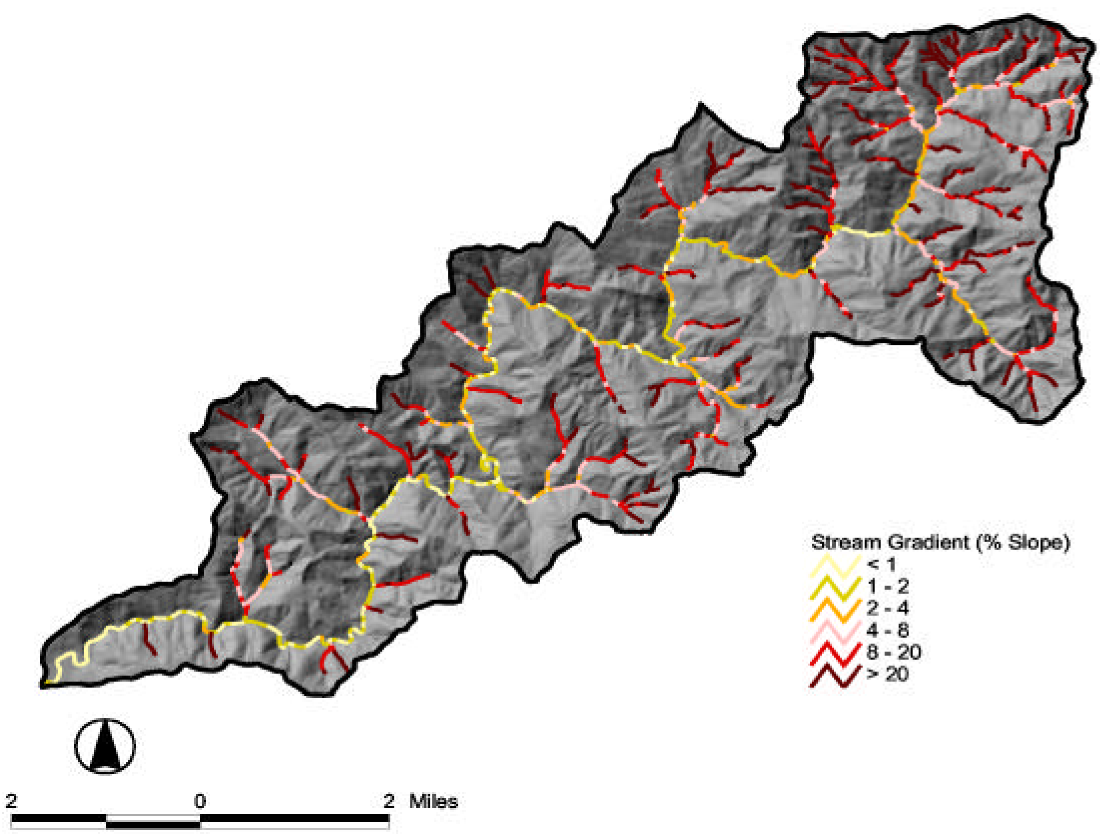


Figure 50: Rockpile Stream Gradients

Table 6: Rockpile Stream Gradients	% stream length
< 1% (Response Reach)	**14.0%**
1-4% (Response Reach)	**31.4%**
4-20% (Transport Reach)	**38.8%**
>20% (Source Reach)	**18.9%**

The narrow Rockpile basin contains similar topography to the North Fork with steep deeply incised terrain in the middle and upper reaches. Similar to the North Fork, there is a higher gradient contrast between the unnamed tributaries in upslope areas, and the main stem Rockpile in the lower and central basin reaches. Smaller unnamed tributary streams line both sides of the Rockpile basin throughout generally steep terrain. This high gradient contrast directs sediment transport to the lower basin reaches. Historic terraces would be most likely found at the base of Red Rock Creek and Horsetheif Canyon.

With 73.5% of the subbasin harvested between 1952 and 1968, only 40 years has passed since the end of the tractor era. This limits the potential for historic sediment transport out of the subbasin This substantiates many field observations of residual historic sediment still noted in the lower to central basin reaches. Future large storm events will likely continue to move large amounts of the residual pre-1973 sediment. 16 miles of mid century in stream roads represent a substantial sediment source during present day storm events by activated channel bank erosion. Both the geologic and historic in channel sediment formations represents a considerable proportion of any estimated sediment budget for the subbasin. Large natural earth flow complexes occupy the east basin reaches, and high residual pre-1973 historic sediment is likely stored in channel and possibly along sediment terraces. Any remedial actions to abate current sediment sources with the objective of habitat improvement will not likely create immediate benefits, and need to be considered as long term objectives.

BUCKEYE

Mid century pre-1973 tractor method harvesting has been the dominant land use period in the Buckeye basin, removing most of the old growth conifer dominated stands throughout the lower and central reaches of the basin in a comparatively narrow time frame between 1952 and 1968. Streamside and instream roads and landings lined Little Creek, Franchini Creek, Grasshopper Creek, Flatridge, and Osser Creeks. 1965 aerial photo coverage shows heavy storm damage from the 1964 storms including streamside road fill failures accessing creeks, incised and failed streamside landings, and gully/ trench erosion down unwaterbarred roads and skid trails. Effects from other mid century storms exhibiting similar peaks flows were not evaluated. The 1966. 1962, and 1970 storms rank 2, 3, and 5 on peak disharge flows, respectively. Road washouts during the 1986 and 1996 storms generally characterize contemporary land use induced sediment pulses. The original turn of the century operations were limited to the lowest reaches of the basin due to limited rail access from the South Fork.

Streams reaches throughout the wider Buckeye basin show longer reaches of moderate gradients compared to the North Fork and Rockpile basins. This indicates slower transport of sediment. Moderate stream gradients form a longer portion of the overall stream in Little, Grasshopper, and Osser Creeks. This shows a higher potential for historic sediment accumulations and residual terrace formations in these areas, especially along the lower reaches of these tributary streams. Similar to Rockpile, with 68% of the Buckeye subbasin harvested by pre-1973 tractor methods between 1952 and 1968, only 40 years has elapsed for subsequent storms to transport the pre-1973 soil debris depositions through the subbasin. Numerous field observations document historic sediment accumulations still located in the lower to central basin reaches. Future large storm events will likely move large amounts of the historic sediment stored in channel, along terraces, and along 25 miles of the mid century in stream road network by activated bank erosion. The combination of the large natural earth flow complexes in the east basin reaches, and high residual pre-1973 historic sediment depositions represent a considerable proportion of any estimated sediment budget. Remedial actions to abate current sediment sources with the objective of habitat improvement will not likely create immediate benefits in the Buckeye Subbasin.

Table 7: Buckeye Stream Gradients	% stream length
< 1% (Response Reach)	**13.6%**
1-4% (Response Reach)	**30.5%**
4-20% (Transport Reach)	**37.6%**
>20% (Source Reach)	**18.3%**

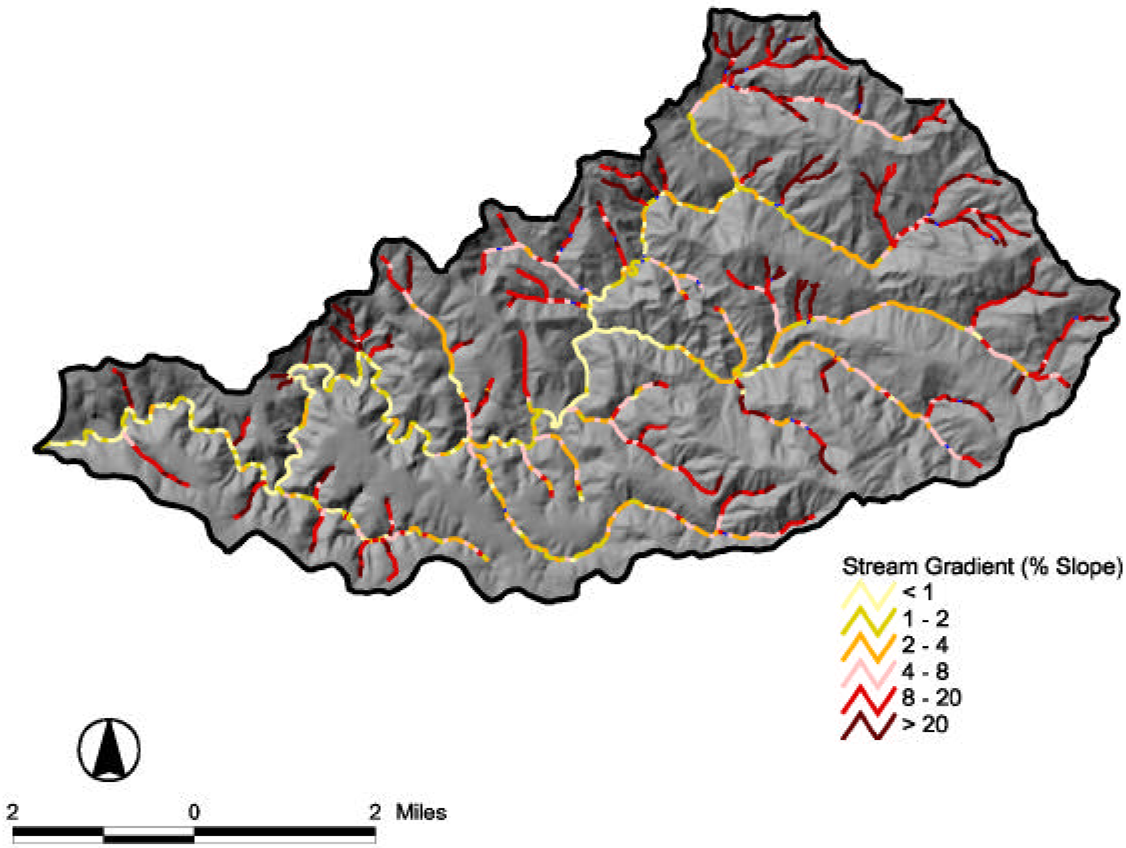


Figure 51: Buckeye stream gradients

WHEATFIELD FORK

Tractor method harvesting during the middle part of the century was the dominant land use era of the Wheatfield basin. The original old growth logging followed the South Fork, with some operations extending upstream into Wheatfield, but only in the lowest reaches. With the Annapolis Road built along the main stem Wheatfield Fork as early as 1942, large tracts of coniferous forests were tractor cleared during the late 1950s throughout the lower and middle reaches of Fuller, Haupt, and Tobacco Creeks. Approximately 13 miles of historic logging roads built in or along the streambed in the Lower Wheatfield SPW simplified pool structure and complexity throughout Fuller, Sullivan, Haupt, and Tobacco Creeks.

Larger undisturbed conifered tracts along House, Pepperwood, and Tombs Creeks, primarily on north slopes, were similarly tractor cleared. Many of these areas were then converted to pastureland. Tractors skidded logs up and down smaller creeks, and built roads and landings in or on larger streams. The lack of any erosion control measures made these areas of the Wheatfield basin particularly vulnerable to large storm events. The 1965 Cal Trans photos showed extensive storm damage from the 1964 flood. 1965 photos over Fuller and Sullivan Creeks show stream channel burial of silt and sand depositions. Tractor harvesting slowed down appreciably after 1968. There has been scattered timber harvesting in the basin since this time to present.

There are steep gradient differences in Fuller, Haupt, and Wolf Creeks. This directs sediment transport.to lower stream reaches, Historic sediment accumulations and historic terraces have likely formed in lower tributary stream reaches and confluence points with the Wheatfield Fork. Field observations confirm a largely graveled substrate at the confluence point of Haupt Creek with Wheatfield Fork. Comparing current stream surveys with historic surveys in Fuller Creek indicats net sediment transport out of the tributary basin. The sharp gradient differences likely washed historic sediment debris downstream and decreased bed loads. The GRWC indicated that the 1996 storms washed much of the remaining soil debris out the Fuller Creek basin. 1965 photos show a stream substrate dominated by silt and sand in these same reaches. 2001 stream surveys in Fuller Creek show a graveled substrate today.

The California Geological Survey reported net sediment outflow from the lower Wheatfield since 1942. Air photos since 1942 indicate degradation of the stream channel in the lower Wheatfield suggesting sediment transport exceeding resupply. Bed elevations have definitely lowered since 1942 and perhaps since 1921 (Appendix 2). Major disruptions along the San Andreas Fault and tributary faults basically define sediment sources over geologic time. Large seismic events including the 1906 earthquake probably generated larger sediment inputs that required decades to fully move out of the basin. Net degradation of the stream channel was also noted in the South Fork Noyo Watershed study.

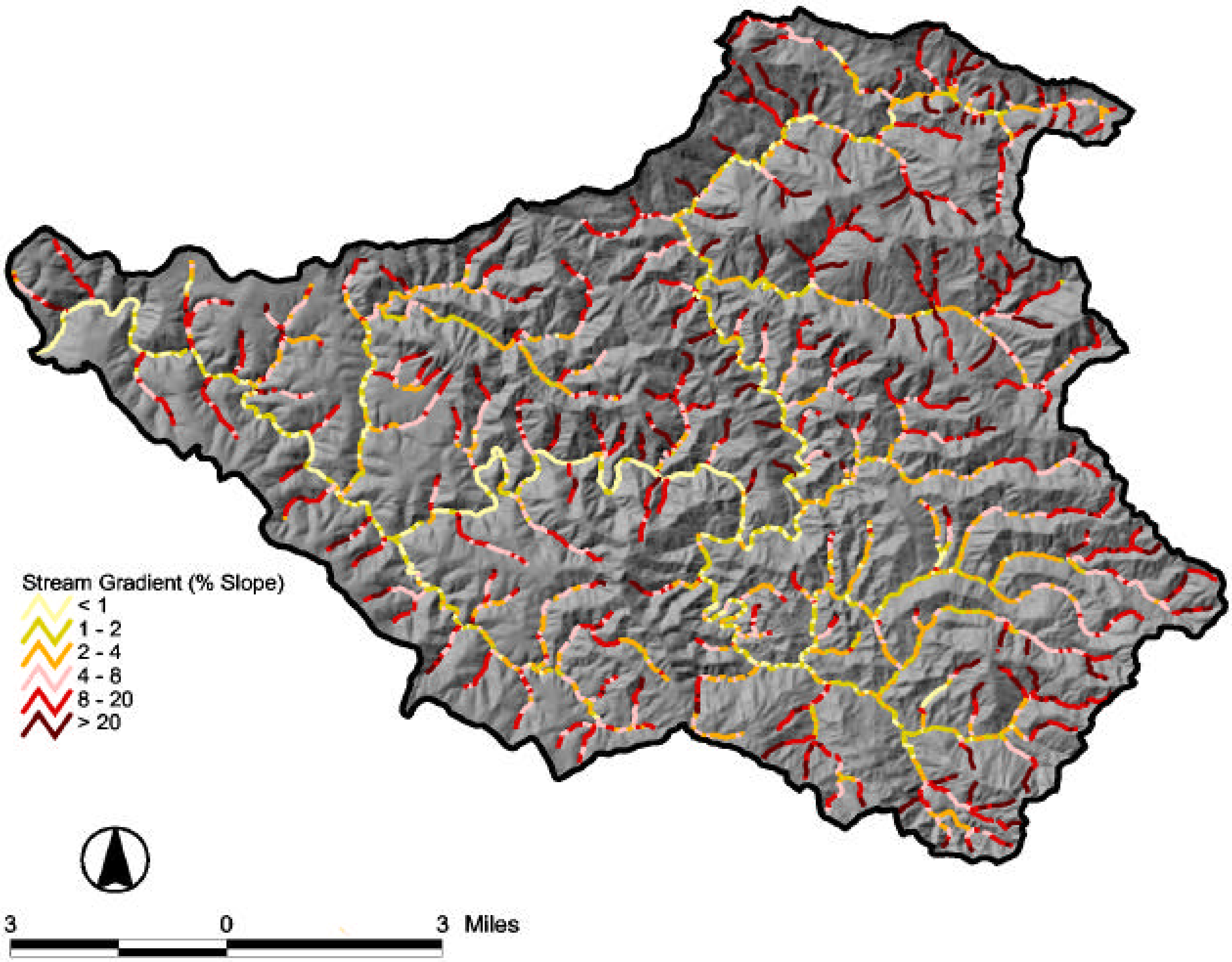


Figure 52: Wheatfield Fork Stream Gradients

Table 8: Wheatfield Stream Gradients	% stream length
< 1% (Response Reach)	10.9%
1-4% (Response Reach)	32.2%
4-20% (Transport Reach)	40.6%
>20% (Source Reach)	16.3%

SOUTH FORK

Upper South Fork (Upstream Of The Confluence With Wheatfield Fork)

Similar to the Wheatfield basin, mid century tractor operations have been the dominant land use activity in the Upper South Fork. Harvest activities at this time used inner riparian areas as the central locus of road/ landing construction and tractor skidding. Approximately 15 miles of historic logging roads built in or along the streambed simplified pool structure and complexity throughout the Marshall and McKenzie Creeks, and the upper main stem tributaries. Subsequent ground stream surveys in these areas documented stream simplification and pool compaction by these operations.

Old growth tractor harvesting was particularly concentrated in the McKenzie, and upper Marshall tributaries, including Palmer and Wildcattle Canyons. The upper basin has been comparatively inactive since 1960, allowing legacy sediment sources to revegetate and increasingly stabilize. The 2001 DF&G surveys found longer portions of riffle along the McKenzie Creeks. Streamside roads built through the McKenzie Creek basin simplified the stream channel and probably contributed to the riffle development. Successive air photos and gravel mining records indicate that the lower South Fork may actually be degrading between 1921 to 1993, suggesting sediment transport exceeding supply. The S.F. Noyo study also documented net degradattion of the central stream channel during the last half century (see Figure 46).

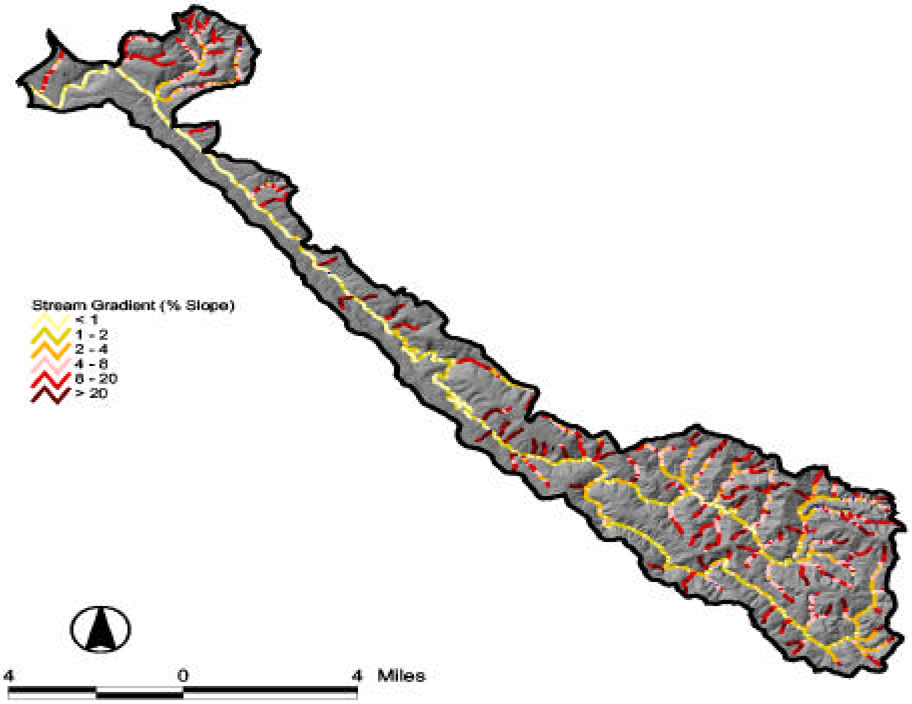


Figure 53: South Fork stream gradients.

Lower South Fork
Downstream of the confluence with Wheatfield Fork, the South Fork Gualala consists of an aggraded channel leading to the estuary. Substrate in the flood plain is almost completely gravel, with some pockets of sand and silt. During low summer flows, the active channel up to 25 feet wide shifts to each side of the gravel basin over 200 feet wide in some areas. Pools greater than 2 ft. in depth between Wheatfield Fork and Big Pepperwood Creek comprise less than 10% total survey length. 1936 and 1942 photos show this same pattern with over 80% of the watershed in an old growth, undisturbed condition at this time. This further substantiates a basic finding of the study that geologic processes define habitat conditions. The basin is filled with probably more than 100 feet of alluvium deposited probably over many thousands of years, presumably in-step with sea level rises since the last Ice Age. The estimated thickness of the alluvium is collaborated in places with drillers logs that show alternating sequences of sand, silt, and clay sediment probably indicating repeated transitions between estuarine and fluvial conditions. Natural conditions favor aggradation in the lower reaches of the South Fork. Major disruptions along the San Andreas Fault and tributary faults bisecting the South Fork subbasin basically define sediment sources over geologic time. Sediment sizes in the lower basin reaches are largely controlled by declining stream gradient. This decline in gradient occurs as the Gualala River encounters deep alluvial valley fills that have been deposited over geologic time to rising sea levels.

Two land use eras characterize the Lower South Fork (1) steam donkey, redwood old growth harvesting between 1868 and 1911, and (2) tractor/ cable harvesting 1991 to present. Most of the entire Lower South Fork basin (downstream of the Wheatfield confluence) was cleared of old growth timber by 1911. After this time, the Lower South Fork was inactive up to the late 1980s. Mid century tractor operations mostly avoided the area. This minimized overall construction of in stream landings and streamside roads in this part of the watershed.

Small unnamed tributary streams line both sides of the basin throughout generally steep terrain. This high gradient contrast can indicate a potential for comparatively rapid sediment transport to the Lower South Fork. The contemporary active harvest activity during the 1990s reentered an area long dormant from large scale disturbance. As part of contemporary construction, new roads now primarily follow ridgelines and mid slope benches

Table 9: Gualala South Fork Stream Gradients	% stream length
< 1% (Response Reach)	19.6%
1-4% (Response Reach)	31.6%
4-20% (Transport Reach)	36.4%
>20% (Source Reach)	12.4%

V PROGRESSION OF TIMBER HARVEST OPERATIONS AND RANCHLAND DEVELOPMENT

The progression of timber operations has been blocked by air photo availability. This includes 1936 (Mendocino), 1942 (Sonoma), 1952 (Mendocino) 1961 (Entire Watershed) 1963 (Mendocino) 1965 (Sonoma) and 1981 (Entire Watershed). Gaps in air photo coverage have been age projected back by vegetational typing (ie 1952 and some 1965 interpretations). 1965 to 1973 era operations have been blocked by vegetational interpretation from 1981 photos and yarding methods characteristic of pre-1973 harvesting. For the 1974 to 1990 era, a combination of LANSAT imagery and 1988/ 1996 air photo interpretation was used. The CDF THP GIS overlays were used to develop the 1991 to 2001 harvest mapping.

<u>1868 to 1911</u> The original old growth harvesting was limited (1) the alluvial basins of the North Fork and (2) throughout the narrow South Fork Valley basin. No more than 33% of the North Fork basin was harvested by 1911. Only the lowest reaches of Rockpile, Buckeye, and Wheatfield basins were harvested (12 to 15% of the total acreage). This was due to limited access by rail.

<u>Pre-1936 Timber Harvest</u> The mid sized second growth stands in the 1936 photos show a long period of inactivity. There are no logging roads leading inland from the coast. The original rail-line network had long been abandoned during the Great Depression. Some fruit orchard ownerships were scattered along the coastal plain.

<u>1936-1952</u> The first timber operations after the Great Depression and WWII were small scale overstory removal/ higher grade timber harvests shown in the 1952 photographs. These are located in the North Fork (Dry and Robinson Creeks) and Pepperwood Creek tributaries. The first interior logging road was built along the North Fork to Dry Creek. Ranchland conversions started along the lower Wheatfield Fork and the central reaches of the South Fork, upstream of the confluence with Wheatfield Fork.

<u>1952-1960</u> Between the mid 1950s to the late 1960s, most timbered areas of the watershed were logged. Both the Gualala and Annapolis Mills were running at full capacity. Huge log decks can bee seen in the aerial photos. Between 1952 and 1960, large timbered block areas were removed. In time, these often merged to form larger continuous harvest areas. A total of 32.5% of the North Fork, 47% of the Rockpile, 41% of Buckeye, and 23% of the Wheatfield basin had been logged cumulatively since 1942. Haul roads were built directly in the mid and upper reaches of Rockpile and Buckeye Creeks. Similarly, roads were built up the lower and middle reaches of Fuller, Haupt, Tobacco, Tombs, and McKenzie Creeks.

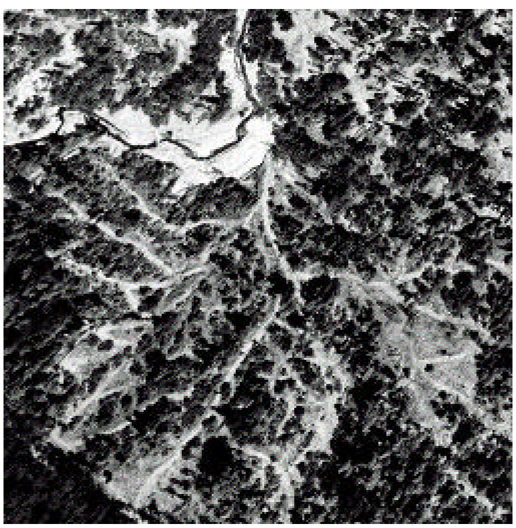
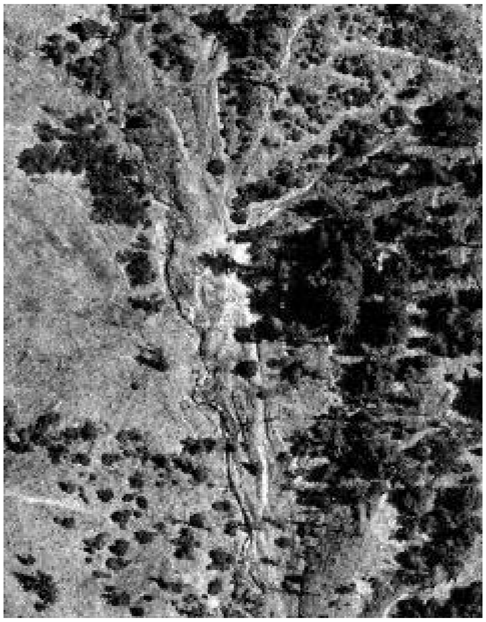


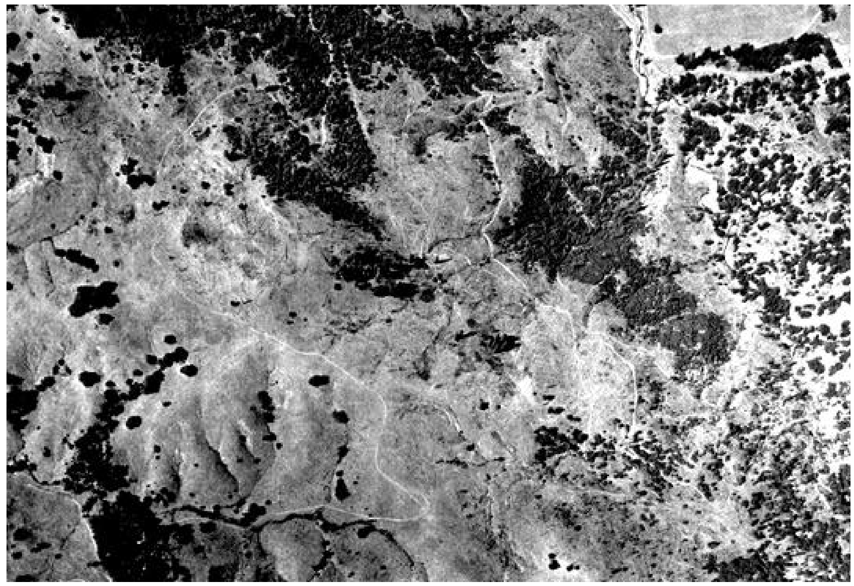
Figure 54: Left: Streamside road network leads to a landing complex adjacent to the North Fork Wheatfield. This streamside landing was built onto a natural geologic sediment terrace, as verified in 1942 photos.
Right: Kelly road built through an active slide area, 1965. The left bridge approach was built onto the slide mass that had slumped into Buckeye Creek. The 1964 flows undermined the left bridge approach, causing the edge of the road to collapse (red arrow). Note braided channel pattern patterns indicating an aggraded stream channel. 1999 photos show this same area with fewer braided channel patterns indicating decreasing bed loads. Also note log debris that had floated down onto the bridge approach.

Harvest methods frequently removed larger dimensional conifer timber leaving defective trees and hardwoods. Riparian areas containing the largest trees were essentially clearcut harvested. Mid slope to higher reaches of mixed conifer-hardwood timberstands were selectively harvested leaving tanoak and madrone to create hardwood dominated stands. Pocket conifer areas were left on very steep ground and inner gorge canyons beyond the reach of the tractor winch.

With 95% of the watershed in private ownership, high market demand coincided with active logging on private ranchlands. In contrast to the 1936 and 1942 photos which show agricultural/ ranch development limited to the coastal plain, the 1950s was a period of initial ranch development inland. Old growth coniferous stands were logged in conjunction with fencing and road development as part of expanding ranch operations. Growing herds of cattle roamed former forestlands as converted pastureland. Land clearing for ranch development is the dominant land use in Tombs, Wolf, McKenzie, Pepperwood, and Wolf Creeks, the Upper South Fork, and Upper Wheatfield Forks. To the north, Osser and Roy Creeks, tributary to Buckeye Creek. were entirely logged by this time under private ranch ownerships. Many of the ranches later sold to larger timberland companies representing a consolidation of private ownerships over time.

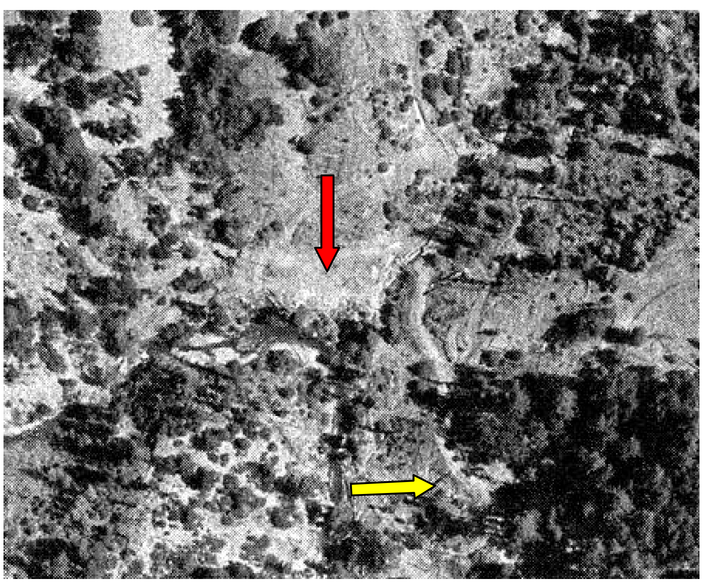


McKenzie Creek (1965)



Pepperwood Creek (1965)

Figure 55: Ranchland conversions to pastureland (1) in McKenzie Creek (center of photo) and (2), in Pepperwood Creek (upper right of photo) 1965.



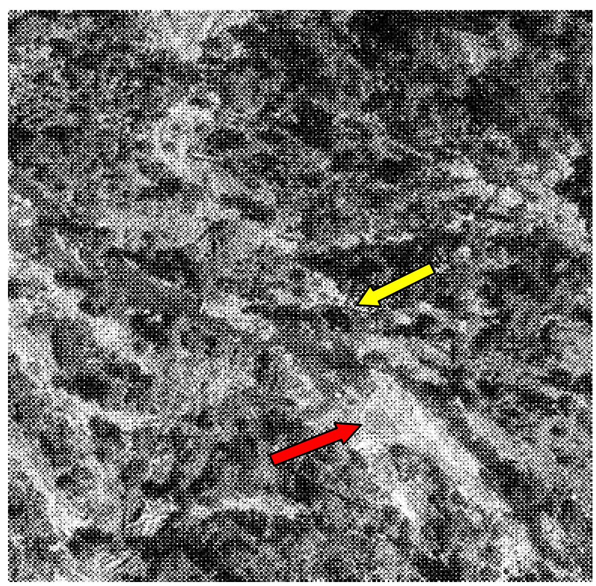


Figure 56: Left: In stream landing operations (red arrow) adjacent to an old growth residual stand (yellow arrow) showing original conifer tree cover over an upper tributary stream to Marshall Creek.
Right: In stream landing operations (red arrow) disrupted stream flow patterns (yellow arrow) of a larger order fish bearing watercourse in the Marshall Creek tributary subbasin by flattening stream channel structure (1965).

<u>1960-1964</u> The 1960 to 1964 era is blocked to show the rapid continuous rate of logging operations leading up to the 1964 flood event This is based on the availability of 1965 air photo coverage. As shown in the logging history maps (Main Gualala Report) isolated harvest block had merged by 1964 to form larger continuous areas. This extended throughout the central

reaches of the watershed to comprise a total of 47% of the North Fork, 61% of the Rockpile, 65% of the Buckeye, and 30% of the Wheatfield sub-basins cumulatively since 1942. Only the lower South Fork Upper South downstream of the confluence with Wheatfield Fork remained inactive.

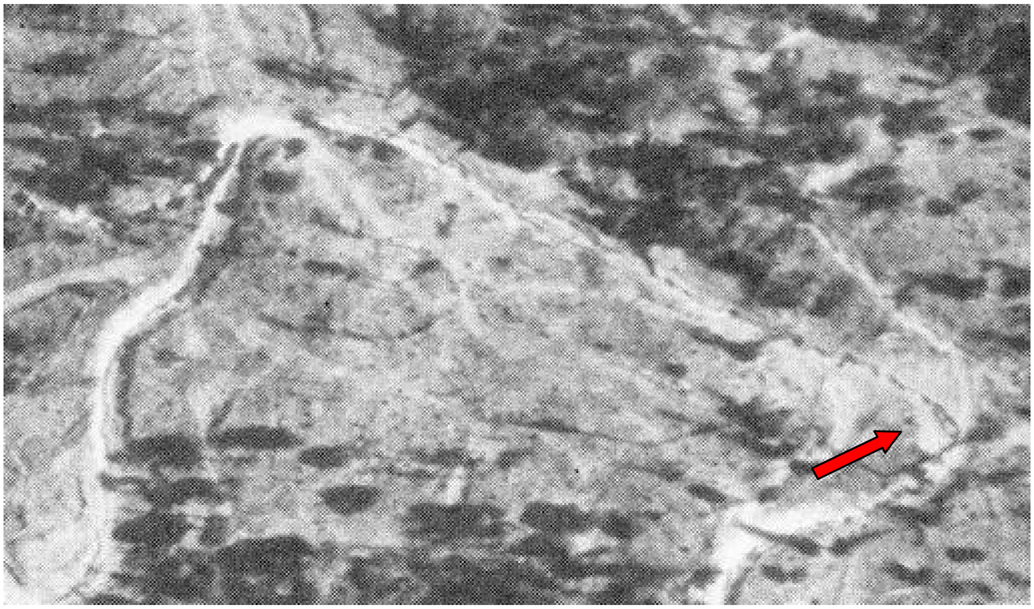
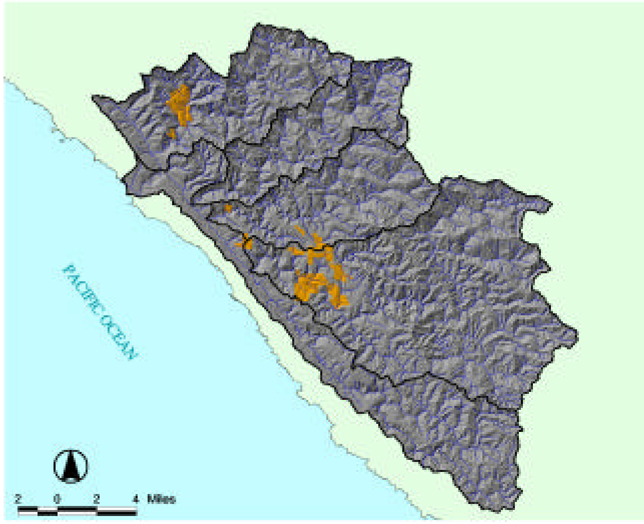


Figure 57: Stream diversion (red arrow) of a tributary stream to the North Fork Wheatfield onto a logging road

1964-1973 After 1964, harvest operations continued at an active rate in the lower and middle reaches of the North Fork and entire Little North Fork areas to remove most of the available timber base in these areas by 1973. Harvest operations removed an additional 10% of the North Fork basin to total 60% of the sub-basin acreage by 1968. Other areas of mature conifer timber in (1) higher elevation areas and (2) east reaches of the watershed, were harvested during this time. Only pocket stands and scattered larger timbered blocks remained. Road and landing locations continued to be located low on the sideslope, frequently following the stream channel. Subsequent landing blowouts and road failures have been documented along the Little North Fork and central North Fork. There were large storm events in 1972 and 1975 affecting these areas. Other timbered areas in (1) higher elevations, and (2) east reaches of the watershed, were harvested during this time. Only pocket stands and scattered larger timbered blocks remained be 1968. Continued forest clearance on ranchlands was pronounced in the middle to upper reaches the Wheatfield Fork sub-basin, including the upper House, Pepperwood, Wolfe, and Tombs Creeks.

1973-1990 This was a period of relative inactivity compared to previous eras. Logging operations were slow during the recessions of 1970 and 1973. During the later 1970s, partial stand entries and commercial thinnings were the dominant stand treatments. Smaller selection method harvests were predominant. By this time, tractor yarding methods changed to maintain equipment exclusion zones and minimum vegetation retention standards adjacent to watercourses per 1973 Forest Practice Rules. New road locations were moved upslope. The new forest practice rules limited the cutblock size, creating smaller logged areas. In the 1990s, harvest activity increased. Smaller but numerous clearcut blocks appear in the redwood lowland areas of the Gualala Redwoods ownership. Throughout the watershed, cable method yarding appears with new road construction now moved to mid-slope bench and ridgeline locations. Many sections of the older seasonal roads following the stream channel are either abandoned or removed.

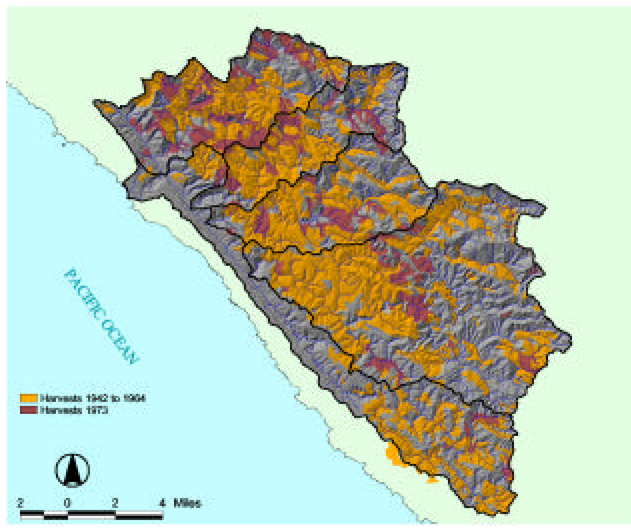
1991-present Active harvest operations resumed during this decade. The clearcut method becomes predominant. Original turn of the century harvest areas were reentered. These areas had been avoided during the 1960s. By the late 1980s, the timberbase in the alluvial basins had become mature and was subject to harvest. Smaller but multiple clearcut blocks appear in the lower and central reaches of the North Fork and lowest reaches of the Rockpile, Buckeye, and South Fork sub-basins In a ten year period between 1991 and 2001, a total of 36.6 % of the North Fork sub-basin has been subject to timber harvest plans. 50% of the Rockpile basin, 32% of the Buckeye, and 15% of the South Fork. However, many of these THPs consisted of partial stand entries and thinnings. These operations do not compare to the large continuous block clearance harvests of the 1950s and 1960s. In addition, the cable yarding method has become more routine during the last decade. The shift in the road network to upslope locations in recent times is more suited to cable yarding. During the mid 1990s, Coastal Forestlands (formerly R&J Timber Co.), purchased by Pioneer Resources in 1998, submitted numerous seed tree overstory removal/ dispersed harvest THPs. These THPs covered large areas but removed scattered single trees and remnant stands left from 1960s era entries. The THPs comprised a significant part of total acreage in the Rockpile and Buckeye basins between 1991 and 2001. Agency review of these THPs clarified road upgrade work requirements to repair erosion conditions of pre-1973 operations. There has been little harvesting in these areas since 1998.



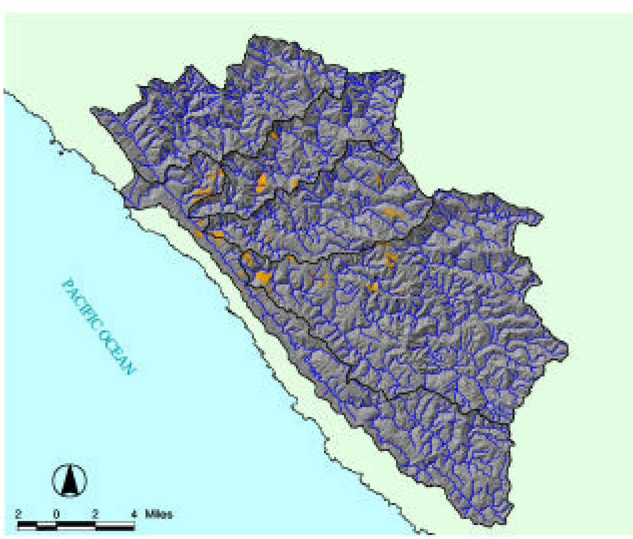
1942 – 1952 Stand Replacement Operations.

1942 – 1960 Stand Replacement Operations

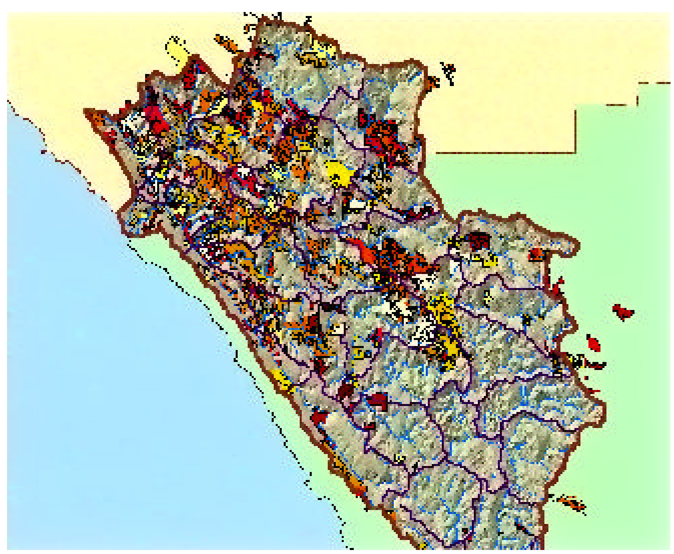
1942 – 1964 Stand Replacement Operations.



1942 - 1973 Stand Replacement Operations
[1964 – 1973 (red)]

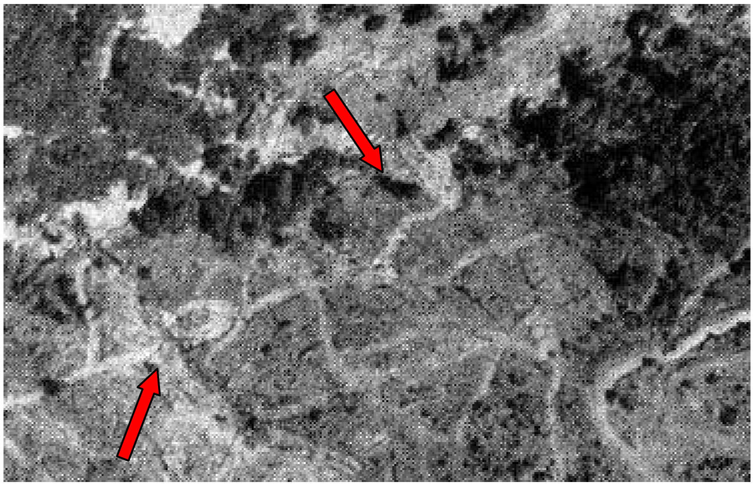


1973 – 1990 Stand Replacement Operations



1991 – 2001 Timber Harvest Plans

Figure 58: Cumulative Progression of Timber Harvesting and Ranchland Conversions 1942 – 1973, and post 1973 Harvests



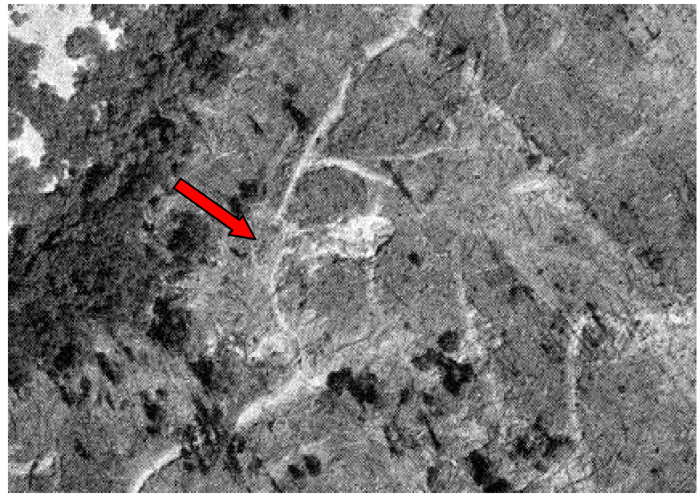
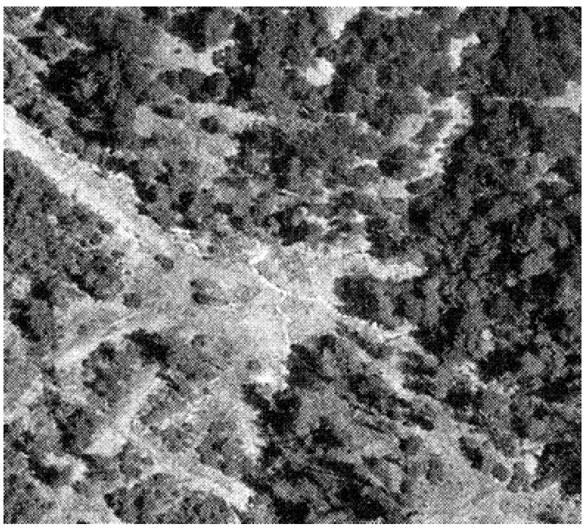


Figure 59: Left: Road washouts on a tributary to Britain Creek. Right: An earth flow complex buries a logging road in the Britain Creek tributary subbasin.



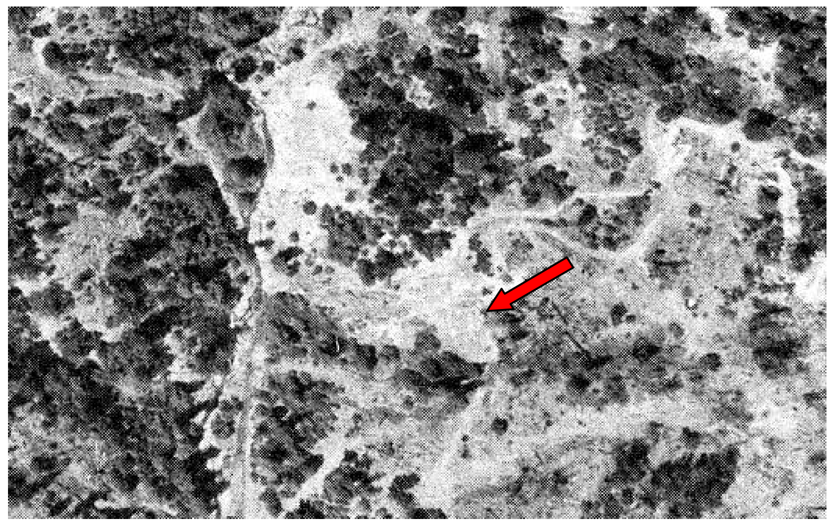
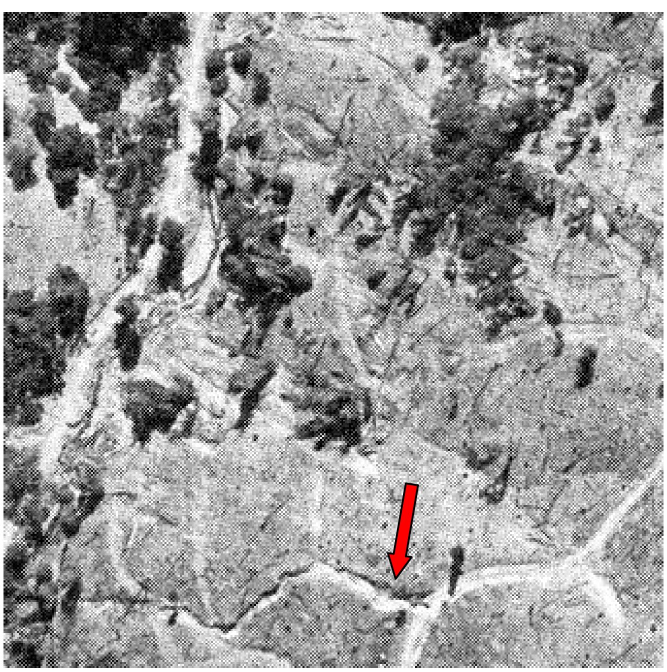


Figure 60: Left: In stream landing. Right: A large debris slide removed a portion of the logging road.



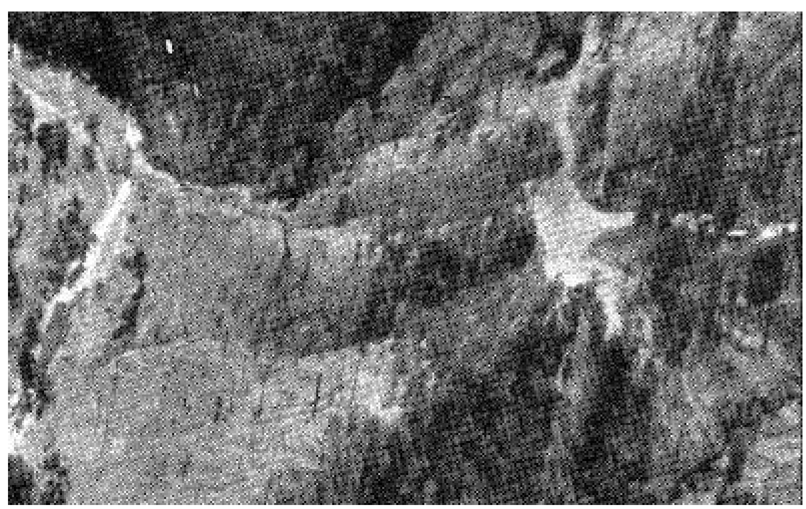


Figure 61: Top: Landing complex covering three watercourses.
Left: Stream diversion (red arrow) down a logging road

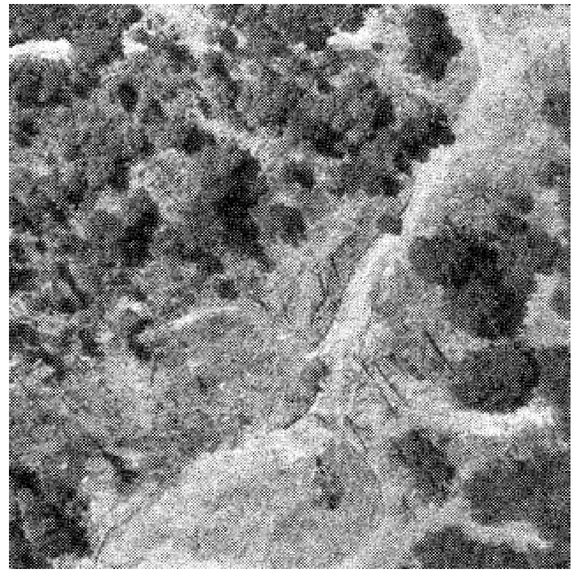


Figure 62 : Top: Road building along the streambed graded the channel smooth and straight creating a ditch. Left: Riparian clearance and logging debris over a tributary to Danfield Creek. Note debris accumulations over channel at a skid crossing (red arrow).

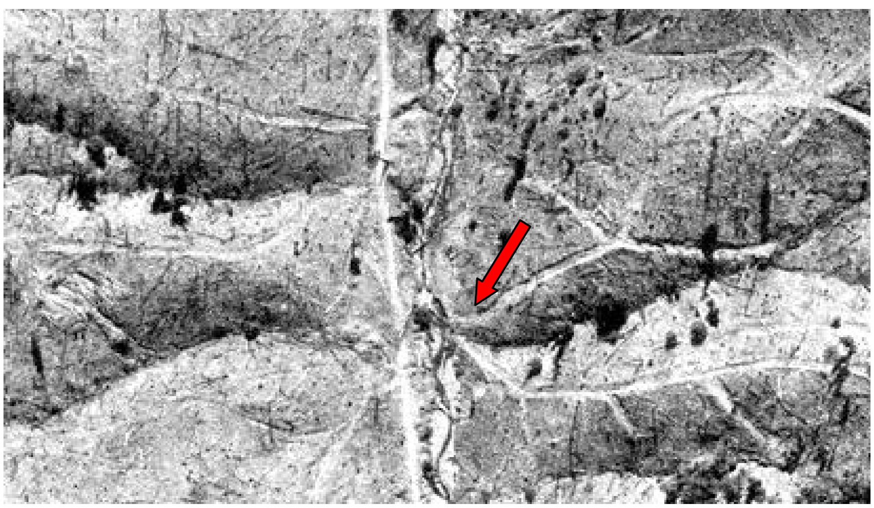


Figure 63: Left: Riparian clearance over a tributary to Danfield Creek. Note skid crossings incised down by the main channel (red arrow). The streams were not used as skid trails in this area. Right: Riparian conifer removal along an unnamed tributary to the Main Stem Wheatfield Fork downstream of the confluence with House Creek.

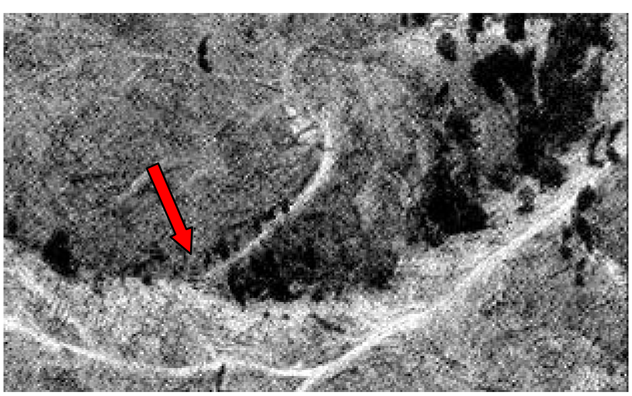


Figure 64: Potential THP repair site of a legacy stream crossing. Right: Concurrent logging operations in Pepperwood Ck.

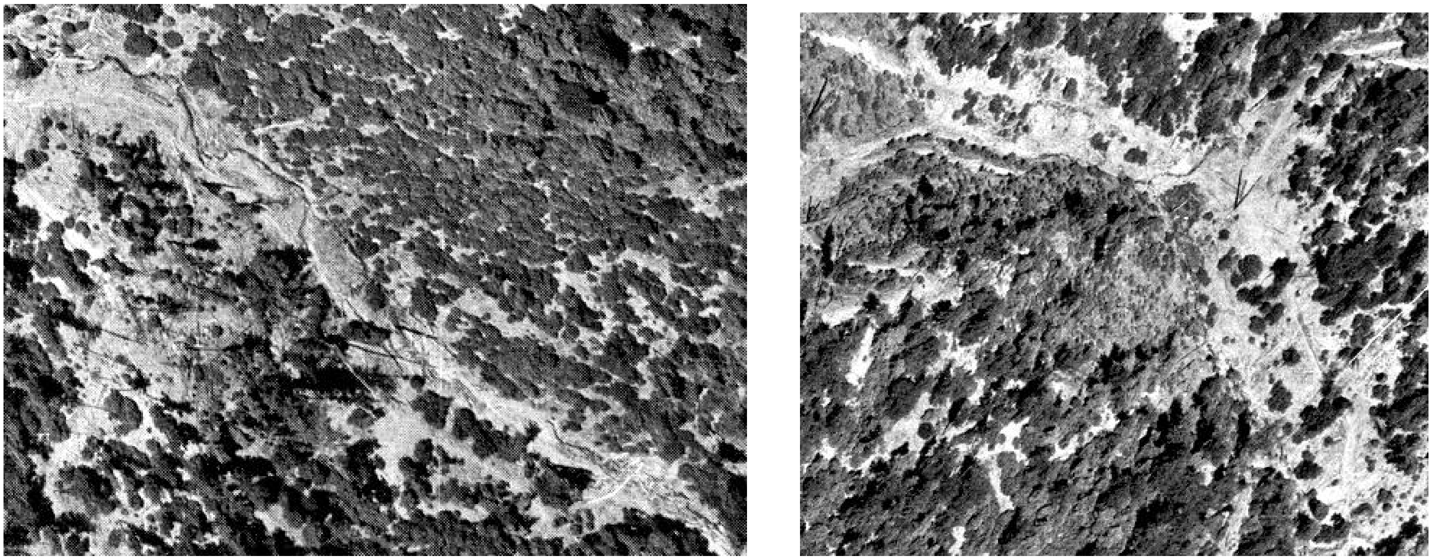


Figure 65: Streamside roads often made several crossings over channel to avoid ungradable obstacles along the streambed in a lower tributary stream to House Creek.

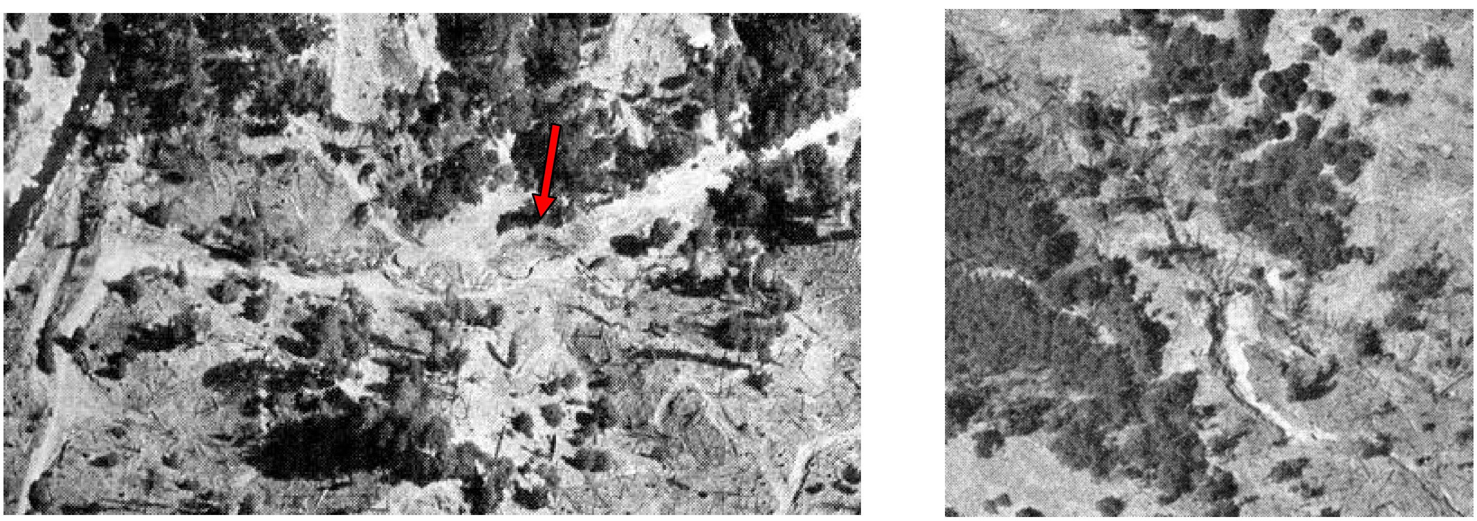


Figure 66: Wheatfield Fork (upper left) downstream of the confluence with House Creek. Red arrow shows a washout of a portion of the streamside road. Right: Debris torrent slide in the Danfield Creek tributary subbasin within a logging area in 1965.

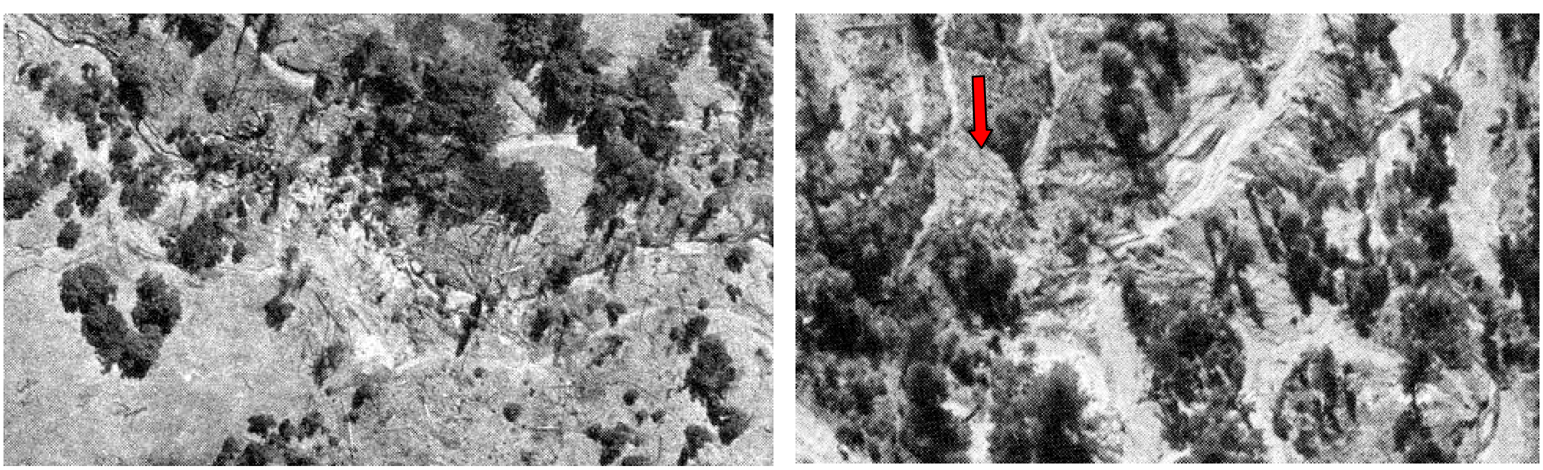


Figure 67: Left: Angular channel pattern at a stream crossing. Right: A debris slide breaching three road contours at Wolfe Creek (right).

VI DISTRIBUTION OF FOREST TYPE

Prior to European settlement, coniferous forest extended throughout approximately two thirds of the watershed. Dense old growth redwood forests occupied the narrow South Fork Valley basin, and throughout the lower alluvial basins of the North Fork. Mixed Redwood/ Douglas-fir and then pure Douglas-fir stands generally predominated in central and mid slope locations more distant from the coast. Further inland in the east portion of the watershed, the natural distribution of conifers becomes increasingly fragmented. Here, the long summer drought limits conifers to north facing slopes. The oak-woodland predominates as a more continuous distribution on higher, inland terrain the more distant from the coastal marine influence. Large areas of prairie grassland occupy the driest sites along ridge and upslope locations. These occupy larger continuous areas on the highest and easternmost areas of the watershed.

With ranching the dominant use in mixed conifer –oak woodland areas, coniferous logging was frequently followed by prolonged cattle grazing. This reduced, and in many locations prevented conifer reestablishment altogether. Grassland became permanently established throughout compacted ground. In addition, removal of Douglas-fir in mixed conifer-hardwood forests frequently converted these stands to pure tan oak and madrone. 1936,and 1942 aerial photos show larger areas of mature mixed Redwood/ Douglas-fir stands under various stages of harvest removal. These stands consisted of homogenous mature conifer timber lining creeks and becoming mixed hardwood stands upslope. The 1981 and 2000 photos often show hardwood stands, brushfields, and grasslands in these same areas The natural conifer distribution has been appreciably replaced in the central and east portions of the watershed. With abandonment of many ranching operations in recent years, site regeneration of conifer seedling and sapling sized trees has been noted in riparian areas and north slopes on former ranchland, as described in various PHI reports.

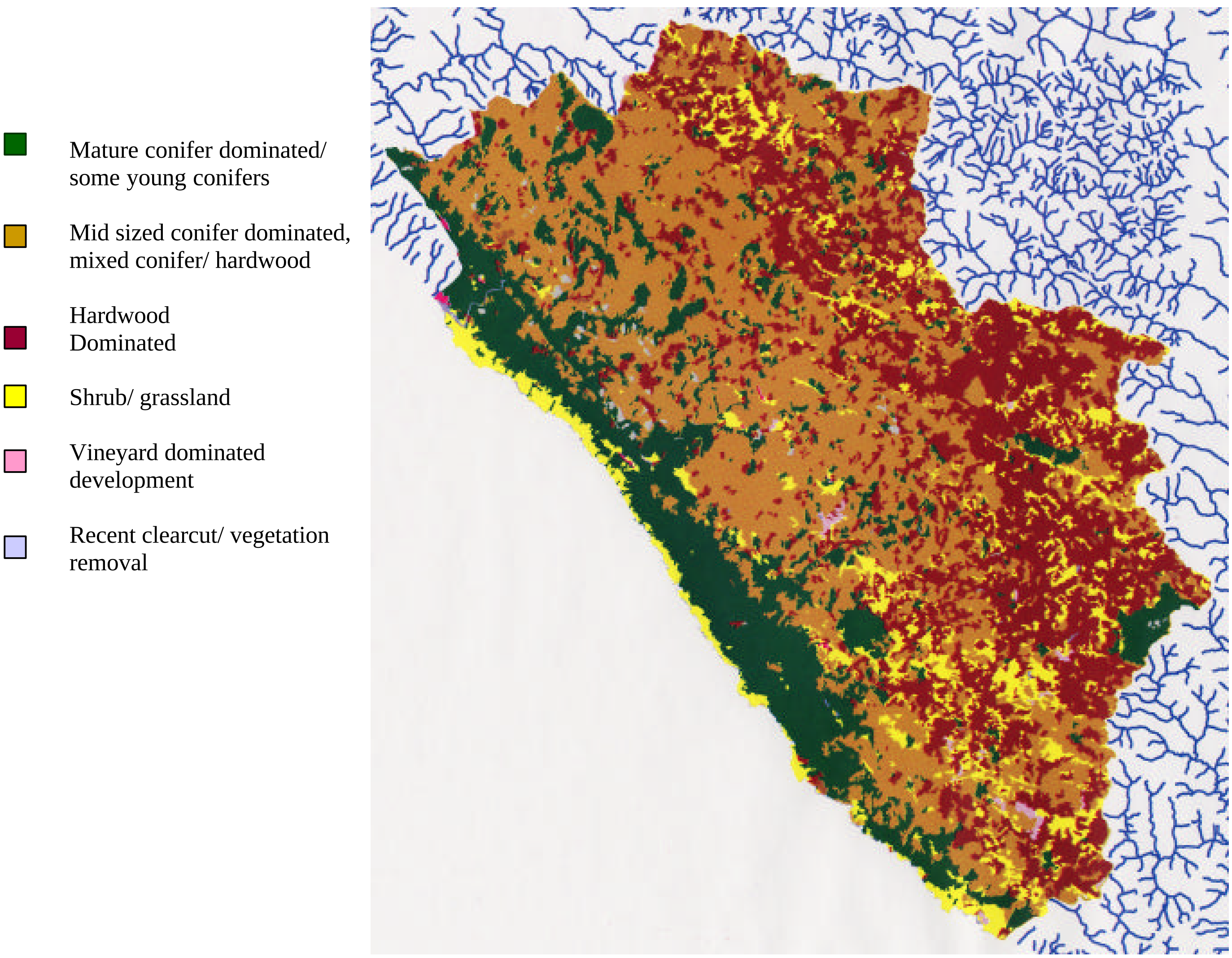


Figure 68: Vegetation Type Classifications of the Gualala Watershed

Vineyards have been established in more recent years, mostly on ridgeline locations. However, Lansat imaging shows that conversion acreage of conifer to vineyard and other agricultural uses does not exceed 700 acres for the watershed. (Table 11). In addition, the CDF THP Conversion Files show a total of 500 acres of approved conversions of timberland to alternative uses. The 1999 vegetation cover map above (Figure 68) shows vineyard development limited to scattered block areas in the southeast portion of the watershed.

Mid sized conifer/ mixed conifer hardwood stands dominate overall vegetational distribution. This reflects younger ingrowth from the wide scale block clearance harvesting in the late 1950s/ early 1960s throughout the central reaches of the watershed. The narrow South Fork rift zone has the largest concentration of mature conifer timber. These areas have been subject to recent THP activity. Much of the mature second growth conifer stands in the lower to central reaches of the North Fork have also been subject to recent THP activity. This has created a mosaic of mature coniferous stands intermixed by young third growth conifer plantations.

MAJOR VEGETATION TYPES BY SUBBASIN (Table 11)

North Fork Subbasin 30,583 Acres

North Fork Vegetaton Type	Acres	% Area
Timberland	25,390	83.0
Hardwood/ Brush	3,639	11.9
Grassland	1,504	4.9
Agriculture	18	0.1
Development	32	0.1

Rockpile Subbasin 22,389 Acres

Rockpile Vegetaton Type	Acres	% Area
Timberland	17,701	79.0
Hardwood/ Brush	4,000	17.8
Grassland	687	3.2
Agriculture	0	0.0
Development	0	0.0

Buckeye Subbasin 25,761 Acres

Buckeye Vegetaton Type	Acres	% Area
Timberland	25,390	80.5
Hardwood/ Brush	4,411	17.1
Grassland	578	2.2
Agriculture	27	0.1
Development	21	0.1

Wheatfield Subbasin 71,385 Acres

Wheatfield Vegetaton Type	Acres	% Area
Timberland	41,584	58.3
Hardwood/ Brush	23,597	33.0
Grassland	6,004	8.4
Agriculture	195	0.3
Development	3	0.0

Gualala South Fork 40,736 Acres

South Fork Vegetaton Type	Acres	% Area
Timberland	30,532	73.0
Hardwood/ Brush	7,200	17.7
Grassland	2,488	6.1
Agriculture	425	1.0
Development	92	0.2

FIRES

Fires have played a major role in shaping the vegetation, especially in the east portions of the watershed.. Young hardwood stands of madrone and California Bay are particularly vulnerable fuels to fires. The earliest known recorded large fire occurred in 1901 along the Upper South Fork. Subsequent fires have largely occurred in the Wheatfield and Upper South Fork sub-basins (see Figure 69 below) Many of these have been lightning induced.

Modern fires tend to be larger, but less frequent. With a large build-up of fuels spanning decades, contemporary fires crown out more often, eliminating the entire stand. Pre-historic fires were more frequent, but covered less acreage. These typically burned close to the ground, limited to brush and understory vegetation fuels only. Overall acreage between historic and pre-historic fires is generally similar, reflecting eventual elimination of fuels, and evolutional adaptation of the vegetation to fires.

Erosional impacts from these fires are unknown. Mid century tractor logging patterns were comparatively more erosive. Runoff during large storm events concentrated down skid trails and roads triggering debris slides into streams. Although fires can scarify the ground, runoff is comparatively more dispersed.

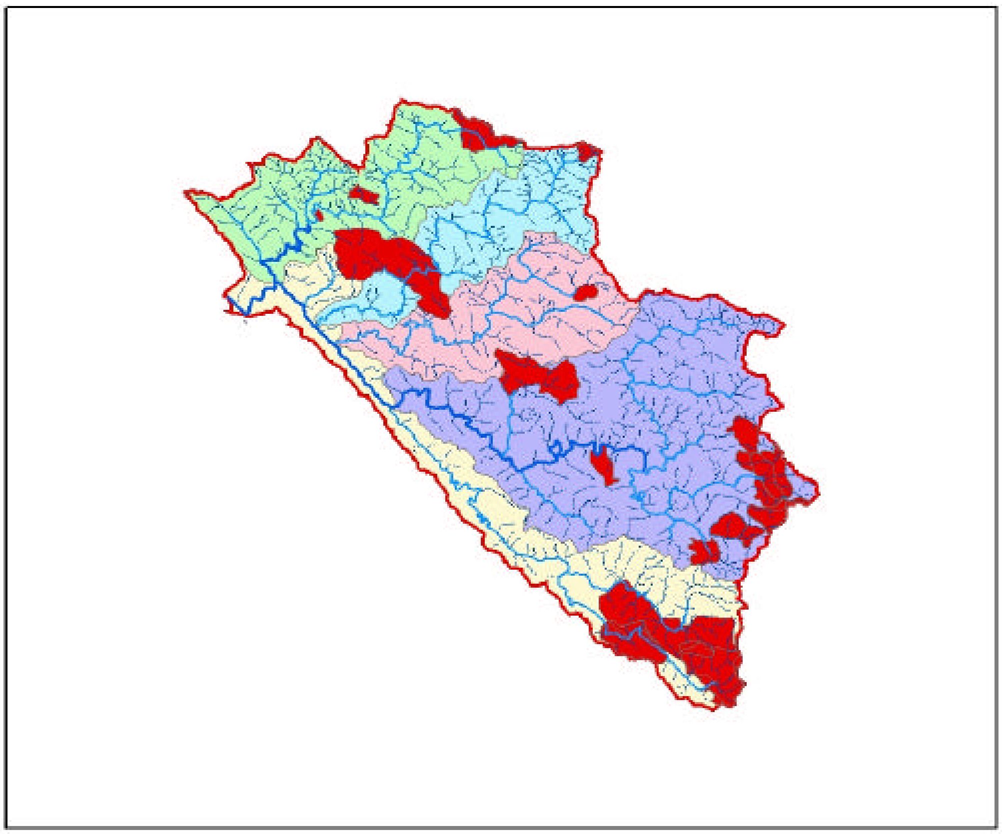


Figure 69: Post WW II fires in the Gualala Basin (red)

Approximately 60% of the mapped fires occurred between 1950 and 1959. The 1982 Creighton Ridge Fire has been the largest fire during the last 20 years. However, there continues to be a general lack of recent fire activity. This indicates a fuels build-up. The vegetation type map (Figure 31 above) shows large areas of small hardwoods and shrubs in the east basin reaches. Ground surveys confirm large distributions of mid sized tan oak, laurel, and madrone in these areas. This indicates a potential for a large catastrophic fire in the near future.

Major Vegetation Cover Type Along Blue Line Streams

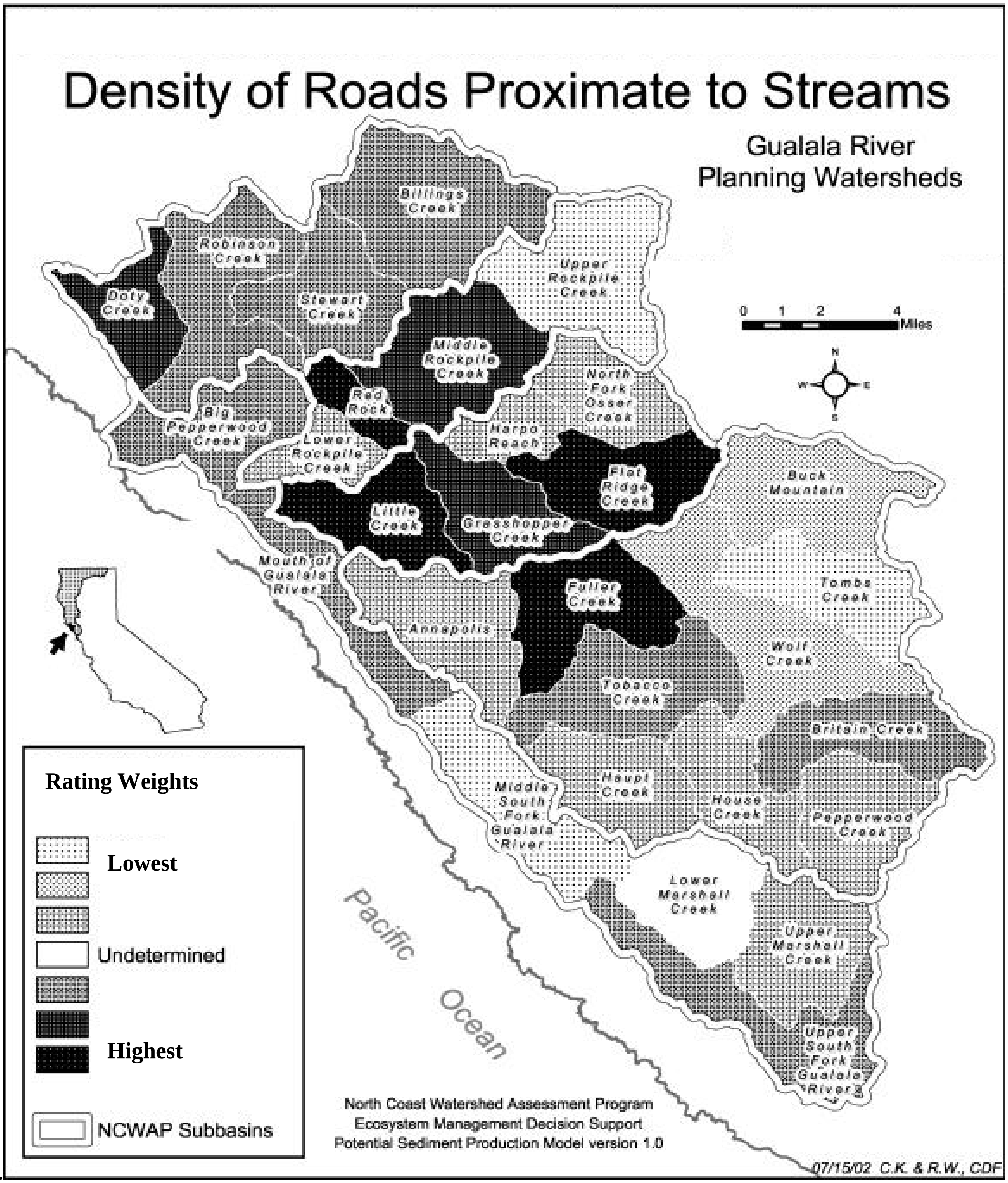
CWHR Vegetation Type Along Streams — 1st, 2nd, 3rd

Gualala Watershed

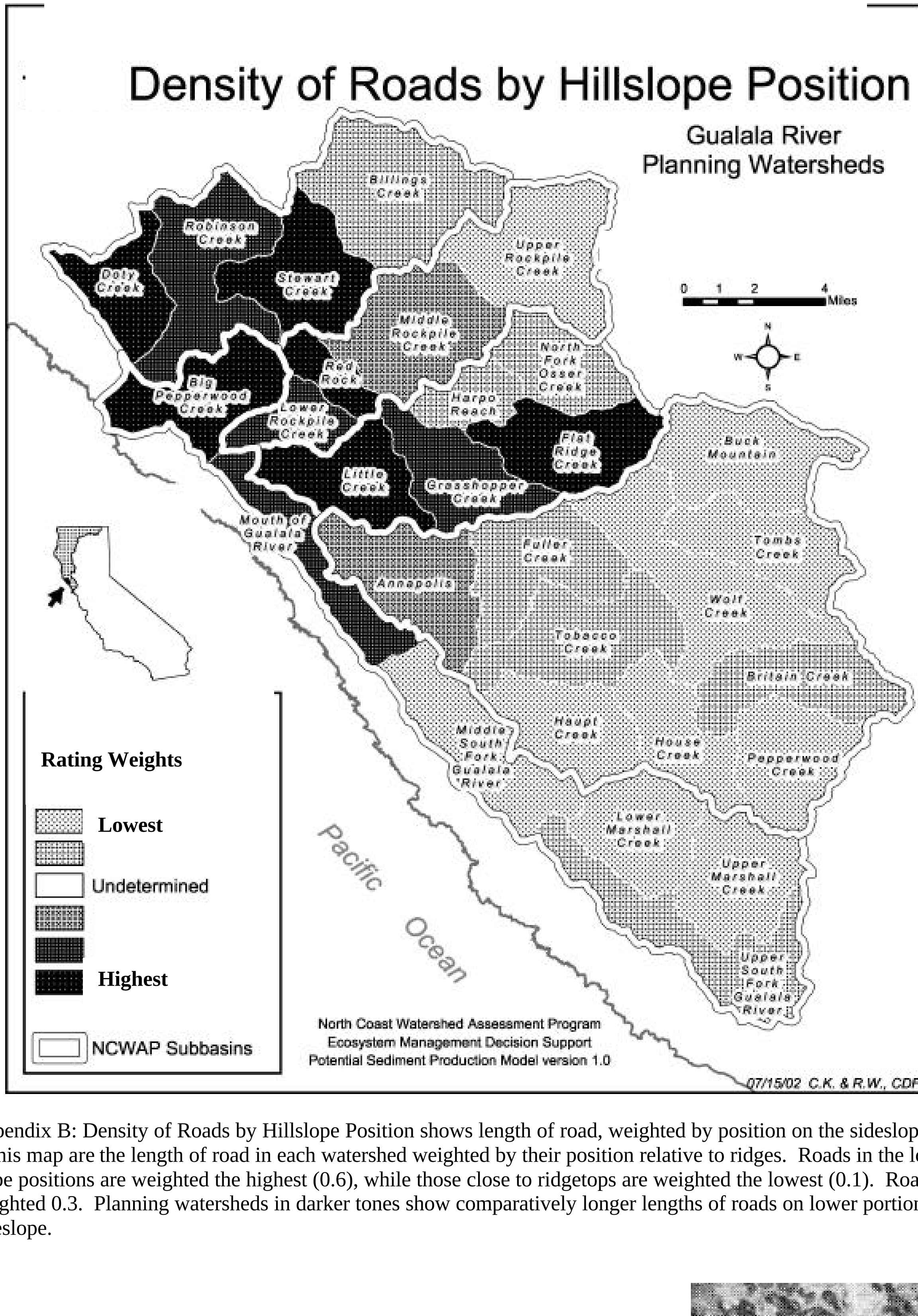
[meters(percent)]	*Douglas Fir*		*Montane Hrdwd*		*Mont. Hrdwd-Cnfr*		*Ann. Grassland*		*Redwood*		*Co. Oak Wdlr*
Planning Watershed Name											
Billings Creek	20477	33%	24702	40%	1617	3%	9237	15%	5156	8%	0
Robinson Creek	162	0%	5702	8%	978	1%	122	0%	65371	90%	0
Upper Rockpile Creek	32072	48%	27190	41%	2071	3%	5382	8%	0	0%	0
Stewart Creek	4714	11%	4964	12%	1107	3%	297	1%	31991	74%	0
Doty Creek	0	0%	1023	4%	738	3%	7	0%	22016	93%	0
Middle Rockpile Creek	642	1%	16625	37%	2032	4%	1602	4%	24522	54%	0
North Fork Osser Creek	10702	35%	13143	44%	1130	4%	4464	15%	740	2%	0
Big Pepperwood Creek	0	0%	4668	14%	562	2%	1244	4%	22643	66%	0
Red Rock	0	0%	1216	10%	431	4%	16	0%	10072	86%	0
Harpo Reach	1943	11%	5787	32%	391	2%	395	2%	9612	53%	0
Lower Rockpile Creek	0	0%	752	5%	281	2%	11	0%	13847	93%	0
Grasshopper Creek	9307	30%	6622	22%	1782	6%	406	1%	12586	41%	0
Flat Ridge Creek	13150	20%	21458	33%	2884	4%	3928	6%	24252	37%	0
Buck Mountain	8494	17%	34881	71%	625	1%	4621	9%	0	0%	0
Liittle Creek	0	0%	5645	17%	814	2%	1039	3%	25513	77%	0
Mouth of Gualala River	0	0%	103	0%	7	0%	527	3%	18892	90%	0
Wolf Creek	11130	20%	37669	66%	3729	7%	3374	6%	162	0%	122
Tombs Creek	9501	27%	20948	59%	534	1%	4166	12%	0	0%	0
Annapolis	0	0%	2367	7%	81	0%	1203	4%	29318	87%	0
Tobacco Creek	5280	11%	9590	21%	1246	3%	5902	13%	24214	52%	0
Middle South Fork Gualala Riv	0	0%	2235	6%	118	0%	1549	4%	34435	89%	0
Britain Creek	3521	9%	24845	65%	214	1%	5743	15%	92	0%	0
House Creek	5426	19%	15369	55%	1338	5%	4773	17%	7	0%	0
Haupt Creek	3680	12%	9650	32%	398	1%	3480	11%	13425	44%	0
Pepperwood Creek	2254	6%	20246	53%	74	0%	7313	19%	0	0%	1315
Lower Marshall Creek	1932	5%	16183	45%	1123	3%	11116	31%	5368	15%	0
Upper Marshall Creek	7031	17%	12274	29%	3517	8%	6762	16%	9626	23%	2708
Upper South Fork Gualala River	1489	4%	14744	35%	2855	7%	7424	18%	12616	30%	2921
Total	142453	15%	317398	33%	25179	3%	70799	7%	388863	40%	1437
Subbasin											
Buckeye Creek	31357	22%	46496	32%	5655	4%	9322	6%	50650	35%	0
Gualala	10389	5%	50605	24%	8244	4%	28195	14%	103458	50%	5756
North Fork	25329	13%	36698	18%	4418	2%	9495	5%	124439	62%	0
Rockpile Creek	32809	24%	46056	33%	4775	3%	6839	5%	48307	35%	0
Wheatfield Fork	53026	14%	182386	48%	9627	3%	40748	11%	89275	24%	1479

Figure 70: CWHR vegetation type along streams, Gualala Watershed

APPENDIX

5. 

Appendix A: Density of Roads Proximate to Streams *shows total length of roads near watercourses. Planning watersheds with a high density of roads near streams show where additional field scrutiny is advised to determine the necessity of road upgrade and improvement work. Planning watersheds in lighter tones show lower priority areas based on this assessment.*

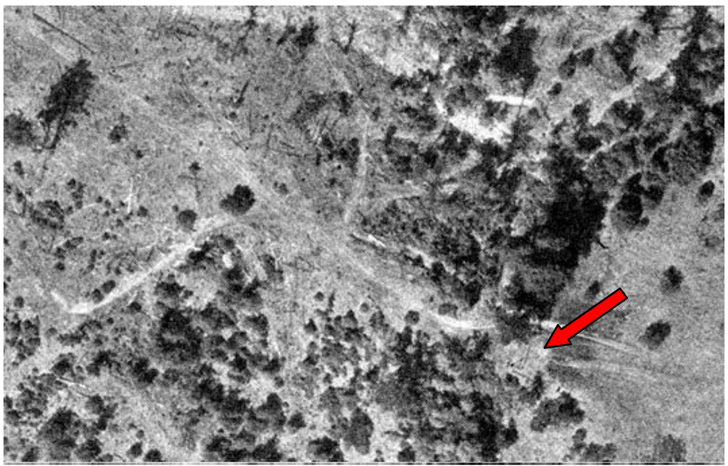


Appendix B: Density of Roads by Hillslope Position shows length of road, weighted by position on the sideslope.. The tones in this map are the length of road in each watershed weighted by their position relative to ridges. Roads in the lowest 40% of slope positions are weighted the highest (0.6), while those close to ridgetops are weighted the lowest (0.1). Roads between are weighted 0.3. Planning watersheds in darker tones show comparatively longer lengths of roads on lower portions of the sideslope.

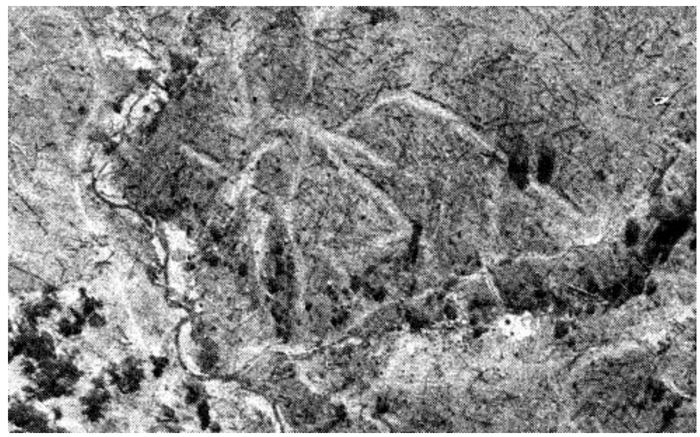
Appendix C

Landing complex built on an alluvial terrace

Top: Riparian clearance and channel disruption in Upper Wolfe Creek. 1965.



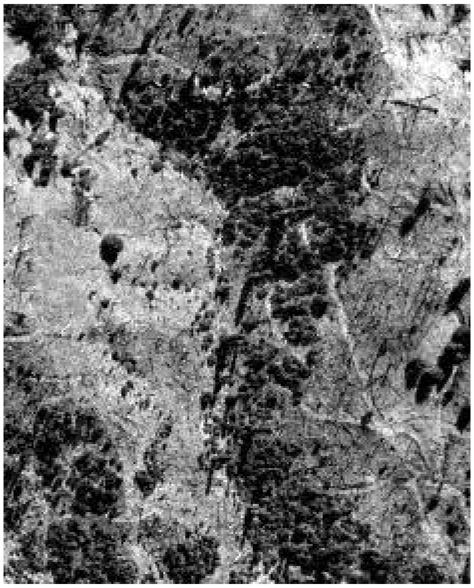
Disrupted channel pattern at a stream crossing.

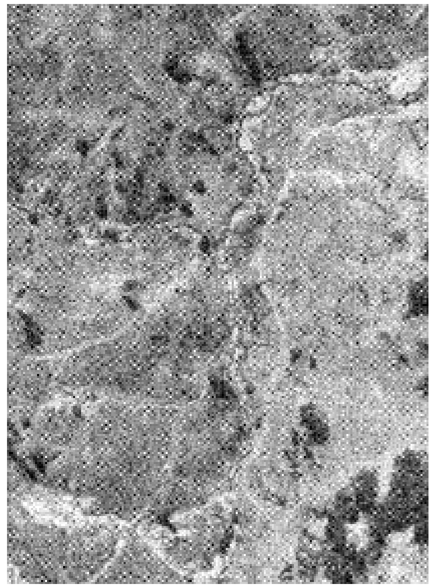


Upper House Creek tributary subbasin

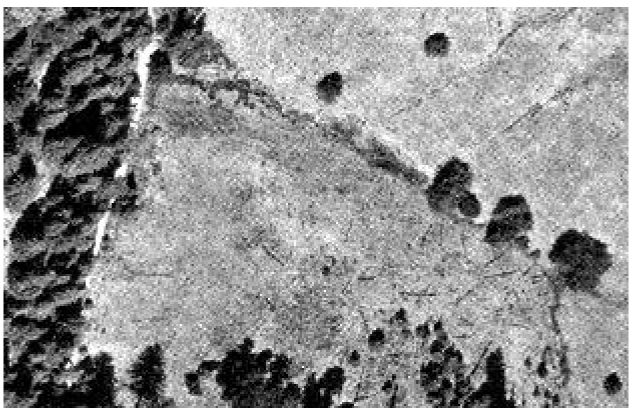
Tributary Upper South Fork

Road network leading downslope to a mainline streamside road along Wolfe Creek

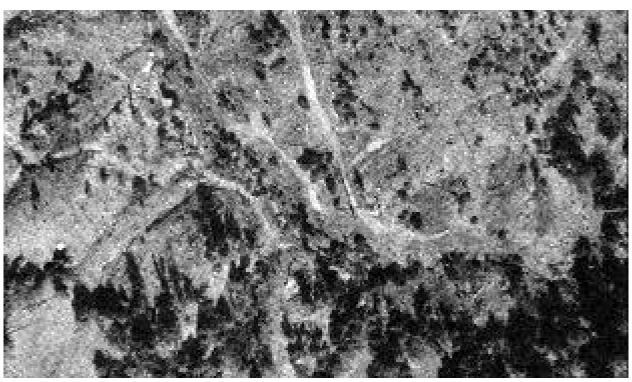




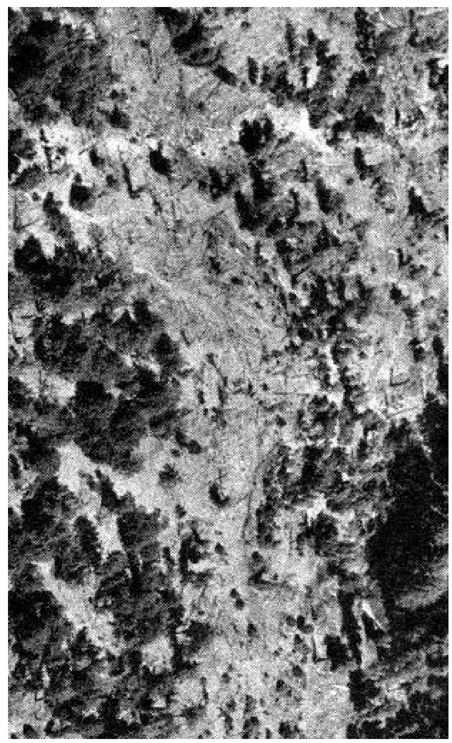
Riparian clearance in the central House Creek Subbasin.



Conversion to pastureland



Streamside road network, McKenzie Creek tributary subbasin



Riparian canopy clearance and streamside road network, McKenzie Creek tributary subbasin