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Department of Fish and Wildlife

M e m o r a n d u m

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Subject: REVISED Flood Prone Area Assessment of the "Little" Timber Harvesting Plan (1-18-095 MEN), Mendocino County, California

<u>Introduction</u>

As per your request, I am providing this memorandum to address a conflict that has arisen between the Gualala Redwood Timber, LLC (GRT) and the California Department of Fish and Wildlife (CDFW) regarding environmental protections for "Little" Timber Harvesting Plan (THP) 1-18-095 MEN. The conflict centers around delineating the extent of the *"flood prone area"* as defined in California's Forest Practice Rules (FPRs). More specifically, GRT proposes to limit the extent of the Little North Fork Gualala River (Little North Fork) *flood prone area* to only that part of the valley floor which is inundated by the 20-year recurrence interval flood flow event (20-year floodplain). In contrast, CDFW considers the outer boundary of the *flood prone area* to be the valley walls. The difference in areal extent between the 20-year floodplain versus that of the full width of the valley floor is considerable, so issues associated with habitat protection are potentially significant. Based upon a review of pertinent literature, reconnaissance level surveys at six sites, and detailed analysis of topography derived from Light Detection and Ranging (LiDAR) data, this memorandum explores GRT's technical basis for adopting the 20-year floodplain as the *flood prone area* instead of the full valley floor width. The memorandum is divided into multiple sections that begin with a discussion of definitions related to the term *flood prone area*. Subsequent sections review the findings of a recent Channel Migration Zone (CMZ) evaluation; sets forth a conceptual model of watershed and floodplain processes; and characterizes the existing geomorphic conditions of the valley floor. Delineations for both the *flood prone area* and CMZ are proposed, and the memorandum concludes with a short summary, two recommendations, and a list of references.

<u>Definitions</u>

Flood prone areas represent a unique set of hydrologic, geomorphic, and biological processes that collectively support high levels of biodiversity for both terrestrial and aquatic species (Naiman and Bilby, 1998). *Flood prone areas* of the coast redwood zone of northwestern California are considered to be the highest productivity timberlands available and are also recognized to be biologically important for aquatic and terrestrial species (CalFire, 2005). The term *flood prone area* is included, but not formally defined in the FPRs at least as far back as the middle 1990's. At that time, the term is one of several in a list of water-related features to be evaluated by a Registered Professional Forester (RPF) in the course of preparing a THP. In the early 2000s, disagreements emerged between timberland managers and THP reviewing agencies regarding the potential impacts of proposed timber operations within *flood prone areas*. In response to those disagreements, CalFire convened the interagency Riparian Protection Committee (RPC). Several meetings of the RPC were held in 2005 to discuss the issues of concern related to *flood prone area* timber operations. Subsequent to those meetings, a white paper report was prepared titled: *Flood Prone Area Considerations in the Coast Redwood Zone* (CalFire 2005). The paper formally defines *flood prone area* to be *"the area adjacent to a watercourse or lake that is periodically covered with water and contributes to the interchange between terrestrial and aquatic components of the watershed. The frequency of inundation can vary from more than once a year to greater than every 100 years"* (CalFire, 2005, p. 6).

A formal definition of flood prone area was not included in the FPRs until 2010, and it states:

> **Flood Prone Area** *means an area contiguous to a watercourse channel zone that is periodically flooded by overbank flow. Indicators of flood prone areas may include diverse fluvial landforms, such as overflow side channels or oxbow lakes, hydric vegetation, and deposits of fine-grained sediment between duff layers or on the bark of hardwoods and conifers. The outer boundary of the flood prone area may be determined by field indicators such as the location where valley slope begins (i.e., where there is a substantial percent change in slope, including terraces, the toes of the alluvial fan, etc.), a distinct change in soil/plant characteristics, and the absence of silt lines on trees and residual evidence of floatable debris caught in brush or trees. Along laterally stable Watercourses lacking a Channel Migration Zone where the outer boundary of the flood prone area cannot be clearly determined using the field indicators above, it shall be determined based on the area inundated by a 20-year recurrence interval flood flow event, or the elevation equivalent to twice the distance between a thalweg riffle crest and the depth of the channel at Bankfull stage. When both a Channel Migration Zone and flood prone area are present, the boundaries established by the Channel Migration Zone supersede the establishment of a flood prone area*.

There are several phrases within the FPR definition that require clarification: *periodically flooded*, *laterally stable watercourses*, *channel migration zone, and elevation equivalent to twice the distance between a thalweg riffle crest and the depth of the channel at Bankfull stage*.

1. *Periodically flooded* - Neither CalFire (2005) or the FPRs define "*periodically*" in terms of a recurrence interval flood event, and the CalFire (2005) definition is explicit in stating that the frequency of inundation of a *flood prone area* can be greater than 100-years. Similarly, the term *"floodplain"* is not used in either of the definitions. CalFire (2005, p. 6) defines floodplains "*as a subset of flood prone areas*." CalFire further defines floodplains in accordance with statistical frequencies of flood inundation (e.g., the area inundated by the 10-year recurrence interval flood versus the area inundated by a 100-year recurrence interval flood event). Such an approach is straightforward and mirrors that employed by the Federal Emergency Management Agency (FEMA, 2008) which

requires greater levels of flood insurance protection for structures built within the 100-year floodplain area (i.e., Special Flood Hazard Areas) versus those constructed outside that inundation area.

2. *Laterally stable watercourse* – This term is not explicitly defined in either the FPRs or CalFire (2005). However, a review of pertinent literature (Rapp and Abbe, 2003; and the WFPB, 2004) indicates that a laterally stable watercourse is one that exhibits little active bank erosion and has not shifted its course over a considerable period of time. An extreme example of a laterally stable stream channel is one incised into bedrock. Relatedly, the FPRs define a *confined channel* as being "*an incised channel that does not shift position on a floodplain, the channel has no contiguous flat, flood prone areas, and the width of the valley floor is less than 2 times the channel width at Bankfull stage*." In other words, confined or incised channels are commonly considered to be laterally stable. At the other end of the scale are *alluvial channels* that are formed, maintained, and controlled by the stream's volume of water and debris load. Alluvial channels are therefore self-adjusting to alterations that change the timing and volume of stream flow, wood, and sediment. In this manner, alluvial channels build floodplains, migrate laterally, and can be considered laterally unstable (WFPB, 2004, p. M2-45).

3. *Channel Migration Zone (CMZ)* – This term is formally defined in the FPRs which state that a CMZ is "*the area where the main channel of a Watercourse can reasonably be expected to shift position on its floodplain laterally through avulsion or lateral erosion during the period of time required to grow forest trees from the surrounding area to a mature size, except as modified by a permanent levee or dike. The result may be the loss of beneficial functions of the Riparian zone or Riparian habitat"*. Specific to the term *mature*, the FPRs rely on Dunning's Classification of tree maturity and define a *mature* coniferous tree as being at least 150 years old. Thus, the period of time under consideration for channel migration to occur is 150 years into the future. Similarly, when evaluating channel migrations of the past, it makes sense to consider the past 150 years.

4. *Elevation equivalent to twice the distance between a thalweg riffle crest and the depth of the channel at Bankfull stage* – As described by the State of California (2014, p. 20), the 2X bankfull stage depth elevation, measured from the thalweg riffle crest, has been found to equate approximately to the water surface elevation of the 40 to 50-year return period flood event in the California Coast Range. This method serves as a straightforward alternative to conducting the more technically challenging analyses necessary to quantify and delineate the 20-year floodplain.

As per the FPRs definition of *flood prone area*, the primary field indicator of the outer boundary of the flood prone area is the location where valley slope begins (i.e., the valley wall). After that, more subtle indicators such as vegetation patterns, geomorphic features, and flood flow evidence can be used to delineate the *flood prone area*. Finally, in those situations "*along laterally stable Watercourses lacking a Channel Migration Zone where the outer boundary of the flood prone area cannot be clearly determined using the field indicators above, it shall be determined based on the area inundated by a 20-year recurrence interval flood flow event, or the elevation equivalent to twice the distance between a thalweg riffle crest and the depth of the channel at Bankfull stage".*

Little North Fork Gualala River Floodplain Studies and CMZ Evaluation

In an August 6, 2019 cover letter to CalFire introducing responses to Pre-Harvest Inspection (PHI) recommendations, the Plan Submitter makes clear its intention to limit the *flood prone area* to that part of the valley floor which is inundated by the 20-year flood. No explanation is provided as to why the primary field indicator of the outer boundary (i.e., valley walls) of the *flood prone area* was not used. The CDFW interprets the FPRs as specifically limiting adoption of the 20-year floodplain area as the *flood prone area* to those particular situations in which the outer boundary of the *flood prone* area cannot be clearly determined using the field indicators, or when the stream channel is laterally stable and lacking a channel migration zone. In proposing the 20-year floodplain area as the *flood prone area*, GRT may be asserting that not only are field indicators of the *flood prone area* lacking, but that the stream channel is laterally stable and lacking a channel migration zone. This is perplexing because field indicators of channel migration, avulsions, and bank erosion are documented in Section IV of the "Little" THP on pages 139 and 146 (Section IV). Despite that previous characterization of a migrating channel and in an apparent effort to support its decision to adopt the 20-year floodplain as the *flood prone area*, GRT contracted with O'Connor Environmental, Inc. (OEI) to conduct floodplain studies and a channel migration zone (CMZ) evaluation of the Little North Fork (OEI, 2019a, b, and c). Neither of the floodplain studies (OEI, 2019a and b) include the term *flood prone area* nor do they reference the FPRs or the primary field indicators of the *flood prone area*. The studies focus on delineating the limits of the 20-year floodplain through the use of computational hydraulic modeling. The studies do not provide a technical basis for GRT's decision to adopt the 20-year floodplain as the *flood prone area* over that delineated by the valley walls.

OEI's CMZ evaluation (2019c) is based upon established protocols (Rapp and Abbe, 2003; and WFPB, 2004) and is limited in both scope and scale. The evaluation includes an analysis of historic aerial photographs and reconnaissance level surveys of six field sites distributed along approximately 1.8 miles of the Little North Fork valley length. In general, OEI's CMZ evaluation documents numerous examples of recent, ongoing, and potential future episodes of channel migration and avulsion at various locations along the subject reach of the Little North Fork. However, OEI (2019c) uses four confounding terms in reporting its findings: *migrating channel, floodplain flow feature, overbank flow feature, and secondary channel*. Moreover, the terms are defined in awkwardly worded phrases immediately following usage of the terms. In particular, and with emphasis added here in **bold,** page 16 includes the phrase:

> *"A **migrating channel** must be capable of eroding a new channel to a depth comparable to that of the existing principal or secondary channel and be capable of transporting the bedload of the primary channel. That condition is necessary in order that a migrating channel be capable of disturbing forest vegetation on the floodplain that would distinguish it from a **floodplain flow feature** (here defined as concentrated flow following a linear or curvilinear swale carrying overbank flows)."*

Bridging over pages 16 and 17, also with emphasis added here in **bold,** is the phrase:

> *"Consequently, overbank flow tends to concentrate in **overbank flow features** that do not uniformly meet the criteria adopted for a **secondary channel** (depth of channel at least half of primary channel transporting primary channel bedload*

> *sediment and the absence of terrestrial vegetation)".*

None of the leading references on the topic of *characterizing flood prone areas* and *channel migration zones* (Rapp and Abbe, 2003; WFPB, 2004; CalFire, 2005; State of California, 2014; and FPRs, 2018) use the terms *"overbank flow feature"* or *"floodplain flow feature".* Nor do any of those references tie bedload transport to the definition of a migrating channel. Also, the term *"secondary channel"* is formally defined in the glossary sections of both Rapp and Abbe (2003) and WFPB (2004) as:

> *"Any channel in the study area besides the main channel; examples of secondary channels include side channels, abandoned channels, swales, overflow channels, and relic channels."* *(Rapp and Abbe, 2003)*

> *"Any channel on or in a floodplain that carries water (intermittently or perennially in time; continuously or interrupted in space) away from, away from and back into, or along the main channel. Secondary channels include: side channels, wall-based channels, distributary channels, anabranch channels, abandoned channels, overflow channels, chutes, and swales."* *(WFPB, 2004)*

Because these leading references do not attach channel geometry dimensions, bedload transport capacity, or vegetation characteristics to the definition of *secondary channel*, OEI's definition and criteria represent a departure from the established literature. Figure 3 of Rapp and Abbe (2003, p. 4) is particularly useful in this regard because it ties *secondary channels* across the floodplain to the range of different inundation levels (e.g., bankfull). Additionally, OEI's definitions and criteria are embedded within individual site-specific discussions in the latter pages of the report. They are not presented up front as part of the methods nor are they formally compared and contrasted with those in the established literature. Furthermore, by attaching channel geometry dimensions, bedload transport capacities, and vegetation characteristics to the definition of a *secondary channel*, OEI appears to be setting a new and narrow standard for what constitutes a secondary channel and how channel migration zones are to be evaluated.

While challenges to scientific definitions and regulatory protocols are important in advancing professional standards of practice and balancing environmental protection with land management, OEI's presentation regarding the terms above is insufficient. Consequently, the following discussion uses the term *secondary channel* as defined by Rapp and Abbe (2003) and the WFPB (2004) to mean <u>any</u> other channel on the floodplain other than the main channel. More specifically, despite OEI's (2019c) usages of the terms *overbank flow features* and *floodplain flow features*, all such features are considered *secondary channels* in the following discussion. Furthermore, the formal definition of *flood prone area* provided earlier includes the term "*overflow side channels*". For purposes of this discussion, that term is also considered a *secondary channel* as per the definitions of Rapp and Abbe (2003) and the WFPB (2004).

As introduced above, OEI's CMZ evaluation documents numerous examples of recent, ongoing, and potential future episodes of channel migration and avulsion at various locations along the subject reach of the Little North Fork. That evidence includes:

- Secondary channels present at Sites 1, 2, 3, and 4.

- No obvious constraints to lateral movement (migration) at any of the survey sites.

- The channel is unconfined (valley floor widths were found to be greater than twice the bankfull width of the channel).

- *"Small-scale channel migration with lateral channel movement comparable to bankfull width (about 50 ft or less) of the LNFG channel occurs and is caused primarily by large woody debris accumulations associated with redwood trees on stream banks that drive development of short lengths (about 200 ft or less) of secondary channel characterized by widths and depths of about half that of the primary channel (e.g. Sites 1 and 3)."*

- *"Overbank flow on the floodplain of the LNFG is relatively widespread with many dispersed connections where flow between the primary channel and the floodplain is exchanged; this broad dispersal of floodplain flow is believed to limit the energy of flow entering and departing the floodplain such that overbank flows are not generally capable of eroding secondary/migrating channels."*

- *"The topography of the floodplain is relatively flat with gentle slope gradients that are comparable to the gradient of the LNFG primary channel; consequently, overbank flows do not tend to cause development of migrating channels by avulsion. Overbank flows are typically distributed in a network of shallow swales steered by topographic mounds associated with* mature redwood trees and old growth stumps."

The statements above document the presence of *secondary channels*, and also describe an unconfined channel subject to lateral channel migration and avulsions generated by in-channel obstructions of large wood and overbank flooding. Such features and processes are consistent with those described in the THP Section IV discussion. During the August 29, 2019 PHI (August PHI), two distinct types of secondary channels adjacent to the active mainstem channel were observed. One type appears to be older well-established channels of a similar size as that of the mainstem (Figure 1). The other appears new, raw, and the obvious result of recent channel-forming flows scouring the floodplain (Figure 2). In the first case, it is hypothesized that the well-established secondary channel was once the main active channel and an avulsion occurred upstream effectively circumventing or abandoning this length of channel. The second case appears to be the result of water escaping an impoundment created by a channel-spanning accumulation of large-wood.

OEI's CMZ evaluation includes a curious discussion of Site #6 that states: "*Despite the landslide that impinged on the LNFG and that tended to divert additional flow to the eastern floodplain, no avulsion occurred. The floodplain in this area is not considered a channel migration zone."* This statement is curious for two reasons: 1) it appears that OEI is only considering avulsions to represent channel migration; and 2) while the landslide generated a channel-spanning log jam that did not force an avulsion, it is reasonable to consider that

Figure 1. Looking upstream at a dry, well-established and self-formed alluvial secondary channel that empties into active channel just to the right of the photograph at Site #1. It is hypothesized that this channel was once that of the mainstem, but that a recent avulsion has resulted in it being abandoned.

Figure 2. Looking upstream at a dry secondary channel recently carved into the floodplain at Site #3. Note the preponderance of roots that have been exhumed by the scouring. The head of this channel occurs at a sharp bend in the active channel that includes a channel spanning accumulation of large wood. This channel was likely scoured in response to the escape of water impounded behind the large wood accumulation.

additional racking of wood on the jam could in future years force an avulsion similar to that occurring at Site #3 (Figure 2) and that discussed by OEI at Site #4. Additionally, it appears even more likely that the landslide generated channel spanning log jam (Figure 3) will direct streamflow into the left (east) bank which will accelerate local bank erosion and channel migration around the log jam obstruction. The same sort of channel adjustments should be anticipated at all of the numerous large wood accumulations within the channel (Figure 4).

As reported above, OEI's (2019c) CMZ evaluation documents numerous examples of recent, ongoing, and potential future occurrences of channel migration and avulsion at the various survey sites. However, those findings are overshadowed by item #2 of the Summary section describing a *"significant finding"* in which evidence of channel migration processes was not revealed in the aerial photographs. Later in the paragraph is the statement:

> "*The absence of observable channel migration over a ~60-year period strongly suggests that channel migration processes subject to the ASP regulations do not occur in the LNFG"*

The ASP acronym refers to Anadromous Salmonid Protection and appears to be referring to a joint publication prepared by CalFire and the CDFW (State of California, 2014). OEI's (2019c) reference to the publication is primarily in terms of it being a guide to CMZ investigative protocols. Specific ASP regulations are not discussed. If the italicized sentence above was taken out of context as a standalone statement, an argument could be proposed that OEI is concluding that a channel migration zone for the Little North Fork does not exist. Such an argument lacks merit because: 1) the statement is specific to what was "not" observed in the aerial photographs; and 2) it ignores the preponderance of data presented in the CMZ evaluation that documents site-specific evidence of avulsions and channel migration.

For clarity, OEI (2019c) did not observe channel migration processes in the historic aerial photographs because: 1) "*the channel of the LNFG was not visible under the forest canopy*" (OEI, 2019c, p.6); and 2) characteristic signatures of channel migration in the form of curvilinear gaps in the overstory canopy and distinctive seral stage vegetation patterns were also not observed in the historic aerial photographs. OEI opines that the absence of the characteristic signature of channel migration is a *significant finding*, and that significant channel migration on a valley floodplain of this size would be evident. However, OEI does not define what is meant by "significant" channel migration nor is an example provided of a similar sized stream exhibiting channel migration. Most importantly, OEI does not provide for the reader a synthesis discussion that resolves the differences between the *"significant finding"* from the review of aerial photographs versus the findings from the site surveys. Despite the distracting statement above in italics, OEI's CMZ evaluation presents considerable evidence of avulsions and channel migration. Yet, widespread evidence of floodplain aggradation on the order of about three or four feet and subsequent fluvial erosion that has exhumed sawcut old-growth stumps does not appear to have been recognized as evidence of recent channel migration. Additionally, OEI's use of confounding and restrictive definitions related to the term *secondary channel* renders some of the conclusions disavowing channel migration processes as lacking merit. Collectively, OEI's (2019c) CMZ evaluation appears to understate channel migration processes and does not provide a technical justification for GRT's decision to adopt the 20-year floodplain as the *flood prone area* over that delineated by the valley walls.

Figure 3. Looking upstream at the February 2019 landslide generated a channel-spanning multi-stemmed logjam in the Lower North Fork Gualala River at Site #6. Landslide failed out of the hillside along the left (west) side of the photograph. The landslide debris and root wad forces streamflow into the east bank.

Figure 4. Looking downstream at a channel spanning large wood structure that is racking additional wood and capturing sediment (aggrading the bed) at Site #2. Note sawcut stump in middle of the photograph and another stump in the stream along the left side of the photograph.

<u>Historical Context and Watershed Processes</u>

While OEI's reports (2019a, b, and c) advance local understandings of the valley's fluvial geomorphology and site-specific channel adjustments (migrations and avulsions), a comprehensive geomorphic characterization of the valley floor is not provided. Consequently, OEI's conclusions and interpretations are lacking context in terms of the overarching systemic fluvial processes and related landforms that make up the Little North Fork valley floor. In particular, watershed-scale mass wasting processes and patterns of sediment discharge are not discussed, valley floor geomorphology is not well characterized, and no mention is made of geomorphic impacts associated with past timber harvesting or the 1906 earthquake. Additionally, widespread evidence of floodplain aggradation on the order of about three or four feet and subsequent degradation does not appear to have been recognized. More specifically, recognizing and characterizing the geomorphic linkages as well as the temporal and spatial scale of the various processes are central to accurately evaluating the ecological value of floodplains and anticipating future channel and floodplain evolution (Cluer and Thorne, 2014). To provide a larger context for OEI's work, the following sections more fully characterizes the fluvial geomorphic processes and related channel adjustments within the Little North Fork valley.

As per Dunning's classification introduced above, the appropriate time frame with which to evaluate channel migration zones is 300 years; one hundred and fifty years in the past and 150 years into the future. One hundred and fifty years ago in 1869, old growth redwood timber harvesting was underway in the lower reaches of Little North Fork and persisted until 1911 (Klampt and others, 2002). On April 18, 1906 a major earthquake occurred along the San Andreas fault and created a nearly continuous fissure of right-lateral ground displacement extending for approximately 190 miles along the coast of northern California. Near the divide between the Garcia River and the Little North Fork valley, the principal horizontal displacement across the fissure was measured to be 10 feet at a fence line. In the Little North Fork valley, the fissure was traced along the west side of the valley, and railroad tracks along the valley floor were found buckled and torn to pieces. Just north of the Little North Fork confluence with the mainstem North Fork Gualala River, the fissure was observed within the Little North Fork streambed and crossed into the mainstem at a point 200 feet east of the confluence (Lawson, 1908; Brown and Wolfe, 1972; and Slossen, 1974).

Modern earthquake analysis indicates that the moment magnitude of the 1906 earthquake was about Mw 7.7 (Wald and others, 1993). Strong seismic shaking associated with major earthquakes of this magnitude are well-known for generating landslides in adjacent hillside areas (Harp and Jibson, 1995; and Meunier and others 2007). Active landslides also shed copious volumes of debris into adjacent watercourses for many years. In one study, landslide debris generated during the 1923 Kanto Earthquake was found to still be a measurable quantity of contemporary sediment discharge 80 years after the event (Koi, and others 2008). The California Geological Survey (CGS) has mapped multitudes of landslides in and around the Little North Fork valley and the adjacent subwatersheds that drain to the valley. Local exposures of the German Rancho formation composed of sandstone, claystone, and conglomerate are mapped amongst the landslides comprising the valley walls. Thus, the landslide complexes of the valley walls are likely derived from this formation. The German Rancho formation lies in fault contact with fractured metasandstone of the Franciscan Complex which underlies the subwatersheds farther to the east that drain to Little North Fork (Fuller and others, 2002; and Davenport, 1984). It is reasonable to hypothesize that many landslides in this region were triggered or reactivated in response to the 1906 earthquake and that substantial volumes of sediment were delivered downslope to stream channels for many years.

CGS's geologic and geomorphic mapping shows the Little North Fork valley floor as underlain by alluvial sediments comprised of clay, sand, and gravel transported by rivers and streams (Fuller and others, 2002; Davenport, 1984; and Williams and Bedrossian, 1976). Similarly, the National Resource Conservation Service (NRCS, 2019) defines the Little North Fork valley floor soil as Bigriver loamy sand. That soil is described as occurring within floodplains that are frequently flooded, and the parent material of the soil is *"alluvium derived from sandstone"*. Alluvial sediments composed of clay, sand, and gravel were directly observed during the August PHI confirming the accuracy of the published mapping. Because alluvial sediments are transported and deposited by rivers and streams, the published mapping of such sediments across the entire width of the valley floor means that the river and tributary streams have wandered back and forth across the full-width of the valley floor over time. In other words, published geologic, geomorphic, and soils mapping supports the conclusion that the entire floor of the Little North Fork valley is the result of fluvial processes and prone to flooding.

Between 1942 and 1968, intensive tractor-based timber harvesting was conducted in the watershed. Aerial photographs from 1963 document watershed-scale clearcutting and a dense web-like network of skid trails and haul roads in the subwatersheds draining to the Little North Fork. During that time of intensive timber harvesting, two major rainstorms events occurred in northern California during 1955 and 1964. These storms caused dramatic flooding and mass wasting throughout northern California. Detailed geomorphic investigations of storm related impacts within watersheds containing protected groves of old-growth redwood trees have been conducted for Bull Creek (Jager and LaVen, 1981; LaVen, 1987; and Merrill and Vadurro, 1999), and Redwood Creek (Janda and others, 1975; and Nolan and Marron, 1995) in Humboldt County. In the Redwood Creek investigation, the U.S. Geological Survey (USGS) determined that the large 1964 storm generated landslides into the upper basin tributaries and main channel. Coincident storm-related discharges flushed the sediment out of the tributaries and into the Redwood Creek channel and floodplain which aggraded several feet.

The post-flooding investigation of Redwood Creek documents that climatic factors (i.e., the unusually large storm) caused much of the change along the stream. More specifically, the USGS study revealed that the substantial runoff associated with large storms links hillslope and channel processes together resulting in accelerated erosion of both hillsides and stream channels. It also found that timber harvesting activities such as clearcutting and road construction tend to increase the scale and number of such linkages further increasing the vulnerability of the watershed to erosion. Aerial photographs of the subwatersheds that drain to Little North Fork watershed from the early 1960s resemble those of Redwood Creek in terms of widespread clearcut areas, roads constructed along the axes of primary drainages, and a dense network of skid trails on the steep slopes above the drainages. It is therefore reasonable to infer that the Little North Fork subwatersheds were similarly vulnerable to mass wasting and accelerated erosion prior to the storms of 1964. That inference in conjunction with the channel and floodplain aggradation documented within the Redwood and Bull creek watersheds is used to construct a hypothesis in which the Little North Fork valley was also subject to several feet of channel and floodplain aggradation related to the 1964 storms.

Significant channel and floodplain aggradation within the Little North Fork valley is exhibited by the presence of numerous sawcut old-growth tree stumps that appear once buried by three or four feet of sediment aggradation and are now in various stages of exhumation (Figures 5 and 6). These observations were documented at five of the six sites reconnoitered during the August PHI, and similar conditions are assumed to exist throughout the full width and length of the alluvial valley floor. The substantial floodplain aggradation and subsequent exhumation documents both historic and contemporary channel migration processes at work along the floor of the Little North Fork valley. Moreover, because the sediment comprising the aggradation was transported, deposited, and is now being reworked under the same general hydrologic regime, the Little North Fork can be considered a self-formed, self-adjusting, an unconfined alluvial channel. Contemporary channel migration is also exhibited by the numerous exhumed stumps that are found in the active channel (Figures 4, 5, and 6). More specifically, the upright tree stumps are assumed to be in their growth position and because old growth redwood trees do not grow in active channels, the fact that such a stump now exists in the active channel is clear evidence that the stream has migrated to that location.

Figure 5. Looking downstream at exhumed sawcut old growth redwood stump within the active channel at Site 3. Note that the channel sediment is relatively fine-grained and the exposed roots to the left of the stump that indicate active bank erosion.

Figure 6. Looking downstream at exhumed sawcut old-growth redwood stump immediately adjacent to the active channel (lower left) at Site 5. Note the coarse-grained gravel deposits that have been recently eroded in response to streamflow around the stump.

Assuming that the 1964 storm event triggered the floodplain aggradation, it is reasonable to hypothesize that sediment delivery rates into the Little North Fork valley remained high for many years and that additional floodplain aggradation and channel migrations persisted for some time. It is further hypothesized that vegetation growth eventually stabilized the bulk of sediment source areas in the upper watershed areas such that the sediment delivery into the valley was gradually reduced. Ten years is proposed as a reasonable estimate for the time necessary to effectively stabilize the sediment source areas with vegetation. Consequently, the year 1974 is considered a likely turning point (i.e., crossing of a geomorphic threshold), in which floodplain aggradation and shallow multi-thread distributary channel patterns across the Little North Fork valley floor transitioned to downcutting and the formation of a more-or-less single-thread channel planform with concentrated stream power to erode and rework the floodplain sediment. In other words, it is hypothesized that the contemporary channel planform has developed over the past 45 years.

<u>Floodplain Geomorphology</u>
The contemporary morphology of the Little North Fork valley floor is characterized with a topographic contour map and longitudinal profile (Figures 7 and 8) that were derived from the USGS LiDAR dataset (USGS, 2018). Based upon the reconnaissance level investigations at six representative sites (shown on Figures 7A and B) during the August PHI, the LiDAR based topography appears highly accurate. The contour interval of the map is two feet, and the patterns exhibited by the contours depict the valley floor morphology in fine detail. Identifiable on the map along the west side of the valley are the trenches and lineaments generated by

repeated movements along the San Andreas fault (Lawson, 1908; and Brown and Wolfe, 1972). What is not present are similarly well-defined fault-related lineaments within the alluvial valley floor, nor is there any obvious evidence of old remnant fluvial terraces. In this regard, the morphology of the valley floor appears relatively young. This is consistent with the evidence above regarding the floodplain aggradation.

Multiple sets of parallel and bulging (convex down gradient) contours issue forth sinuously from nearly all of the tributaries and debouch upon the valley floor as well-defined alluvial fans. In several instances the fans have displaced the Little North Fork to the opposite side of the valley, and they likely serve as a fundamental hydraulic control for Little North Fork streamflow. In fact, some of the best developed channel meanders of the Little North Fork have formed within these constricted reaches. The topographic sharpness of these fan features implies they too are youthful features. Such youthfulness is also consistent with voluminous sediment discharge from contributing subwatersheds underlain by a variety of landslides and related features that were clear-cut and highly modified by skid trails.

Between the tributary fans and the active channel corridor, the valley floor contours exhibit broad patterns of shallow undulatory relief. More specifically, several areas of concave down-gradient contours indicative of topographic depressions exist along the valley floor. In several cases, these depressions are hydrologic “sinks” where surface water accumulates and forms wetland areas (Figures 7A and B). The valley floor contour lines also exhibit a pattern of narrow and sharp upstream v’s that are paired with similar features on adjacent contour lines up- and downslope. These patterns are interpreted to represent the remnant, largely distributary, drainage network that is assumed to have formed as part of the depositional processes that accomplished the floodplain aggradation. The drainage paths are generally straight and form a somewhat braided stream network that is activated during higher runoff events (OEI, 2019a). These remnant channels are *secondary channels* discussed previously (Rapp and Abbe, 2003; and WFPB, 2004). As depicted on the geomorphic map, the remnant channel network and hydrologic sink areas occur across local differences in topographic relief which creates the potential for different channel avulsion scenarios.

Little North Fork follows a somewhat tortuous path as it flows through the aggraded floodplain containing buried tree stumps, impinges upon valley walls, and is locally constrained by numerous alluvial fans. The longitudinal profile (Figure 8) of Little North Fork derived from the LiDAR data exhibits generally smooth concavity which is suggestive of a well-graded alluvial stream in dynamic equilibrium (Mackin, 1948). However, a recognizable topographic bulge underlies approximately one mile of stream segment between Doty Creek at the upstream end and opposing tributary fans deposits downstream of Site #4 (Figures 7A and 8). This provides additional context for both the widespread channel and floodplain aggradation as well as the stream’s success in downcutting and reworking the floodplain sediment. While the contemporary Little North Fork thalweg appears to be evolving toward dynamic equilibrium, longitudinal profiles of the major tributaries do not appear similarly at grade with the Little North Fork. Such a situation is consistent with a recent period of substantial sediment deposition and creates a potential for accelerated erosion (headcutting) up through the tributary channels and concomitant sediment delivery to the Little North Fork as the tributaries work to achieve a graded condition with the mainstem.

Much of the Little North Fork is a single-thread channel that is approximately 60 feet wide. However, numerous secondary channels weave in, out, and around the main channel. While most of these side-channels are localized and randomly distributed along the length of the Little North Fork, there are two distinct reaches that include multiple bifurcations with a relatively short distance creating that resemblance of a well-established anabranching channel pattern. These complex multi-thread reaches enlarge the active channel width to approximately 150 feet and are designated with “An” on the geomorphic map (Figures 7A and B). Sites #1 and #3 both include well-developed secondary channels, and Site #3 lies within one of the reaches exhibiting the anabranching pattern. At Site #1, considerable discussion ensued during the August PHI regarding whether or not the secondary channel, with a bed elevation higher than that of the active channel, could accommodate a channel avulsion. Fresh sediment deposits and preferentially flattened vegetation indicates that the channel was full and active for some period of time during the winter of 2018-2019. Therefore, it appears obvious that if streamflow were sufficiently obstructed in the mainstem by a large wood jam, this secondary channel could accommodate an avulsion. Furthermore, the geomorphic map indicates that the dry side-channel may also have connectivity with overbank spills occurring 1,500 feet up upstream. The Site #1 secondary channel was introduced previously as part of the review of OEI’s (2019c) CMZ evaluation (Figure 1). It is hypothesized here to have once been a portion of the active channel that has since been abandoned in response to an upstream avulsion. Such channel adjustment is consistent with the hypothesis of the stream now in a phase of downcutting and reworking.

<u>Delineation of Flood Prone Area and the Channel Migration Zone</u>
Site observations by both OEI (Table 2) and the CDFW document both past and currently active secondary channels, lateral channel migration processes, and avulsion events. Published geologic and soils mapping in conjunction with interpretations derived from the highly accurate topographic map support the assumption that similar evidence of channel migration and avulsions exists throughout the entire width of the valley floor. Consequently, it is reasonable to conclude that the entire valley floor fits the definition of *flood prone area* as defined in the FPRs. To test that assumption, a desktop exercise was conducted using the “*elevation equivalent to twice the depth of the channel at bankfull stage”* method of estimating the 40 to 50-year return period flood event in the California Coast Range as outlined by the State of California (2014, p. 20). Nine cross-valley topographic profiles were generated from the LiDAR dataset using an ArcMap Geographic Information System platform. Bankfull depths were measured from the profile data, doubled, and added to the thalweg elevation. In all cases, the calculated elevation value extended beyond the valley floor and up onto either the valley walls or the tributary fans. A water surface level for that estimated flood event throughout the entire valley segment was then drawn by interpolating between the section points and following the pattern of adjacent contour lines. This line, along the valley walls, is delineated with a series of open blue dots on the geomorphic map (Figures 7A and B) and proposed herewith as the outer boundary of the *flood prone area*.

As defined in the FPRs, a CMZ is the area where the main channel of a watercourse can reasonably be expected to shift position on its floodplain laterally through *avulsion* or *lateral erosion* during the period of time required to grow forest trees from the surrounding area to a mature size. As per Dunning’s classification, the time period under consideration is 150 years. Avulsions and lateral erosion are fundamentally different processes of fluvial geomorphic adjustment. An avulsion represents a relatively abrupt whole-scale diversion of streamflow out of an established channel (drainage path) and the subsequent redirection of the flow into a different drainage path. The new drainage path does not need to be a single thread channel and could be water broadly distributed across the floodplain. There just needs to be sufficient elevation difference (head) to perpetuate stream flow away from the original channel. Causes of an avulsion have been previously described to be the result of either a major channel obstruction (e.g., log jam or landslide), or dramatic flood flows that overtop the channel and scour through the streambank. In contrast, lateral erosion (i.e., migration) refers to the continuous and gradual adjustment of the channel in response to generally slow but persistent streambank erosion, sediment transport, and sediment deposition that creates meander bends, point bars, and floodplains. This definition is consistent with the classic understanding of alluvial floodplain formation as described by Wolman and Leopold (1957) and Leopold and others (1964) as they describe self-formed alluvial streams that meander and migrate across their valleys via a continuous cycle of bank erosion, lateral accretion of point bars, and vertical accretion of floodplains. Because avulsion and lateral migration processes are fundamentally different and operate at different spatial and temporal scales, a CMZ must also anticipate and accommodate these different geomorphic processes as well as the different spatial and temporal scales with which the processes act.

Given the required 150-year time frame, the delineation of CMZ must anticipate large storm events that generate floods, deliver substantial sediment to streams, and trigger landslides. Accelerated tributary downcutting is another contributor of sediment to mainstem streams. Strong ground shaking and fault rupture are possible in this area, and sea level rise should be expected to create more instances of backwater flooding in the mainstem North Fork Gualala River. While all of these variables play a role in long-term geomorphic channel adjustments, it is not realistic to conduct multi-faceted probabilistic analyses to predict the outcome of those stochastic events on channel migration processes. Instead, it is proposed that the variables be recognized and that a generally conservative (i.e., err on the side of including more area within the area) qualitative approach be adopted in delineating the CMZ.

Avulsions can occur in response to a channel-spanning obstruction or overwhelming flood flows. However, because it is not possible to predict future channel obstructions, the delineation of potential avulsion sites is focused on those portions of the channel that are relatively shallow compared to the floodplain and that exhibit evidence of recent or seasonal overbank spills. Such evidence includes natural levees and fresh sediment deposits immediately adjacent to the channel. In addition, the streambank must be erodible and the *"receiving"* area beyond the channel must be "*down-slope*" in order to perpetuate streamflow. Several such areas are visible on the geomorphic map and are designated "Av" (Figures 7A and B). Moreover, the topographic depressions associated with these designations include remnant or "*secondary*" channels that will facilitate an avulsion. In adopting a conservative approach, overbank spills are considered likely to occur anywhere along a vulnerable streambank and then drain in and out of the receiving topographic depression at multiple locations. Consequently, delineating avulsion type CMZs necessarily must include the entirety of the vulnerable bank and that of the potential receiving area (topographic depression) as well.

As for lateral migration, the delineation of a CMZ begins with the existing channel pattern that defines the contemporary scale of channel adjustment. As presented above, it is hypothesized that the Little North Fork is now in a phase of reworking the floodplain sediment. Moreover, as suggested by the longitudinal profile (Figure 8), the stream appears well on its way toward achieving dynamic equilibrium in terms of vertical downcutting which suggests that future channel adjustments will likely be focused in a horizontal direction via lateral erosion. While much of the Little North Fork is a single-thread channel that is approximately 60 feet wide, it also includes numerous secondary channels that weave in and out and around the main channel. In adopting a conservative approach, the various secondary channels combined with the primary active channel are interpreted to represent the contemporary scale of active lateral migration currently underway and defines an active CMZ of approximately 150 feet in width. In anticipation of 150 years of future channel migration and a conservative approach, a nominal value of one inch per year of lateral erosion is assumed. This equates to 12.5 feet over that period of time. Adding 12.5 feet to either side of the contemporary CMZ equates to a proposed lateral migration CMZ width of 175 feet. The combined avulsion and lateral migration CMZ is delineated on the geomorphic map with heavy dashed dark blue line (Figures 7A and B).

<u>Summary and Recommendations</u>
In an August 6, 2019 cover letter to CalFire introducing responses to Pre-Harvest Inspection recommendations, the Plan Submitter makes clear its intention to limit the *flood prone area* to that part of the valley floor which is inundated by the 20-year flood. No explanation is provided as to why the primary field indicator of the outer boundary (i.e., valley walls) of the *flood prone area* was not employed. The CDFW interprets the FPRs as specifically limiting adoption of the 20-year floodplain area as the *flood prone area* to those particular situations in which the outer boundary of the *flood prone* area cannot be clearly determined using the field indicators, or when the stream channel is laterally stable and lacking a channel migration zone. In proposing the 20-year floodplain area as the *flood prone area*, GRT appears to be asserting that not only are field indicators of the *flood prone area* lacking, but that the stream channel is laterally stable and lacking a channel migration zone. This is perplexing because field indicators of channel migration, avulsions, and bank erosion are documented in Section IV of the "Little" THP on pages 139 and 146 (Section IV). Despite that previous characterization of a migrating channel and in an apparent effort to support its position, GRT contracted with OEI to conduct floodplain studies and a channel migration zone (CMZ) evaluation of the Little North Fork (OEI, 2019a, b, and c). Neither of the floodplain studies include the term *flood prone area* nor do they reference the FPRs or the primary field indicators of the *flood prone area* as defined in the FPRs. Thus, neither of the floodplain studies provide a technical basis for GRT's decision to adopt the 20-year floodplain as the *flood prone area* over that delineated by the valley walls.

OEI's CMZ evaluation follows well-established protocols and is limited in both scope and scale. The evaluation includes an analysis of historic aerial photographs and reconnaissance level surveys of six field sites distributed along approximately 1.8 miles of the Little North Fork valley length. The evaluation documents several examples of recent, ongoing, and potential future episodes of channel migration and avulsion at several locations along the Little North Fork. Such features and processes are consistent with those described in the THP Section IV discussion. However, OEI's findings regarding channel adjustments are somewhat overshadowed by item #2 of its Summary section describing a *"significant finding"* in which evidence of channel migration processes was not observed in the aerial photographs. Later in the paragraph is the statement:

> "*The absence of observable channel migration over a ~60-year period strongly suggests that channel migration processes subject to the ASP regulations do not occur in the LNFG"*

If the italicized sentence above was taken out of context as a standalone statement, an argument could be proposed that OEI is concluding that a channel migration zone for the Little North Fork does not exist. Such an argument lacks merit because: 1) the statement is specific to what was "not" observed in the aerial photographs; and 2) it ignores the preponderance of the CMZ evaluation that documents site-specific evidence of avulsions and channel migration. For clarity, OEI did not observe channel migration processes in the historic aerial photographs because: 1) "*the channel of the LNFG was not visible under the forest canopy*" (OEI, 2019c, p.6); and 2) characteristic signatures of channel migration in the form of curvilinear gaps in the overstory canopy and distinctive seral stage vegetation patterns were also not observed in the historic aerial photographs. OEI opines that the absence of the characteristic signature of channel migration is a *significant finding*, and that significant channel migration on a valley floodplain of this size would be evident. However, OEI does not define what is meant by "significant" channel migration nor is an example provided of a similar sized stream exhibiting channel migration. Most importantly, OEI does not provide for the reader a synthesis discussion that resolves the differences between the *"significant finding"* from the review of aerial photographs versus the findings from the site surveys. Despite the distracting statement above in italics, OEI's CMZ evaluation presents considerable evidence of avulsions and channel migration. However, widespread evidence of floodplain aggradation on the order of about three or four feet and subsequent fluvial erosion that has exhumed sawcut old-growth stumps does not appear to have been recognized as recent and ongoing channel migration. Additionally, OEI's use of confounding and restrictive definitions related to the term *secondary channel* renders some of the conclusions disavowing channel migration processes as lacking merit. Collectively, OEI's (2019c) CMZ evaluation understates channel migration processes and does not provide a technical justification for GRT's decision to adopt the 20-year floodplain as the *flood prone area* over that delineated by the valley walls.

OEI's floodplain studies and CMZ evaluation advance local understandings of the valley's fluvial geomorphology and site-specific channel adjustments (migrations and avulsions). However, those findings are without scale and context in terms of the overarching geologic and geomorphic processes and related landforms that make up the Little North Fork valley floor. Such context appears essential given the important issues under consideration. Consequently, a broader geologic and geomorphic characterization of the Little North Fork was prepared as part of this memorandum. Collectively, the geologic and geomorphic characterization supports the following conclusions and interpretations.

1. Published geologic mapping by the California Geological Survey and the National Resource Conservation Service depict the Little North Fork valley floor as being underlain by alluvial sediments comprised of clay, sand, and gravel. Alluvial sediments composed of clay, sand, and gravel were directly observed during the August PHI confirming the accuracy of the published mapping. Because alluvial sediments are transported and deposited by rivers and streams, the occurrence of such sediments across the entire width of the valley floor demonstrates that the river and tributary

streams must have wandered back and forth across the full-width of the valley floor over time. In other words, published geologic, geomorphic, and soils mapping supports the conclusion that the entire floor of the Little North Fork valley is formed and maintained by fluvial processes and prone to flooding.

2. A desktop exercise estimating the stage of the approximate ~50-year return period flood event in the Little North Fork valley was conducted using the "*elevation equivalent to twice the depth of the channel at bankfull stage"* method. Those results show the limits of that flood event to extend beyond the valley floor and up onto either the valley walls or the tributary fans. This further supports the conclusion that the that the entire floor of the Little North Fork valley is prone to flooding.

3. Numerous observations of buried sawcut old-growth redwood stumps in growth position support the conclusion that generally widespread channel and floodplain aggradation occurred along the floor of the Little North Fork valley in the recent past.

4. The recent exhumation of the buried stumps demonstrates generally widespread channel migration, downcutting, and sediment transport subsequent to the aggradation.

5. The numerous observations of exhumed sawcut old-growth redwood stumps standing in growth position within the active channel support the conclusion of generally widespread channel migrations. More specifically, because old-growth trees do not grow within active stream channels, the streams must have migrated in recent time to exhume the stumps.

6. The topographic analysis found no obvious evidence of fault rupture lineaments or older alluvial terraces within the Little North Fork valley floor. Thus, the morphology of the valley floor appears to be generally young which is consistent with the model of widespread floodplain aggradation discussed above.

7. Little North Fork follows a somewhat tortuous path as it flows through the aggraded floodplain containing buried tree stumps, impinges upon valley walls, and is locally constrained by tributary fans. However, the longitudinal profile of Little North Fork exhibits generally smooth concavity which is suggestive of a graded alluvial stream in dynamic equilibrium. This supports the hypothesis above regarding the stream now in a phase of downcutting and reworking of the floodplain sediment.

8. As per the LiDAR derived topographic map, valley floor contours exhibit broad patterns of shallow undulatory relief. Topographic depressions form hydrologic "sinks" where surface water accumulates and forms wetland areas. Additionally, distinct contour patterns are interpreted to represent the remnant drainage network that formed to accommodate the floodplain aggradation. These *"secondary"* channels and the hydrologic sink areas occur across local differences in topographic relief which creates the potential for a variety of different channel avulsions.

9. Evidence of past and incipient avulsions are widespread and appear well correlated with channel-spanning accumulations of large wood. It appears likely then, that future avulsions will be similarly generated by channel-spanning accumulations of large wood.

10. Numerous lines of evidence document that the Little North Fork Gualala River is an alluvial stream with an erodible bed and streambanks. The stream is neither confined or laterally stable, and both channel migration and avulsions are common channel adjustments. Because both avulsions and channel migrations are likely to occur within the next 150 years, the formal CMZ delineation must accommodate both potential forms of channel adjustment.

In closing, GRT presents no technical basis or justification supporting its decision to adopt the 20-year floodplain as the *flood prone area* over that delineated by the valley walls. Similarly, no meaningful justification is presented to support the opinion that a Channel Migration Zone (CMZ) does not exist throughout the length of the Little North Fork. The collected geologic and geomorphic work discussed above documents that the Little North Fork Gualala River is an alluvial stream subject to ongoing channel adjustment associated with both avulsions and lateral channel migration. The work also presents evidence supporting the interpretation that the outer boundary of the Little North Fork *flood prone area* extends from valley-wall to valley-wall. It is therefore recommended that the entire valley floor, from valley-wall to valley-wall be formally delineated as the *flood prone area*. It is further recommended that a formal CMZ designed to accommodate the potential for both avulsions and lateral channel migration during the next 150 years be adopted for the “Little” THP as per the FPRs. To facilitate such a delineation, a CMZ and associated technical rationale is provided as a part this memorandum.

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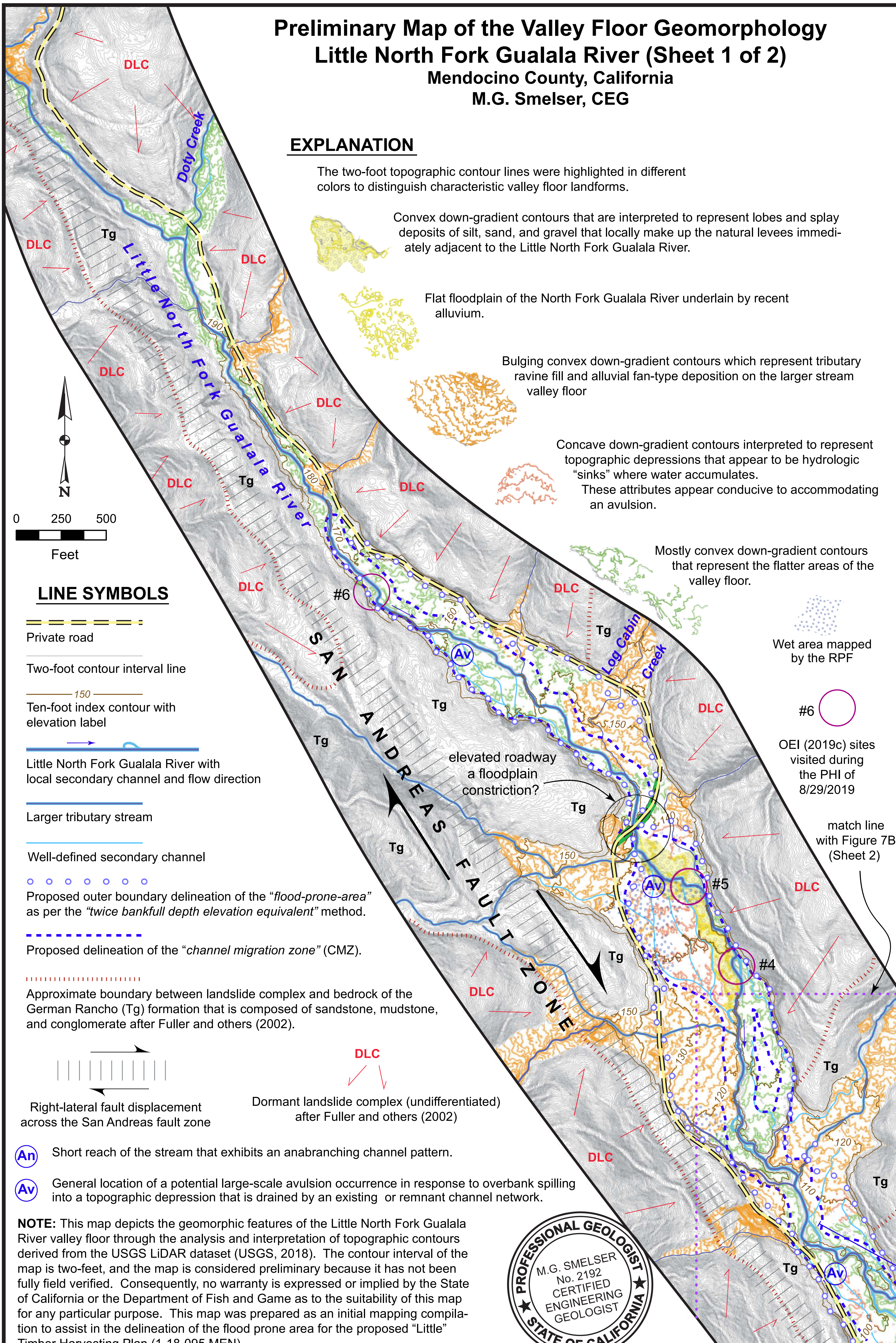
Preliminary Map of the Valley Floor Geomorphology
Little North Fork Gualala River (Sheet 1 of 2)
Mendocino County, California
M.G. Smelser, CEG



EXPLANATION

The two-foot topographic contour lines were highlighted in different colors to distinguish characteristic valley floor landforms.

Convex down-gradient contours that are interpreted to represent lobes and splay deposits of silt, sand, and gravel that locally make up the natural levees immediately adjacent to the Little North Fork Gualala River.

Flat floodplain of the North Fork Gualala River underlain by recent alluvium.

Bulging convex down-gradient contours which represent tributary ravine fill and alluvial fan-type deposition on the larger stream valley floor

Concave down-gradient contours interpreted to represent topographic depressions that appear to be hydrologic "sinks" where water accumulates. These attributes appear conducive to accommodating an avulsion.

Mostly convex down-gradient contours that represent the flatter areas of the valley floor.

Wet area mapped by the RPF

#6 OEI (2019c) sites visited during the PHI of 8/29/2019

LINE SYMBOLS

Private road

Two-foot contour interval line

150 Ten-foot index contour with elevation label

Little North Fork Gualala River with local secondary channel and flow direction

Larger tributary stream

Well-defined secondary channel

Proposed outer boundary delineation of the "*flood-prone-area*" as per the *"twice bankfull depth elevation equivalent"* method.

Proposed delineation of the "*channel migration zone*" (CMZ).

Approximate boundary between landslide complex and bedrock of the German Rancho (Tg) formation that is composed of sandstone, mudstone, and conglomerate after Fuller and others (2002).

Right-lateral fault displacement across the San Andreas fault zone

DLC Dormant landslide complex (undifferentiated) after Fuller and others (2002)

An — Short reach of the stream that exhibits an anabranching channel pattern.

Av — General location of a potential large-scale avulsion occurrence in response to overbank spilling into a topographic depression that is drained by an existing or remnant channel network.

NOTE: This map depicts the geomorphic features of the Little North Fork Gualala River valley floor through the analysis and interpretation of topographic contours derived from the USGS LiDAR dataset (USGS, 2018). The contour interval of the map is two-feet, and the map is considered preliminary because it has not been fully field verified. Consequently, no warranty is expressed or implied by the State of California or the Department of Fish and Game as to the suitability of this map for any particular purpose. This map was prepared as an initial mapping compilation to assist in the delineation of the flood prone area for the proposed "Little" Timber Harvesting Plan (1-18-095 MEN).

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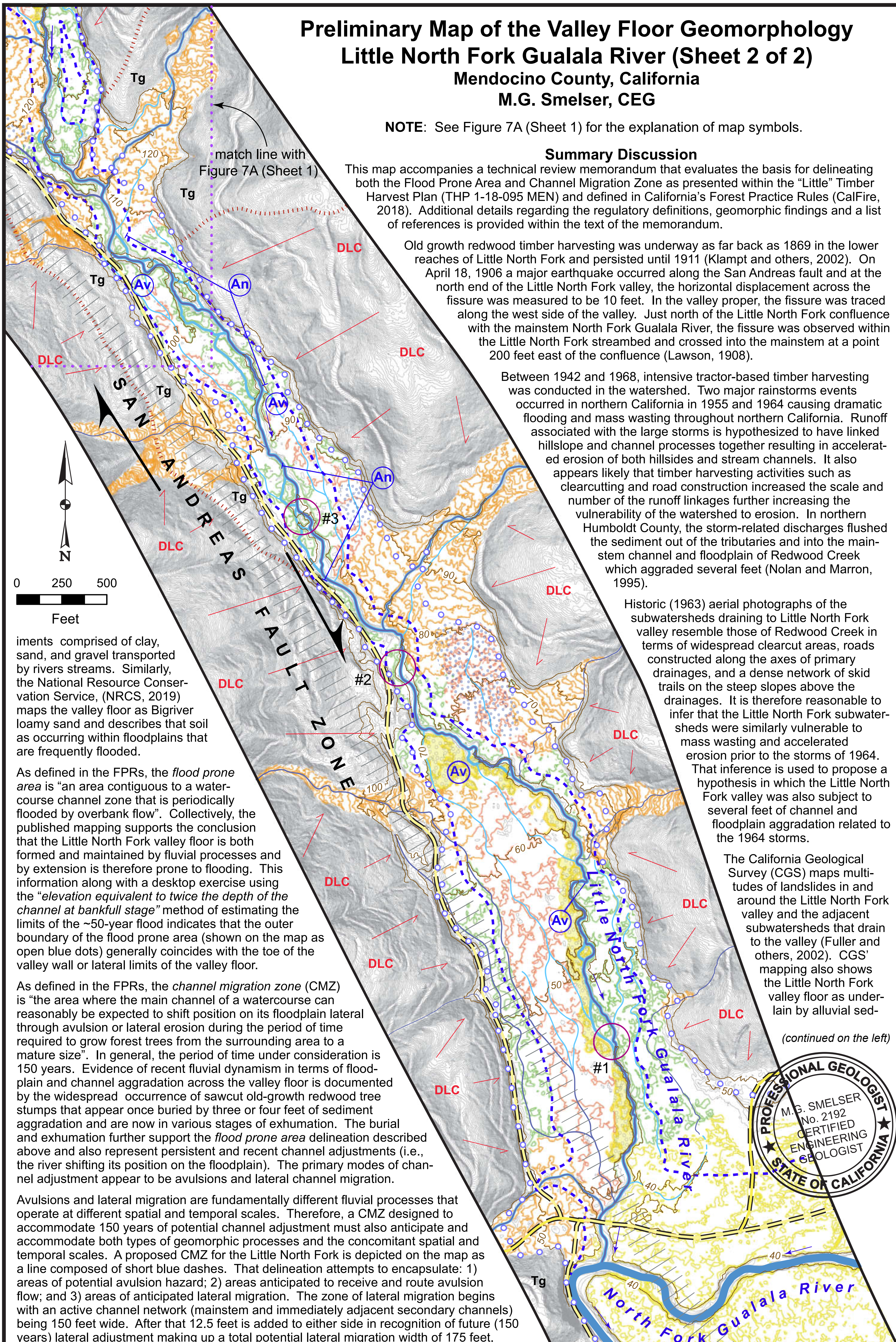
CALIFORNIA DEPARTMENT OF FISH & WILDLIFE	**Flood Prone Area Assessment** **"Little" Timber Harvesting Plan** **(1-18-095 MEN)**	TITLE: Little North Fork Gualala River Valley Floor Geomorphology Sheet 1 of 2 DATE: Revised November 7, 2019 SCALE: As shown	FIGURE: 7A

Preliminary Map of the Valley Floor Geomorphology
Little North Fork Gualala River (Sheet 2 of 2)
Mendocino County, California
M.G. Smelser, CEG

NOTE: See Figure 7A (Sheet 1) for the explanation of map symbols.



Summary Discussion

This map accompanies a technical review memorandum that evaluates the basis for delineating both the Flood Prone Area and Channel Migration Zone as presented within the "Little" Timber Harvest Plan (THP 1-18-095 MEN) and defined in California's Forest Practice Rules (CalFire, 2018). Additional details regarding the regulatory definitions, geomorphic findings and a list of references is provided within the text of the memorandum.

Old growth redwood timber harvesting was underway as far back as 1869 in the lower reaches of Little North Fork and persisted until 1911 (Klampt and others, 2002). On April 18, 1906 a major earthquake occurred along the San Andreas fault and at the north end of the Little North Fork valley, the horizontal displacement across the fissure was measured to be 10 feet. In the valley proper, the fissure was traced along the west side of the valley. Just north of the Little North Fork confluence with the mainstem North Fork Gualala River, the fissure was observed within the Little North Fork streambed and crossed into the mainstem at a point 200 feet east of the confluence (Lawson, 1908).

Between 1942 and 1968, intensive tractor-based timber harvesting was conducted in the watershed. Two major rainstorms events occurred in northern California in 1955 and 1964 causing dramatic flooding and mass wasting throughout northern California. Runoff associated with the large storms is hypothesized to have linked hillslope and channel processes together resulting in accelerated erosion of both hillsides and stream channels. It also appears likely that timber harvesting activities such as clearcutting and road construction increased the scale and number of the runoff linkages further increasing the vulnerability of the watershed to erosion. In northern Humboldt County, the storm-related discharges flushed the sediment out of the tributaries and into the main-stem channel and floodplain of Redwood Creek which aggraded several feet (Nolan and Marron, 1995).

Historic (1963) aerial photographs of the subwatersheds draining to Little North Fork valley resemble those of Redwood Creek in terms of widespread clearcut areas, roads constructed along the axes of primary drainages, and a dense network of skid trails on the steep slopes above the drainages. It is therefore reasonable to infer that the Little North Fork subwatersheds were similarly vulnerable to mass wasting and accelerated erosion prior to the storms of 1964. That inference is used to propose a hypothesis in which the Little North Fork valley was also subject to several feet of channel and floodplain aggradation related to the 1964 storms.

The California Geological Survey (CGS) maps multitudes of landslides in and around the Little North Fork valley and the adjacent subwatersheds that drain to the valley (Fuller and others, 2002). CGS' mapping also shows the Little North Fork valley floor as underlain by alluvial sed-

(continued on the left)

iments comprised of clay, sand, and gravel transported by rivers streams. Similarly, the National Resource Conservation Service, (NRCS, 2019) maps the valley floor as Bigriver loamy sand and describes that soil as occurring within floodplains that are frequently flooded.

As defined in the FPRs, the *flood prone area* is "an area contiguous to a watercourse channel zone that is periodically flooded by overbank flow". Collectively, the published mapping supports the conclusion that the Little North Fork valley floor is both formed and maintained by fluvial processes and by extension is therefore prone to flooding. This information along with a desktop exercise using the "*elevation equivalent to twice the depth of the channel at bankfull stage"* method of estimating the limits of the ~50-year flood indicates that the outer boundary of the flood prone area (shown on the map as open blue dots) generally coincides with the toe of the valley wall or lateral limits of the valley floor.

As defined in the FPRs, the *channel migration zone* (CMZ) is "the area where the main channel of a watercourse can reasonably be expected to shift position on its floodplain lateral through avulsion or lateral erosion during the period of time required to grow forest trees from the surrounding area to a mature size". In general, the period of time under consideration is 150 years. Evidence of recent fluvial dynamism in terms of floodplain and channel aggradation across the valley floor is documented by the widespread occurrence of sawcut old-growth redwood tree stumps that appear once buried by three or four feet of sediment aggradation and are now in various stages of exhumation. The burial and exhumation further support the *flood prone area* delineation described above and also represent persistent and recent channel adjustments (i.e., the river shifting its position on the floodplain). The primary modes of channel adjustment appear to be avulsions and lateral channel migration.

Avulsions and lateral migration are fundamentally different fluvial processes that operate at different spatial and temporal scales. Therefore, a CMZ designed to accommodate 150 years of potential channel adjustment must also anticipate and accommodate both types of geomorphic processes and the concomitant spatial and temporal scales. A proposed CMZ for the Little North Fork is depicted on the map as a line composed of short blue dashes. That delineation attempts to encapsulate: 1) areas of potential avulsion hazard; 2) areas anticipated to receive and route avulsion flow; and 3) areas of anticipated lateral migration. The zone of lateral migration begins with an active channel network (mainstem and immediately adjacent secondary channels) being 150 feet wide. After that 12.5 feet is added to either side in recognition of future (150 years) lateral adjustment making up a total potential lateral migration width of 175 feet.

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE	**Flood Prone Area Assessment "Little" Timber Harvesting Plan (1-18-095 MEN)**	TITLE: Little North Fork Gualala River Valley Floor Geomorphology Sheet 2 of 2 DATE: Revised November 11, 2019 SCALE: As shown	FIGURE: 7B

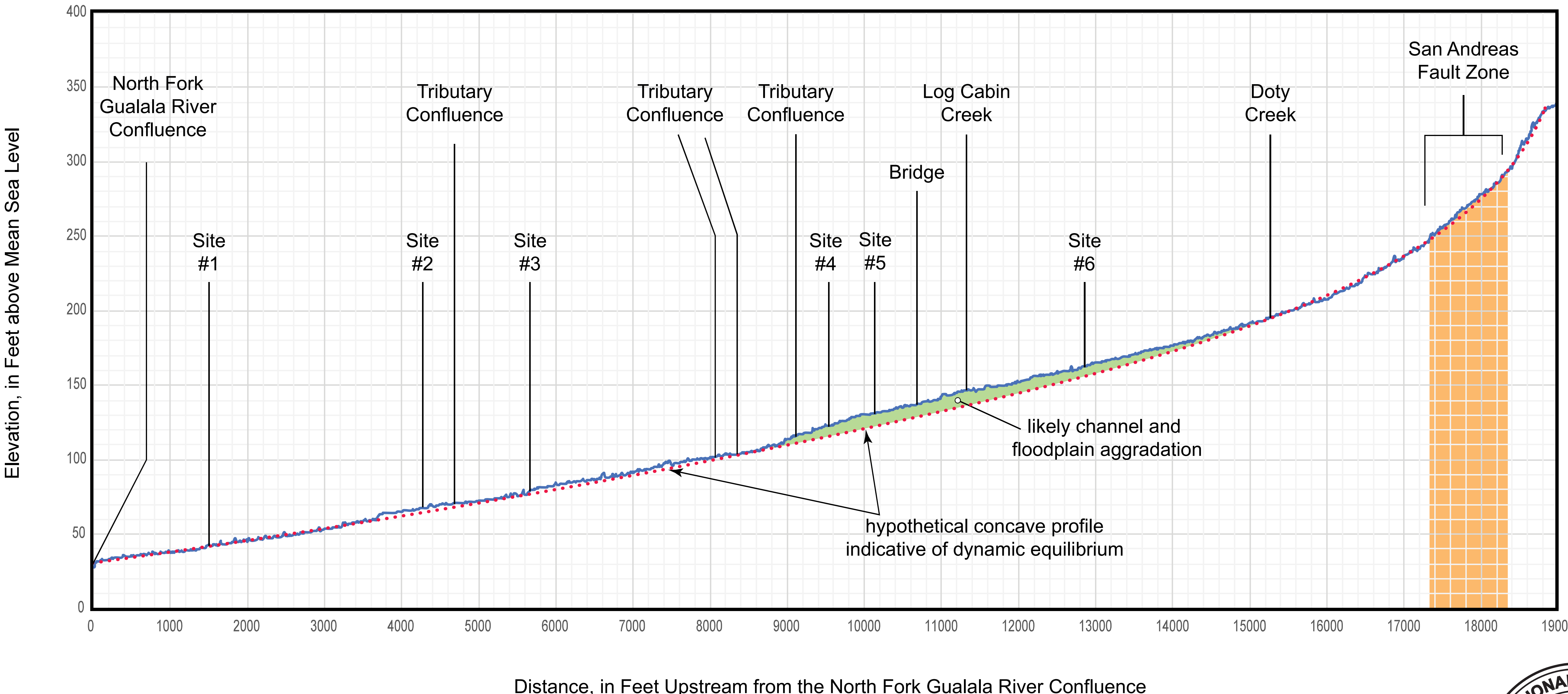


FIGURE: 8

TITLE: Little North Fork Gualala River Longitudinal Profile

SCALE: As shown

DATE: Revised November 8, 2019

Flood Prone Area Delineation Effort
"Little" Timber Harvesting Plan
(1-18-095 MEN)

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