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CONTENTS

FIGURES

1 OVERVIEW OF SURFACE RUPTURE IN THE HUMBOLDT REGION

Active faults and fault-related structures, including folds, are located within the onshore and offshore Cascadia subduction margin (Figure 1; see *Geologic Technical Memo 1: Strong Ground Motion* for discussion of seismic sources). Offshore fault and fold structures in the upper plate of the subduction zone tend to be located within the accretionary prism away from land for the majority of the CSZ (McNeill et al., 1999). Field et al. (1980), Clarke (1990), and Clarke and Carver (1992) identified these structures in the offshore sediments of the Eel River basin. (Figure 2). More recently, high-resolution multichannel seismic reflection surveys and detailed bathymetry have provided even better imaging of offshore structures (Hill et al., 2020). Further understanding of deformation of the Gorda plate, which is a major contributing source to current regional seismicity, came from seismic reflection surveys beyond the subduction margin (Gulick et al., 1998, 2001) and analysis of seismicity within the plate (Chaytor et al., 2004; Furlong & Schwartz, 2004; Rollins & Stein, 2010; Smith et al., 1993; Stoddard, 1991; Wilson, 1989, 1993).

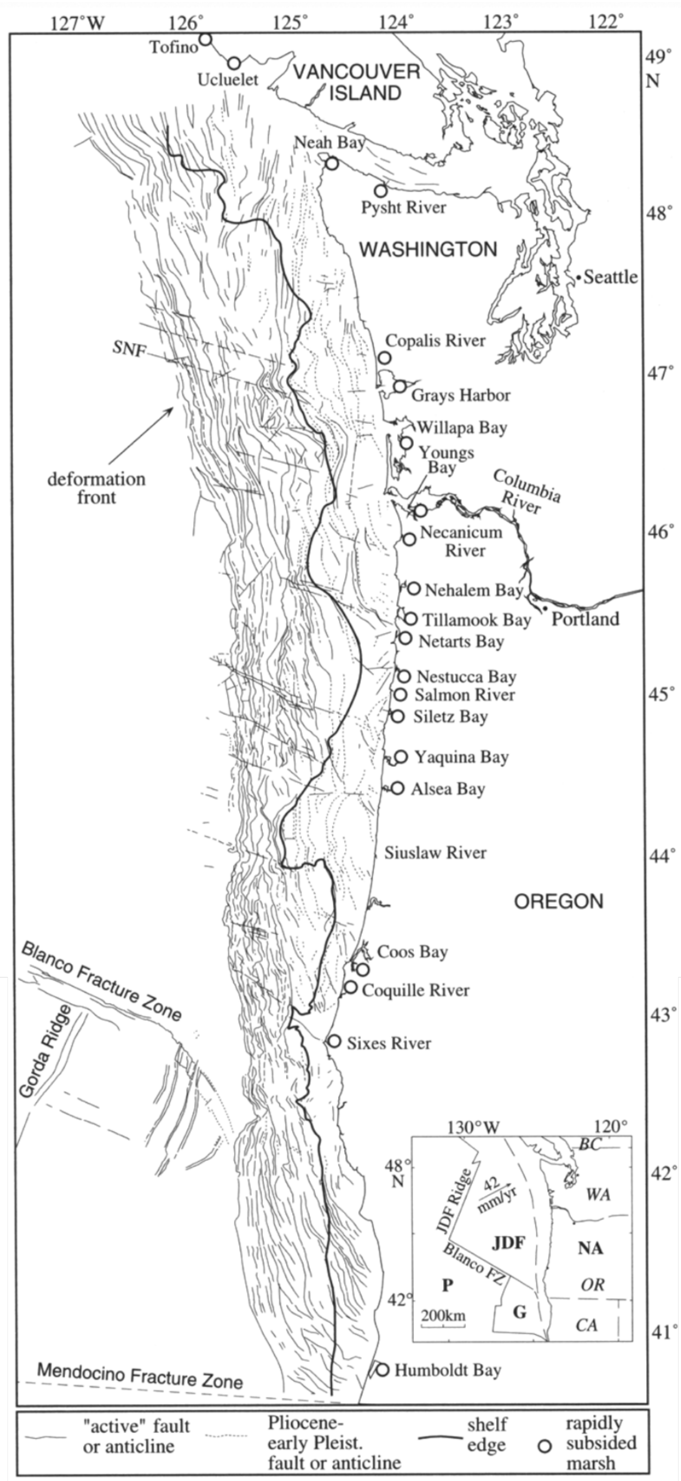

Figure 1 - Faults and folds within the offshore accretionary prism of the entire Cascadia Subduction Zone. This map does not include onshore faults and folds which exist primarily in the southern part of the subduction zone. The megathrust is farther offshore in the Oregon – Canada portion of the margin. North of the Blanco Fracture zone most structures are older "Pliocene to early Pleistocene." From McNeill et al. (1998).

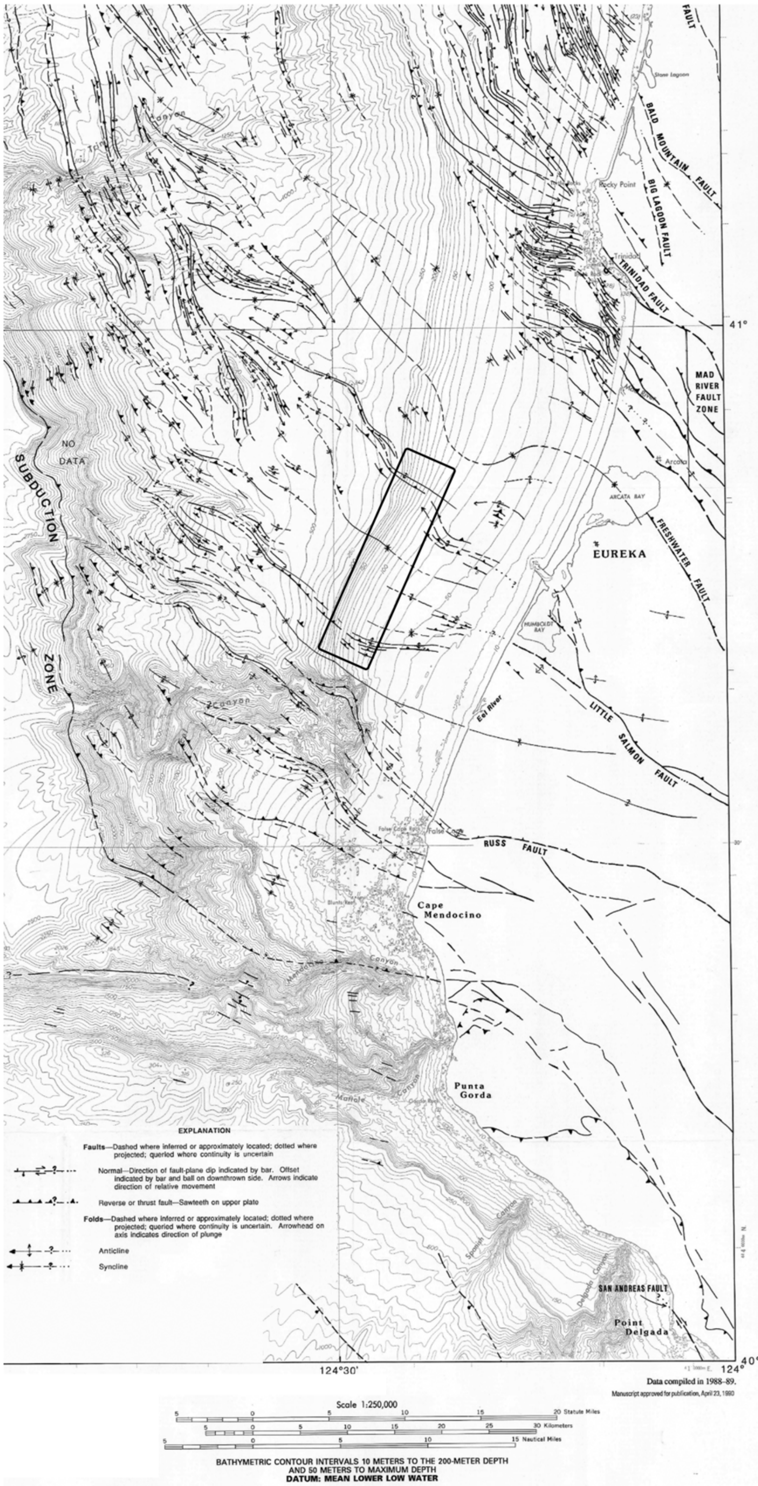

Figure 2. Map showing locations of faults and folds identified from multi- and single-channel deep- to intermediate-depth seismic-reflection profiles and side-scan sonar mosaics of the portion of the CSZ south of Oregon (modified from Clarke, 1990). These fault interpretations include those offsets interpreted in the pre-Tertiary Franciscan basement and do not necessarily reflect offset in the younger, overlying Quaternary sediments. Note the continuation of faults and folds onshore at the southern end near Humboldt Bay. Black box is the approximate location of the seismic profile in Figure 5.

The on-land faults and associated folds are the extension of these offshore accretionary prism faults. These are features unique to this area in that most fold and thrust structures associated with subduction zones are located offshore, including the majority of the CSZ from Oregon through southwestern Canada. (Figure 1 & 2). Previously, these structures were mapped onland within the terrestrial Eel River basin by Ogle (1953) but a greater understanding of these faults, with recognition they are Quaternary—and in many cases Holocene—active structures came from paleoseismic studies by Woodward-Clyde Consultants (1980) and later by local academic studies and consultants' investigations (Burke & Carver, 1992; Carver, 1992; Carver & Burke, 1988; Clarke & Carver, 1992; Hemphill-Haley & Witter, 2006; Kelsey & Carver, 1988; Nelson et al., 1995; Vadurro, 2006; Valentine et al., 2012; Witter et al., 2002). Summaries of seismic sources include Woodward-Clyde Consultants (1980), McCrory (2000) and Swan et al. (2002).

Faults and associated structures that may pose surface rupture hazards for the CalTrans HWY 101 project area include the Fickle Hill fault, a part of the Mad River fault zone (Carver et al., 1982; Smith, 1982; California Division of Mines and Geology, 1983; Vick, 1988; Vick and Carver, 1988; McLaughlin et al., 2000). The fault is interpreted to be a southwest-vergent, northeast dipping thrust fault consisting of numerous sub-parallel splays faults (McLaughlin et al., 2000). It is located at the north end of the project area and traverses the Arcata city boundary along a northwest-southeast trending series of scarps formed within marine terrace deposits (Figures 3 and 4). As the fault trends to the southeast it exposes progressively older Quaternary-Tertiary nearshore marine deposits (Wildcat of Ogle (1953) and Cretaceous-Jurassic Franciscan formation rocks in increasingly larger range-front scarps that form Fickle Hill (Figure 5). To the southwest a series of faults exist which have been poorly documented. The Bayside fault appears to be a possible subsidiary splay of the Fickle Hill fault (Figure 4). It appears to displace late Pleistocene marine terrace deposits (Figure 5). Further to the southwest, the Bracut and Freshwater faults project to Hwy 101 and displace Qtw deposits. An apparent lack of Qm marine terrace deposits preclude assessment of late Pleistocene activity on these faults however they do not appear to deform Holocene bay deposits. The USGS Quaternary fault and fold database (USGS, 2020) considers the Fickle Hill fault to be active, the Bayside fault to be potentially active and the Bracut and Freshwater faults to be poorly constrained in age of activity but Quaternary. They have a low probability of activity that might affect the highway project.

Slip rates for the Fickle Hill fault are poorly constrained but are considered to be approximately 5 mm/yr (USGS, 2020).

Most of the paleoseismic information for area faults within the fold and thrust belt comes from investigations of the Little Salmon fault zone (LSFz) located to the south of Eureka and outside the project area. Investigations of the LSFz were conducted to evaluate seismic hazards of the Humboldt Bay Power Plant. This is the best information available on deformation style and activity of an active fold and thrust fault in the region. We consider it an appropriate analog to the Fickle Hill fault although the Little Salmon fault is likely more active.

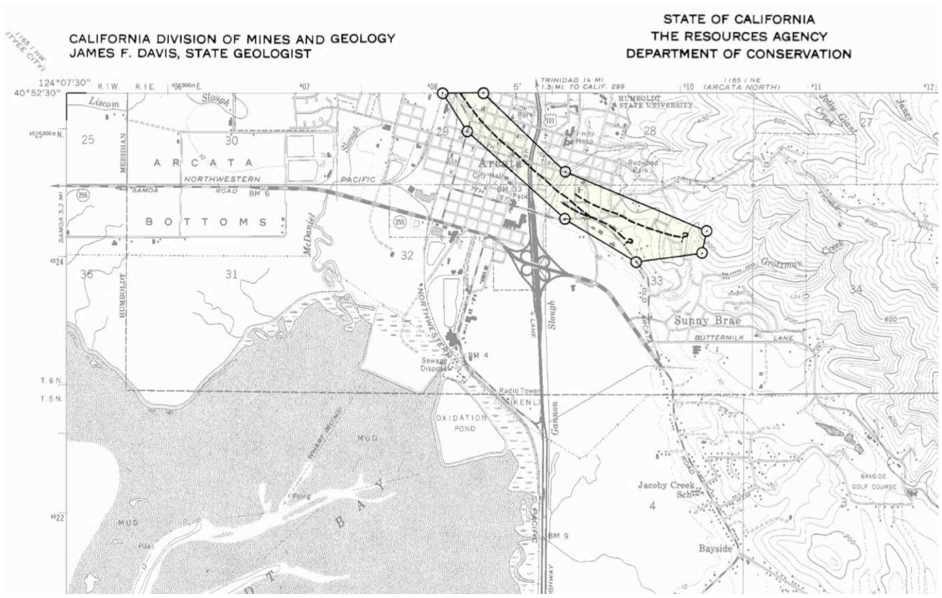

Figure 3. Alquist-Priolo Special Studies delineation of the Fickle Hill fault as understood in 1983 (California Division of Mines and Geology, 1983; T. C. Smith, 1982). Further investigations (Carver, 1992; Clarke & Carver, 1992b; McCrory, 1996; G. S. Vick & Carver, 1988) suggest the fault extends further to the SE and NW than shown here (see Figure 4).

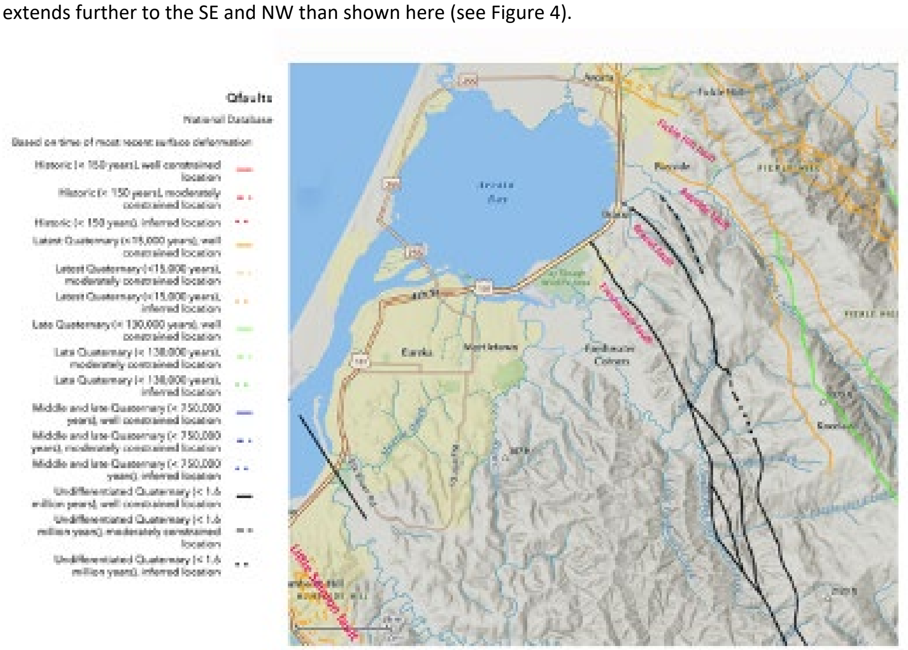

Figure 4. Faults listed as part of the Mad River fault zone that include the Fickle Hill fault and associated splays to the southwest that include the Bayside, Bracut and Freshwater faults (from the USGS fault and fold database (https://www.usgs.gov/programs/earthquake-hazards/faults). The Fickle Hill and Bayside faults are reported as latest Quaternary (<15,000 years) while the Bracut and Freshwater faults are considered to have had Quaternary active (<1.6 million years) but there is no substantive evidence for younger activity.

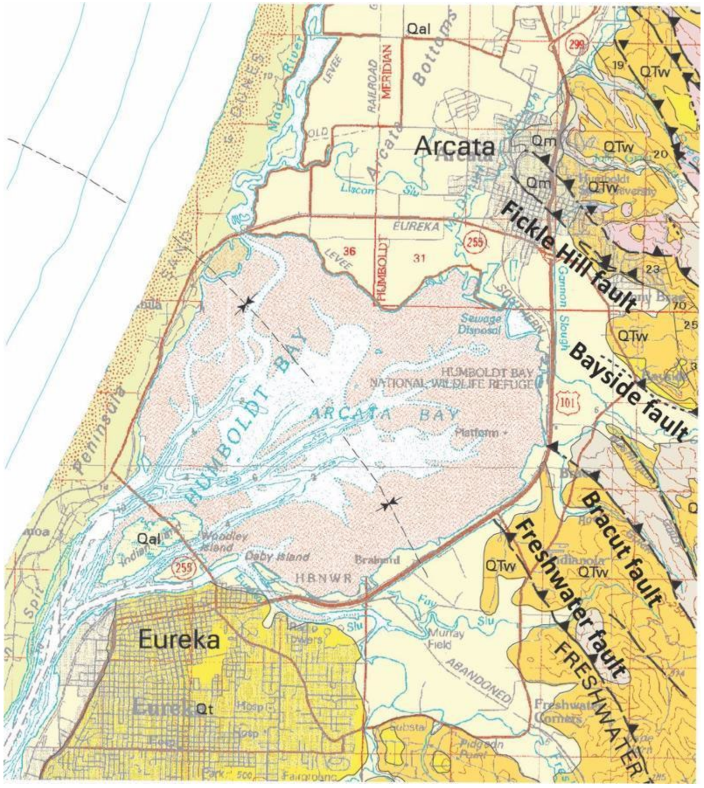

Figure 5. Geologic map of Arcata Bay, northern Humboldt Bay (modified from McLaughlin et al. (2000). Several faults transect the project portion of Hwy 101 including, from north to south, the Fickle Hill, Bayside, Bracut and Freshwater faults. . These fault all displace Quaternary/Tertiary Wildcat formation (QTw) of Ogle (1953). The Fickle Hill fault also displaces late Pleistocene marine terrace deposits (Qm). The Bayside fault forms a prominent scarp in QTw deposits and possibly Qm terraces. The Bracut and Freshwater faults deform QTw deposits but not Holocene bay muds adjacent to the highway.

As stated in Page and Swan (2002, p. 8-2) regarding the LSFz, *"The style of faulting and related surface deformation, width of the deformed area, amount of surface displacement, and relative contributions of fault displacement and folding to the total slip on a fault commonly change within short distances along strike."* Surface rupture may simply be along a single low angle fault plane or may involve a complex array of imbricate, stacked faults, back-thrusts and normal faults as well as folds. End member complexity may include hundreds or thousands of closely spaced conjugate faults that occur in a broad deformation zone (Page and Swan, 2002). Further, as noted by Page and Swan (2002), thrust faults are often "blind" and do not reach the ground surface, although the upper plate deformation includes faults and folds (Figure 6).

Investigation of the Little Salmon fault at College of the Redwoods by Witter et al. (2001) revealed a complex, broad zone of faults and folds in the upper plate (Figure 7). A similar geometry of upper plate deformation might be expected along the Fickle Hill and Bayside faults if they are involved in an earthquake sufficient in size to create surface deformation.

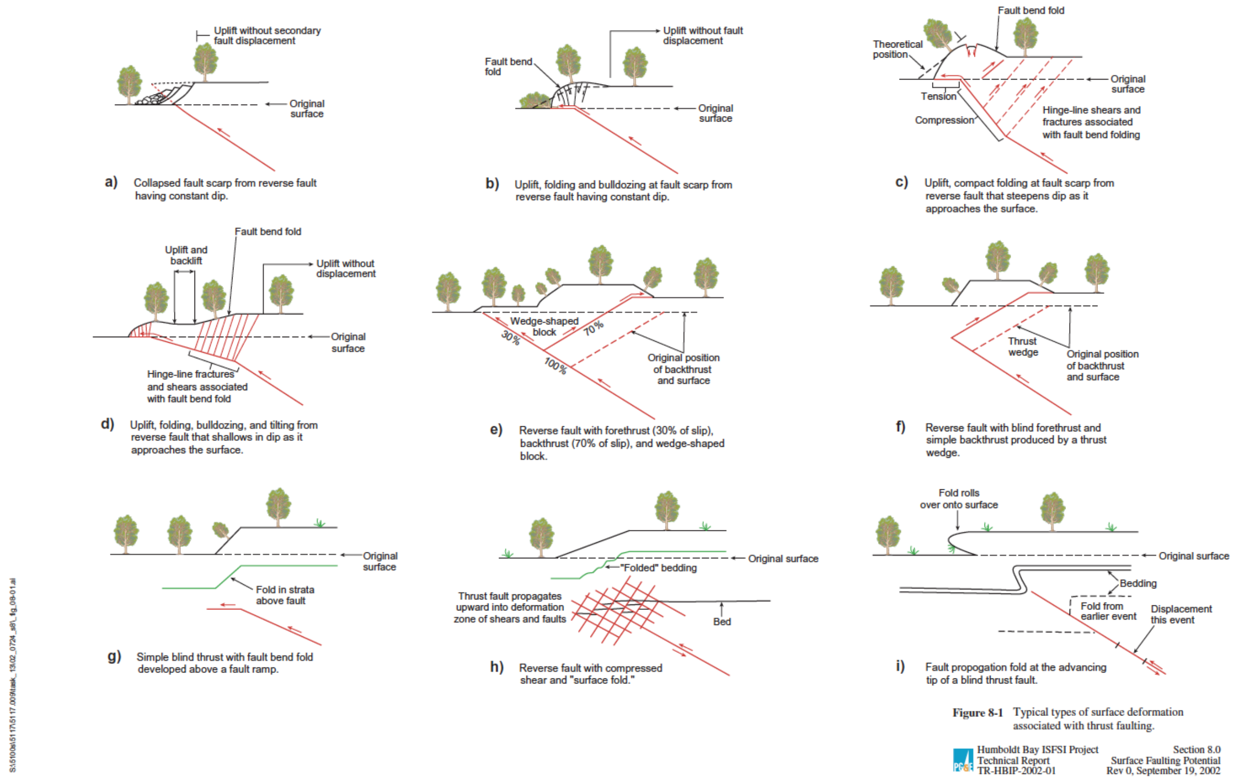

Figure 6. Potential upper plate structures that might be associated with slip along a basal thrust fault. Configurations and geometries of upper plate faults and folds largely are dependent on changes in fault dip and depth. (From Swan, 2002, his Figure 8-1.)

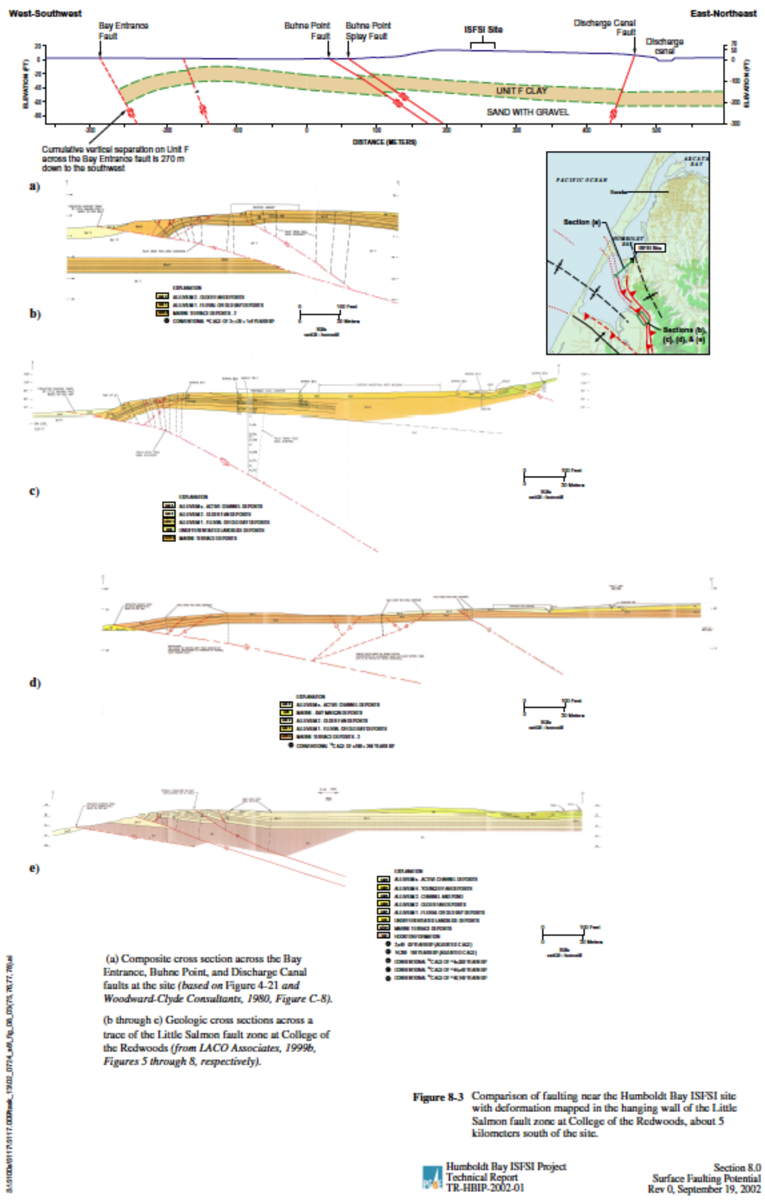

Figure 7. Diagrams of onshore surface faulting within the hanging wall of splays of the Little Salmon fault zone at the Humboldt Bay power plant and College of the Redwoods. (From Swan, 2002, his Figure 8-3.)

Figure 7. Diagrams of onshore surface faulting within the hanging wall of splays of the Little Salmon fault zone at the Humboldt Bay power plant and College of the Redwoods. (From Swan, 2002, his Figure 8-3.)

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