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Twentieth Century Channel Change of the Green River in Canyonlands National Park, Utah

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TWENTIETH CENTURY CHANNEL CHANGE OF THE GREEN RIVER IN CANYONLANDS NATION PARK, UTAH

by

Alexander E. Walker

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Watershed Science

Approved:

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ABSTRACT

Twentieth Century Channel Change of the Green River in Canyonlands National Park, Utah

by

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Utah State University, 2017

Major Professor: Dr. John C. Schmidt
Department: Watershed Sciences

The lower Green River within Canyonlands National Park has narrowed substantially since the late 1800s, resulting in a narrower channel. Changes to flood magnitude, rate and timing since 1900, driven by increased water storage and diversion in the Green River basin and declines in annual precipitation, were responsible for inset floodplain formation.

Multiple lines of evidence were used to reconstruct the history of channel narrowing in the lower Green River and identify processes of floodplain formation. In the field, stratigraphy, sedimentology and dendrogeomorphology exposed in a floodplain trench were described to identify rate, timing and magnitude of floodplain formation. Channel and floodplain surveys were conducted to determine possible changes in bed elevation. Additionally, I analyzed existing aerial imagery, hydrologic and sediment transport data. I applied these techniques to determine magnitude, timing and processes of floodplain formation at multiple spatial and temporal scales.

My investigation shows that the floodplains of the contemporary lower Green River began forming in the late 1930s and continued to form and vertically accrete in the 20th century by inset floodplain formation. During this time period, peak flow and total runoff declined due to climatic changes and water development. Inset floodplains continued to form and vertically aggrade along the lower Green River since the mid-1980s, narrowing the river by an additional 9 %. Analysis of aerial imagery shows that changes to the floodplain identified in the trench occurred throughout the 61 km of river I studied. Non-native tamarisk *(Tamarix spp.)* did not drive channel narrowing, though dense stands stabilized banks and likely promoted sediment deposition. Inset floodplain formation reflects changes to flood magnitude and timing resulting from water development and climate change.

My findings have implications for the long-term management of the riverine corridor within Canyonlands National Park and endangered endemic native fishes – particularly the Colorado pikeminnow (*Ptychocheilus lucius*) and the razorback sucker (*Xyrauchen texanus*). Collaboration with upstream stakeholders and managers is necessary to preserve elements of the flow regime that preserve channel width and limit channel narrowing.

(415 pages)

PUBLIC ABSTRACT

Twentieth Century Channel Change of the Green River in Canyonlands National Park, Utah

Alexander E. Walker

Since the early 20th century, river channels of the Colorado River basin have narrowed, decreasing available riparian and aquatic habitat. Changes are considered to be the result of three major factors: wide-spread water development, increasing hydroclimate variability and the invasion of non-native tamarisk *(Tamarix spp.),* altering flow regime and sediment supply. Different studies have reached different conclusions about the relative roles of flow regime, sediment supply and tamarisk in causing narrowing.

I investigated channel change in the lower Green River within Canyonlands National Park to describe channel changes in the 20th century and understand the roles of shifting flow regime and changing vegetation communities on 20th century channel narrowing.

The lower Green River within Canyonlands National Park has narrowed substantially since the late 1800s, resulting in narrower channel. Changes to flood magnitude, rate and timing since 1900, driven by increased water storage and diversion in the Green River basin and declines in annual precipitation, was responsible for inset floodplain formation documented in this study.

I used multiple datasets to reconstruct the history of channel narrowing in the lower Green River and identify processes of floodplain formation. In the field, analyses of a floodplain trench were described to identify rate, timing and magnitude of floodplain formation. Channel and floodplain surveys were conducted to determine possible changes in bed elevation. Additionally, I analyzed existing aerial imagery, hydrologic data, and sediment transport data. I applied these techniques to determine how floodplain formation occurred at multiple spatial and temporal scales.

My investigation shows that the floodplains of the contemporary lower Green River began forming in the late 1930s and continued to form in the 20th century by inset floodplain formation. During this time period, peak flow and total runoff declined due to climatic changes and human water development. Since the mid-1980s, inset floodplains continued to develop along the lower Green River since the mid-1980s, narrowing the river by an additional 9.4%. Analysis of aerial imagery shows that changes to the floodplain identified in the trench occurred throughout the 61 km of river I studied. Non-native tamarisk *(Tamarix spp.)* did not drive channel narrowing, though dense stands stabilized banks and likely promoted sediment deposition. Inset floodplain formation reflects changes to flooding resulting from water development and climate change.

My findings have implications for the long-term management of the lower Green River and endangered endemic native fishes – particularly the Colorado pikeminnow (*Ptychocheilus lucius*) and the razorback sucker (*Xyrauchen texanus***)**. Collaboration with upstream stakeholders and managers is necessary to preserve elements of the flow regime that preserve channel width and limit channel narrowing.

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Alexander E. Walker

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CHAPTER 1

INTRODUCTION

In three days in mid-July 1869, nine men in three boats rowed the 160-km length of the lower Green River between the mouth of the San Rafael River and its confluence with the Grand River. The group, led by John Wesley Powell, rowed, because “The water is as calm as a lake” (W. C. Bradley journal, July 15, 1869, edited by Darrah, 1947). There were few cottonwood trees (Populus spp.) in the “symmetrically curved and grandly arched” canyons that Powell (1895) named Labyrinth and Stillwater. Although cottonwoods were “scrubby” and “very scarce,” “there is in some places a small table that affords a footing for a few willows” (J. C. Sumner journal, July 14, 1869, edited by Darrah, 1947). On the inside of bends, Powell (1895) observed a “long peninsula of willow-bordered meadow” and “the talus at the foot of the cliff is usually covered with dwarf oaks.” These observations and subsequent photographs taken by E. O. Beaman in early September 1871 during Powell’s second expedition (Figure 1.1), as well as photographs taken in the early 20th century (summarized by Webb et al., 2007) describe a wide active channel with abundant emergent sand bars and lined by “dense willow and greasewood chaparral” (F. M. Bishop journal, September 11, 1871, edited by C. Kelly, 1947) that comprised “a dense jungle of rose-bushes, willows, and other plants” (Dellenbaugh, 1908). The modern channel of the lower Green River is also lined by woody riparian vegetation that forms dense thickets. Although willow and oak are still present, much of the vegetation is non-native tamarisk (*Tamarix spp.*) and today’s channel is narrower. There are fewer emergent sand bars, islands, and secondary channels (Webb et al., 2004, 2007).

Riparian and riverine environments play a critical role in providing habitat for threatened and endangered species in the contemporary Colorado River basin (Merritt and Cooper, 2000; Mortenson and Weisberg, 2009; Merritt and Poff, 2010; Keller et al., 2014; Sankey et al., 2015). The dramatically different environments today are responses to three major disturbances, all of which have occurred within the last 150 years: alteration of the hydrologic and sediment regime by dams and impoundments, climatically driven changes in hydrology, and invasion of nonnative tamarisk onto the floodplain and active channel bars.

Dams, diversions, and irrigation withdrawals fragment the Colorado River watershed, disrupting downstream hydrology, sediment supply, and sediment transport characteristics. Flood discharge declines, with the effects reaching hundreds of miles downstream (Graf, 1999). The sediment mass balance of reaches immediately downstream from dams are typically perturbed into sediment deficit, resulting in evacuation of sediment from the bed and sometimes from the banks (Williams and Wolman, 1984; Schmidt and Wilcock, 2008). Concurrently with the construction of dams throughout the watershed, there have been widespread changes to riparian vegetation communities, the most notable being the spread of invasive tamarisk (*Tamarix spp*) (Merritt and Cooper, 2000; Sher et al., 2000; Webb et al., 2007; Auerbach et al., 2013). Today, tamarisk is a dominant component of riparian communities (Friedman et al., 2005).

Assessing the impact of non-native vegetation invasion and basin-wide water impoundment, diversion, and withdrawal is complex, due in part to climatically driven shifts in hydrology during the 20th century. The early 20th century was one of the wettest periods in the last 450 years (Woodhouse et al., 2006) and during the last century, total annual runoff declined independent of direct and indirect human disturbances to the flow regime. Precipitation remained relatively constant in the 20th and 21st centuries, but increases in temperature contributed to decreasing stream flow and continued temperature increases are expected to drive expected future declines in stream flow (Udall and Overpeck, 2017).

In the Green River, the longest tributary of the Colorado River, construction of large dams, trans-basin diversions, and within-basin diversions for agriculture and other uses altered the flow regime during the last century. Channel narrowing and other geomorphic responses to these flow-regime changes have been documented on different parts of the Green River and its tributaries (Andrews, 1986; Lyons et al., 1992; Allred and Schmidt, 1999; Grams and Schmidt, 2002; Gaeuman et al., 2003; Grams and Schmidt, 2005; Alexander, 2007; Manners et al., 2014). Additionally, tamarisk spread rapidly through the basin in the early to mid-20th century. On the unregulated Yampa River, colonization by tamarisk, in conjunction with a shift in the natural flow regime, facilitated channel narrowing by trapping sediment and reducing floodplain erosion (Manners et al., 2014).

Comparatively little research has been conducted in the most downstream part of the Green River, where it flows through Canyonlands National Park (CNP) (Graf, 1978; Webb et al., 2004; Birken and Cooper, 2006; Webb et al., 2007). Historic channel narrowing is readily evident in this reach. The wide channel with numerous bare sand bars described by the Powell expedition is now a narrower river with fewer in-channel features. The area of backwater habitat has generally decreased, with likely adverse effects on native fish populations (Bestgen and Hill, 2016).

Graf (1978) argued that tamarisk invasion in the 1940s and 1950s in the lower Green River stabilized sand bars and banks and was the primary cause of narrowing. Graf (1978) estimated that the channel narrowed by approximately 27% within CNP between the early 20th century and the 1950s, and he estimated that the channel did not narrow significantly after 1951 despite construction of upstream dams and diversions in the 1960s and 1970s. Subsequent studies questioned these findings (Everitt, 1979; Andrews, 1986; Allred and Schmidt, 1999), linking channel narrowing primarily to changes in peak flow magnitude and timing, but Graf's (1978) work remains influential in highlighting the contribution of riparian vegetation invasion to channel narrowing (Scott et al., 1996; Birken and Cooper, 2006). These findings influence reservoir and nonnative vegetation management strategies (Merritt and Wohl, 2006; Vincent et al., 2009; Manners et al., 2014).

My study in the lower Green River seeks to better understand the magnitude, timing and processes of geomorphic change during the 20th century and in doing so, resolve the differing conclusions of Graf (1978), Andrews (1986), Allred and Schmidt (1999), and Birken and Cooper (2006). To resolve differences in findings, I integrate data collected at the site, cross-section and reach scale on the lower Green River. A multi-scale approach has not been previously applied to investigate channel change and offers the ability to create a unified conceptual model of channel change.

The lower Green River flows through CNP and park managers, motivated by goals of ecosystem protection and management for this reach of river, desire a clear understanding of historical geomorphic changes and the mechanisms of such changes. At present, CNP has an incomplete understanding of how invasive vegetation and hydrology influence floodplain formation and channel narrowing. Quantifying rates and timing of narrowing, along with identifying causes of channel narrowing, will provide CNP with detailed information on the geomorphology of the lower Green River to improve future park management policies.

Chapter 2 investigates the history of the lower Green River using multiple lines of evidence to determine the timing and processes of floodplain formation at multiple spatial and temporal extents. Historic channel conditions are analyzed using aerial photographs and repeat channel surveys. A floodplain deposition history is developed using stratigraphic analysis of a floodplain trench, including the dating of floodplain deposits by dendrogeomorphology. Sediment transport and hydrologic data are interpreted to explore linkages between channel change and the drivers of water and sediment supply. An important goal of the work is to determine the history of channel narrowing and the prospects for future narrowing. By combining observations in this study with previous work, I explore whether a unified conceptual model of channel change can be developed for channel change in the Green River.

Chapter 3 presents detail on the stratigraphic, sedimentologic and dendrogeomorphic analyses at a trench excavated on the floodplain of Hardscrabble Bottom inside of CNP. Different floodplain facies defined in the trench are linked to different types of inset floodplain formation. Timing of floodplain formation is determined by using dendrogeomorphic techniques of Friedman et al. (Friedman, Vincent, et al., 2005) to determine ages of floodplain deposits. Where possible, those ages are constrained with available hydrologic data. Methods of tree-ring counting, anatomical changes, and cross-dating used to determine ages of individual beds are discussed. These analyses identified a new, previously undiscovered, period of floodplain formation by vertical accretion after 1985.

Chapter 4 concludes the thesis with a discussion of management implications which arise from this study. Findings from previous chapters are placed within the context of current reservoir management strategies and conservation polices in the Green River basin.

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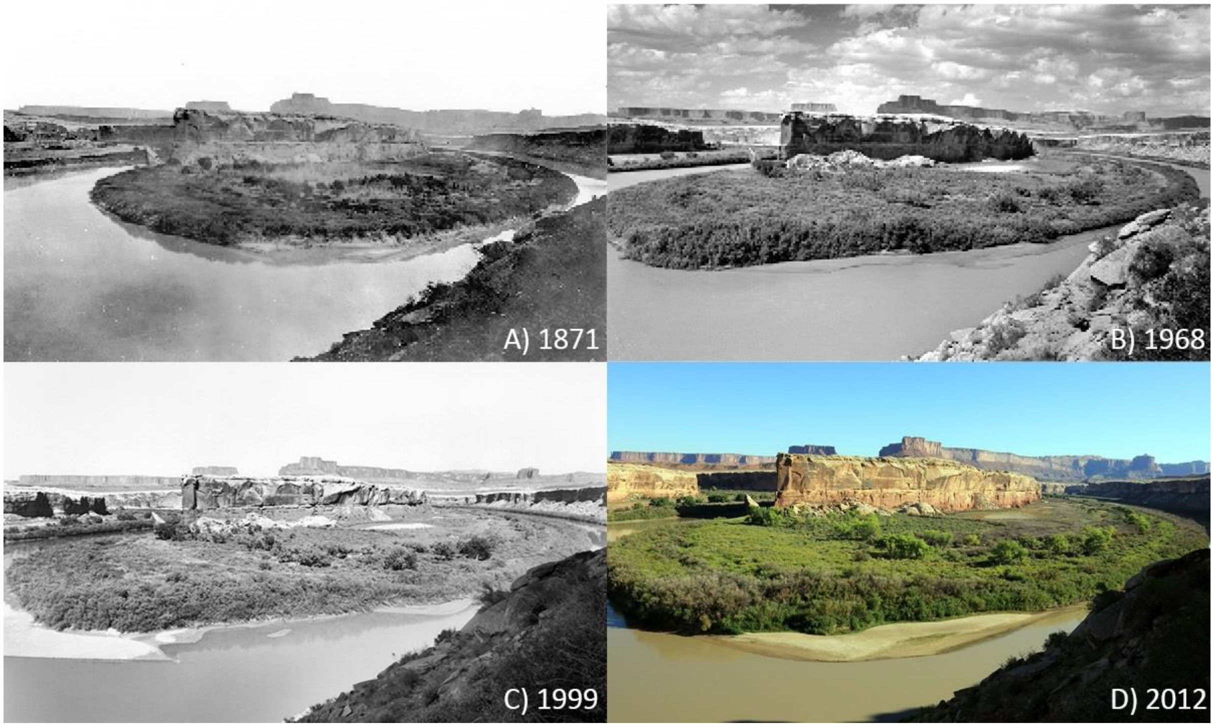

Figure 1.1: A photo match taken at Bonita Bend, on the lower Green River at RM 30, 50 km upstream from the Green-Grand confluence on the right bank at the apex of the bend, looking east. Flow is from left to right. A) Taken by E.O. Beaman on September 9, 1871 during the second John Wesley Powell expedition. B) Taken by E.G Stephens on August 19, 1968 (Stephens and Shoemaker, 1987). C) Taken by Dominic Oldershaw October 13, 1999 D) Taken by Mark E. Miller September 28, 2012. The channel is wide in 1871 and the banks of the bend are vegetated. In 1968, the channel has narrowed; the vegetation next to the water's edge is tamarisk. Channel width remains stable in the 1999 and 2012 photos. A small emergent bar visible in the center of the 1968 is present in 2012. Tamarisk in 2012 shows widespread mortality due to effects of the tamarisk beetle. Dead tamarisk is purplish-brown in the 2012 photo. Photos courtesy of Southwest Biological Science Center, USGS, Flagstaff, AZ.

CHAPTER 2

THE TIMING AND MAGNITUDE OF 20TH CENTURY CHANNEL NARROWING BY INSET FLOODPLAIN FORMATION OF THE LOWER GREEN RIVER IN CANYONLANDS NATIONAL PARK, UTAH[1]

ABSTRACT

Channel narrowing of the Green River since the late 1800s is well documented; however, different studies have reached different conclusions on the rate, timing and magnitude of channel change. To understand whether or not the lower Green River continues to narrow, I use aerial imagery, dendrogeomorphology exposed in a 50-m long, 2-m deep trench excavated in the floodplain, sediment transport data and bathymetric surveys. These techniques are applied to the determine magnitude, timing and processes of floodplain formation at multiple spatial and temporal scales. My results show that the contemporary floodplains of the lower Green River began forming in the late 1930s, and continued to form and vertically accrete in the second half of the 20th century. During this time period, peak flow and total runoff declined due to climatic changes and water development. The most recent phase of floodplain formation began during a period of drought that followed the unusually high runoff years from 1983 to 1985. From the mid-1980s to present, active channel width decreased by 9%. Floodplain formation occurs during spring peak floods, which are the only flows large enough to inundate the floodplain. Bed elevation remained constant during the last two decades and changes to the channel were primarily changes in width. Inset floodplain formation within the banks

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[1] Coauthored by John C. Schmidt, Paul E. Grams and Johnnie N. Moore

of the previous river channel was the primary mechanism of narrowing and the widespread establishment of invasive tamarisk *(Tamarix spp.)* did not play a primary role in channel narrowing. The most recent episode of channel narrowing reflects changes to flood magnitude and timing resulting from water development and climate change.

2.1 INTRODUCTION

The influences of flow regime and sediment supply are central questions in the study of fluvial geomorphology. Changes to these inputs alter the influx and efflux of transported sediment in a river reach. River channels respond to such changes by modifying channel form to optimize the conveyance of water and sediment so that the mass balance is achieved again (Lane, 1955). Changes in the influx of sediment may be caused by changes in the flow regime, watershed sediment supply, or the grain size of the supply. Changes to flow regime and supply rate may be caused by upstream impoundments or diversions or by watershed response to changes in precipitation, land use, or vegetation.

The style of channel change is affected by factors such as the degree of valley confinement and the characteristics of riparian vegetation that can trap moving sediment and give strength to banks (Tal et al., 2004). Channel change may include changes in many attributes, including bed material size and distribution, cross-section size and shape, planform configuration and channel slope. Cross-sectional changes can occur to both size and shape of river channels; changes to channels size can occur by both width and depth. Channel width is generally adjusted to the magnitude of common floods and when flood magnitude declines, channels narrow (Leopold and Maddock, 1953). Decreasing channel width may occur by a diverse range of morphological adjustments, including a decrease in flow resulting in channel abandonment, channel incision with no new floodplain formation or inset floodplain formation (see Thorne, 1998 for a review of river width adjustments). Additionally, active mid-channel bars can convert to stable, vegetated islands, reducing active channel width.

Dams and other impoundments often reduce or eliminate floods and divert stream flow, while also trapping the upstream sediment supply, perturbing the mass balance of the downstream regulated river (Schmidt and Wilcock, 2008). Immediately downstream from dams, sediment deficit conditions exist, and sediment evacuation can occur, causing bed incision if the substrate can be entrained by post-dam floods (Schmidt and Wilcock, 2008). Farther downstream from dams, regulated rivers may be in sediment surplus if the magnitude of natural sediment supply exceeds the capacity of the regulated river to transport that sediment (Dean et al., 2016). Dams alter the variability of the annual flow regime, reducing peak flood magnitude, increasing base flows and shifting flood timing.

Changes to the annual flow regime, coupled with declines in total annual flow from climate variability, resulted in channel narrowing within the Green River basin in the 20th century (Williams and Wolman, 1984; Graf, 2006). In the lower Green River, surveys and photographs taken in the 1910s and 1920s demonstrate that the active channel was wide with abundant alternate bars. Today, the active channel is narrow and there are fewer active in-channel bars, channel planform is less complex and floodplains are densely vegetated.

Natural climate variability contributes to declines in total annual flow, often to a greater degree than human water development. Changes to climate in the 20th century in the Colorado River basin decreased total precipitation, resulting in diminished flood magnitude and a lower total runoff. Evidence of decreased total stream flow and decreased flood flows due to climate have been demonstrated on the San Rafael River, UT (Fortney, 2015), Paria River, AZ (Hereford, 1986; Graf et al., 1991), and Little Colorado River, AZ (Hereford, 1984). Similar trends have been documented for the Green River and Colorado River (Stockton and Jacoby, 1976; Allred and Schmidt, 1999). Hydrologic characteristics of the 20th century do not represent the full range of variability present in the paleohydrologic record (Woodhouse et al., 2016), which documents numerous multi-year droughts with flows less than the lowest years of 20th century runoff (Woodhouse et al., 2010). Anthropogenic climate change has further reduced runoff in the Colorado River basin and climate models project future declines in flow driven by greenhouse gas emissions (Udall and Overpeck, 2017).

Widespread establishment of nonnative tamarisk occurred during a period that coincides with change in the flow and sediment regime of the Green River (Christensen, 1962; Robinson, 1965; DiTomaso, 1998). Tamarisk root systems stabilize stream banks (Hereford, 1984; Everitt, 1993; Friedman et al., 2014), making them more resistant to erosion and scour than native shrubs (Polvi et al., 2014; Griffin et al., 2014), thereby restricting bank erosion and channel widening (Pollen-Bankhead et al., 2009; Jaeger and Wohl, 2011). Above ground, tamarisk stems increase the hydraulic roughness of the floodplain (Manners et al., 2013), and promote overbank deposition by exerting a drag effect on flow (Griffin et al., 2014). Tamarisk establishes in a wider range of flow conditions compared to native vegetation (Auerbach et al., 2013), allowing it to adventitiously colonize and outcompete native vegetation in low flow years and under altered flow regimes (Stromberg et al., 2007).

Renewed interest by the National Park Service in the relations among channel narrowing, flow regime change, and riparian vegetation invasion in the lower Green River inspired and funded this study. In this study, 'lower Green River' refers to a 155-km reach of river beginning at the mouth of the San Rafael River and ending at the Green-Colorado confluence. Canyonlands National Park (CNP) manages the downstream 76 km of the lower Green River, and the Bureau of Land Management manages the 79 km of this popular recreational river between Green River, UT and CNP. Understanding whether or not the lower Green River continues to narrow or has established a new equilibrium width is important in managing the riparian corridor, backwater habitat for endangered fishes, sandbars for recreational use, and releases from upstream reservoirs. Understanding how changes in width influence the formation and maintenance of backwaters is particularly important because the entire lower Green River is designated critical habitat for the endangered razorback sucker (*Xyrauchen texanus*) and Colorado pikeminnow (*Ptychocheilus lucius*) (U.S. Fish and Wildlife Service, 1994).

2.1.1 Previous research

Previous studies of channel change on rivers with high suspended loads described channel narrowing by deposition of an inset floodplain in the Powder River, MT (Pizzuto, 1994), Rio Grande, TX (Dean and Schmidt, 2011), Colorado River, CO (VanSteeter and Pitlick, 1998; Pitlick and Cress, 2002) and Green River, UT (Grams and Schmidt, 2002; Allred and Schmidt, 1999) due to changing discharge and altered sediment transport regimes. Inset floodplains on these rivers typically form by vertical accretion. Deposition begins on mid-channel or bank-attached bars during periods of relatively low flow, continuing whenever floods carrying high concentrations of fine sediment inundate the aggrading deposit. As sediment is deposited, floodplains vertically accrete, typically forming levees at the channel margin (Ferguson and Brierley, 1999; Pizzuto et al., 2008; Dean et al., 2011). The coarsest suspended sediment is deposited on levees and finer silts and clay deposit in back-basin depressions, or troughs (Pizzuto et al., 2008; Dean et al., 2011). Inset floodplain formation additionally involves colonization of low-elevation bars by vegetation which helps stabilize the bar and promote sediment deposition (Shafroth et al., 2002; Manners et al., 2014).

In the 20th century, channel narrowing by inset floodplain formation occurred along both the Colorado River and the Green River. Research on the Colorado River identified upstream water development (VanSteeter and Pitlick, 1998) and fine sediment deposition by the floods of 1983 and 1984 (Pitlick and Cress, 2002) as causes of inset floodplain formation. In the Green River, upstream from the Yampa River, changes to flow and the resulting channel changes are primarily determined by operations of Flaming Gorge Dam (Grams and Schmidt, 2002, 2005; Alexander, 2007), whereas the regime of the Green River downstream from the Yampa River is additionally affected by diversions in tributaries. Trans-basin diversions constructed on the Duchesne River reduced stream flow by 50% concurrent with an increase in fine sediment supply causing channel narrowing and bed aggradation (Gaeuman et al., 2005). Flow regulation in the headwaters of the San Rafael River decreased flood magnitude and shifted flood timing, resulting in aggradation within the alluvial valley and simplification of channel planform in a formerly wide channel (Fortney, 2015). Channel narrowing is also observed on unregulated rivers. In the unregulated Yampa River tributary, Manners et al. (Manners et al., 2014) demonstrated narrowing by tamarisk invasion into the active channel during multi-year droughts.

Tamarisk was sparsely distributed along the lower Green River in the 1940s (Clover and Jotter, 1944) and was densely distributed by the 1950s (Christensen, 1962; Graf, 1978). Dense stands of tamarisk are evident in photographs taken in the early 1950s. Today, large areas of tamarisk have been defoliated by the tamarisk beetle (*Diohrada spp.*) and may be dead, but the skeletal woody stems and roots remain.

The first study of channel change in the lower Green River by Graf (1978) concluded that invading tamarisk had trapped and stabilized fine sediment, inducing vertical accretion on formerly active bars, stabilizing banks, and narrowing the channel. All subsequent studies agree that the modern channel is narrower than the channel in the early 20th century, and there is consensus that the invasion of tamarisk on the lower Green River began in the 1930s. Different studies, seeking to clarify some of Graf's (1978) findings, reached different conclusions about when narrowing began, if narrowing eventually stopped or is progressive, and whether tamarisk is the primary cause of narrowing.

Everitt (1979) observed that narrowing occurred during a period of declining stream flow, and he suggested that tamarisk may only have played a passive role in channel narrowing. Andrews (1986) analyzed suspended sediment data measured at Green River, UT and argued that the effective discharge of the Green River had been reduced after completion of Flaming Gorge Dam in 1963. He predicted the equilibrium width of the post-dam river using hydraulic geometry relations for the post-dam effective discharge. Because the Green River in the mid-1980s was still wider than this value, Andrews (1986) predicted further narrowing of the lower Green River.

Allred and Schmidt (1999) compiled and analyzed discharge measurement notes that describe the channel cross-section at current and former US Geological Survey (USGS) gage locations near Green River, UT. They concluded that channel narrowing had occurred in two phases, one related to a climatically-induced reduction in total stream flow in the mid-20th century and one related to flood control associated with operations of Flaming Gorge Dam. Their findings were applicable to a 26-km study reach, because the temporal pattern of narrowing that had occurred at the Green River, UT gage had also occurred throughout the Gunnison Valley.

Birkin and Cooper (Birken and Cooper, 2006) dated tamarisk and cottonwood trees and excavated pits in order to describe processes of tamarisk invasion and floodplain formation for a 2 km segment of river centered on Potato Bottom at River Mile (RM)[2] 37, corroborating the findings of Graf (1978) that the majority of narrowing occurred before 1951. They argued that tamarisk had played an active role in narrowing, with vegetation establishment triggering bar stabilization, sediment accretion, and the attachment of bars and islands to channel banks. They determined channel width remained relatively stable between 1976 and 2002.

In order to provide a quantitative understanding of the rate and timing of channel changes on the Green River in the 20th century as well as describing the relation between stream flow and fluvial geomorphic process, I set out to answer the question: what are the magnitude, timing and processes of channel change in CNP? To answer, I examined multiple data sets to synthesize temporally precise evidence of geomorphic processes from a floodplain trench with spatially robust large-scale channel changes interpreted

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[2] Measured upstream from the Colorado River confluence. The location system of River Miles was established by Herron (1917) and is still used today.

from aerial photos. Ten aerial photograph series, taken between 1940 and 2015, were analyzed to determine channel change in a 61-km study area near the upstream boundary of CNP. In collaboration with partners, I excavated a 50-m long trench through the floodplain. I described the stratigraphy and sedimentology of deposits identified in the trench, dated numerous alluvial deposits using the tamarisk stem-burial dating method (Friedman et al., 2005), and related the timing and sequence of inset floodplain deposition to the flow regime by developing a local stage-discharge rating relation for the trench site.

Hydrologic data from nearby gaging stations were analyzed such that the time sequence of changes in channel width could be compared with flow regime changes. I analyzed components of the flow regime important to inset floodplain formation and to better understand changes to flow regime in the 20th century. I compared and combined historic flow records at Green River, UT with similar data for the San Rafael River to estimate the flow regime of the lower Green River near the trench. To evaluate potential changes to channel bed slope, I supplemented aerial imagery analyses with repeat channel cross-section surveys.

Additionally, I interpreted sediment transport data collected since 2014 by the USGS at Mineral Bottom (RM 55), located 106 km downstream from the Green River, UT gage and 14 km upstream from the trench. My research not only builds on previous studies of channel change of the lower Green River, but also on similar studies elsewhere of the Green River (Lyons et al., 1992; Merritt and Cooper, 2000; Grams and Schmidt, 2002, 2005; Manners et al., 2014) and on other rivers that transport large suspended sediment loads (Dean and Schmidt, 2011; Cadol et al., 2011; Swanson et al., 2011).

2.2 STUDY AREA

The Green River drains 124,600 km^2, flowing 1,175 km from the Wind River Mountains of Wyoming, through Colorado and Utah, to join the Colorado River in southeastern Utah. Green River, UT is the former site of Gunnison Crossing in Gunnison Valley, 193 km upstream from the Colorado River confluence. In Gunnison Valley, the Green River has carved a wide alluvial valley into the erodible Cretaceous Mancos shale. The only major tributary downstream of Green River, UT, the San Rafael River drains the east side of the Wasatch Plateau (drainage area of 6,255 km^2), joining the Green River in Gunnison Valley. A large part of the San Rafael watershed is in the San Rafael Swell and San Rafael Desert where fine sediment yield is high (Fortney, 2015).

Downstream from the San Rafael-Green confluence, the lower Green River carves through progressively older Jurassic to Permian Mesozoic sedimentary rocks, forming canyons. The upstream end of Labyrinth Canyon is approximately 3 km downstream from the San Rafael River where Navajo Sandstone is first exposed at river level. Farther downstream, the cliff-forming Wingate Sandstone and the erodible Moenkopi Formation are exposed. The downstream end of Labyrinth Canyon is approximately 58 km upstream from the Colorado River confluence, where the White Rim Sandstone emerges, followed by the Organ Rock, Cutler, and Elephant Canyon Formations in Stillwater Canyon. The alluvial valley in Stillwater Canyon is narrower than in Labyrinth Canyon, and there are smaller floodplains and terraces. The names of these two canyons were given by John Wesley Powell, who also named the transitional area between the two canyons as Tower Park (Powell, 1895), although this name is infrequently used today. In this study, I use the term “floodplain” to reference flat lying alluvial landforms adjacent to the river channel and inundated by the current flow regime.

This definition encompasses two inset floodplains, at different elevations above the river channel, both containing sediment deposited in the current flow regime. We use the term "valley floor" to refer to landforms above floodplains which are never inundated in the present flow regime.

The banks and bed of the lower Green River are alluvial, and primarily composed of fine sediment. Isolated bedrock banks are present. Gravel is scarce or nonexistent on the channel bed, although Pleistocene gravel terrace deposits occur in Labyrinth Canyon (Pederson et al., 2013).

My study area is a 61-km portion of lower Labyrinth Canyon and upper Stillwater Canyon, centered on Tower Park. The study area extends from upstream of Hell Roaring Canyon near River Mile (RM) 57 to near Turks Head at RM 26 (Figure 2.1). The contemporary channel is single-threaded with vertical, vegetated banks, bank-attached active bars, and occasional islands. The floodplain is densely covered by tamarisk and willow (*Salix spp.*). Cottonwoods *(Populus fremontii)* are infrequent, typically mature, and generally located on higher elevation floodplains or the valley floor, above the active channel and floodplain.

The local climate is semi-arid, with 250 mm or less of precipitation annually (Gillies and Ramsey, 2009). The maximum average precipitation of 31 mm occurs in October and minimum average precipitation of 10 mm falls in June. The North American (NA) monsoon is active in southern Utah (Adams and Comrie, 1997; Higgins et al., 1997), but its effects are relatively weak. On average, 45% of yearly precipitation falls from July to October (Western Regional Climate Center, 2017). Flash floods are a minimal contributor to total stream flow of the Green River but are a major mechanism for delivering fine sediment to the river (Andrews, 1986).

Stream flow is measured 100 river km upstream from the study area at RM 120 by the USGS at Green River, UT (gage 09315000, 1885-1899, 1904-present) and within the study area at Mineral Bottom (RM 52, gage 09328920, 2014-present). Stream flow of the San Rafael River is measured near Green River, UT (gage 09328500, 1909-1918, 1945-present) and near its confluence with the Green River (gage 09328910, 2015-present). Sediment transport data were collected at Green River, UT between 1941 and 1984 and continuous suspended sediment data using acoustical sensors, calibrated with occasional physical samples, has been collected at Mineral Bottom since 2014 (GCMRC, 2016; Topping and Wright, 2016).

The Green River's annual flow regime is dominated by the spring snowmelt flood. Iorns et al. (1965) demonstrated the key role of Rocky Mountain snowmelt in the flow regime of the Green River by estimating the average annual flow of gaging stations throughout the watershed for water years 1914-1957, just before construction of large dams in the 1960s. They estimated that approximately 61% of the total annual flow measured at Green River, UT entered the Green River from the Rocky Mountains upstream from Greendale, UT or from the Yampa River upstream from Maybell, CO. An additional 24% of the total annual flow was delivered to Green River, UT from the headwaters of the Duchesne and White Rivers. In contrast, less than 2% of the annual flow at Green River, UT was contributed from the Price River and an additional 2% entered from the San Rafael River.

2.3 ESTIMATING THE FLOW OF THE LOWER GREEN RIVER

To evaluate the effects of the San Rafael River on the hydrology of the lower

Green River, I estimated daily discharge at Mineral Bottom for 1909-1918 and 1945-2015 by adding the mean daily stream flow of the Green River and the San Rafael River. The San Rafael gage did not collect discharge between 1918 and 1945. The two gages measure stream flow from 96% of the watershed area upstream from Mineral Bottom; the ungaged 5,392 km^2 are primarily in the San Rafael Desert, west from the Green River, where precipitation is minimal. Visual inspection of the data show a difference in peak flow timing of one day between the synthesized and Mineral Bottom records. I shifted the estimated flow one day forward so that upstream daily discharges were coincident with Mineral Bottom daily discharge. To evaluate the accuracy of these estimates, I compared the time-shifted estimated daily discharge to the measured mean daily discharge at Mineral Bottom collected since March 2014 (Figure 2.2). The linear fit between the time-shifted synthesized and the observed Mineral Bottom discharge is

$$Mineral\ Bottom = 0.996 \pm 0.005\ Estimated - 17.2\ \pm 32.7 \qquad (1)$$

with an R^2 of 0.99. Using the estimated record, I extended the record of streamflow at Mineral Bottom to the period 1909-1918 and 1945-2017, covering 98% of days in those two periods.

I compared flow duration curves measured at Green River, UT and estimated for Mineral Bottom. In both time periods, there is no difference between the flow duration characteristics calculated from measured data at Green River, UT and the estimated data at Mineral Bottom (Figure 2.3), because the San Rafael River contributes a relatively small amount of water during most of the year.

2.4 EFFECTS OF MONSOON FLOODS ON THE HYDROLOGY OF THE LOWER GREEN RIVER

The only season when inflow from the San Rafael River can affect flow at Mineral Bottom is during summer and early fall when flash floods sometimes occur in the San Rafael watershed. In order to account for the effect of monsoon floods on floodplain formation, I employed a peaks-over-threshold analysis (Lang et al., 1999; Kidson and Richards, 2005) to construct a partial duration flood frequency series for peak flows between August 1 and November 1 for all years of the synthesized record.

Flow from the main-stem Green River measured at Green River, UT dominates the flow regime at Mineral Bottom. Summer and fall floods rarely contribute a significant portion of flow at Mineral Bottom. For summer and fall months of 2014-2016, 20 of 276 daily discharges from the San Rafael River contributed 5% or more of the daily discharge measured at Mineral Bottom. Estimated summer/fall peak flows at Mineral Bottom exceeded 10,000 ft^3/s in 12% of all years (1909-1918, 1945-2017) and no estimated flows have exceeded 13,000 ft^3/s since 1951. Under the current flow regime, the only floods which can inundate the floodplain happen during spring snowmelt. In the study area, 98% of the estimated flow at Mineral Bottom comes from the watershed upstream from Green River, UT.

2.5 CHANGES TO THE FLOW REGIME OF THE LOWER GREEN RIVER

I examined the flow record at Green River, UT because there is only a relatively small difference between measured flow at Green River, UT and estimated flow at Mineral Bottom and because the available data at Green River, UT extends back to 1895. Changes in peak discharge magnitude were evaluated by change-point analysis using the nonparametric Pettitt test (Pettitt, 1979) to detect changes in the mean of peak flow distribution (Villarini et al., 2009) at the 5% significance level. Change-point analysis checks for shifts in flow regime, by identifying abrupt changes in the mean or variance of the variable of interest (in this case, peak flows). The Pettitt test allows for detection of changes when the change point time is unknown and is less sensitive to outliers. For each flow period determined by change points, I calculated flood frequency curves (Dalrymple, 1960), mean annual discharge and mean daily discharge. To describe flood frequency, I characterized high and low peak flow years based on whether peak annual flow was greater than the 75th percentile or less than the 25th percentile, respectively, of the average for each period of flow regime. I chose to analyze peak flow magnitude because inset floodplain formation is often linked to changes in flood magnitude and frequency, and it is the same dataset analyzed by Allred and Schmidt (1999).

Allred and Schmidt (1999) distinguished three historic hydrologic flow regimes based on the peak flow record at Green River, UT: 1895-1929, 1930-1962 and after 1963. The Pettitt test I performed identified two changes in the mean of peak flow distributions for the Green River, UT record, 1923 ($p=0.015$) and 1958 ($p=3.87x10^{-6}$), resulting in 3 periods of flow regime (Table 2.1) different from Allred and Schmidt (1999): 1895-1923, 1924-1958, and 1959-2015 (Figure 2.4). The first break point in 1923 occurs at the end of the early 20th century period of high flows. The second break point, 1958, is the last large flood year prior to the closure of Flaming Gorge Dam.

The 2-year flood peak has progressively declined at Green River, UT since 1895. Between 1895 and 1923, the 2-year flood was 41,200 ft^3/s, declining to 28,500 ft^3/s from 1924-1958 and to 21,800 ft^3/s since 1958 (Figure 2.4), a decline of 47% from 1895-1923.

The largest floods since 1958 occurred in 1983, 1984, and 2011, but the magnitude of these floods is less than the magnitude of the 5-year recurrence flood (54,600 ft^3/s) of the period before 1923.

High and low peak flow years occur randomly in the first period of flow regime, from 1895 to 1923. After 1923, high and low peak flow years have a tendency to cluster together and clusters tend to follow each other. High flows from 1927-1929 were immediately followed by low peak flow years from 1930-1931. High peak flows in 1983 and 1984 were followed by years of low peak flow from 1989-1992. Isolated years of high and low peak flow occurred in 1986 and 1987, respectively, with moderate peak flows in 1985 and 1988. Generally, 1983-1986 can be classified as a period of high peak flows, and 1987-1992 as a period of low peak flows. Clustering frequency has remained relatively stable since 1924, but the only clusters since 1985 have been multiple years of low peak flow. Clustering of high and low peak flow years does not have any meaningful impact on changes to periods of total annual flow.

Operations of Flaming Gorge Dam increase base flows during low-flow months. Mean September-February discharge increased by 16%, from 2,580 ft^3/s from 1895-1923 to 3,080 ft^3/s from 1959-2015 (Figure 2.5). Mean annual flow at Green River, UT declined 32%, from 7,870 ft^3/s between 1895 and 1923, to 5,370 ft^3/s after 1959 (Figure 2.6). Declines in mean annual flow were lower than peak flow declines because increased base flow contributions made up in part declines in peak flow. The difference between the magnitude of typical flood floods and typical base flows in now less than at any previous time of measurements, because the flood flows are smaller and the base flows are higher. Presently, the unregulated Yampa River contributes most of the volume of the annual spring snowmelt flood, and contributions from other upstream tributaries have decreased (i.e., Gaeuman et al., 2005).

2.6 CHANGES TO CHANNEL WIDTH AND DEPTH

2.6.1 Aerial imagery analysis

I analyzed ten sets of aerial images, spanning 1940-2014, for channel width (Table 2.2). Six series covered the entire study area and two covered most of the study area. The remaining two sets (1976 and 1988) covered a 15-km segment of river between RM 45.5 and RM 36, centered on Fort Bottom. Six orthorectified image sets (1966, 1993, 2002, 2009, 2011, 2014) are available from public sources. The other sets (1940, 1951, 1976, 1988) were rectified by Pinnacle Mapping Technologies (PMT) of Flagstaff in ERDAS IMAGINE using photogrammetric block calibration. The Root Mean Square Error (RMSE) of the images rectified by PMT ranged between 0.2 and 1.5 m, depending on quality and scale of the photo set.

Within the study area, I digitized bank lines manually in ArcGIS at a 1:3,000 scale for each year of aerial imagery. I defined the boundary of the active channel by the abundance of vegetation; therefore, the active channel includes the area inundated by water at the time of each photo, as well as emergent bars that were free of vegetation. I excluded vegetated islands from the active channel. Discharge at the time of each photo series ranged from 1,820 to 3,820 ft^3/s, with the exception of the 1993 image set, which was photographed at 13,700 ft^3/s. The exact date of photography for the 1966 set is unknown.

Following digitization of the active channel, I calculated changes in reachaveraged active channel width (RAACW, in m) for each year of available photos (Hughes et al., 2006; Fortney, 2015), in 1-km reaches through division of active channel area (m²) by reach length (m). I estimated total width error (E_w, m) in RAACW calculation using the Mount et al. (Mount et al., 2003) method, that uses two independent error estimates: errors associated with bank line digitization and distortion within images:

$$E_w = \sqrt{2}p + 2\theta \tag{2}$$

where $\sqrt{2}p$ is the error associated with digitizing bank lines as a function of the mean width between repeat bank line digitizations (p) in meters. The magnitude of error was similar for both left and right banks, so I compared centerlines that incorporated both left and right banks. For each aerial imagery set, I calculated p by repeatedly digitizing bank lines for three 5-km segments, deriving a centerline from each repeated bank line set, and taking the mean distance between centerlines as the p for that set. Image distortion error measurements (θ) in meters were derived by calculating the dRMS (Gaeuman et al., 2005) for each year at 10 floodplain locations that could be identified accurately on all image sets, and comparing those positions to an unanalyzed image set from 2011 (Table 2.3).

Prior to the first aerial photo set in 1940, oblique photos show a wide channel in 1871 and 1914 (Webb et al., 2007); in 1914 the average width of the lower Green River was 218 ± 32 m (Herron, 1917). There were no documented changes in width from 1871-1914 (Graf, 1978).

For the entire study area, mean RAACW decreased by 9.4% from 138.2 ± 8.79 m in 1940 to 124.6 ± 5.10 m in 2014 (Figure 2.8A, Table 2.4). Channel width was relatively stable from 1940-1966, then narrowed 5.31 m from 1966-1993. The 1976 and 1988 image sets, covering a 15-km reach centered on Fort Bottom (RM 44.5-36), show the timing of narrowing between 1966 and 1993. RAACW near Fort Bottom was stable from 1966-1988 and narrowing began after 1988. Between 1988 and 1993, channel width near Fort Bottom decreased from 145.89 ± 5.52 m to 134.02 ± 10.12 m (Figure 2.8B, Table 2.5). The entire study area narrowed on average 8.87 m from 1993-2009, to a mean RAACW of 124.8 ± 5.10 m in 2009. This period of floodplain formation occurred in the aftermath of the two largest floods of the recent period - 1983 and 1984. Because timing of narrowing is the same in Fort Bottom and the rest of the study area, we infer that that the channel in our study area remained relatively stable from 1940-1988, and the majority of inset floodplain formation detected from aerial imagery began after 1988. Average channel width did not increase in the years during which the largest floods occurred: 1976-1988 and 2009-2014.

The net change in channel width in any short reach or in the entire study area was the result of inset floodplain formation in some places and floodplain erosion elsewhere (Figure 2.9). Erosion exceeded inset floodplain formation for some of the 1-km reaches in every image set, but those increases in width were outweighed by deposition and inset floodplain formation in other 1-km reaches. Thus, numerous portions of the study area both eroded and deposited over the 75 years of aerial imagery, and some 1-km reaches widened between 1940 and 2014.

As the channel has narrowed, channel width has become more homogenous and is now approximately the same width everywhere. The range of RAACW values remained relatively constant until 1993, when the variability of channel widths began to decline, and continued to decline, reaching the lowest range of variability in 2009. Variability in channel widths increased slightly in 2014, but was still lower than channel width variability from 1940-2002.

The primary process of floodplain formation was conversion of bare sand bars to vegetated floodplains (Figure 2.10). Both bank-attached and mid-channel bars have been converted from bare sand to vegetated floodplains since the 1940s (Figure 2.11). As bars and islands became more densely vegetated, small secondary channels accreted, decreasing active channel area (Figure 2.12). The majority of deposition occurred at bars on the inside of bends and adjacent to existing alluvial floodplains. Bedrock banks of the river remained stable and little new floodplain deposition occurred in these places. Sixty percent of all narrowing that occurred between 1988 and 1993 was due to the conversion of a large sand bar (118,460m^2) to floodplain, narrowing RAACW at RM 36.5 by 57 m.

2.6.2 Repeat channel surveys

To assess potential changes in channel bed elevation, I reoccupied channel cross sections near Hell Roaring Canyon (RM 55) and remapped the channel bed around Fort Bottom (RM 40) in collaboration with the USGS Grand Canyon Monitoring and Research Center (GCMRC). Cross-sections near Hell Roaring Canyon were established by the USFWS Upper Colorado River Endangered Fish Recovery Program and surveyed in 1995 and 1996 by Guensch and Schmidt (1996). Channel surveys around Fort Bottom were first conducted in 1998 by the National Park Service and published in a flow model by Gessler and Moser (2001). Re-surveys were performed in 2015 using an Odom CV-100 echo sounder with a 200 kHz transducer inside of the wetted channel combined with an RTK-GPS on the banks. Positioning was by RTK GNSS survey with a local base station set to the coordinate system UTM Zone 12N, North American Datum of 1983

(EPSG 26912). Single beam sonar data was processed at GCMRC to create a digital elevation model (DEM) of the channel bed. Bathymetric data was then merged with Lidar data collected in October 2015 by the state of Utah to produce a combined DEM of the channel and floodplain.

There was no substantial change to channel bed elevation at Hell Roaring Canyon and Fort Bottom between the mid-1990s and 2015. At Fort Bottom, the 1998 survey was conducted when discharge was at 22,500 ft³/s, in 2015, the discharge was 11,800 ft³/s. The large difference in discharge introduces uncertainty in the interpretation when the two surveys are compared (Figure 2.7A). Near Hell Roaring Canyon, the channel bed scoured during high discharges and filled as discharge decreased (Figure 2.7B). Both channel surveys show a minimal change in bed elevation and if any change to bed elevation did occur, it happened within the range of annual scour and fill and consistent, progressive change is undetectable. Though no bed aggradation or incision was detectable, both surveys of the lower Green River clearly show changes in channel width since the early 1990s. The same processes of scour and fill were observed by Allred and Schmidt (1999) during snowmelt flooding and summer low flows at Green River, UT. Because of the limited progressive bed level change at Hell Roaring Canyon and Fort Bottom, I infer that the majority of channel change in our study area was channel narrowing.

2.7 FLOODPLAIN STRATIGRAPHY AND SEDIMENTOLOGY

In August 2015, a 50-m long trench, extending across the entire floodplain, was excavated on the left bank at Hardscrabble Bottom (RM 43). Because aerial photographs only describe the plan view characteristics of the river corridor, it can be difficult to fully describe the processes by which inset floods form. The trench provides information on the vertical growth of floodplains and mechanisms of inset floodplain formation near the trench site.

The right bank of the river at the trench site is a bedrock canyon wall, and inset floodplain formation is presumed to be confined to the left bank. I mapped floodplain deposits and linked stratigraphic contacts to seven tamarisk trees in the trench. The trees were cut into slabs at each stratigraphic contact, and I analyzed each slab at the USGS lab in Fort Collins, CO for tree age, germination year, and year of burial (Friedman et al., 2005). Deposit age was determined from burial year at each contact. I collected sediment samples from deposits in the trench for grain size distributions. For the oldest deposits in the trench, samples were collected and analyzed for age of deposition by the Utah State University Luminescence Lab. The regenerative-dose procedure for single grain optically stimulated luminesce (OSL) dating was used in anticipation of partial-bleaching issues common of Holocene alluvium.

I estimated the discharge required to inundate each mapped floodplain deposit by calculating a stage-discharge relationship for the river section at the trench by collecting water surface elevations and compared its slope to the slope of the stage-discharge relationship for the Mineral Bottom gage (Figure 2.18). The rating relation at the trench is

$$Q = 1493.2e^{0.6658WSE} \tag{3}$$

where Q is discharge (ft^3/s) and WSE is water surface elevation in meters. I coupled these inundation levels with floodplain deposit ages derived from dendrogeomorphology to identify flows which contributed to the accretion of each floodplain deposit.

At Hardscrabble Bottom, the riparian zone is a set of inset floodplains, a higher elevation tamarisk dominated floodplain (F1) and a lower elevation floodplain with a mixed tamarisk-willow community (F2). A levee and trough are present on both floodplains. Below the surface, there are three major inset deposits. F1 is composed of a vertically accreting levee and trough formation, and an intermediate laterally accreting series of beds. F2 is a vertically accreting levee and trough. The F1 sequence of deposits vertically truncates the edge of the valley floor, and in turn, is vertically truncated by F2 (Figure 2.19).

Levee deposits are coarse rippled cross-laminated sand dominated units, which fine onshore into troughs. Troughs are primarily composed of horizontally laminated silt-dominated sediments. The intermediate, laterally accreting deposits are mixed beds of sand and mud. Beds typically fine upward. Sand and mud beds are present throughout the trench at all elevations, and beds near the surface are extensively bioturbated and weathered. Sedimentologic and stratigraphic characteristics of the trench are discussed in detail in Chapter 3.

Sediment samples collected from the floodplain trench and analyzed for grain size show that trench samples are 70% silt-and-clay on average (Figure 2.20). Trench samples are finer than suspended sediment, bed sediment samples and bar sediment samples (Figure 2.14). 25% of samples have a D_{50} of very fine sand and 1% are fine sand. The median grain size of the sand fraction within samples is 0.15 mm – fine sand. The only sand-dominated beds in the trench are in the valley floor. Samples collected from the trench contained small (<10%) proportions of clay, with the exception of samples collected in floodplain troughs. Trough samples are between 4-22% clay, and are much finer on average than all other samples collected from the floodplain. No grains >2 mm were found in the trench. Silt-and-clay is the majority of suspended sediment measured at Mineral Bottom and forms the majority of material in the trench, despite the high amount of sand transport during annual peak flows.

Using sedimentology, stratigraphy and dendrogemorphology, I distinguished additional periods of floodplain formation, unaccounted for in aerial imagery. The oldest tree in the trench germinated in 1939 and thus, the period of floodplain formation I describe using dendrogeomorphology is 1939-2015. A total of four major sequences of floodplain formation were identified: vertical accretion and levee formation from 1939-1952, lateral accretion from 1957-1982, overbank deposition from 1983-2015, and vertical accretion and levee formation from 1985-2015.

Beds in the valley floor dated using OSL are 300 ± 150 and 440 ± 250 years old, and are the oldest deposits in the trench. All other beds identified in the trench are >50 years younger and formed inset of valley floor deposits.

The first period of floodplain formation occurred at the trench site following the recession of high flow in the early 1920s. From 1939-1952, at least 18 m of narrowing and 1.1 m of vertical accretion occurred. Deposits accreted 1.5 m at the levee and 1.0 m in the trough. The 1939-1952 deposits are truncated by unconformable contacts. Following this period, small scale vertical accretion of at least 0.30 m occurred at station 35 from 1953-1982.

At the edge of the 1939-1952 deposits near station 23, the floodplain vertically accreted from 1952-1975. A portion of those deposits eroded in 1975 and an unconformity of 8 years exists in the stratigraphy, until the next record of deposition began in 1983. I identified this sequence of erosion and deposition by repeated anatomical changes to a buried tamarisk tree (T25-1 in Figure 2.19C), similar to repeated burials and excavations described by Sigafoos (1964) on the floodplains of the Potomac River, VA.

From 1957-1982, tree-ring dating shows F1 grew at least 10 m laterally and 1.25 m vertically. Floodplain accretion occurred by lateral accretion of fining upward mixed sand and silt-and-clay deposits bounded on all sides by distinct unconformable contacts. These deposits exhibit some characteristics of oblique accretion, accreting both laterally and vertically. However, the stratigraphic evidence does not support the definition of oblique accretion introduced by Page et al. (Page et al., 2003) as *"the lateral accumulation of fine-grained floodplain sediment by progradation of a relatively steep convex bank in association with channel migration"* because beds do not prograde. Instead, lateral growth was due to repeated deposition of horizontally laminated, vertically truncated, beds. Erosion in 1975 occurred at a higher elevation than these deposits, and it is likely that some lateral accretion occurred prior to erosion in 1975. Erosion documented in 1975 potentially stripped sediment from both floodplain and channel margin facies in F1.

From 1983-2015, overbank deposition vertically accreted 1 m above the 1939-1952 and 1957-1982 deposits, across all of F1. This deposit contains super critically climbing ripples, indicating rapid deposition, and no significant surface exposure. The peak annual flows with the ability to deposit these large packages were during 1983 and 1984, and I infer that the majority of this vertical accretion occurred in 1983-1984.

From 1985 to 2015, F2 accreted at least 10 m laterally and 2 m vertically, building a new inset floodplain. The upper portion of the floodplain contains beds of cross-stratified sandy material that forms a natural levee. Formation of F2 began as bank-attached bar deposition inset of pre-1985 deposits. From 1985-1986, vertical accretion built 0.45 m of floodplain. In this period, deposits were inundated more than 50% of the time (Figure 2.21). Basal deposits were deposited as part of the active channel. From 1987-1992, F2 vertically accreted 0.60 m. During this period, all annual peak flows were of less than 20,000 ft^3/s. Peak discharges during this period were able to deposit sand, but did not erode emergent bars and floodplain. Floodplain formation shifted from deposition on a frequently inundated surface to deposition during episodic, moderate peak flows. Between 1993 and 2004, F2 accreted 0.60 m as the rate of vertical accretion slowed. High peak flows returned in the 1990s, but had decreased effects despite their higher discharges and did not cause increased vertical accretion. The floodplain built slowly after 2004, accreting 0.30 m across the levee and trough from 2004-2015. No evidence exists for floodplain stripping between 2005 and 2015 despite a 44,900 ft^3/s flood in 2011, the 3rd highest since 1959 (Figure 2.21). F2 continues to vertically accrete when floods are greater than the 2-year flood (22,000 ft^3/s).

2.8 SEDIMENT TRANSPORT AND THE MODERN ACTIVE CHANNEL

The contemporary lower Green River is a sinuous channel with a meandering thalweg alternating between deep pools and shallow crossovers. Bank-attached and mid-channel bars are located at bends in the river. These “curvature-driven bars” (Parker and Johannesson, 1989) do not migrate downstream because their locations are controlled by periodic bedrock banks. Bars are primarily composed of sand. I visually observed small gravel deposits at one location, on top of sand bars at the upstream channel margin of a large island at Fort Bottom (RM 41.5). In low velocity backwaters and channel margins, thick deposits of silt-and-clay are present, transitioning to sand at higher elevations. Thin drapes of mud occur in the troughs of bedforms. Erosion and deposition of emergent bars is constant during summer low flow periods (Figure 2.13). Bars are subject to scour and fill during the year, but the location of these bars is consistently in the same place (Figure 2.10-Figure 2.12). Grain sizes from physical samples collected on the surface of bars near Fort Bottom in February 2017 have a median grain size of 0.095 mm – very fine sand (Figure 2.14).

The continuous record of suspended sediment transport at Mineral Bottom (GCMRC, 2016) measured by acoustic sensors since March 2014 provides a precise understanding of the grain sizes in transport during spring snowmelt floods and during the summer/fall monsoon season. These are the two flow regimes that potentially contribute to the formation of inset floodplains and channel narrowing, although high suspended sediment concentration flows must attain a stage sufficient to inundate aggrading bars if inset floodplains are to form. An unknown proportion of sediment is transported as bedload by migrating downstream dunes.

The median suspended sand concentration between March 2014 and June 2017 was 97 mg/L (Figure 2.15A) and the median grain size of suspended sand was very fine sand - 0.11 mm (Figure 2.15B). Suspended sand concentrations increase with increasing discharge (Figure 2.16A), and the median grain size of suspended sand decreases as discharges increases (Figure 2.16B, Figure 2.16C). Sand concentrations increase during the spring snowmelt flood and again during the summer/fall flash floods.

The median suspended silt-and-clay concentration for the same measurement period were much greater than sand concentrations - 310 mg/L (Figure 2.15C). Silt-and-clay concentrations are highest during the summer and fall months when upstream flash floods occur, but are not controlled by the magnitude of Green River discharge. Silt-and-clay concentrations do not increase meaningfully during the spring snowmelt flood (Figure 2.16D). The median suspended silt-and-clay concentration of snowmelt-derived flows in May and June was 850, 1100, and 570 mg/L in 2014, 2015, and 2016, respectively. The median suspended silt-and-clay concentration in August and September was 2400, 410, and 570 mg/L in the same 3 years.

Physical bed sediment samples (n=133) collected as part of Mineral Bottom sediment monitoring (GCMRC, 2016) show the median grain size of bed sand is medium sand - 0.30 mm. Ninety percent of collected bed sediment samples have a median sand grain size between 0.18-0.38 mm, coarser than suspended sand, which 90% of the time were between 0.09-0.19 mm. Bed sediment fines during peak snowmelt flooding and exhibits hysteresis, coarsening from the rising to falling limb of yearly snowmelt peak floods (Figure 2.17).

Grain size distributions comparing samples collected from the trench, in-channel bars, suspended sediment samples, and bed sediment samples show that substantial difference between each set of samples, with little overlap (Figure 2.14). The only two sets of samples with overlapping grain size distributions are suspended sediment samples and in-channel bars. While there appears to be some interaction between the bed, grains in suspension, in channel bars and the floodplain, when comparing grain size distributions, floodplain building material is primarily sourced from finer suspended sediments and little, if not none, sediment in the floodplain is sourced from the bed.

2.9 DISCUSSION

Within the study area, the primary mechanism of inset floodplain formation from 1940-2015 was vertical accretion. Formation began by the accretion of bank-attached bars as part of the active channel. In the trench, accretion of bank-attached bars occurred during periods of relatively low peak flow, preserving the stability of bar deposits throughout the year. Vertical accretion transitioned active channel bars in 1-2 years to an intermittingly inundated floodplain, decreasing channel width. Continued vertical floodplain accretion during our period of record occurred on a yearly timescale when the floodplain was inundated.

Accretion at the channel margin was a secondary process for floodplain growth. Lateral floodplain accretion narrowed the channel with minimal vertical accretion. The other major process of floodplain formation is large scale vertical accretion during large floods. This process of floodplain formation, previously unidentified in the lower Green River, is similar to episodic aggradation of terraces described by Moody and Meade (2008) during a large flood in 1978 on the Powder River, MT. The thickness of large flood deposits is likely influenced by floodplain vegetation, and floodplain stripping may be limited by vegetation (Phillips and Tadayon, 2006; Griffin et al., 2014; Manners et al., 2014). However, flow magnitude may not have reached the threshold for stripping to occur. High flows did not produce floodplain stripping after 1985 and there is no widening associated with recent high flows. Narrowing after 1985 occurred in years of low peak flow.

Processes of channel narrowing by inset floodplain formation are episodic, and the channel changes I documented happened in a small number of years. Channel widths in the study area were stable for most years, even as vertical accretion took place.

The relative roles of flow and vegetation in promoting channel narrowing of the lower Green River are complex and it is difficult to fully unwind the contributions of each potential driver. Channel narrowing occurred after both changes in flow regime and establishment of invasive vegetation. Previous studies on the interactions between flow and tamarisk mostly focused upon the differences between non-vegetated and vegetated surfaces, and have not investigated how changes to community composition potentially alter geomorphic process. Tamarisk and native trees were equivalent in promoting floodplain deposition on the San Pedro River in Arizona (Stromberg, 1998), but the dominant woody plants identified by Stromberg (1998) were Fremont cottonwood and the fruticose shrub seepwillow (*Baccharis salicifolia*). How tamarisk influences river form differently than communities of single-stemmed *Salix exigua* is still unknown.

Riparian vegetation communities changed in CNP during the 20th century as tamarisk established, and tamarisk is the dominant riparian species, although increases in the extent of sandbar willow account for much of the vegetation growth after 1976 (Mortenson and Weisberg, 2009). Recently formed floodplains and low elevation benches are mixed tamarisk-willow communities. Riparian vegetation density increased in the 20th century and dense stands of tamarisk and willow presumably influenced floodplain deposition by decreasing velocity of overbank flows and increasing hydraulic roughness (Griffin et al., 2014; Manners et al., 2014)

Flow regime changed at the same time as widespread changes to vegetation communities in the lower Green River, decreasing discharge. The inset floodplain formation I documented matches expected declines in channel width as a response to decreases in total discharge (Leopold and Maddock, 1953; Thorne, 1998). Further, my findings are consistent with other studies that observed channel narrowing as a response to decreasing discharge (Pizzuto, 1994; Allred and Schmidt, 1999).

Tamarisk induced channel narrowing elsewhere in the Green River basin (Manners et al., 2014) and is considered a contributor to channel narrowing at Green River, UT (Allred and Schmidt, 1999). However, there is no direct evidence that channel narrowing in the lower Green River was a response to the establishment of tamarisk. Recent channel narrowing occurred decades after the establishment of tamarisk and changes to width are linked to hydrology, a finding established in this study and others (Allred and Schmidt, 1999; Manners et al., 2014). Nevertheless, increased deposition and floodplain formation in the 20th century was likely due in part to the spread of tamarisk. The establishment of tamarisk on floodplains in years of low peak flow contributed to the creation of dense floodplain vegetation communities, stabilization of banks, and greater floodplain deposition. Thus, changes to the hydrologic regime are the primary cause of inset floodplain formation on the lower Green River.

Inset floodplain formation is not directly linked to changes in flow magnitude. Instead, the stabilization of flood deposits and vertical or lateral floodplain formation is a result of yearly peak flood magnitude. Clustered years of low peak flow initiated floodplain formation, subsequently, in-channel bars vertically accreted and converted to floodplain. The role of high flows is at least partially independent of flow regime, because the most recent phase of narrowing occurred well after a shift in flow regime in 1959, beginning instead in years of low peak flow from 1987-1992. Under this model, lateral channel narrowing will likely occur again during a cluster of low or moderate-to-low peak flow years allowing for bar deposition without erosion, stabilization of in-channel deposits, and conversion of channel to floodplain.

I identified floodplain growth in the second half of the 20th century, with the greatest narrowing taking place after 1985. Birken and Cooper (2006) asserted that channel width (determined from air photos) decreased in this study area by 1-2% from 1976-2002; for the same time period, I found channel narrowing of 13% near Fort Bottom; over the entire study area, the channel narrowed 8% between 1966-2002. Our larger narrowing result is due to our larger study area and more years of aerial imagery. We used 50-km and 15-km portions of river, much larger than the single 2-km reach at Potato Bottom selected by Birken and Cooper (2006). Further, our selected areas covered both stable and active reaches of river. In the 20th century, channel width at Potato Bottom was very stable, and minimal narrowing occurred. The magnitude of change varies by reach of river and study area; however, for both our study area and Fort Bottom reach, we document consistent and substantial changes to width since the 1940s. We do not know if there were changes to channel width in the early 20th century on the lower Green River, however, little change in width occurred at Green River, UT between 1912 and 1928 (Allred and Schmidt, 1999). After 1929, channel width at Green River, UT declined, narrowing approximately 5 m between 1930 and 1939. Because flow regime is the same for Green River, UT and the lower Green River, it is possible that the timing of change is similar at both locations and that changes in width began in the late 1920s.

My description of channel narrowing near Fort Bottom in response to changes in flow regime agrees with the work of Allred and Schmidt (1999) who described a corresponding sequence of narrowing at Green River, UT. It is possible that the Green River near Green River, UT has remained stable since the early 1990s. Future analysis of cross section data (outside the scope of this study) at Green River, UT over the same time range as our recent work (1984-2015) would allow us to determine if the timing of channel change is simultaneous or if an equilibrium state is propagating downstream (*sensu* Andrews, 1986). Comparison of the timing of channel narrowing in the Yampa River (Merritt and Cooper, 2000; Manners et al., 2014) and at Green River, UT will better link changes in channel width for the lower Green River to other locations in the basin, illustrating effects of hydrologic, vegetative and climatic changes on the entire basin.

Anthropogenic and natural changes in hydrology both play important roles in affecting channel form of the lower Green River. Since 1900, climatically driven declines in runoff have been the primary cause of declines in peak flow magnitude. Anthropogenic effects, in particular Flaming Gorge Dam, contribute to changes in flow regime, by decreasing total runoff, decreasing peak flow magnitude, and increasing base flow. Despite the relatively small impact of upstream water development on past channel narrowing, the lower Green River is sensitive to future changes in peak flow magnitude and timing. The low impact of local tributaries and dominance of snowmelt flooding means that changes to peak flow timing and magnitude will influence downstream morphology and will continue to do so in light of future changes, either climatically or anthropogenically driven.

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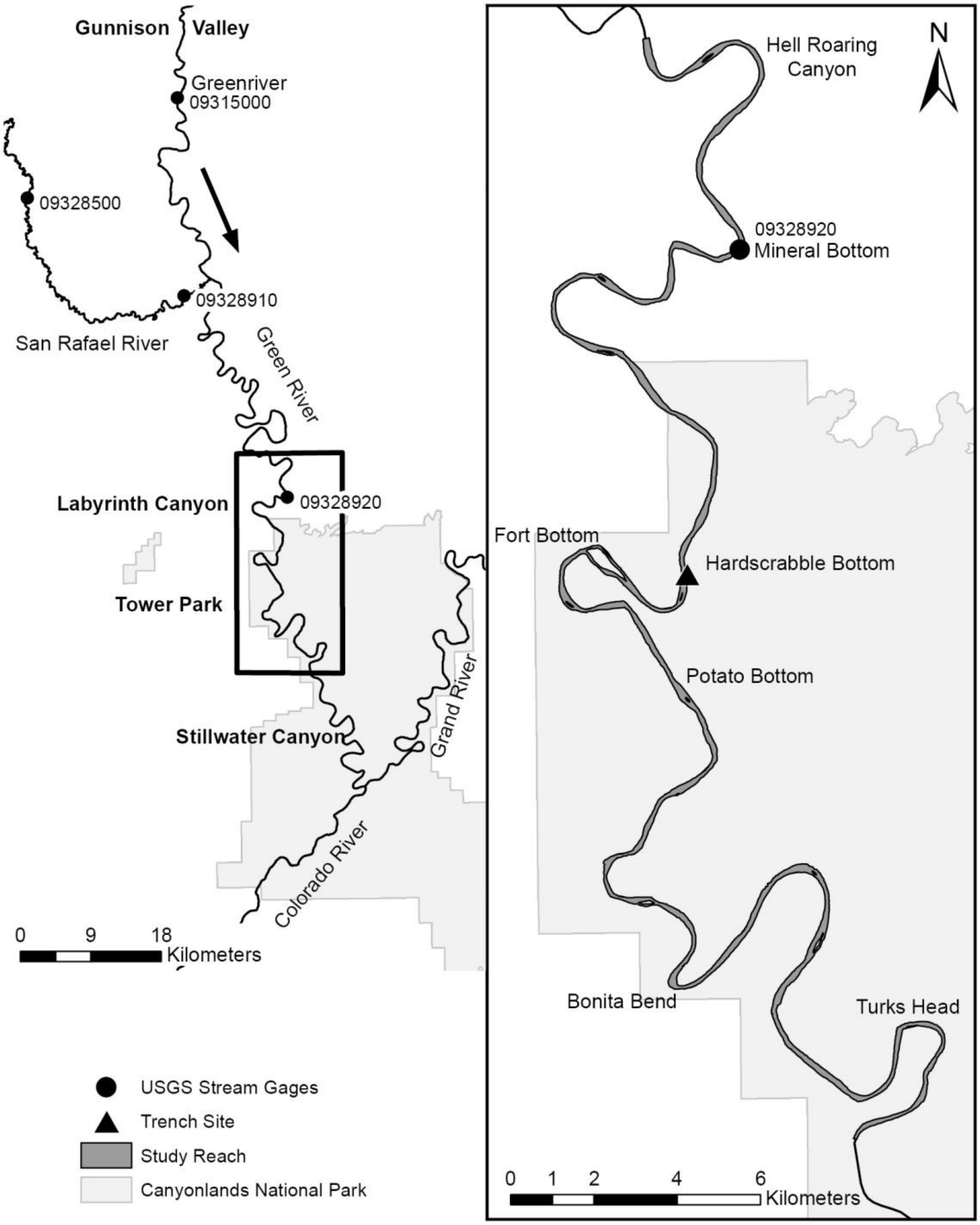

Figure 2.1: Map of the lower Green River and study area. Gages are 09315000 Green River at Green River, UT, 09328500 San Rafael River near Green River, UT, 09328910 San Rafael River at mouth near Green River, UT and 09328920 Green River at Mineral Bottom, UT.

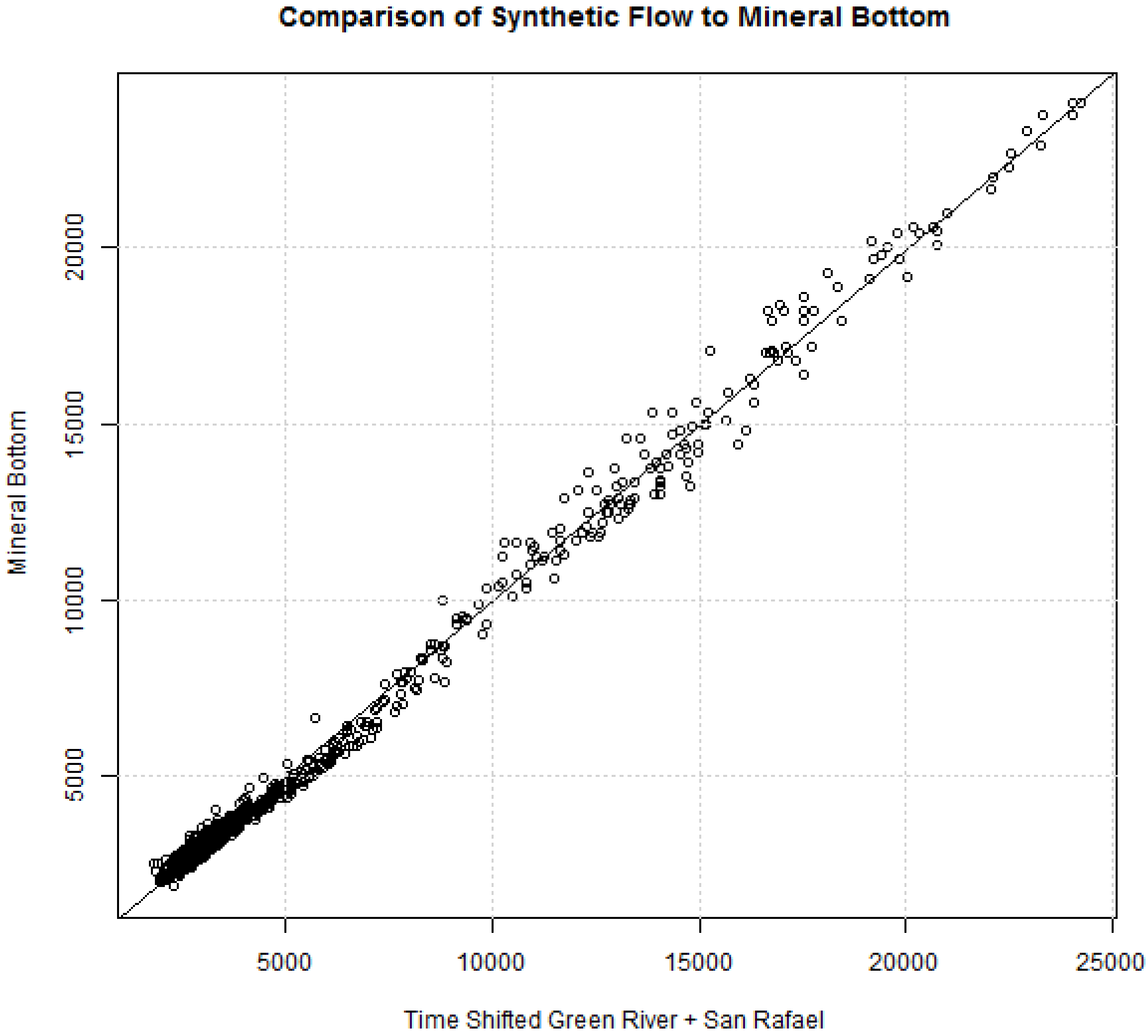

Figure 2.2: Comparison of daily discharge values for the time shifted synthetic flow method (Green River + San Rafael) and data collected at Mineral Bottom, UT from March 3, 2014 to February 1, 2017 (n=1006).

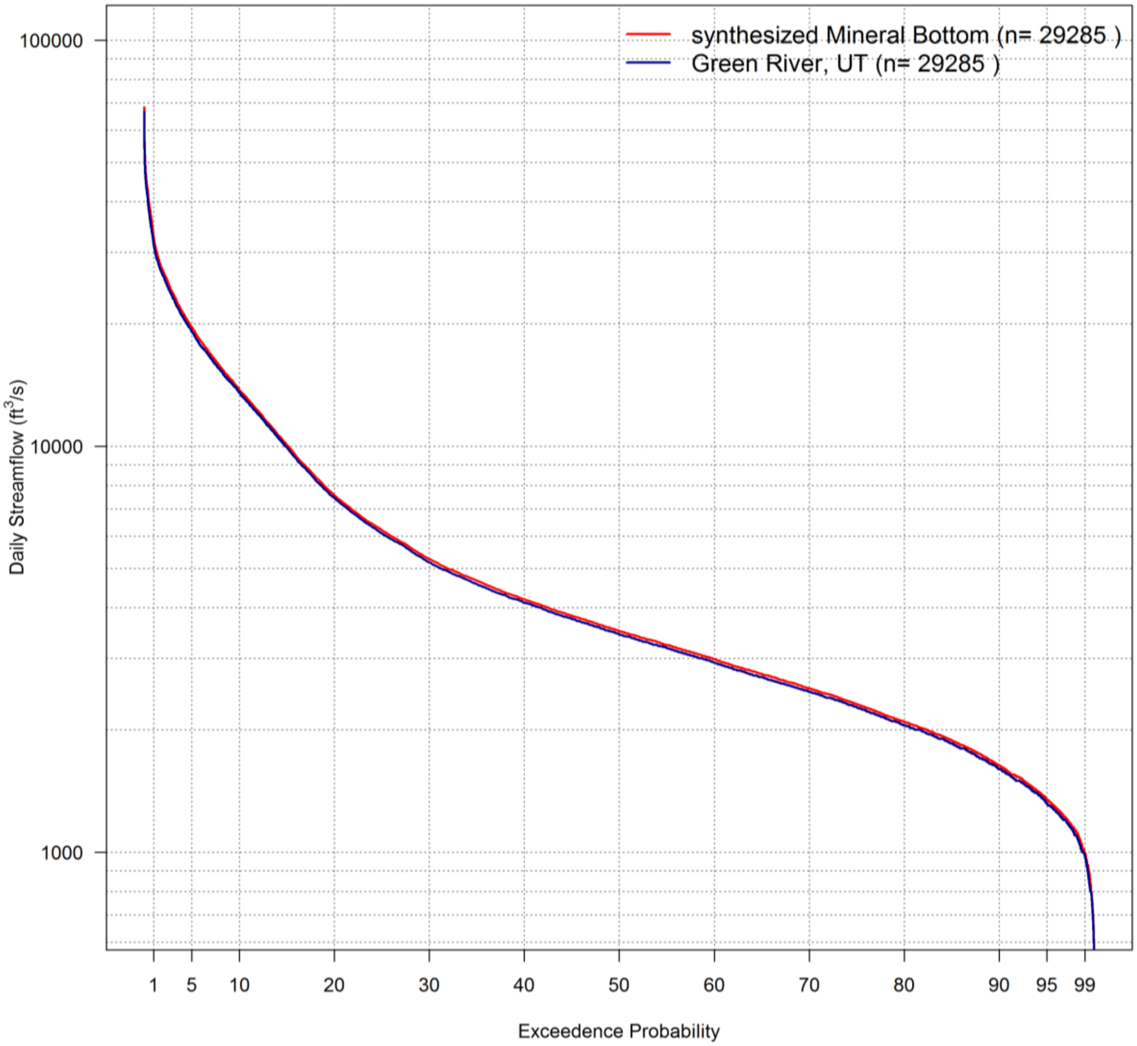

Figure 2.3: Flow duration curves for Mineral Bottom and Green River, UT, comparing pre-(1909-1918) and post-(1950-2015) major river regulation.

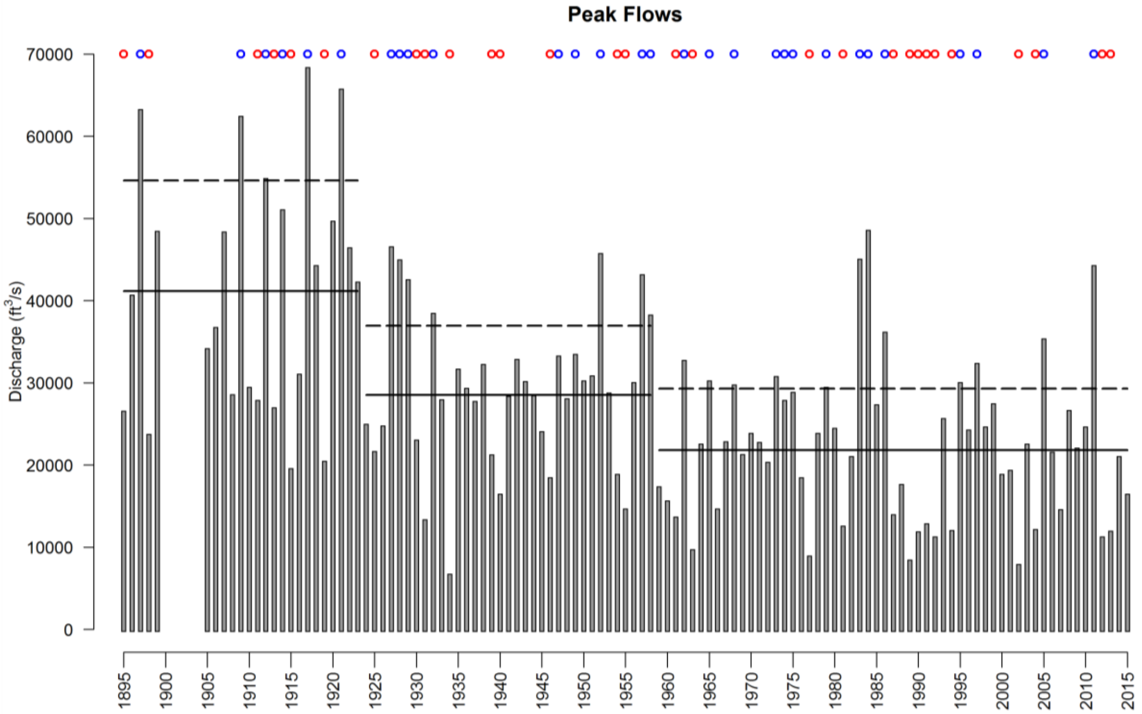

Figure 2.4: Time series of instantaneous annual peak flows at Green River, UT (gage 09315000). The 2-year (solid line) and 5-year (dashed line) recurrence intervals are shown for each period of flow regime determined by the Pettitt test. High (red circles) and low (blue circles) peak flow years are identified as defined in the text.

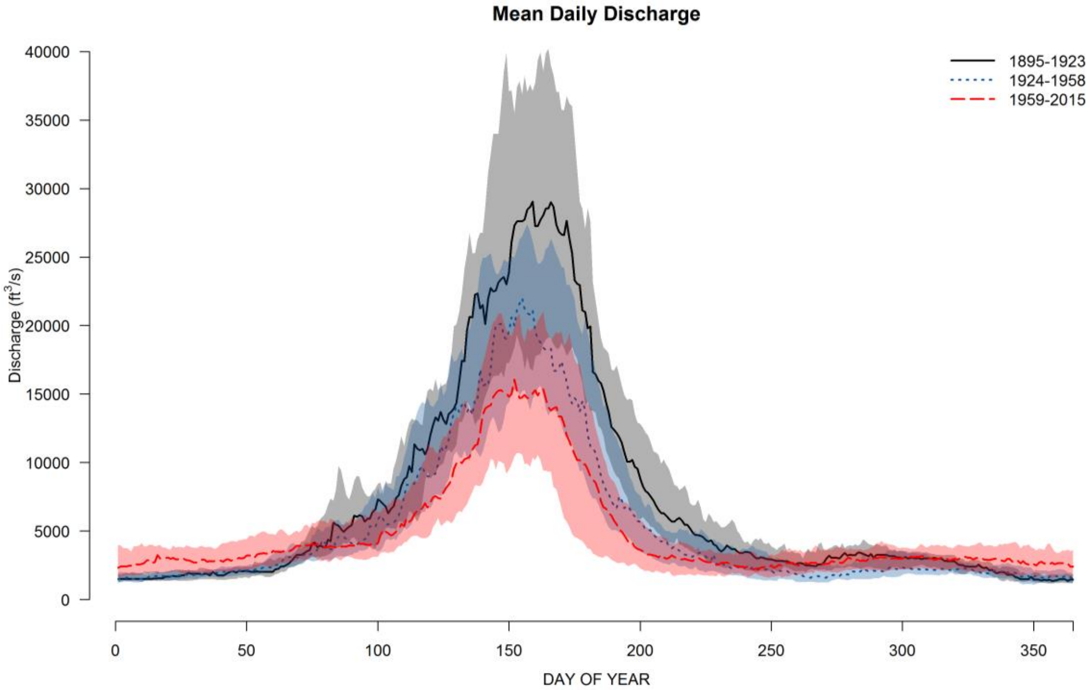

Figure 2.5: Mean daily discharge at Green River, UT for each period of flow regime identified by a Pettitt test of instantaneous annual peak flows. Shaded areas show the interquartile range for each period of flow regime.

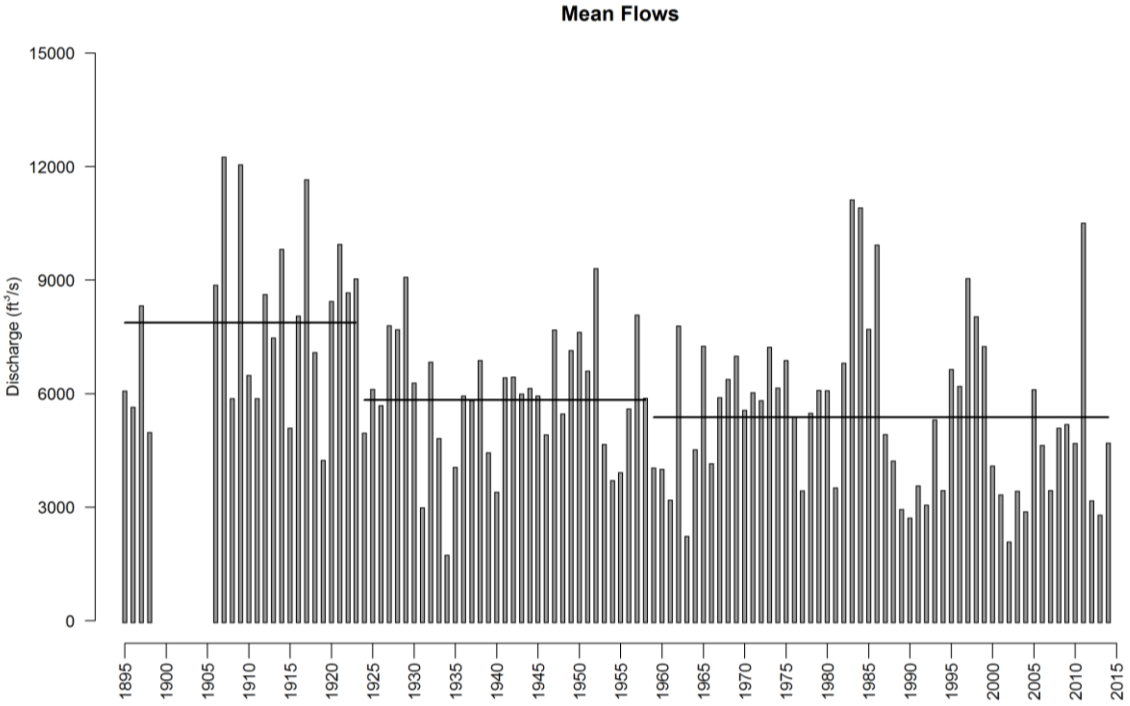

Figure 2.6: Mean annual flows at Green River, UT (gage 09315000) showing mean annual flow for period of flow regime identified by a Pettitt test of instantaneous annual peak flows.

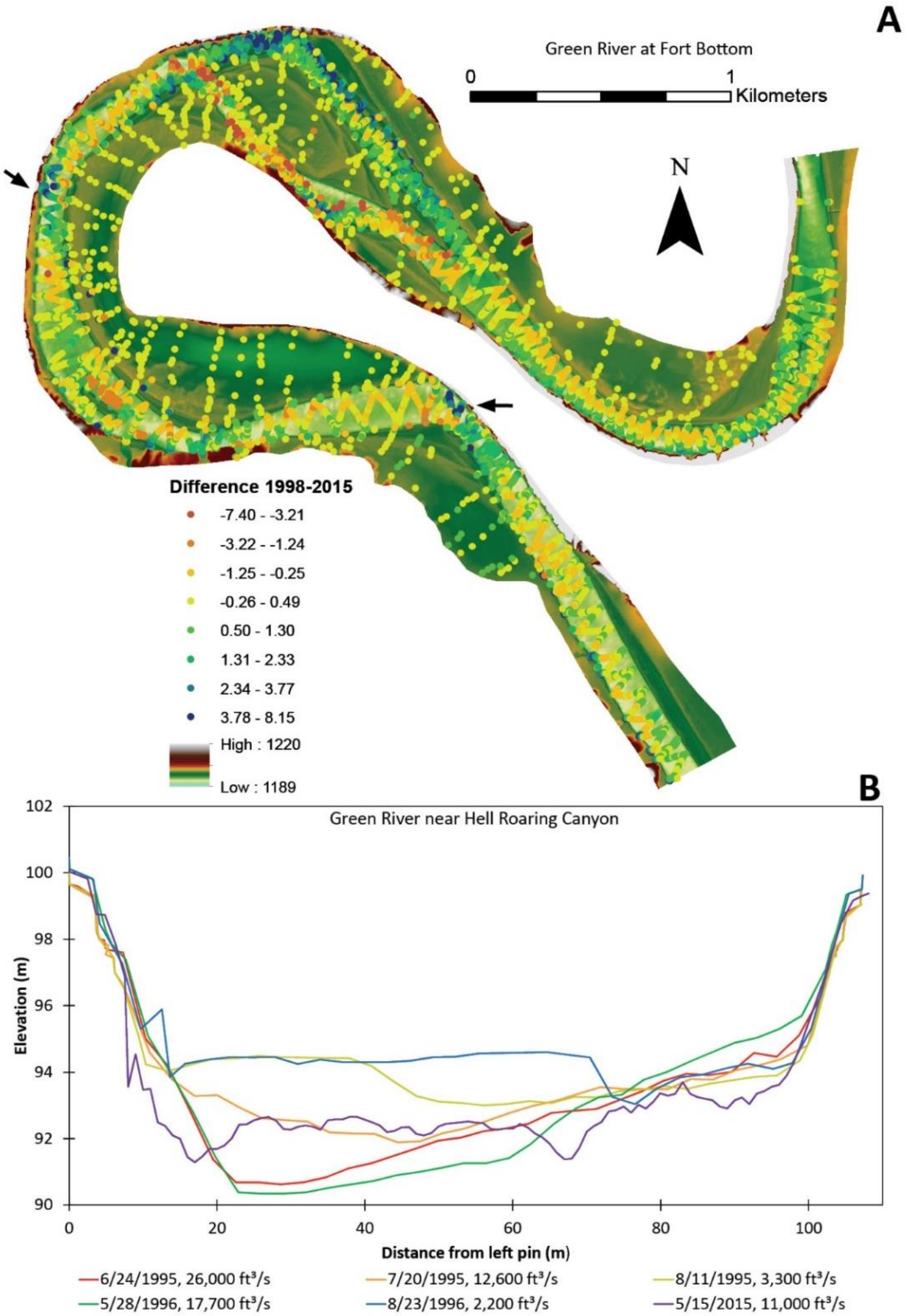

Figure 2.7: A) Results of channel surveys near Fort Bottom, showing large (>3 m) deposition in deep pools at the outside of bends where the channel contacts bedrock (black arrows). This deposition is likely due to differences in discharge between the 1998 and 2015 surveys. Points in A are locations of the 1998 and their color corresponds to the difference between the 1998 and 2015 surveys in meters. B) Comparison of cross-section surveys near Hell Roaring Canyon, showing yearly scour and fill.

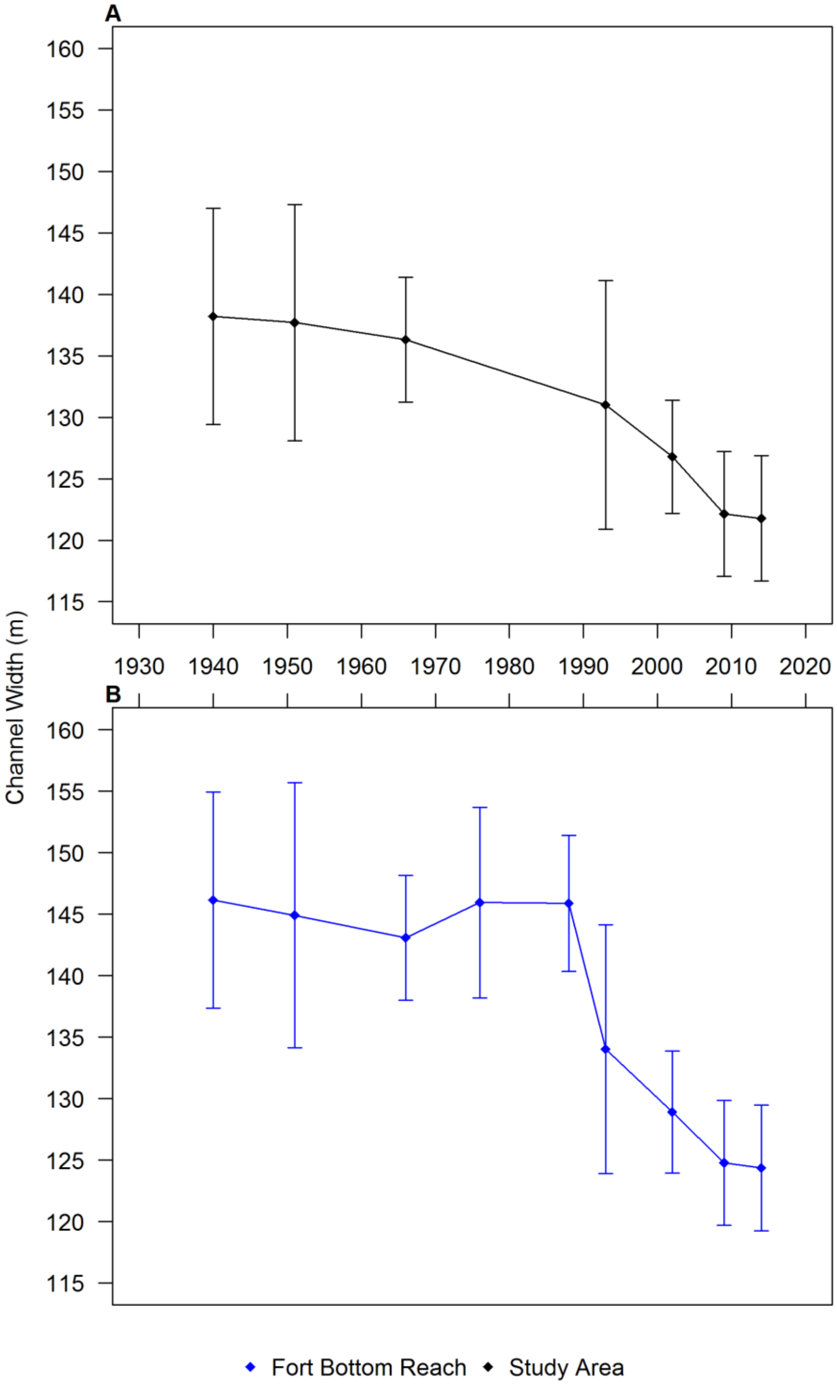

Figure 2.8: Changes in channel width for all years of aerial imagery reach showing A) mean RAACW in the 61 km study area for each year with error bars showing E_w. Maximum RAACW decreased by 63 m from 1988 to 1993, minimum width remained stable from 1940 to 2014 and A) mean RAACW in the 15 km Fort Bottom reach for each year with error bars showing spatial uncertainty (E_w)

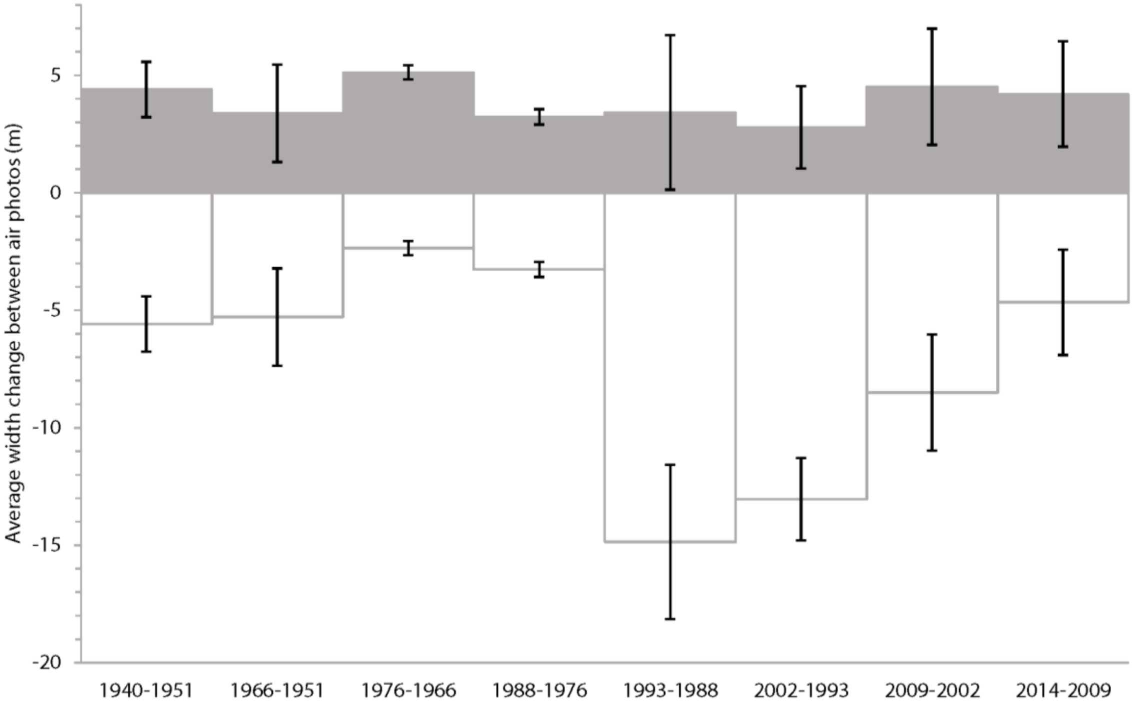

Figure 2.9: Changes in active channel width by floodplain formation (white boxes) and floodplain erosion (gray boxes). Net narrowing over the Fort Bottom reach includes floodplain deposition in every single year, but that deposition is outweighed by a greater amount of erosion. Error bars represent uncertainty associated with active channel boundary digitization ($\sqrt{2}p$) in Table 2.

Figure 2.10: Conversion of a bare sand bar to vegetated floodplain at Potato Bottom (RM 36.5). Flow is from top to bottom. An active mid-channel bar in 1951 (A, Q = 2,300 ft^3/s) is located in the middle of the channel. The white arrow in A) shows the mid-channel bars. White areas in the picture are higher elevation sands. In 1966 (B, Q = unknown), the black arrow points to an emergent bar on river right. The emergent bar is gone in 1993 (C, Q = 13,700 ft^3/s), instead vegetation has established on bank-attached bar (black arrow) in 1993. By 2014, the bar (white arrow) is heavily vegetated and is part of the floodplain (D, Q = 3,820 ft^3/s).

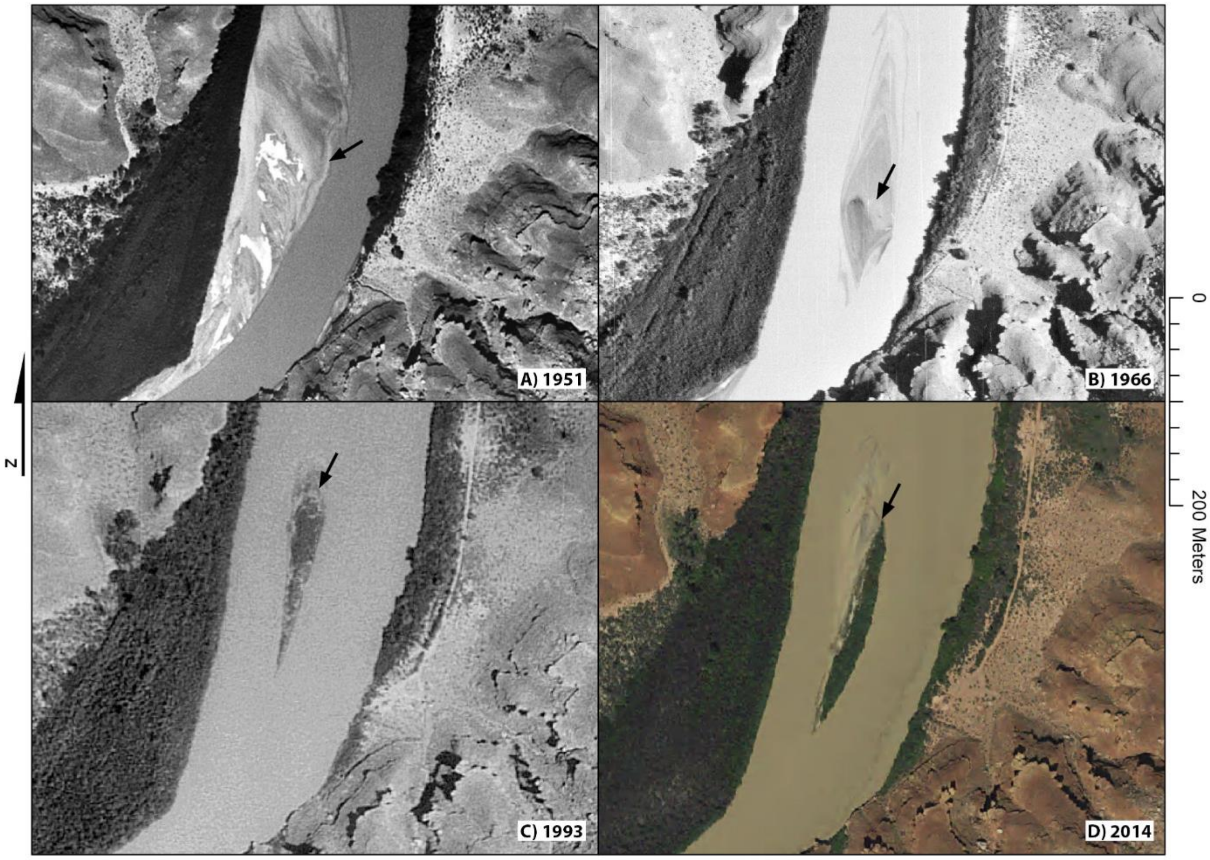

Figure 2.11: Conversion of a mid-channel bar at the downstream end of Hardscrabble Bottom (RM 42.5). Flow is from top to bottom. An emergent bar in 1951 (A, Q = 2,300 ft^3/s) shown by the black arrow and a mid-channel bar in 1966 (B, Q= unknown), transitions to a vegetated island by 1993 (C, Q = 13,700 ft^3/s) and remains vegetated in 2014 (D, Q = 3,820 ft^3/s). The mid-channel bar and island are shown by the black arrow.

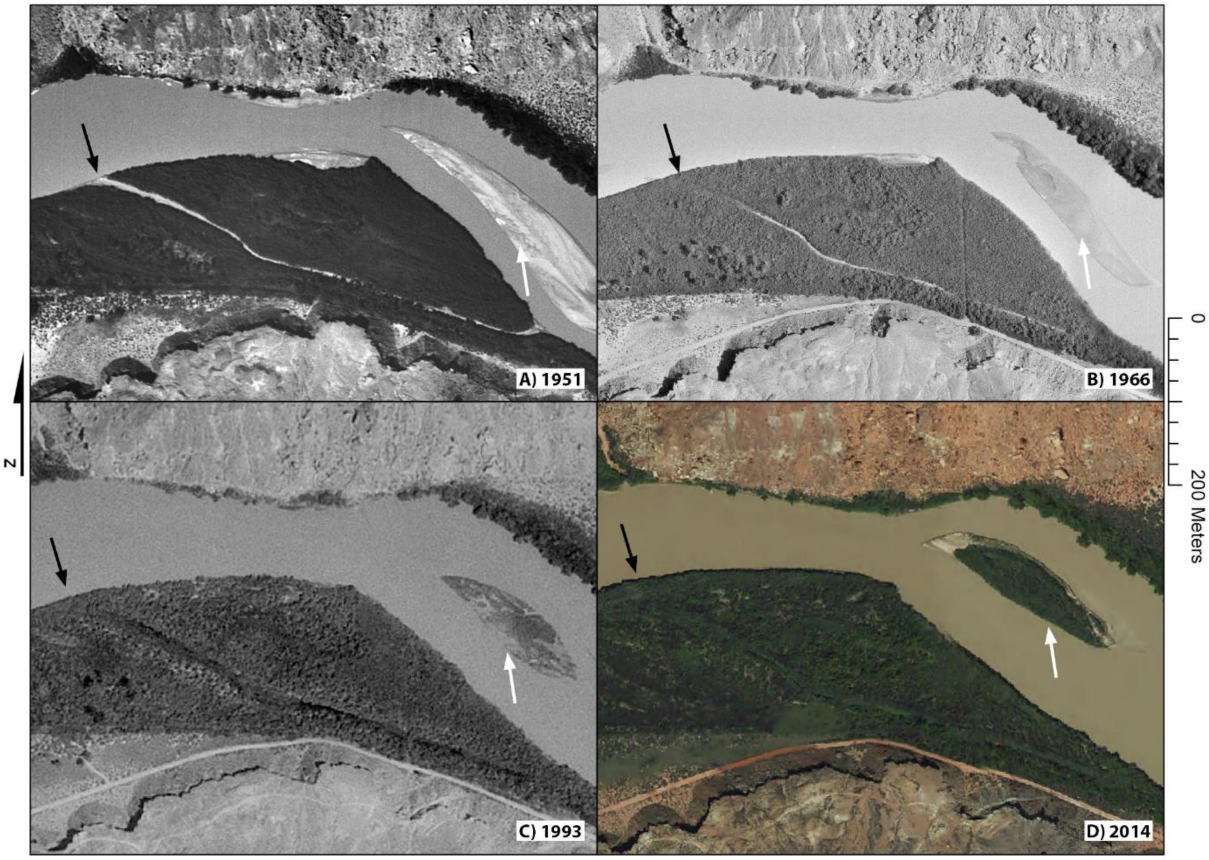

Figure 2.12: Aggradation of a secondary channel at Point Bottom (RM 49). Flow is from right to left. A secondary channel exists in 1951 (A, Q = 2,300 ft^3/s), creating a large vegetated island. The open channel is clearly seen at the downstream end of the bar (black arrow). In 1966 (B, Q = unknown), vegetation has established in the upstream and downstream ends of the channel (black arrows). The secondary channel is fully vegetated in 1993 (C, Q = 13,700 ft^3/s) and 2014 (D, Q = 3,820 ft^3/s) (black arrows). Mid-channel bar conversion immediately offshore of Point Bottom happens at the same time the secondary channel aggrades, converting a bar to vegetated island by 1993 (white arrows).

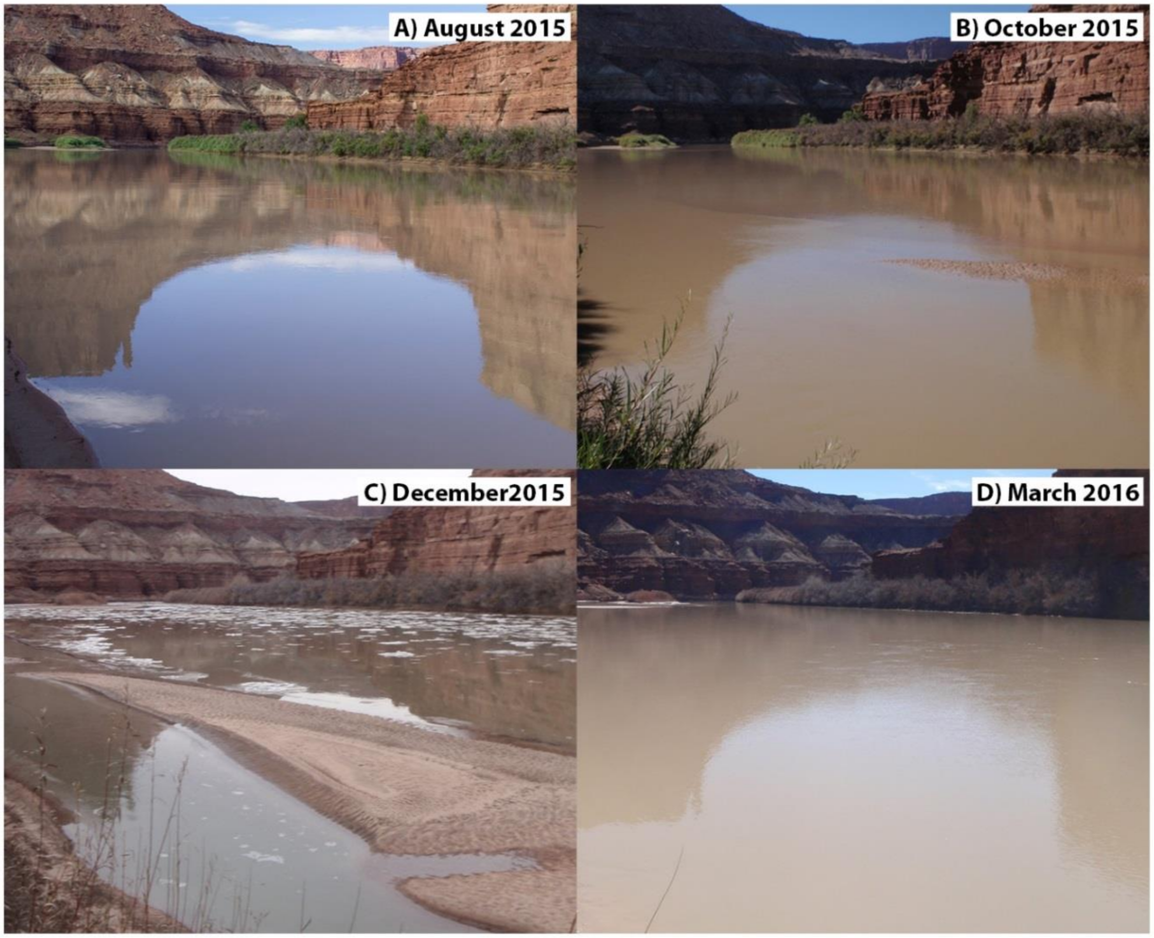

Figure 2.13: A photo match taken at the Hardscrabble trench, showing offshore bar deposition and erosion in summer and fall low flows. Photos are looking downstream. A) Photo taken August 7, 2015 at 2,610 ft^3/s, B) Photo taken October 15, 2015 at 2640 ft^3/s, C) Photo taken December 6, 2015 at 2,820 ft^3/s and D) Photo taken March 2016 at 3,400 ft^3/s. Discharge values are from the Mineral Bottom gage. The highest flow in this time period was 6,650 ft^3/s on October 20, 2015.

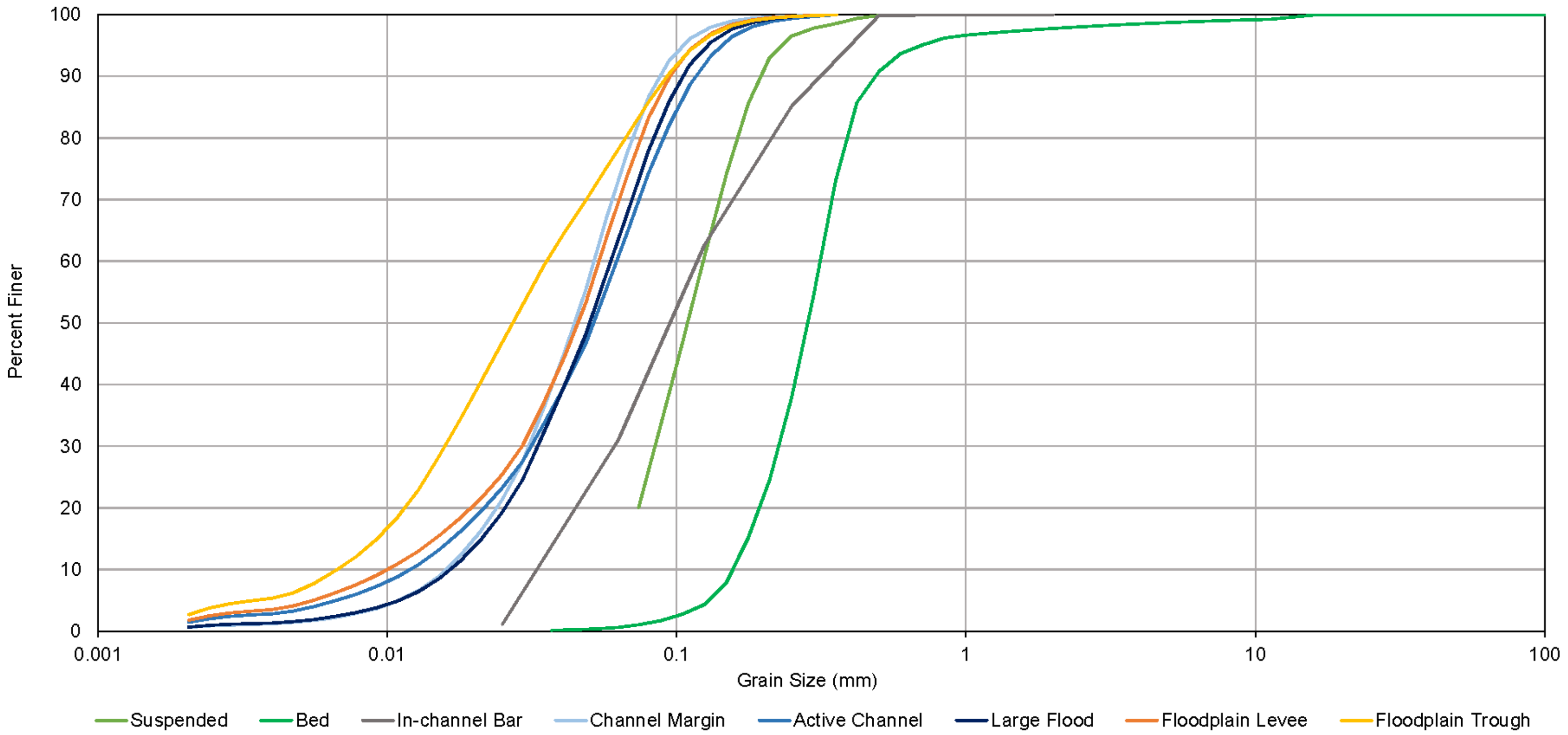

Figure 2.14: Grain-size distribution of sediments collected in the lower Green River. The suspended and bed sediments (in shades of green) are from physical samples collected from cross-sections at Mineral Bottom to calibrate acoustic suspended sediment monitoring. In-channel bar sediments, in gray, were collected from exposed in-channel bars near Fort Bottom and the trench. The remaining samples were collected from the trench and represent each facies. The floodplain facies is split into trough and levee to illustrate differences between the two parts of the facies.

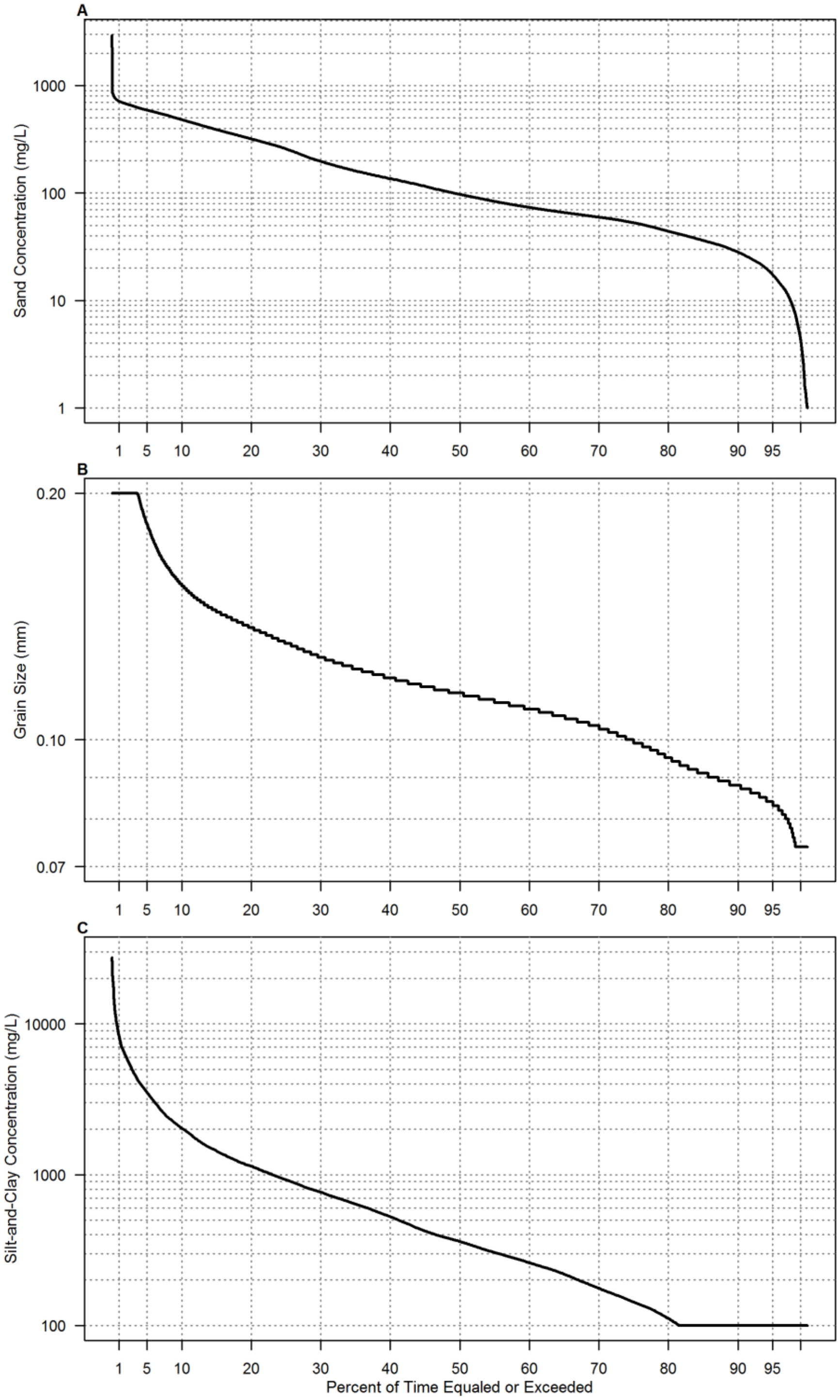

Figure 2.15: Duration curves for A) suspended sand concentration, B) suspended sand median grain size and C) suspended silt-and-clay concentration collected by acoustic sediment monitoring at Mineral Bottom. Concentrations of suspended silt-and-clay are almost an order of magnitude greater than concentrations of suspended sand.

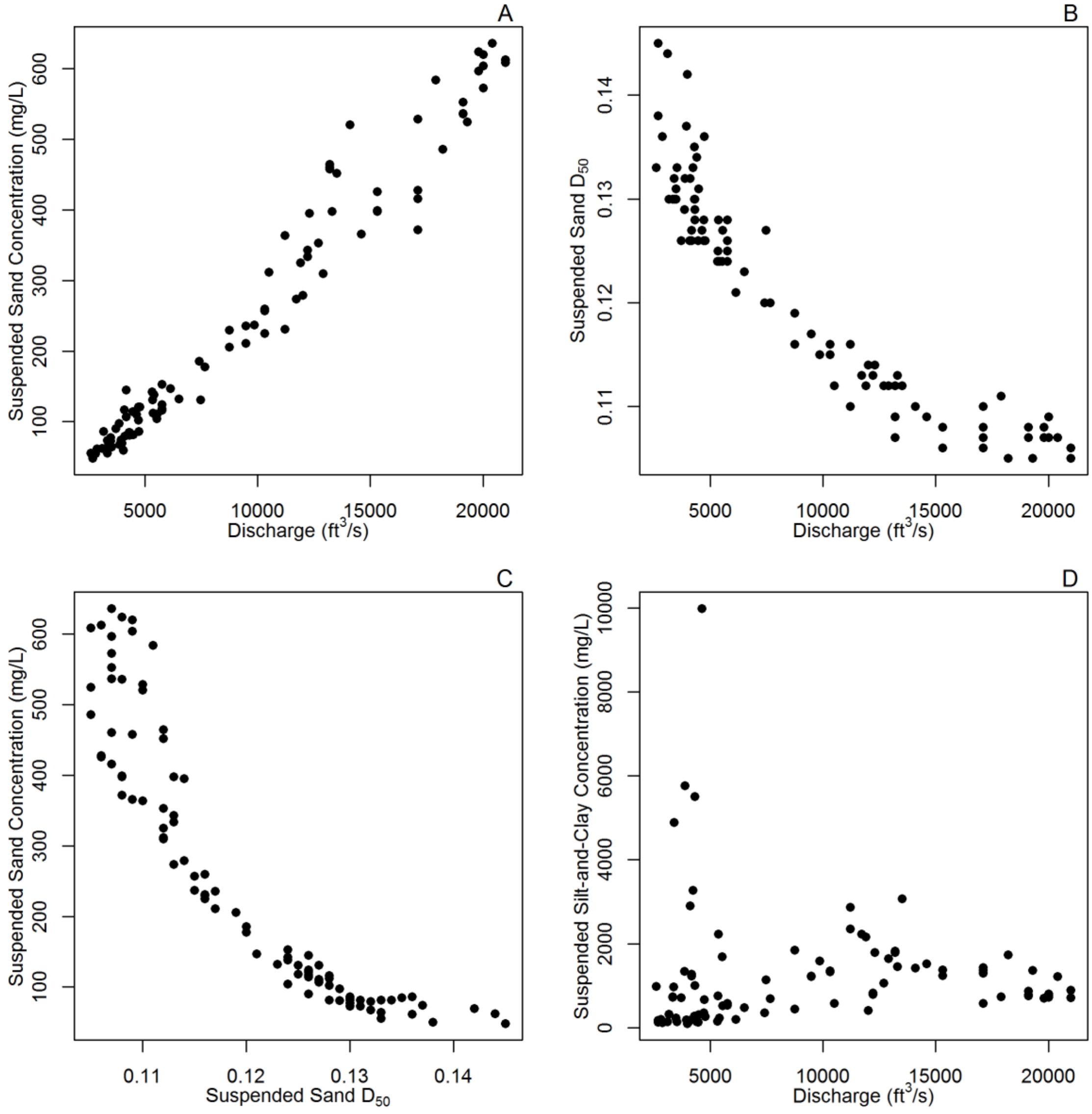

Figure 2.16: Characteristics of physical suspended sediment samples collected by ISCO pump sampler at Mineral Bottom from March 2014-October 2016 (n=133). A) Suspended sand concentrations increase with rising discharge. B) Median suspended sand grains size decreases with increasing discharge. C) Suspended sand decreases in relation to increasing median grain size. D) Suspended silt-and-clay remains relatively constant with increasing discharge.

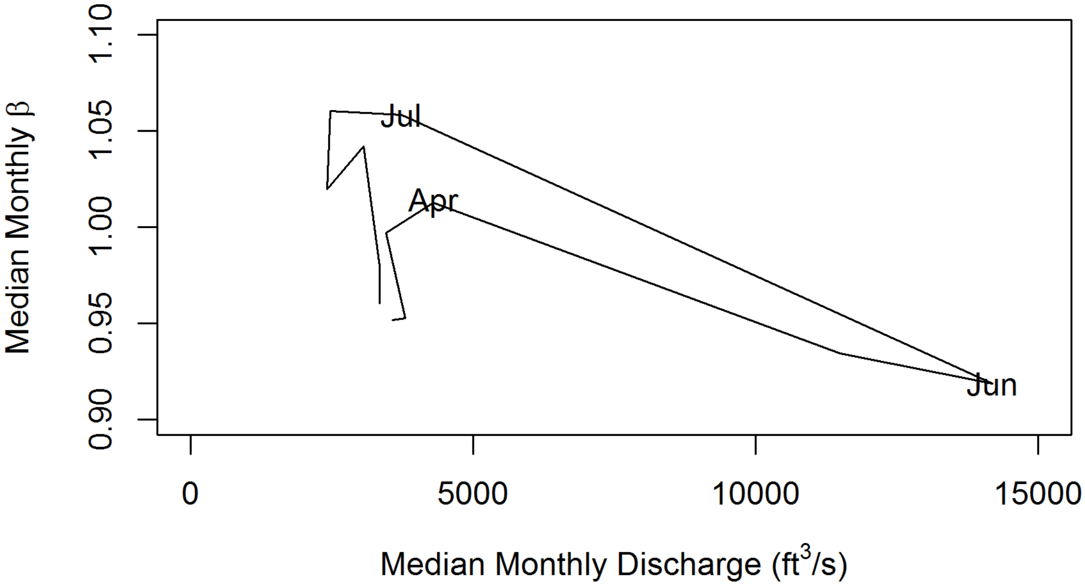

Figure 2.17: Plot of β, a dimensionless measure of bed sediment as function of discharge and suspended sediment. As bed sediment fines, β decreases. The pattern of hysteresis is the same as one described for the Colorado River at Lee's Ferry and in the Grand Canyon before the construction of Glen Canyon Dam (Rubin and Topping, 2001).

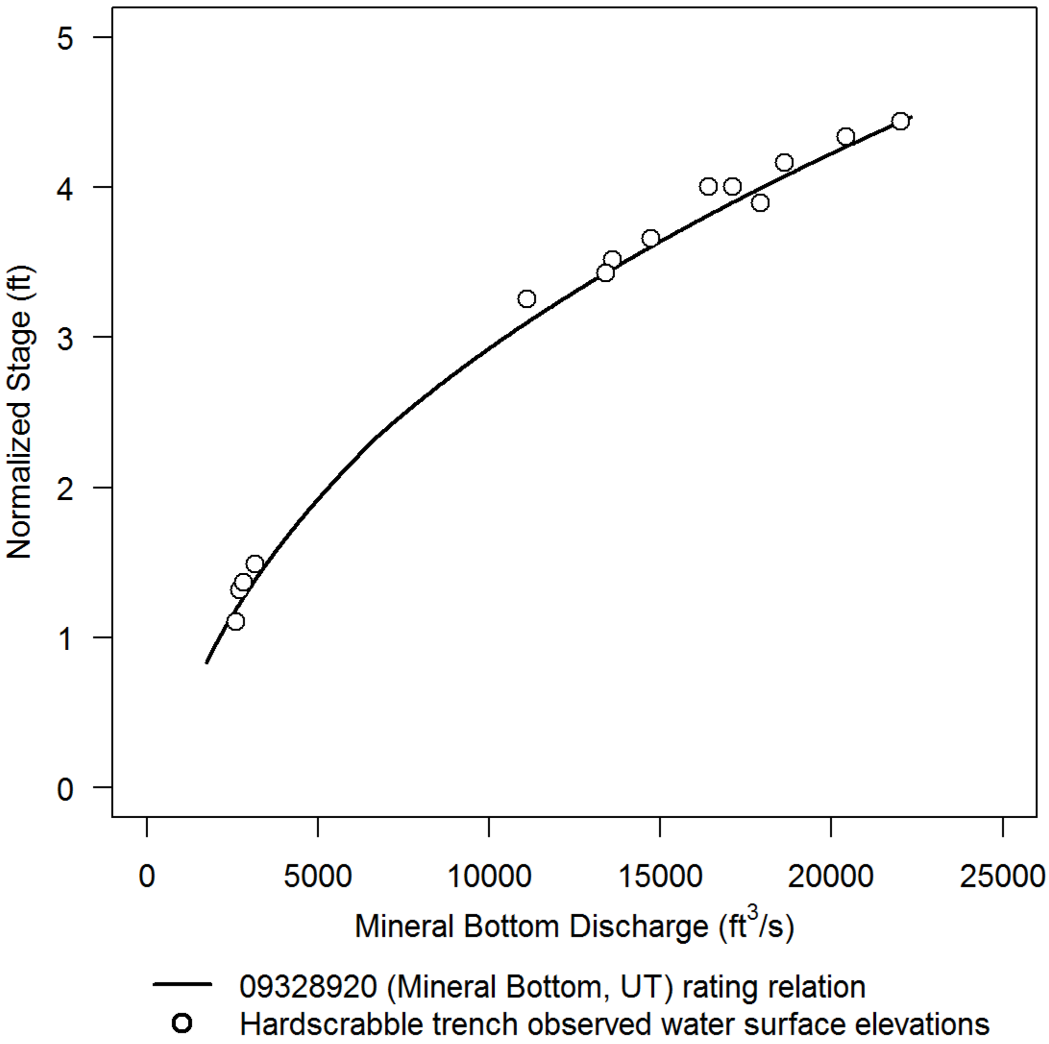

Figure 2.18: Stage-discharge relation at Hardscrabble trench site compared to the USGS rating relation for Mineral Bottom. Stage for both relations is normalized to make comparisons.

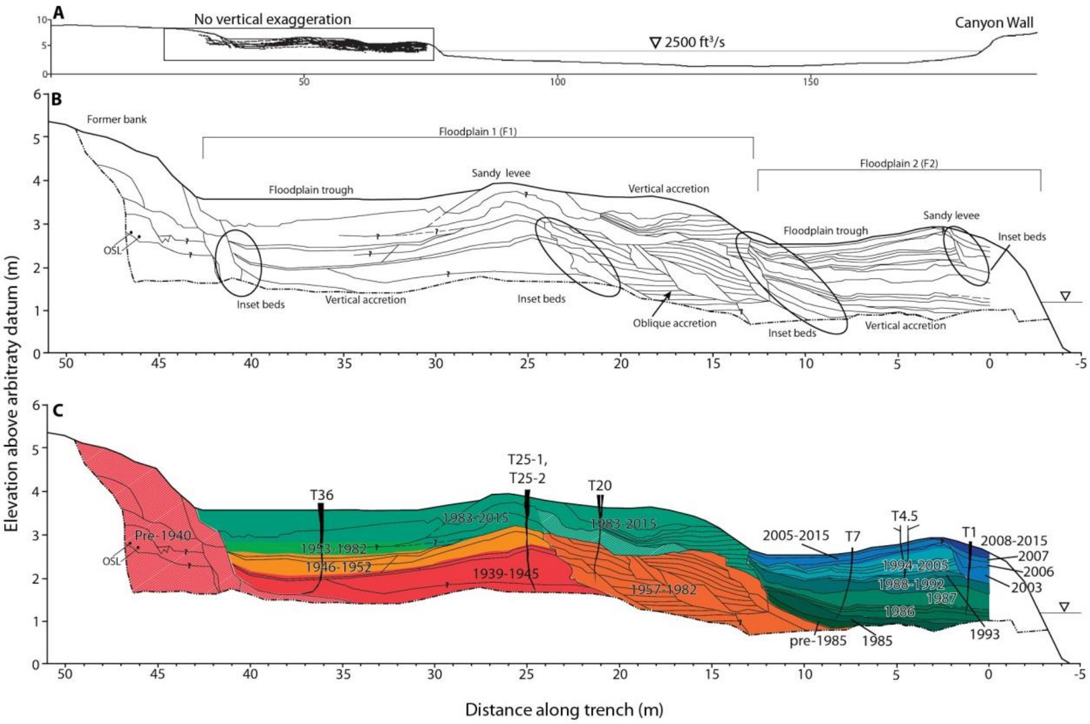

Figure 2.19: Trench stratigraphy and dendrogeomophology. A) Complete cross section profile shown with no vertical exaggeration. The box in A covers the trench and is the location of B, C and D. B) Stratigraphy and major locations within the trench. C) Chronology of deposition determined from tree-ring dating and OSL.

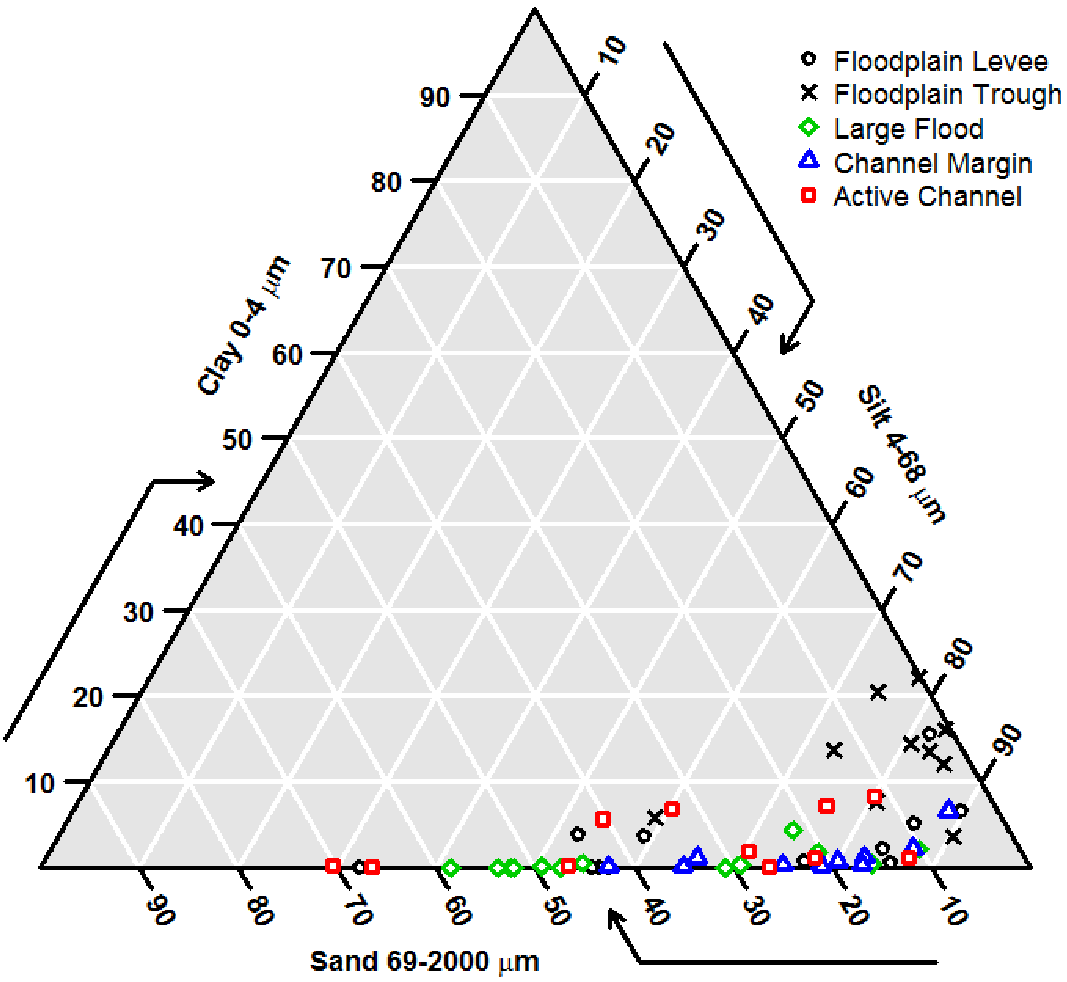

Figure 2.20: Ternary diagram for samples collected from each facies identified in the trench. Floodplain levees and trough are subdivided.

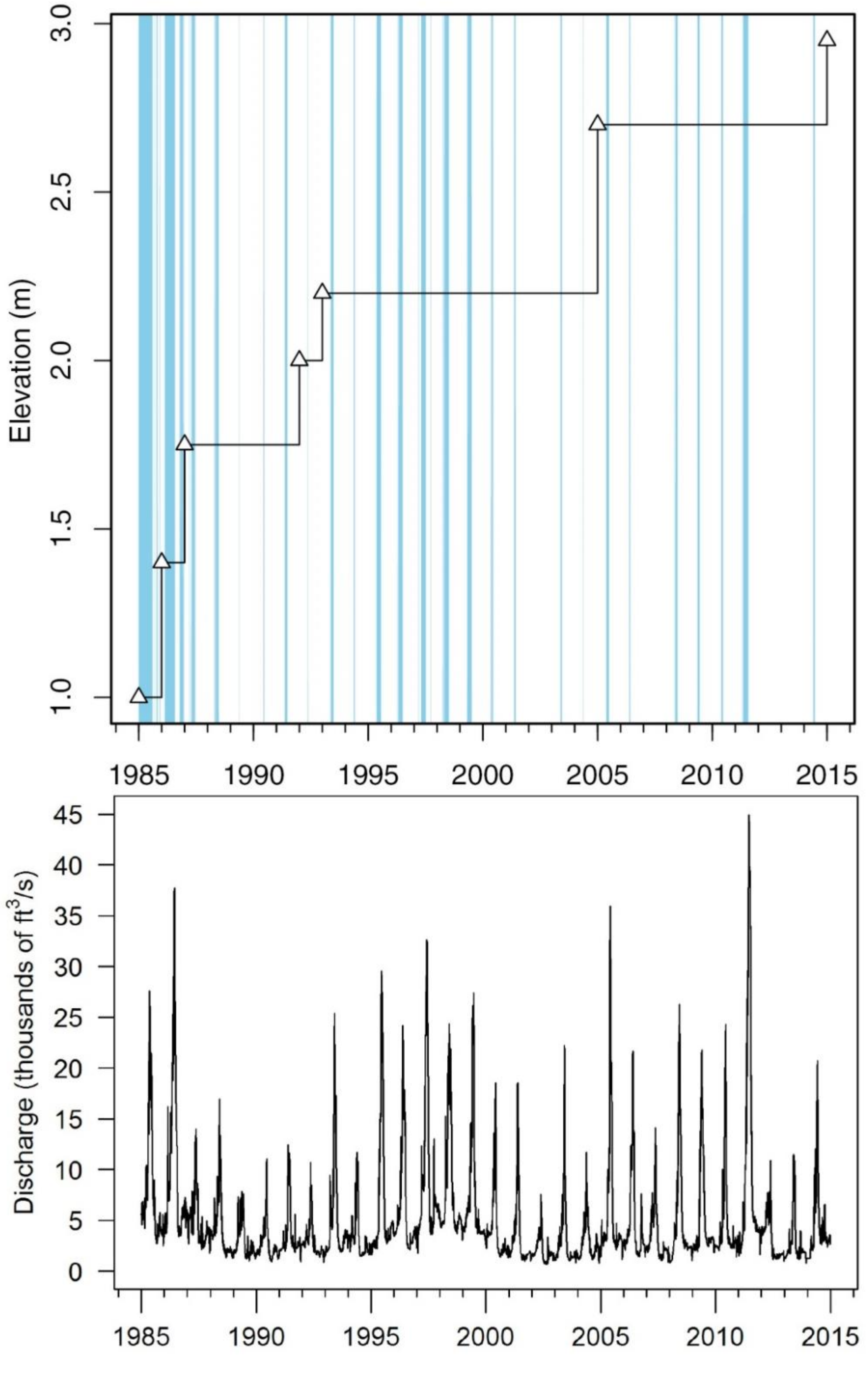

Figure 2.21: Plot of floodplain elevation for post 1985-deposits and daily discharge for same time period (1985-2015). On the upper plot, the elevation of the floodplain is represented by the black line and time when the floodplain was inundated by blue shaded areas. Triangles represent ages of stratigraphic contacts determined by dendrogemorphology aging. For the inset floodplain which formed after 1985, the amount of time it was inundated decreased substantially after 1987, but was still inundated on a 1.5-2 year recurrence interval until 2011.

Table 2.1: Flow regime periods identified from Pettitt test

Period	Number of Years	Mean Annual Flow (ft^3/s)	2-year flood (ft^3/s)	5-year flood (ft^3/s)	P-value of break point*
1985-1923	23	41,200	41,200	54,600	
1924-1958	34	28,500	28,500	36,900	0.015
1959-2016	58	22,000	21,800	29,300	3.87x10-6

*Two break points exist, 1 in 1924 and 1 in 1959

Table 2.2: Aerial imagery information

Year	Dates	Agency	Film Type	Approximate Scale	Pixel resolution (m)	Discharge (ft^3/s)	Coverage of study area (%)
1940	8/30	US Department of Agriculture (USDA)	Black & White	31,680	1	3,950	90
1951	9/19	US Geological Survey (USGS)	Black & White	20,000	0.5	2,300	79
1966	Unknown	Bureau of Land Management	Black & White	15,840	1	Unknown	100
1976	8/31	National Park Service (NPS)	Color	12,000	0.15	3,040	28
1988	8/27	Bureau of Reclamation	Color Infrared	6,000	0.15	1,820	25
1993	6/14	USGS	Black & White	40,000	1	13,700	100
2002	6/18 and 6/19	USGS/NPS	Color	12,000	0.84	2,370	99
2009	8/7	USDA Aerial Photography Field Office (APFO)	Digital Color	-	1	3,100	100
2011	6/22	USDA APFO	Digital Color	-	1	42,300	100
2014	9/11	USDA APFO	Digital Color	-	1	3,820	100

Table 2.3: Errors associated with channel width measurements from aerial imagery. All values are in meters

Year	Width Error (p)	Pixel resolution (R)	Digitization error ($\sqrt{2}pR$)	Image Distortion Error (θ)	Total width error (E_w)
1940	1.91	1	2.7	3.04	8.79
1951	1.66	0.5	1.18	4.22	9.62
1966	1.47	1	2.07	1.5	5.08
1976	1.42	0.15	0.3	2.87	6.05
1988	1.54	0.15	0.33	1.67	3.67
1993	2.32	1	3.29	3.42	10.12
2002	1.47	0.84	1.75	1.43	4.61
2009	1.75	1	2.47	1.31	5.09
2014	1.59	1	2.24	1.43	5.1

Table 2.4: Reach average channel widths by year for the study area. All values are in meters.

		Reach Average Active Channel Width (m)						
River Kilometer	River Mile	1940	1951	1966	1993	2002	2009	2014
92.50	57.48	-	-	162.23	169.23	169.50	163.23	161.40
91.50	56.86	-	-	102.16	102.59	99.80	99.89	96.35
90.50	56.23	-	-	158.59	159.25	155.51	153.42	151.77
89.50	55.61	-	-	120.93	122.39	138.59	113.19	110.04
88.50	54.99	-	-	118.84	120.55	109.64	112.10	105.28
87.50	54.37	182.02	-	172.03	174.53	169.10	167.79	164.53
86.50	53.75	156.46	-	146.54	137.13	139.47	134.51	132.82
85.50	53.13	113.27	-	112.61	113.36	113.28	112.39	111.23
84.50	52.51	148.59	149.51	147.06	153.00	150.57	148.34	145.34
83.50	51.88	122.01	126.79	119.96	116.96	112.83	106.78	108.88
82.50	51.26	135.61	132.34	129.98	131.76	129.14	124.26	125.50
81.50	50.64	100.62	109.01	118.54	123.20	120.53	121.28	117.60
80.50	50.02	117.44	116.75	117.28	121.80	118.35	118.48	116.08
79.50	49.40	137.19	139.94	130.35	134.49	139.09	142.42	138.42
78.50	48.78	105.03	108.38	100.55	108.21	102.75	96.49	97.73
77.50	48.16	109.97	110.39	111.24	111.41	105.60	102.51	99.40
76.50	47.53	118.00	112.17	112.37	115.45	111.39	114.50	113.34
75.50	46.91	148.93	149.32	151.48	147.11	138.74	131.95	134.29
74.50	46.29	160.84	165.61	163.55	168.09	169.75	170.96	168.88
73.50	45.67	126.57	127.93	125.54	129.65	125.36	124.67	122.36
72.50	45.05	122.17	110.31	114.03	117.07	113.85	115.56	113.95
71.50	44.43	112.78	115.23	116.68	117.73	114.40	116.44	109.67
70.50	43.81	169.04	169.90	170.51	164.40	167.13	150.32	148.30
69.50	43.19	141.43	142.68	139.95	141.52	121.78	121.12	116.80
68.50	42.56	143.18	139.64	138.10	132.02	130.50	128.16	128.39
67.50	41.94	97.21	100.25	93.94	86.89	84.96	86.82	85.20
66.50	41.32	173.00	174.54	170.04	167.29	161.76	158.25	152.12
65.50	40.70	155.39	153.83	149.02	141.96	133.40	115.59	124.52
64.50	40.08	125.94	123.69	124.75	123.29	114.61	110.04	107.95
63.50	39.46	149.85	148.15	143.06	137.62	135.53	128.38	129.77
62.50	38.84	128.53	128.46	127.26	128.43	124.14	123.00	124.59
61.50	38.21	128.35	132.11	132.93	135.32	129.96	127.73	130.19
60.50	37.59	121.38	118.05	117.07	118.68	113.84	113.14	111.37
59.50	36.97	236.68	234.17	229.62	151.21	151.66	146.85	153.59
58.50	36.35	187.18	182.61	179.36	146.88	136.20	130.34	128.99
57.50	35.73	127.86	126.84	121.32	117.71	111.49	103.23	105.18
56.50	35.11	180.53	-	177.69	154.29	145.44	129.02	129.20
55.50	34.49	131.76	-	137.37	127.48	119.59	114.94	116.12
54.50	33.86	123.77	-	121.11	119.74	113.40	109.73	110.46
53.50	33.24	89.43	-	90.08	90.94	84.95	86.52	83.03
52.50	32.62	133.49	-	147.76	133.51	131.07	123.71	125.95
51.50	32.00	135.29	120.67	140.33	133.38	133.47	127.77	132.86
50.50	31.38	104.11	100.72	101.62	97.52	99.89	92.95	92.07
49.50	30.76	150.04	148.85	148.38	135.60	126.06	123.08	124.35
48.50	30.14	125.40	113.83	113.82	110.31	107.30	110.26	106.42
47.50	29.52	209.74	198.60	196.90	153.55	133.62	127.78	126.19
46.50	28.89	137.70	141.38	136.27	142.44	134.21	122.25	121.36
45.50	28.27	124.56	139.18	139.26	153.42	147.54	146.03	145.77
44.50	27.65	135.79	128.61	119.65	130.03	127.52	110.44	113.45
43.50	27.03	163.82	162.04	165.71	149.49	147.72	142.64	153.94
42.50	26.41	232.05	218.11	201.05	189.37	170.22	143.42	143.67
41.50	25.79	172.76	238.53	251.09	183.49	183.28	150.27	146.10
40.50	25.17	164.90	157.94	145.71	122.88	112.00	110.34	109.76
39.50	24.54	153.29	148.25	144.86	145.92	141.98	141.12	141.48
38.50	23.92	136.00	135.59	132.61	136.19	133.59	133.19	136.40
37.50	23.30	106.81	101.14	99.12	99.38	91.37	88.66	94.01
36.50	22.68	112.74	105.66	106.95	106.63	104.59	99.37	105.03
35.50	22.06	124.53	118.33	119.61	108.32	108.81	105.07	108.43
34.50	21.44	93.55	90.91	97.70	93.25	87.85	87.32	85.25
33.50	20.82	127.05	126.56	126.64	119.80	118.67	118.12	117.52
32.50	20.19	105.13	97.22	95.95	93.67	93.81	91.13	92.35
31.50	19.57	100.96	106.52	105.01	103.61	99.08	103.34	97.59
Median		131.76	128.61	130.16	129.84	125.71	121.20	119.48
Mean		138.21	137.70	136.32	131.01	126.79	122.14	121.78
Maximum		236.68	238.53	251.09	189.37	183.28	170.96	168.88
Minimum		89.43	90.91	90.08	86.89	84.95	86.52	83.03
Standard Deviation		31.47	33.54	31.69	23.21	22.95	20.45	20.54

- denotes a reach with partial or no aerial imagery coverage

Table 2.5: Reach average channel widths by year for a 15 km segment of river near Fort Bottom.

		Reach Average Active Channel Width (m)								
River Kilometer	River Mile	1940	1951	1966	1976	1988	1993	2002	2009	2014
72.5	45.0	122.17	110.31	114.03	114.31	114.53	117.07	113.85	115.56	113.95
71.5	44.4	112.78	115.23	116.68	117.85	114.30	117.73	114.40	116.44	109.67
70.5	43.8	169.04	169.90	170.51	172.72	176.24	164.40	167.13	150.32	148.30
69.5	43.2	141.43	142.68	139.95	145.56	146.40	141.52	121.78	121.12	116.80
68.5	42.6	143.18	139.64	138.10	139.53	138.76	132.02	130.50	128.16	128.39
67.5	41.9	97.21	100.25	93.94	96.91	91.53	86.89	84.96	86.82	85.20
66.5	41.3	173.00	174.54	170.04	176.75	184.75	167.29	161.76	158.25	152.12
65.5	40.7	155.39	153.83	149.02	153.11	157.28	141.96	133.40	115.59	124.52
64.5	40.1	125.94	123.69	124.75	125.68	125.44	123.29	114.61	110.04	107.95
63.5	39.5	149.85	148.15	143.06	146.06	145.28	137.62	135.53	128.38	129.77
62.5	38.8	128.53	128.46	127.26	129.18	129.52	128.43	124.14	123.00	124.59
61.5	38.2	128.35	132.11	132.93	134.40	135.80	135.32	129.96	127.73	130.19
60.5	37.6	121.38	118.05	117.07	118.83	116.66	118.68	113.84	113.14	111.37
59.5	37.0	236.68	234.17	229.62	234.24	231.08	151.21	151.66	146.85	153.59
58.5	36.4	187.18	182.61	179.36	184.10	180.77	146.88	136.20	130.34	128.99
Median		141.43	139.64	138.10	139.53	138.76	135.32	129.96	123.00	124.59
Mean		146.14	144.91	143.09	145.95	145.89	134.02	128.91	124.78	124.36
Maximum		236.68	234.17	229.62	234.24	231.08	167.29	167.13	158.25	153.59
Minimum		97.21	100.25	93.94	96.91	91.53	86.89	84.96	86.82	85.20
Standard Deviation		34.83	34.53	33.46	34.60	35.52	20.33	20.79	17.67	18.23

CHAPTER 3

DETERMINING FLOODPLAIN FORMATION TIMING AND RATES FROM STRATIGRAPHIC AND DENDROGEOMORPHIC ANALYSES IN CANYONLANDS NATIONAL PARK, UTAH

ABSTRACT

The lower Green River has narrowed since the late 1800s and decreased channel complexity, resulting in a narrow channel with fewer active in-channel bars. I conducted stratigraphic and dendrogeomorphic analyses within a floodplain trench to describe the timing, rate and processes of channel narrowing by inset floodplain formation since 1939. I show that the channel narrowed by vertical and lateral accretion. I identified a major period of channel narrowing by vertical accretion after high peak flow years of 1983 and 1984. Narrowing was initiated by vertical accretion in the active channel, deposited by moderate floods exceeded more than 50% of the time. Vertical accretion continued in subsequent years, converting the floodplain into a periodically inundated surface. Suspended-sediment deposition dominated deposits, resulting in the formation of natural levees and floodplain troughs in both inset floodplains. Rates of deposition were highly variable, ranging from 0.03-0.50 m/yr.

3.1 INTRODUCTION

Understanding the rate, timing, and mechanisms of floodplain development is crucial for documenting the geomorphic history of a river reach. Yet, demonstrating the processes by which floodplain formation occurs is difficult. A variety of methods can be used to document floodplain formation, although no single method may be expected to provide a full set of information. Aerial photography has the advantage of broad spatial coverage, but typically contains large temporal gaps. As a result, intermediate periods of widening during a long period of net channel narrowing cannot be detected. Aerial photography also lacks information on bed and floodplain elevations. Data sets such as DEMs and LiDAR surveys are a source of repeated floodplain elevation data, but also have large temporal gaps and cover a smaller range of time (in the ~20 year range) than aerial imagery. Repeat topographic surveys have been used elsewhere to track processes of floodplain formation (Pizzuto, 1994; Moody et al., 1999); however, as Dean and Schmidt (2011) note, surveys cannot look backward in time and are only as good as the frequency of their collection. In contrast, alluvial stratigraphy can cover a greater period of time, have a high temporal precision, and provide information in areas of little to no historical documentation.

The sediments forming floodplains can record major erosional and depositional events, allowing for identification of floodplain depositional processes. An effective method to describe floodplain stratigraphy is to excavate a trench, perpendicular to the direction of flow, encompassing all geomorphic surfaces of interest. Within a trench, stratigraphic, sedimentologic, and dendrogeomophic interpretations are made to precisely determine the age of floodplain deposits. Together, these techniques can be used to identify timing, magnitude, and processes of floodplain formation. Dendrochronologic techniques have previously been applied in reconstructions of geomorphic processes (Hereford, 1984) but lacked the precision required to determine deposition rates. Improved dating techniques now incorporate anatomical responses to burial, allowing the dating of individual stratigraphic units and determination of floodplain deposition rates (Friedman et al., 2005). Floodplain dendrochronology has been used to study the timing of floodplain deposition in the Southwest, notably on the Rio Grande (Dean et al., 2011), Yampa River (Manners et al., 2014), Rio Puerco (Friedman et al., 2014), San Rafael River (Fortney, 2015) and upper Green River (Alexander, 2007).

In the lower Green River, downstream of Green River, UT, channel narrowing is evident, with native and nonnative riparian vegetation established on formerly active channel bars (Figure 3.1). A wide channel with numerous bare sand bars depicted in oblique photographs taken in the late 1800s and in aerial photographs taken in the 1940s is now a narrower river bordered by a densely vegetated floodplain. In cooperation with the National Park Service, a trench was excavated at a site on the lower Green River within Canyonlands National Park. I described the sedimentology and stratigraphy, and dated floodplain deposits by tree-ring dating. My investigation builds upon previous studies of channel change in the lower Green River (Graf, 1978; Andrews, 1986; Allred and Schmidt, 1999; Birken and Cooper, 2006) and expands the record of change by 13 years.

3.2 STUDY AREA

A trench was excavated on the floodplain at Hardscrabble Bottom, a relatively wide alluvial valley, in Canyonlands National Park (CNP) at river mile (RM) 43.5[1] (Figure 3.2). The Green River is single threaded in the vicinity of the trench with vertical banks and periodic active in-channel bars and islands. At the location of the trench, the

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[1] Measured in distance upstream from the Colorado River confluence. This location reference system was established in the 1920s.

channel is relatively stable, with a bedrock canyon wall on river right and alluvial valley on river left. All potential channel change at this location is presumably confined to the left bank. Dense communities of tamarisk *(Tamarix spp.)* and willow (*Salix* spp.) dominate the floodplain vegetation. Cottonwood (*Populus fremontii*) trees are infrequent, typically mature, and generally located on higher floodplain surfaces or terraces. In the case of the study area, I use the term “floodplain” to reference flat lying alluvial landforms adjacent to river channels inundated by the current flow regime. This definition encompasses two floodplains at different elevations, both containing sediment deposited in the current flow regime. I use the term “terrace” to refer to surfaces above floodplains which have never been inundated in the present flow regime.

The Green River has narrowed near our study site since the late 1800s. Near Upheaval Wash, 1 km upstream from our trench, the channel narrowed from a wide channel in 1871 (estimated from Figure 3.1A and aerial imagery to be >270m) to 173m in 1976 and 148m in 2014. At RM 40 near Fort Bottom, channel width declined from 234m in 1914 (Graf, 1978) to 126m in 1976. Channel width declined further to 108m in 2014 (See Chapter 2 for a detailed discussion of channel width changes and the study area). Upstream at Green River, UT, peak flows and total annual flows have declined since the early 20th century and the channel correspondingly narrowed (Allred and Schmidt, 1999). In order to determine the mechanisms and temporal sequence of channel narrowing, this paper presents an evaluation of the floodplain stratigraphy exposed in a trench dug just downstream of Upheaval Wash.

3.3 METHODS

The trench, ~50 m long and with a maximum depth of ~2m, was excavated through the floodplain in August 2015. Stratigraphic units within the trench were mapped and interpreted in the field, and samples from each stratigraphic unit were analyzed for grain size by a LISST-Portable particle size analyzer (Sequoia Scientific, 2016). I collected samples from the trench, the Green River and tributaries for clay minerals analysis by X-ray diffraction to determine the bedrock source of these12 sediments. Ages of deposition for stratigraphic units were determined primarily with dendrochronology using eight tamarisk trees within the trench. I excavated trees and marked each with a nail where it intersected a stratigraphic contact.

Each tamarisk was removed for analysis at the USGS dendrochronology lab in Fort Collins, CO. I cut each tree into slabs and sanded each with sandpaper down to 15 μm. I analyzed each slab under a microscope for changes in tree-ring anatomy following the techniques of Friedman et al. (2005) for tree age, germination year and timing of burial events. The age of each deposit was determined at each stratigraphic contact by counting annual rings from the outermost ring inward. Burial was primarily determined by physical changes in tamarisk; narrower annual rings, increasing xylem size in rings, and decreased clarity of annual ring marking (Friedman et al., 2005). I compared burial timing to each stratigraphic contact to determine the age of each stratigraphic unit.

Multiple trees were dated within the same deposits and I cross-dated between multiple trees in the same deposit to increase the accuracy of floodplain deposit ages. Cross-dating compares growth rings of similar widths or physical characteristics between multiple trees. I applied cross-dating to decrease uncertainty in my ring-counting and better constrain ages of deposition. Additionally, I used cross-dating to date a dead tamarisk in a segment of the trench that did not have any live trees. A dead tree can provide an erroneous age when the tree died prior to being removed from the trench; to accurately date that tree, I related physical characteristics visible in the dead tree to live trees excavated from the trench.

Tamarisk produces distinct annual growth rings and exhibits clear anatomical transformations when buried, making it a viable tree species for dating. For recent sediment deposits of less than 100 years, counting rings is a more accurate floodplain dating method than analysis of ^{14}C, ^{210}Pb and ^{137}Cs isotopes and optically stimulated luminescence (OSL) dating. Tree-ring methods can date the burial age of a bed to within a year, making it an effective technique to describe processes of floodplain formations across short time scales. Tree-ring analysis is the most comprehensive and accurate method for dating the majority of alluvial deposits in the trench of the available techniques to date floodplains.

I partially constrained uncertainty in tree-ring dating for some of the deposits in the trench by determining when each deposit was inundated. I calculated inundation frequency by collecting water surface elevations at the trench, and comparing those elevations to discharge measurements at the nearest gage (USGS gage 09328920, Mineral Bottom) to create a stage discharge relationship at the trench. The predictive relationship from data collected at the trench is:

$$Q = 1493.2e^{0.6658WSE} \tag{1}$$

where Q is flow (ft^3/s) and WSE is water surface elevation (m). Data from trench water-surface elevations are similar to the stage-discharge relation for Mineral Bottom (Figure 3.3). I used equation 1 to determine when each stratigraphic unit was inundated, and then combined inundation information for each stratigraphic unit with the range of possible deposition ages determined from tree-ring dating to identify deposit age. This method decreased uncertainty in ages of deposition by an average of 2 years.

For the oldest deposits in the trench, samples were collected and analyzed for date of deposition by the Utah State University Luminescence Lab using the regenerative-dose procedure for single-grain optically stimulated luminesce (OSL) dating. OSL dating determines the last time sediment was exposed to sunlight, and thus, the time since deposition. This technique has large uncertainty if sediment has not been totally reset from its previous burial history, or is “partially bleached”. Partial bleaching can happen if sediments are carried in turbid water or transported at night and is a common issue when dating fluvial sediments. The single-grain approach corrects for these issues by using the minimum age model of Galbraith and Roberts (2012) and can reliably date fluvial deposits (Rittenour, 2008). Two OSL samples were collected in the lowest, farthest onshore end of the trench in what were assumed to be the oldest deposits.

3.4 RESULTS

Surface topography at the trench site is a set of inset floodplains, a higher elevation tamarisk dominated floodplain (F1) and lower elevation floodplain with a mixed tamarisk-willow community (F2). A levee and trough, onshore of the levee (Figure 3.4B), are present on both flood plains. The F1 levee is located in the middle of F1 at St. 25 and there is less relief above its depression compared to the F2 levee. Offshore of the F1 levee, the floodplain is relatively flat-lying and mostly sandy. A small strip of desert olive (*Forestiera pubescens*) grows at the offshore edge of F1. The F2 levee is higher above the trough compared to the F1 levee and is located at the edge of F2 at Station[2] (St.) 3.

Below the surface, the trench is composed of 3 major inset deposits, two vertically accreting levee formations and an intermediate laterally accreting series of beds (Figure 3.4B). An additional small inset formed at the offshore edge of the trench at St. 0, 1m above the base of the trench. F1 is capped by a large, laterally continuous vertically accreted unit of sand deposits; F1 is inset into higher terraces. Beds in the terrace are vertically truncated by F1. I interpreted those truncations as a former cut bank. Terrace beds are fine cross-laminated fine sand and muddy fine sand.

Two beds at base of the terrace deposits dated by OSL are 300 ± 150 and 440 ± 250 years old, respectively (Table 3.1). Terrace deposits are the oldest in the trench, substantially older than F1 or F2, and the trench encompasses all 20th century inset floodplain formation. Based on OSL ages, I infer the edge of the terrace was the river bank in the late 1800s and early 1900s.

Individual beds within the trench are mixed sands and muds that fine upward within distinct flood units. Units with a higher proportion of sand are tan or buff in color, are often lighter in color than mud dominated units and typically contain ripple forms. Small beds of sand occur throughout the trench, primarily at higher elevations compared to mud dominated units. Mud units generally contain highly visible laminae of red mud. Beds with a large portion of silt-and-clay are present throughout the trench, though generally, those deposits dominated at lower elevations and shoreward of levees. Generally, levee deposits are rippled cross-laminated fining upward units with a higher

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[2] Station refers to distance along the trench from the end closest to the river. The trench begins at St. 0 and ends in a terrace at St. 50.

proportion of sand, which fine onshore into a floodplain trough. Trough deposits are primarily composed of fine, silt-dominated laterally continuous sediments with small laterally continuous beds of sand. Beds near the surface of the floodplain are extensively bioturbated and weathered.

I identified four major depositional facies in the trench: (1) floodplain, (2) channel margin, (3) active channel and (4) large flood deposition (Figure 3.4C). Beds were identified by texture, color and sedimentary structures, if present. I additionally used bed shape and bed orientation as an identifier; levee deposits have a convex shape, beds in the trough have a concave shape, and bank-attached bars dip offshore. Boundaries between beds are typically distinct. Unit descriptions for each individual bed interpreted in the trench are organized by facies in Appendix 1.

3.4.1 Floodplain Facies

The floodplain facies represents deposition and floodplain growth by creation of a natural levee and subsequent vertical accretion of both levee and trough. The characteristics of levees and troughs are very distinct from each other. Levees are constructed of coarse cross-laminated, sand dominated, units fining onshore into a floodplain trough (Figure 3.5A and B). Individual beds in the levees typically fine upward. The F1 levee is tan sand, rippled cross-laminated forms migrating onshore. Supercritically climbing ripples are present as well (Figure 3.5B). The F1 levee is capped by the overbank depositional component. In F2, the levee contains tan cross-laminated sand beds that dip onshore and downstream. Sedimentary structures disappear as the levee transitions into the trough.

Trough deposits are primarily fine horizontally laminated silt-and-clay-dominated laterally continuous sediments with small laterally continuous beds of sand (Figure 3.5C and D). Trough sediments range in color from light gray to tan and distinctive beds of red sediment are present as well (Figure 3.5C). The F2 trough is a series of laminated beds dominated by silt and clay. Periodic layers of red silt-and-clay are present. The F2 trough is deposited above the active channel facies inset of F1. Where the F2 floodplain is deposited against older F1 sediments, it dips offshore. More silt-and-clay is present in the F1 trough compared to the F2 trough, and layers are thinner (Figure 3.5C and D).

Levees and troughs have different grain sizes and sedimentary structures and could possibly be classified as different facies. However, since the formation of the levee means a resultant trough will form as well and levees and troughs occur together, I chose to treat them as a single facies.

3.4.2 Channel Margin Facies

This facies is indicative of deposits at the edge of a channel where sediment is regularly deposited and eroded. Texture consists of mixed sand and silt-and-clay, fining upward, bounded by unconformable contacts (Figure 3.6). Deposits are a series of inset beds, sharply truncated on all sides, generally dipping offshore (Figure 3.6B). Thin laminae of red silt-and-clay are present in multiple beds. The channel margin component truncates the F1 levee and the F1 floodplain facies and is truncated by F2 deposits. Boundaries are diffuse and consist of multiple small inset beds. The composition of beds varies, from sand to beds of laminated sand and mud (Figure 3.6C). Sand beds are rippled cross-laminated units, climbing onshore or offshore, and downstream (Figure 3.6D). I observed multiple sedimentary structures not seen elsewhere in the trench, including flame structures near station 18 (Figure 3.6A) and a 3D bedform at St. 15.

3.4.3 Active Channel Facies

The active channel facies represents vertical deposition and floodplain formation within the active channel at the time of deposition. Beds are vertically accreted against channel margin deposits, 0.20 to 0.60 m thick and composed of mixed sand to fine sand or silt-and-clay (Figure 3.7A). Beds are horizontal or dip slightly offshore. Contacts are conformable. Sand and silt-and-clay are typically mixed within beds, occasionally, beds are composed of rippled cross-stratified sand. The active channel facies lies under the floodplain facies, forming the base of F2. A low-elevation deposit of cross-laminated sand is present at the base; it is deposited against older channel margin sediments and dips offshore (Figure 3.7B). I interpret this bed as a former bank-attached bar deposited inset of F1. Above this are massive, fining upward beds of sand and mud. This is the only lower elevation location in the trench where sand or sand dominated beds are present.

3.4.4 Large Flood Facies

This facies is indicative of floodplain building though vertical accretion during large floods. This facies forms the upper 1-1.5m of F1 sediments. Beds are primarily horizontally laminated, vertically accreting tan or red sands, brecciated in the upper 0.5-1m (Figure 3.7C and D). In F1 above the floodplain trough, deposits are mostly brecciated red sand and silt-and-clay. Brecciated portions contain isolated, small organic horizons near the surface (Figure 3.7D). At the offshore edge of F1, complete flood cyclothems, or rhythmites, of fine sands fining upward into silt-and-clay, are present.

Above the F1 levee are supercritically climbing ripples, migrating onshore and downstream. The offshore edge of the facies is truncated by F2 deposits.

3.4.5 Grain Size

The majority of sediment samples measured by the LISST-Portable were silt-dominated; samples were 70% silt on average. The only samples with a proportion of sand greater than 90% are in the terrace where OSL samples were collected. The active channel, channel margin and large flood facies have similar median grain sizes: 0.05mm, 0.05mm, and 0.07mm respectively. In the floodplain component, levee samples have a median sand grain size of 0.05mm. The finest samples are in the floodplain trough and have a median sand grain size of 0.02mm. Trough samples are on average 13% clay; all other locations in the trench 5% or less clay. The mean sand percentage is 8% in troughs; all other facies and floodplain levees have mean sand proportions of between 22-37%. No gravel is present in the trench. The median grain size collected for each facies is finer than the median grain size of suspended sediment, bed sediment and bar sediment physical samples (Figure 3.9)

Clay mineral analysis shows that differences in chemical composition mirror differences in color (Table 3.2). Red clays are primarily illitic, and are locally sourced, correlating with samples collected from Upheaval Wash, 1 km upstream from the trench. Darker, gray beds of clay contain fractions of smectite, and share physical characteristics with samples collected from the Green River and in the Price River. The majority of deposits in the trench are transported from upstream sources, but horizontal laminae of red sediment present in the trench demonstrate that locally sourced material is part of inset floodplains.

3.4.6 Timing and Rate of F1 Growth

The higher elevation F1 is composed of three different facies, the floodplain component, channel margin component and overbank deposition component. From St. 25 to St. 43, a levee and trough form the bottom half of trench deposits. These deposits are sharply truncated by the channel margin component at St. 25. I interpret this as a former cut bank and channel margin. Above both the floodplain and channel margin components, the large flood deposition facies forms the upper 1m of the profile. Tree-ring dating at St. 25 indicates a stratigraphic unconformity of 31 years between the floodplain component and overbank depositional component. I dated beds using buried tamarisk and cross-dated multiple tamarisk trees in F1 to increase accuracy, including a dead tree that germinated in the channel margin facies.

I documented small annual growth rings in 1983 and 1984 (Figure 3.10) in all trees excavated from F1. The small annual growth rings were preceded and followed by two large rings relative to the 1983-1984 growth rings. This sequence of large, small, large, growth rings is repeated in all four trees recovered from F1. Three of the four trees displayed scar tissue in a single growth ring, presumably due to insect damage. The damaged annual growth ring precedes the 1983 growth rings by 8 years in each of the three trees. Importantly, scar tissue was present in the dead tree, allowing for cross dating. I used the consistent size of annual growth rings from 1981-1986 and scar tissue in 1975 to better constrain the accuracy of tree-ring dating in F1.

The levee and trough of the floodplain in F1 accreted 1m from 1939-1952 (Figure 3.4C) and continued to accrete at an unknown rate until 1975, when a portion of the floodplain was eroded, creating an unconformity in floodplain stratigraphy. In the trough, vertical accretion continued without erosion from 1953-1982. I identified the unconformity by anatomical changes of a tree in the levee at St. 25. The tree showed evidence of burial, a release from burial by an erosion event and then a reburial (Figure 3.11), a sequence similar to burial of an ash tree on the floodplains of the Potomac River described by Sigafoos (1964). The conversion of buried stem wood to unburied root wood is easily identifiable for the slab in 1952, with a conversion back to stem wood visible after 1975. The tree was then buried again in 1983 and new growth after that point was root wood. Erosion in 1975 was confined to the levee, as a tamarisk tree excavated 11m further onshore in the trough (St. 36) showed no evidence of erosion, vertically accreting 1.5 m from 1939-1982.

Lateral accretion of the channel margin facies from 1957-1982 narrowed the channel by at least 10 meters and accreted the floodplain vertically 1.25m. The temporal resolution for ages of the active channel deposits is relatively coarse because only one tree was excavated, and it was rotted at the center under the ground surface. Thus, we were only able to get the germination year of the tree, 1957, at the base of the active channel component. The overbank depositional component above the active channel component is obliquely continuous and we dated that sequence with other trees in F1. The oldest age of the overbank depositional component in F1 is 1983, providing an upper limit for the ages of active channel deposits.

From 1983-2015, formation of the large flood facies vertically accreted F1 1m. The beds are sandy, super-critically climbing ripple-stratified, indicating rapid deposition. I interpret this to mean floodplain deposition occurred within a small number of clustered years or a single year. Analyzing hydrologic records, high flows with the ability to deposit these large packages were during 1983 and 1984. Thus, I infer that the majority of vertical deposition on top of floodplain and active channel components occurred in 1983-1984, accreting at a rate of 0.50 m/yr.

3.4.7 Timing and Rate of F2 Growth

Two facies form F2 in the trench: the active channel component and the floodplain component. The floodplain component vertically accreted above the active channel component and both facies extend the entire width of the floodplain. We dated three tamarisk trees, at St. 1, St. 4.5 and St. 7. I was unable to cross-date between stems, resulting in uncertainty of ± 2 years for deposit ages from tree-ring dating in the floodplain (Figure 3.12). Part of this uncertainty is due to position of the trees in F1. Trees in in the tough were buried at a later date than trees located at the levee. Constructing a chronological stratigraphic sequence requires interpolating between trees using lateral continuous stratigraphy and resolution can decline when creating a chronology for an entire sequence of deposits. Thus, some portions of the trench are dated more precisely than others and developing dates for the entire cross section required a decrease in temporal resolution and application of additional lines of evidence in addition to data from individual trees. Accounting for uncertainty, beds at the base of the floodplain are no older than 1985.

The active channel facies began deposition in 1985 as a bank-attached bar, deposited against channel margin deposits. When deposited, these beds were part of the active channel, and were inundated for greater than 50% of the time. From 1985-1986, the floodplain vertically accreted 0.23 m/yr as part of the active channel. After 1986, the amount of time floodplains were inundated decreased, and the top of the floodplain was infrequently inundated from 1987-1993. No levees were present in the active channel deposits.

After 1993, the floodplain component began to form, vertically accreting 0.12 m/yr during yearly peak flows. The rate of deposition decreased in the mid-1990s to 0.05 m/yr and the floodplain vertically accreted in this time period to an elevation where it was no longer inundated by yearly peak flows. Subsequently, the rate of deposition decreased again from 2004-2015 to 0.03 m/yr. No evidence of floodplain stripping was documented despite a 44,900 ft^3/s flood in 2011, the 3rd highest flood of record since 1960.

3.5 DISCUSSION

Depositional processes observed in the trench range from deposition under regular inundation in the active channel to infrequent inundation and episodic deposition on the floodplain. Key characteristics of active channel deposition are inset beds, dipping offshore, composed of fine sediment. Floodplain deposits are distinguished by a smaller median grain size, and distinctive levee and trough sequences. Channel margin deposits are primarily identified by sharp truncations of beds in the facies on all sides and the key characteristic of large flood deposits are thick beds of horizontally laminated fine sands.

Formation of F1 and F2 occurred by a sequence of vertically and laterally accreting processes which represent different states of floodplain formation by deposition of suspended sediment. Multiple occurrences of the floodplain component show two possible channel margins at the site, one at F1 from 1939-1952 and one in F2 from 1993-2015. The majority of channel narrowing occurred in the earlier stages of floodplain formation under active channel processes. In F2, deposits transition from active channel to levee formation. That transition does not occur in the excavated F1 deposits. It is likely that the transition to floodplain happened below the base of the trench. Levee deposits are possibly due to a change in the suspended sediment relationship as deposits vertically accreted or increasing hydraulic roughness from rising vegetation density post-1985.

Germination years of tamarisk trees excavated from the trench (1940, 1957, 1985 and 1988) matched to within two years cohorts identified by Birken and Cooper (2006) – 1938, 1958, 1984 and 1986. The similarity in establishment years supports my tree-ring dating and deposition timing. I was unable to directly relate individual sediment deposits between floodplain investigations due to insufficient detail in previous work.

Similar to studies on the Powder River, MT (Moody et al., 1999; Moody and Troutman, 2000) and at Green River, UT (Allred and Schmidt, 1999) frequency of floodplain inundation declined as inset floodplain deposits vertically accreted over time. Unlike those studies, I describe an additional stage of floodplain formation, large flood deposition, during the rare flow years of 1983 and 1984, which deposited sediment uniformly across F1. Presumably, continued vertical accretion of the post-1985 floodplain will increase the elevation of F1, depositional events will become less frequent in future years, and the rate of vertical accretion will decrease until floodplain deposition solely occurs during rare years of high peak flow .

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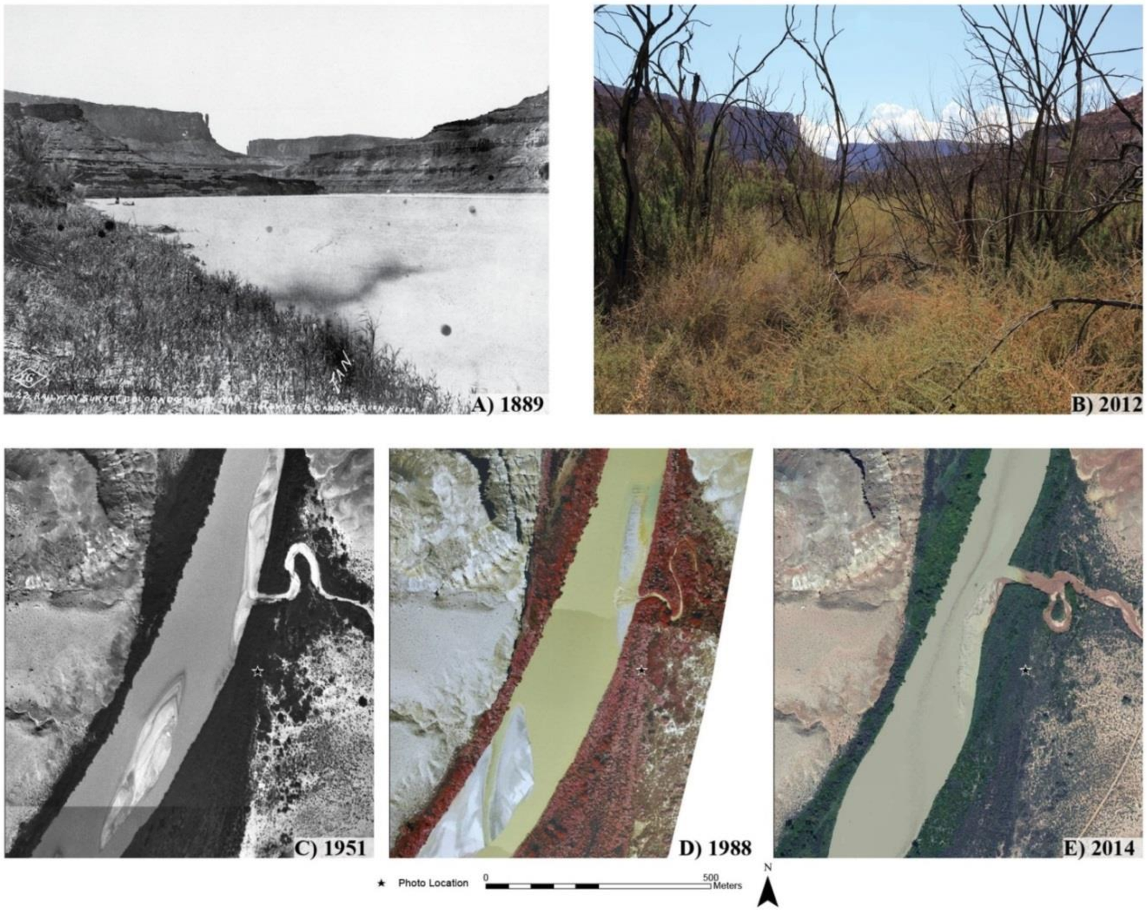

Figure 3.1: Comparison of repeat photos and aerial photos at Upheaval Wash (RM 44) in A) 1889, taken by F.A. Nims showing a wide channel and channel narrowing and in B) 2012, showing floodplain growth and tamarisk defoliated by the tamarisk beetle. Aerial imagery of the same location (photo location marked by a star) in C) 1951 shows that much of the channel narrowed prior to the mid-20th century, remaining stable in D) 1988, and narrowing again prior to E) 2014.

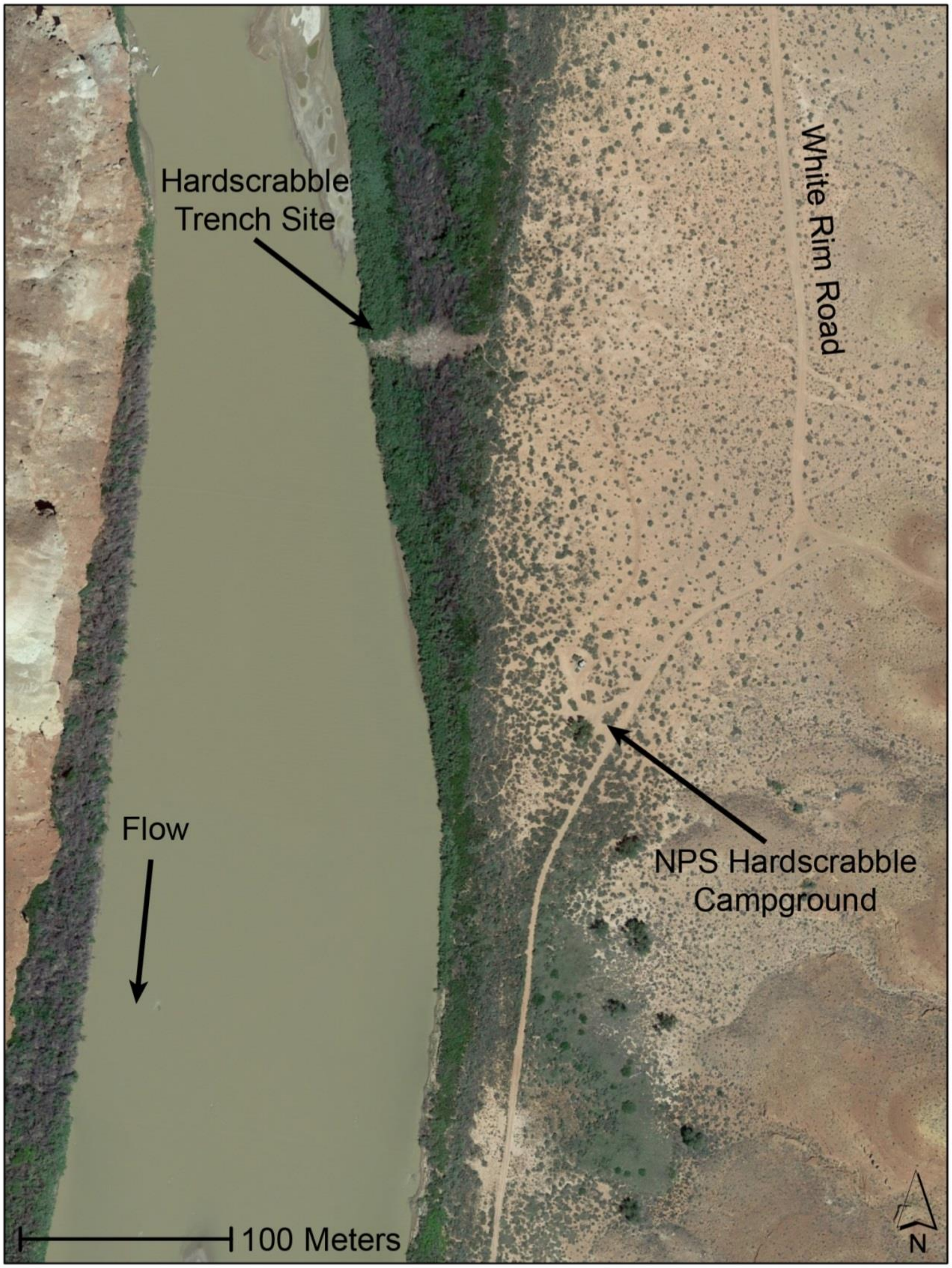

Figure 3.2: Aerial photograph taken in July of 2015, showing the trench site with cleared vegetation and immediate landmarks at Hardscrabble Bottom.

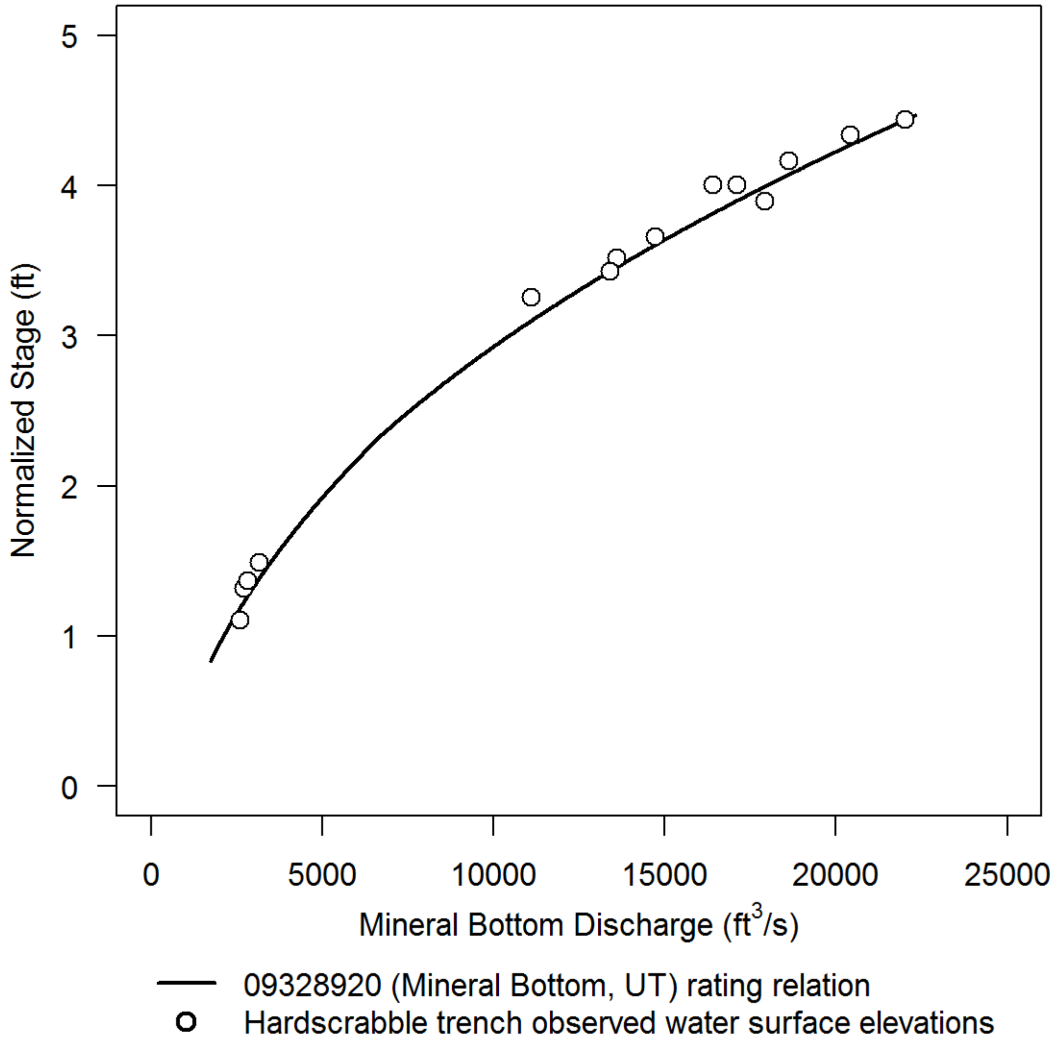

Figure 3.3: Stage discharge relation at Hardscrabble trench site compared to the USGS rating relation for discharge at Mineral Bottom. Stage at both sites is normalized to an arbitrary elevation to make direct comparisons easier.

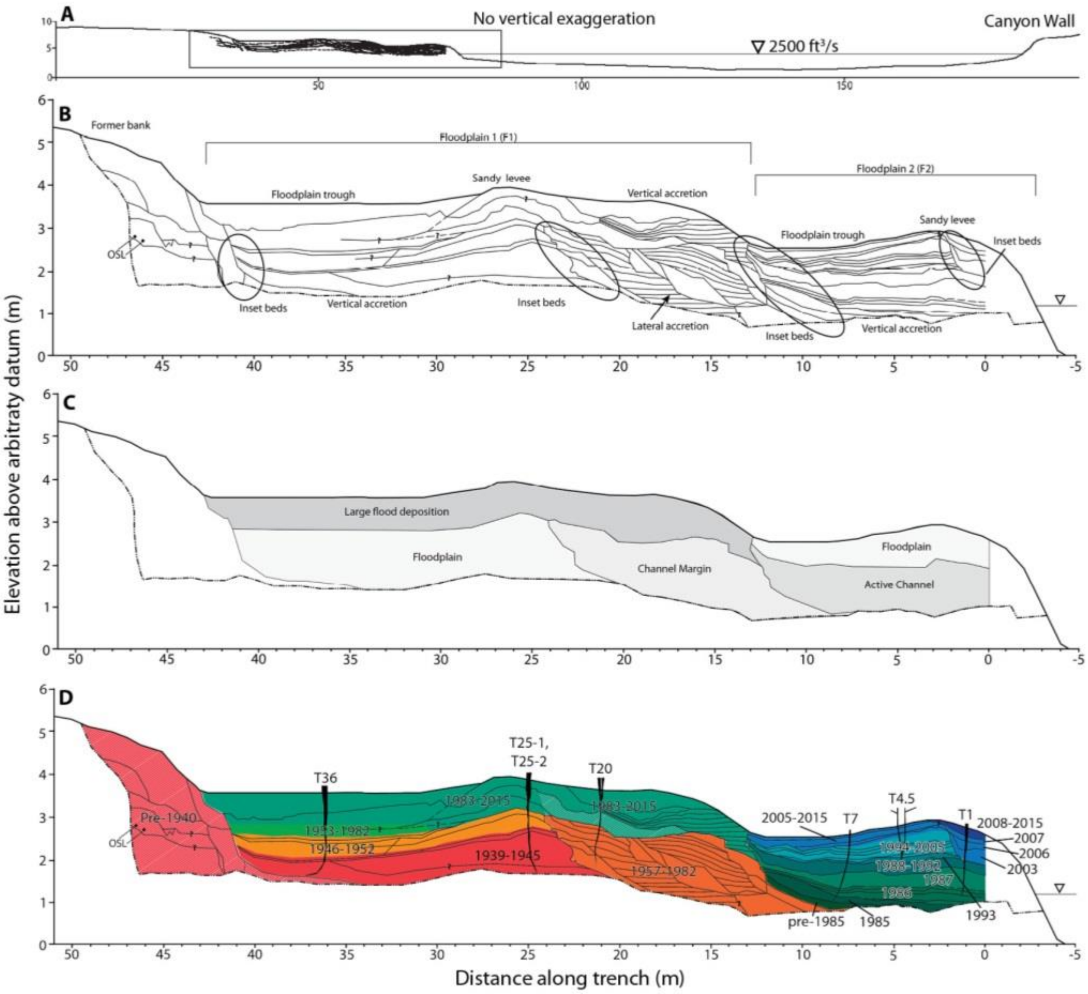

Figure 3.4: Trench stratigraphy and dendrogeomophology. A) Complete cross section profile shown with no vertical exaggeration. The box in A covers the trench and is the location of B, C and D. B) Stratigraphy and major features of the trench. The major inset beds are shown by the black circles. C) Major depositional facies identified in the trench. D) Locations of tamarisk trees removed from the trench and the timing of deposition resulting from tree-ring dating and OSL sampling.

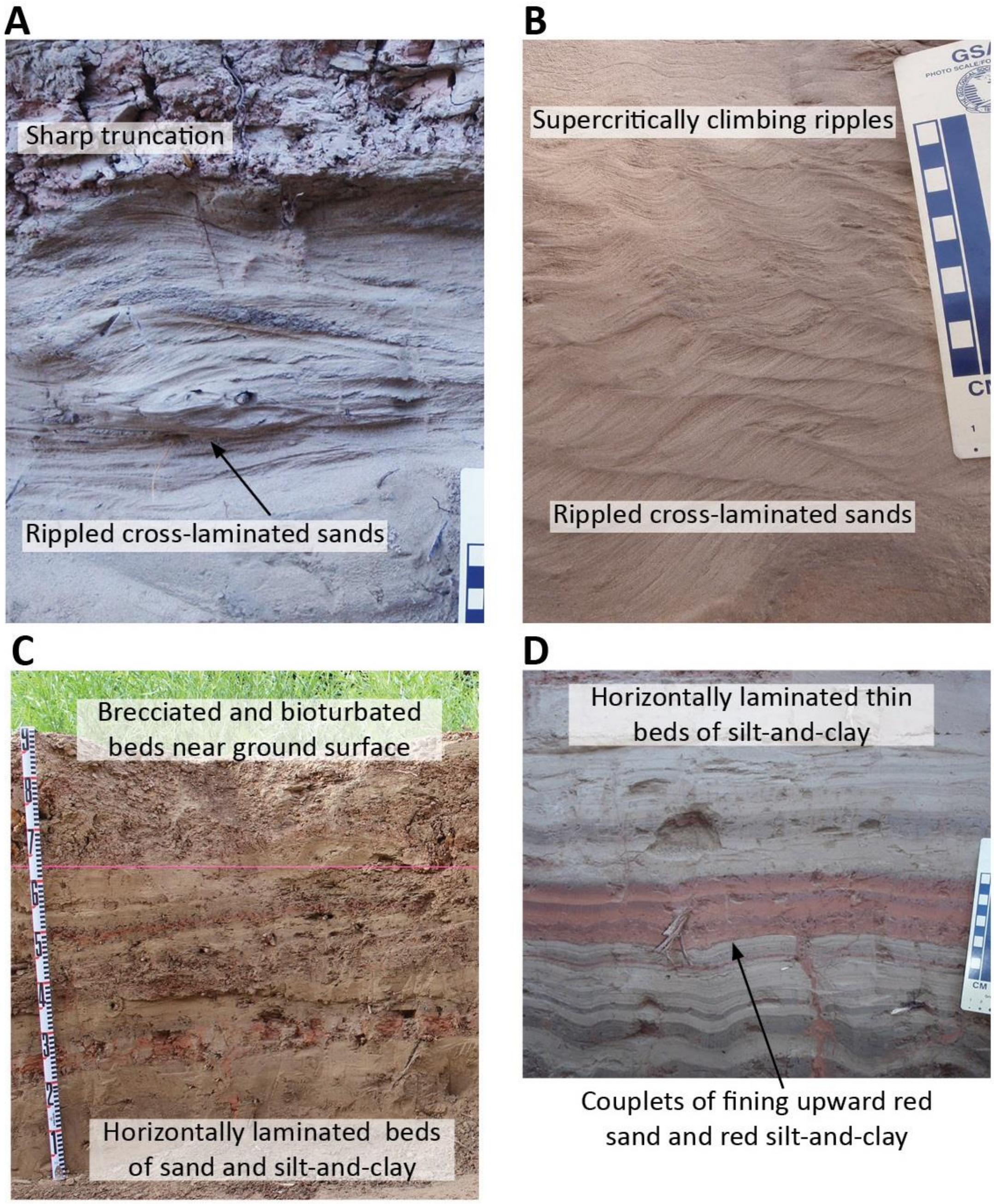

Figure 3.5: Typical sedimentological characteristics observed in floodplain deposits. A) Rippled cross-laminated sand migrating onshore, truncated sharply at top by mud. Mud-dominated beds occur periodically in the F2 levee, but are not dominant. B) Sand beds in the F1 levee. In addition to rippled cross-laminated sand migrating onshore, supercritically climbing ripples were present, showing evidence of rapid deposition. In C), the F2 trough, horizontally laminated beds of sand and mud are present, with distinctive beds of red mud. The F1 trough, D), is dominated by mud and contains few beds of sand. Presumably, red sands and muds are locally sourced.

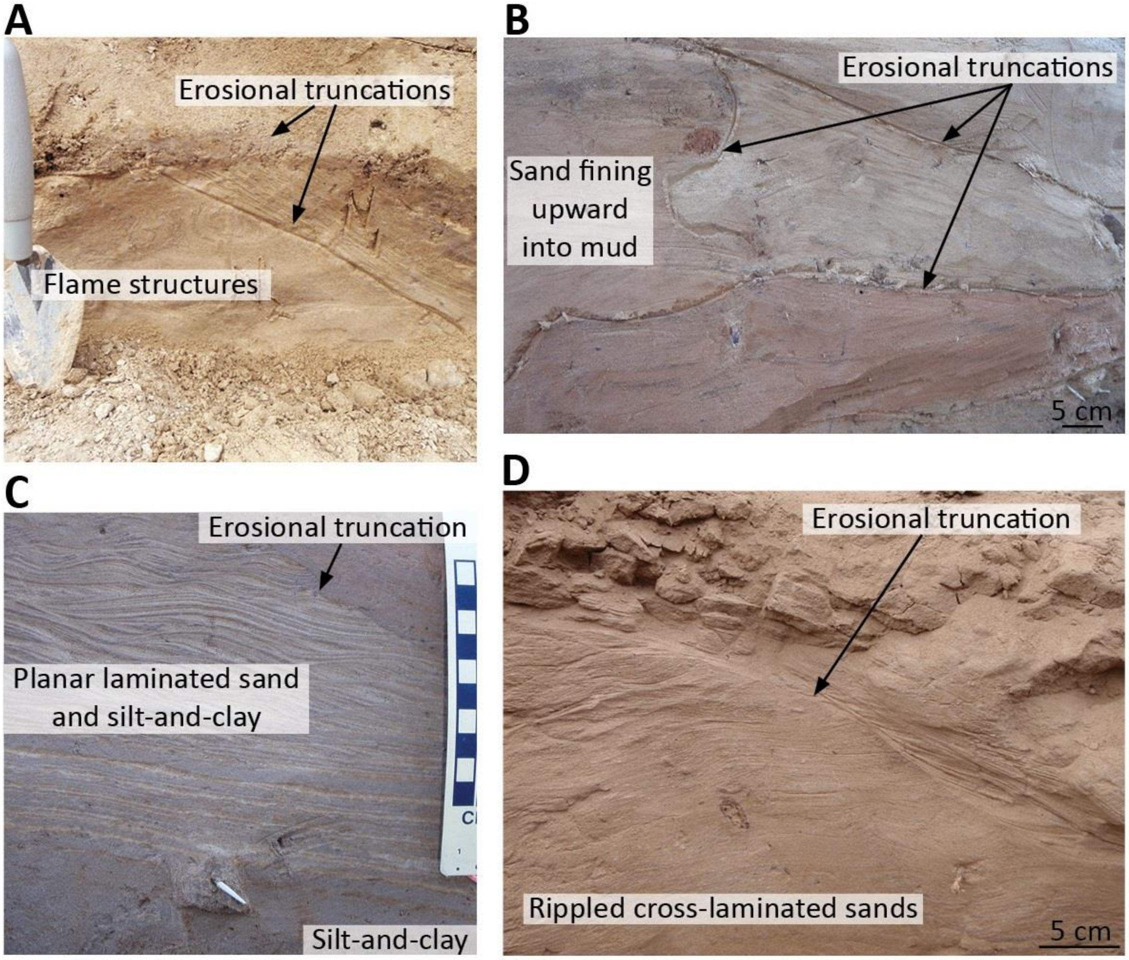

Figure 3.6: Sedimentological characteristics of the channel margin facies. A) Sharp, unconformable truncations which we interpreted as erosional boundaries. A flame structure, indicative of rapid deposition and soft sediment deformation. B) Repeated erosional truncations and sand fining upward into mud. C) Mud converting to laminated sand and mud, then transitioning to cross-laminated sand and muds, truncated at the top by mud. D) Cross-laminated sands, sharply truncated by cross-laminated sands.

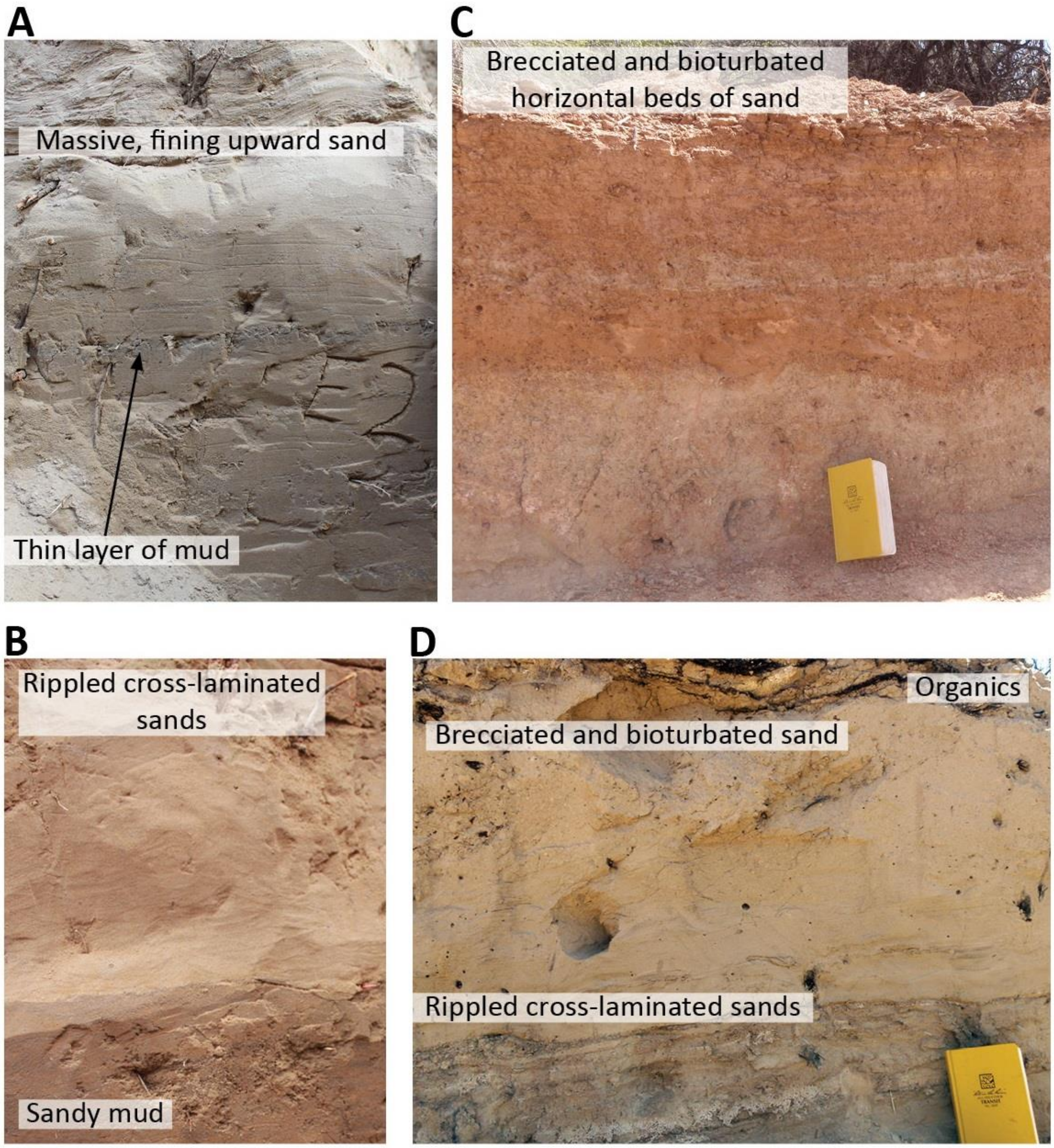

Figure 3.7: Sedimentological characteristics of the active channel and large flood facies. A) Massive, fining upward sand beds, divided by a thin layer of mud. Deposits in the floodplain conversion component generally have more mud than the floodplain component. Sedimentary structures are present (B), but are less frequent. In the overbank depositional component, sands and muds are brecciated and bioturbated near the surface. C) Horizontal beds of sand and red sand. D) Rippled cross-laminated sands at the base of the overbank depositional facies transition to brecciated and bioturbated sand at the top. Layers of organic soil horizons are present at the top of the facies near St. 25.

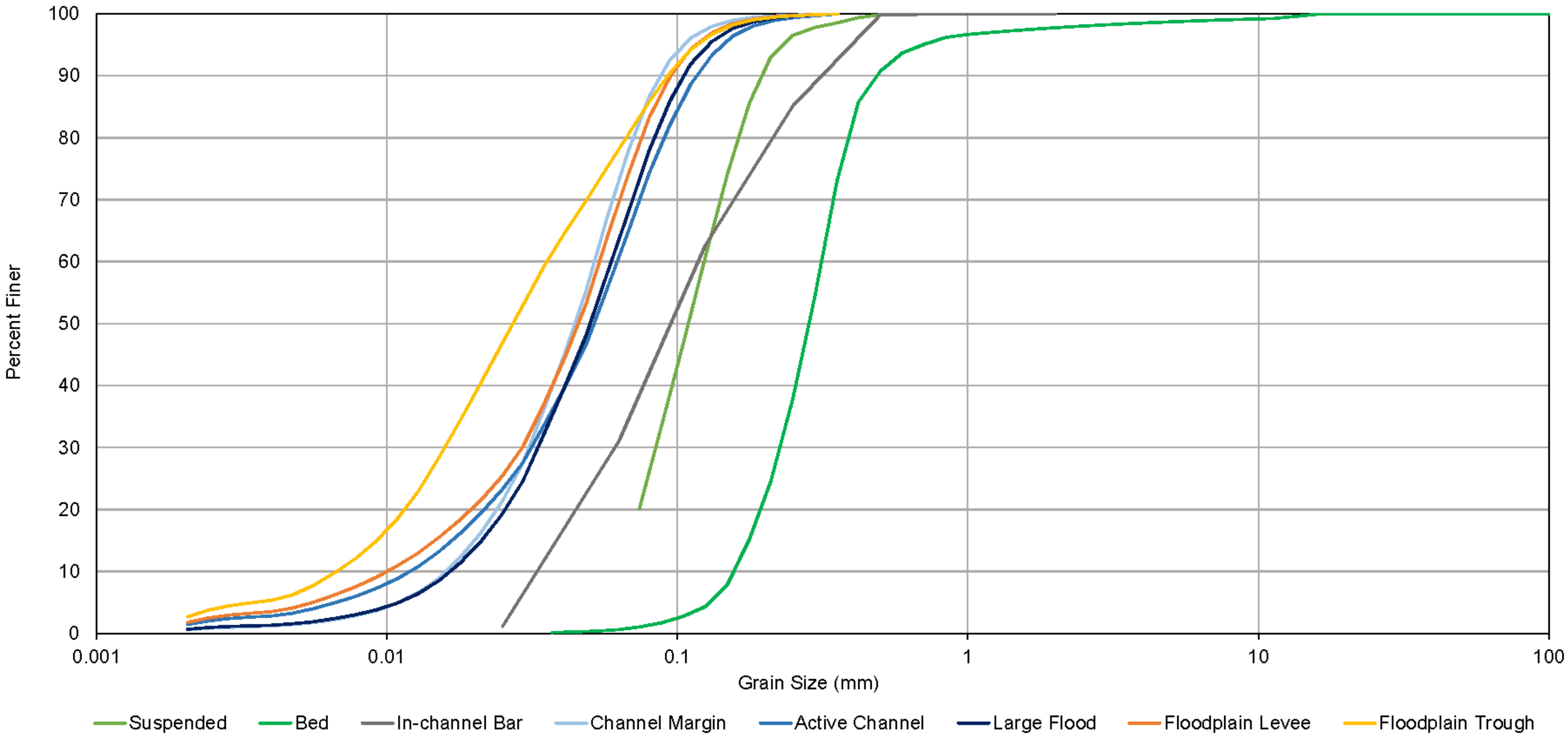

Figure 3.8: Grain-size distribution of sediments collected in the lower Green River. The suspended and bed sediments (in shades of green) are from physical samples collected from cross-sections at Mineral Bottom to calibrate acoustic suspended sediment monitoring. In-channel bar sediments, in gray, were collected from exposed in-channel bars near Fort Bottom and the trench. The remaining samples were collected from the trench and represent each facies. The floodplain facies is split into trough and levee to illustrate differences between the two parts of the facies.

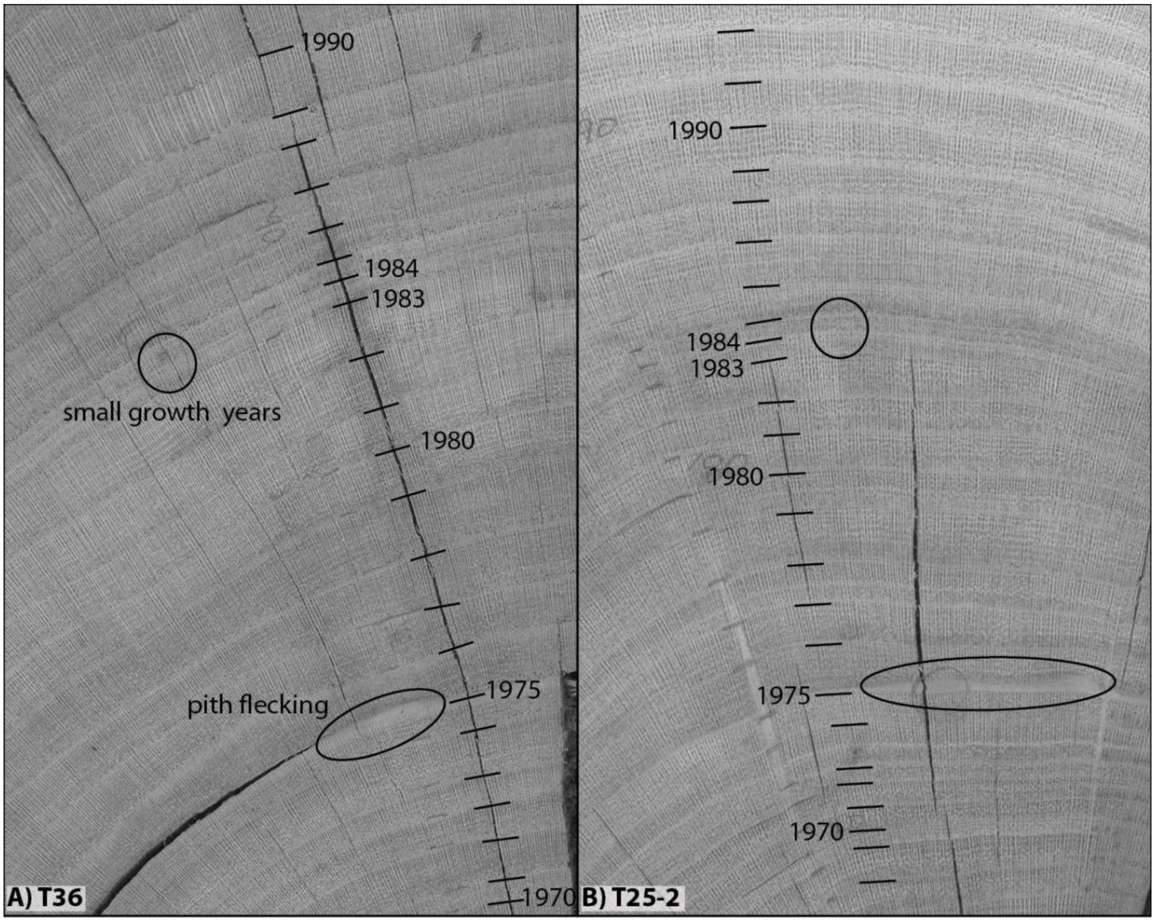

Figure 3.10: Example of cross-dating between trees. A) is a slab from T36, located in the F1 trough. Marks represent annual growth years. The sequence of pith flecking and small annual growth years is the same for A) and B), T25-2. These similar events improve tree-ring dating and decrease uncertainty in floodplain deposit ages.

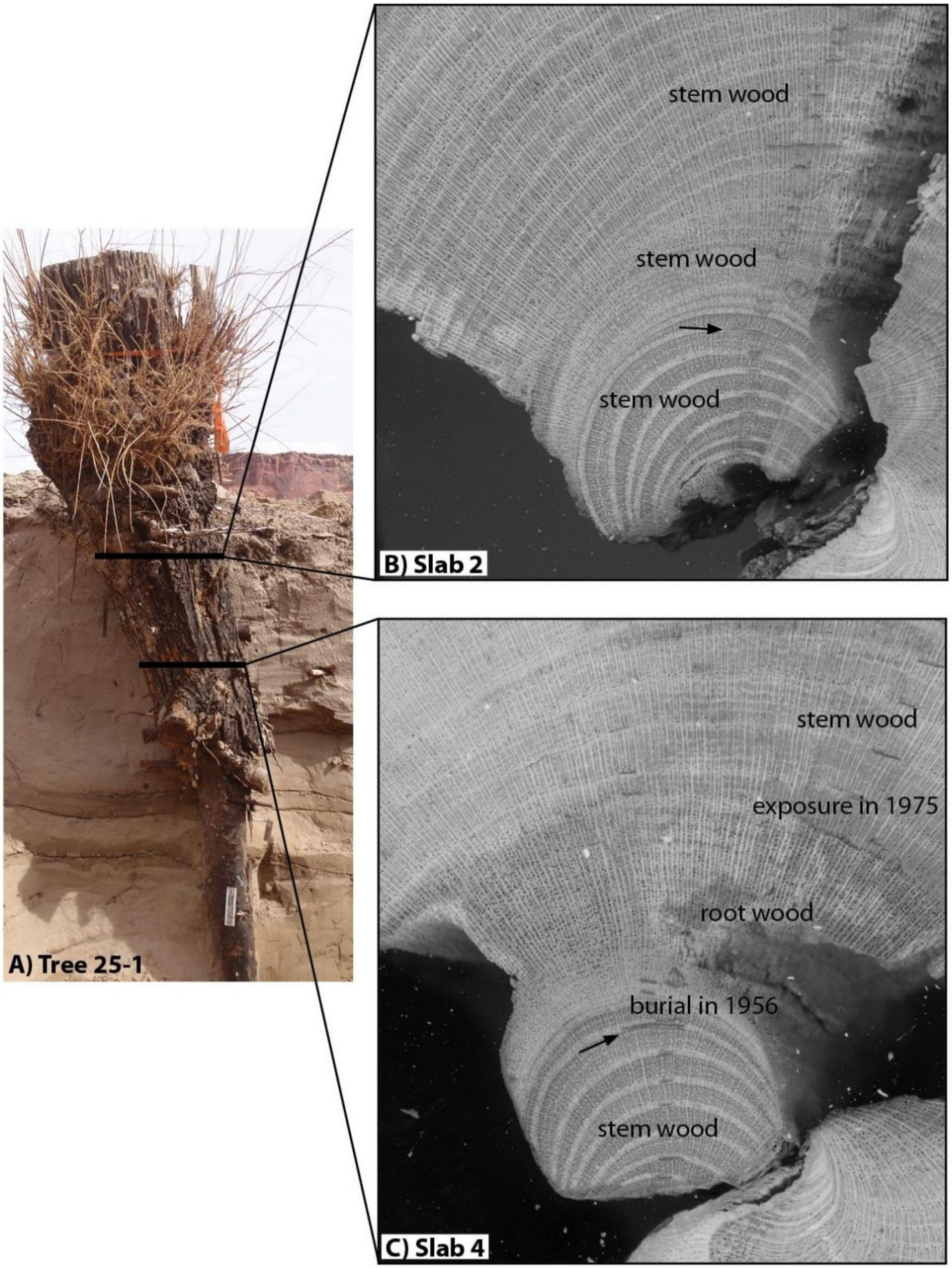

Figure 3.11: Burial and re-burial described in T25-1. The arrows in B) and C) point to the same growth year in both slabs. Slab 2 (B), near the surface, was never buried and its center is entirely stem wood. Slab 4 (C), at a lower elevation was initially buried in 1956, converting stem wood to root wood. The stem of the tree was re-exposed (likely due to floodplain erosion) in 1975 and the anatomy of the tree responded, adding stem wood. The tree was buried again in 1983.

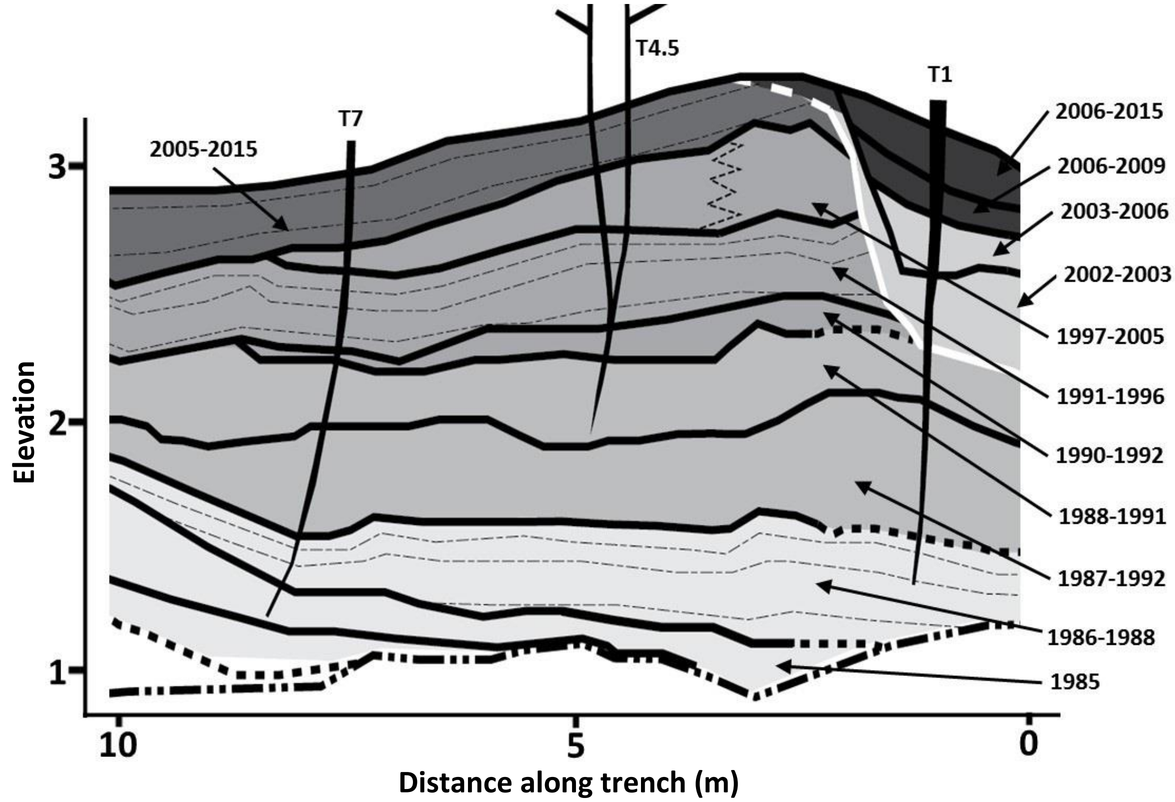

Figure 3.12: Close up of F2 segment of trench showing uncertainty in tree-ring dating of sediments. The ages of beds in F2 overlap due to the differing burial dates for T4.5 in the levee and T7 in the trough. All deposition in F2 occurred in 1985 or later. The uncertainty shown here was constrained with the stage discharge relation in Figure 3.3 to produce the ages of deposition discussed in text and shown in Figure 3.4D.

Table 3.1: Optically Stimulated Luminescence Age Information.

Sample	Depth below ground surface (m)	Grain Size (mm)	Number of grains*	Dose Rate (Gy/ka)	D_E † ± 2σ (Gy)	OD^ (%)	OSL age ± 2σ (ka)
HRD-OSL-1	1.67	.150-.200	65 (2000)	2.32 ± 0.10	0.69 ± 0.33	71.4 ± 15.9	0.30 ± 0.15
HRD-OSL-2	1.76	.150-.200	63 (1900)	2.05 ± 0.09	0.91 ± 0.50	75.2 ± 17.8	0.44 ± 0.25

*Number of grains used in age determination, total grains measured in parentheses

†Equivalent dose calculated by the minimum age model of Galbraith and Roberts (2012)

^Overdispersion represents variance in D_E, an OD large than 20% may indicate scatter by depositional or post-depositional processes

Table 3.2: Clay minerals XRD information by weight percent

Sample ID	**Color in Field**	**Quartz**	**K-feldspar**	**Plagioclase**	**Calcite**	**Dolomite**	**Ank. or exc-Ca Dol.**	***Total Carbonate***	**Pyrite**	**Gypsum**	**Hematite**	**Clinoptilolite/ Analcime**	***SUM NON-CLAY***	**Kaolinite group**	**Chlorite**	**Illite+Smectite group**	**% S est in I-S**	***SUM CLAY***	**is the mineral more illitic or smectitic?**
10.7C-Red	Red	23	7	2	6	4	3	*12*	0	1	1	0	***45***	5	2	48	12	***55***	illitic
10.7C-Grey	Grey	20	6	5	5	3	1	*9*	0	1	0	7	***49***	8	1	42	54	***51***	smectitic
10.7 Cup	Red	28	8	2	5	5	3	*12*	0	0	1	0	***51***	4	1	44	11	***49***	illitic
8.7 Gsub	Tan/Grey	23	6	4	10	3	2	*15*	1	0	0	3	***51***	4	1	44	48	***49***	smectitic
10.7 F	Tan/Grey	29	8	6	7	4	3	*14*	0	0	0	2	***59***	2	2	37	47	***41***	intermed IS
34.0X	Red	37	9	2	5	2	6	*12*	0	0	1	0	***61***	2	1	36	10	***39***	illitic
34.0Y	Grey	32	8	8	8	4	2	*14*	1	0	0	6	***68***	4	2	26	48	***32***	smectitic
34.0W	Grey	31	8	6	9	4	3	*16*	0	0	0	3	***65***	4	1	30	36	***35***	intermed IS
34.0Z	Red	27	7	2	5	4	2	*10*	0	0	2	0	***48***	4	2	46	9	***52***	illitic
GR1	Grey	31	6	3	8	7	1	*15*	0	0	0	2	***56***	5	2	37	42	***44***	intermed IS
UPH1	Red	77	10	1	3	0	3	*6*	0	0	0	0	***95***	0	0	4	6	***5***	illitic
UPH2	Red	81	10	1	3	0	3	*5*	0	0	0	0	***96***	0	1	3	ND	***4***	ND
UPH3	Red	75	11	1	2	2	2	*5*	0	0	0	0	***92***	0	1	7	< 5	***8***	illitic
PR1	Grey	67	3	3	16	2	1	*19*	0	0	0	1	***94***	1	1	4	43	***6***	intermed IS
PR2	Grey	75	4	4	5	3	1	*9*	0	0	0	0	***92***	1	0	7	< 5	***8***	illitic

Ank. or exc-Ca Dol. = Ankerite or excess-Ca dolomite

Illite+Smectite group = total dioctahedral 2:1 layer clay: illite, mixed-layer illite-smectite, smectite, and possibly mica.

Biotite group = total trioctahedral 2:1 layer clays: biotite, phlogopite, biotite/vermiculite, trioctahedral smectites

Serpentine group = total trioctahedral 1:1 layer clay: serpentine-type minerals and berthierine

Kaolinite group = total dioctahedral 1:1 layer clay: kaolinite, dickite, nacrite, halloysite

Siderite, Sphalerite, Halite, Barite and Anhydrite groups all recorded 0% for all samples

CHAPTER 4

CONCLUSIONS

The lower Green River substantially narrowed in the 20th century, based on analysis of aerial imagery, stratigraphy and dendrogeomorphology, hydrologic data and channel cross-section surveys. Narrowing occurred as increasing water development decreased peak flow magnitude and raised baseflow magnitude. Changes to flow regime reduced the amount of sediment transported, decreased the area of regularly inundated channel and scours less vegetation than in the early 20th century. These processes all contributed to floodplain formation, resulting in channel narrowing. Climatically driven declines in precipitation and increases in temperature decreased total annual runoff during the same time period, contributing to narrowing. Channel narrowing occurred in several phases in the 20th century, beginning in the 1930s and continuing in the 21st century. Decreases in channel width happened after a change in flow regime or in a period of low flow following multiple years of peak flow. The primary mechanism of narrowing was vertical accretion, forming floodplains inset within older floodplain deposits. Decreases in width also occurred by the conversion of mid-channel bars to islands and the abandonment of side channels. Establishment of non-native tamarisk in the lower Green River may have promoted floodplain formation by stabilizing banks and inducing greater deposition.

Decreased channel widths in the lower Green River results in channel simplification because the variability of width decreases and multi-threaded channels are reduced to single channels. Channel complexity may be a proxy for fish habitat (Schmidt and Brim Box, 2004), and simplification of the lower Green River may represent a decrease to available fish habitat (Bestgen and Hill, 2016). To restore channel heterogeneity, future management strategies must be focused upon preserving the current snowmelt flood magnitude, coupled with management of both native and non-native riparian vegetation.

4.1 MANAGEMENT RECOMMENDATIONS

In order to limit channel narrowing and potentially restore a more active channel, I recommend multiple management strategies for Canyonlands National Park: a) collaboration and partnership with upstream water managers and fisheries managers on a flow regime beneficial for CNP, and b) active management of native and non-native riparian vegetation.

4.1.1 Collaboration and partnership with upstream water managers, fisheries managers and other invested parties

Currently, flow regime in the middle Green River, downstream of FGD, is managed to benefit endangered fish species, the Colorado pikeminnow (*Ptychocheilus lucius*) and the razorback sucker (*Xyrauchen texanus*). Maintaining the geomorphic attributes of the channel produced by the natural flood regime and preserving the natural hydrograph is a priority for managers in the middle Green River (Bestgen, 2015; Bestgen and Hill, 2016). These management plans focus on native fishes in the middle Green River and do not extensively consider the lower Green River. Additionally, current flow regime plans do not take into account other aspects of the river corridor, such as the restoration of riparian cottonwoods (Scott and Miller, 2017).

Contemporary channel widths and emergent bars are maintained by the current flow regime, and preserving the current flow magnitude and timing will help to preserve channel width and limit channel narrowing. Increasing the frequency and augmenting the magnitude of peak floods are the future steps most likely to increase channel heterogeneity and widen the channel. In the absence of increasing flows, and predicted future declining annual runoff, preserving as much of the current flow regime as possible and reducing the number of consecutive years of low peak annual flow will be an effective method to limit inset floodplain formation.

Flow regime in the lower Green River is determined by the upstream natural hydrograph of the Yampa River and controlled flow releases from Flaming Gorge Dam (Iorns et al., 1965; Andrews, 1986; Allred and Schmidt, 1999). Those two inputs are the largest contributors to the hydrograph at Mineral Bottom. The annual Yampa River snowmelt flood contributes the majority of water in the middle and lower Green River during the April-June spring runoff season. Controlled releases from Flaming Gorge Dam (FGD) provide most of the water flowing through the lower Green River during late summer, fall and winter. If more water is diverted or impounded from the Yampa River basin, a greater portion of the flow would come from the upper Green River, increasing dependence on controlled reservoir releases to maintain the current hydrology of the lower Green River. The full powerplant and bypass capacity of FGD is 8,600 ft^3/s, limiting the ability of reservoir releases to fully replace a natural hydrograph. The inability of FGD to replicate the pre-dam hydrograph means that peak flow magnitude is largely dependent upon unregulated flows from the Yampa River basin.

Increased water development in the Yampa River basin has the potential to change the magnitude and timing of stream flow through the lower Green River and CNP. Changes would likely decrease peak flow magnitude, the timing of peak floods and the quantity of water delivered downstream, affecting geomorphic form and process. Currently, there are no plans for large scale dams or trans-basin diversions in the Yampa River basin, but increasing population and greater energy extraction is projected to decrease total runoff in the coming decades (Yampa/White/Green Basin Roundtable, 2015). The importance of Yampa River flows for the maintenance of native fishes is well understood by managers (Bestgen, 2015), creating an opportunity for collaboration.

The detailed investigation I undertook to describe timing of channel narrowing and processes of floodplain formation provides an understanding of how the lower Green River responds to change in flood magnitude and consecutive years of high or low flow. Current conditions maintain a channel with numerous active in-channel bars. To preserve the current level of channel form, snowmelt floods with a magnitude greater than 22,000 ft^3/s (the 2-year flood) and duration of a week should occur at least 1 out of 3 years. A flood of this type will fully inundate in-channel features and partially inundate floodplains. Flood duration of a week is long enough for sediment to be eroded or deposited and in-channel features to be reworked. The current flow regime supports floods with this recurrence interval and does not require any shifts in the hydrologic operations of FGD. Larger floods are dependent upon natural snowmelt in the Yampa River basin and targeting specific discharges, durations, and recurrence intervals is infeasible. An environmental flow agreement that augments Yampa River floods with releases from FGD may be possible to maximize flood magnitude in high runoff years, but research focused specifically on environmental flows is needed.

Future conditions of the lower Green River are susceptible to further declines in peak flood magnitude and fewer large floods. Processes of floodplain formation show new floodplains forming in repeated years of low peak flows. A new phase of channel narrowing is probable if multiple years occur with a peak flow less than 15,000 ft^3/s, similar to the post-1985 narrowing I described for the lower Green River. Current and future flow regime cannot be controlled within the boundaries of CNP, and will require collaboration with upstream stakeholders.

Maximizing a beneficial flow regime within CNP will require working closely with upstream water and fisheries managers to craft a plan which benefits the largest number of conservation stakeholders. Future work should involve applying this study and others investigating the geomorphologic characteristics of the Green River (Allred and Schmidt, 1999; Grams and Schmidt, 2002, 2005; Alexander, 2007; Manners et al., 2014) to update previous environmental flow studies (Richter and Richter, 2000; Bestgen, 2015) with the long term goal of developing an integrated conservation plan for the middle and lower Green River. Fortunately, the objectives of preserving geomorphic form and endangered fish recovery are complementary. Preserving channel heterogeneity enhances aquatic habitat, and maintaining the current flow regime assists recruitment of endangered fishes while preserving active in-channel bars.

4.1.2 Active management of native and non-native vegetation

The spread of invasive tamarisk may have altered the magnitude of floodplain formation, but did not affect the timing of channel narrowing detailed in this thesis. Thus, the efficacy of vegetation removal will be dependent upon the magnitude of subsequent snowmelt floods. Despite the widespread defoliation of tamarisk caused by the tamarisk beetle, dead stems are still present and will mediate fluvial landforms and riparian vegetation communities for the foreseeable future. Both invasive and native vegetation should both be cleared from emergent and low-elevation bars to create substrate which can be easily reworked during snowmelt floods, because the lowest portions of the inset floodplains in CNP are covered with willow, rather than tamarisk. For the goal of clearing new substrate, management of both species is the same, because both provide physically trap sediment and stabilize landforms. Clearing dead and live vegetation will create new substrate which can be modified by peak flows, but the rate of channel adjustment after vegetation removal will depend on flow magnitude, timing and duration in the years following removal.

To maximize the effects of vegetation removal, clearing of vegetation should be timed to early spring and/or early fall. Early spring removal will create bare substrate for snowmelt floods to rework. An early fall removal will clear seedlings, preventing new cohorts of vegetation from stabilizing bars. Clearing mature tamarisk will require complete removal of the tree and root system, because merely cutting trees to the ground surface will not increase bank erosion until the stump and root system decompose (Jaeger and Wohl, 2011). Because vegetation removal is labor-intensive and infeasible for the entire lower Green River, clearing will ideally be focused at locations where the flow of the river will have the greatest effect; for example, at the outside of bends and the location of former in-channel bars.

4.2 REFERENCES

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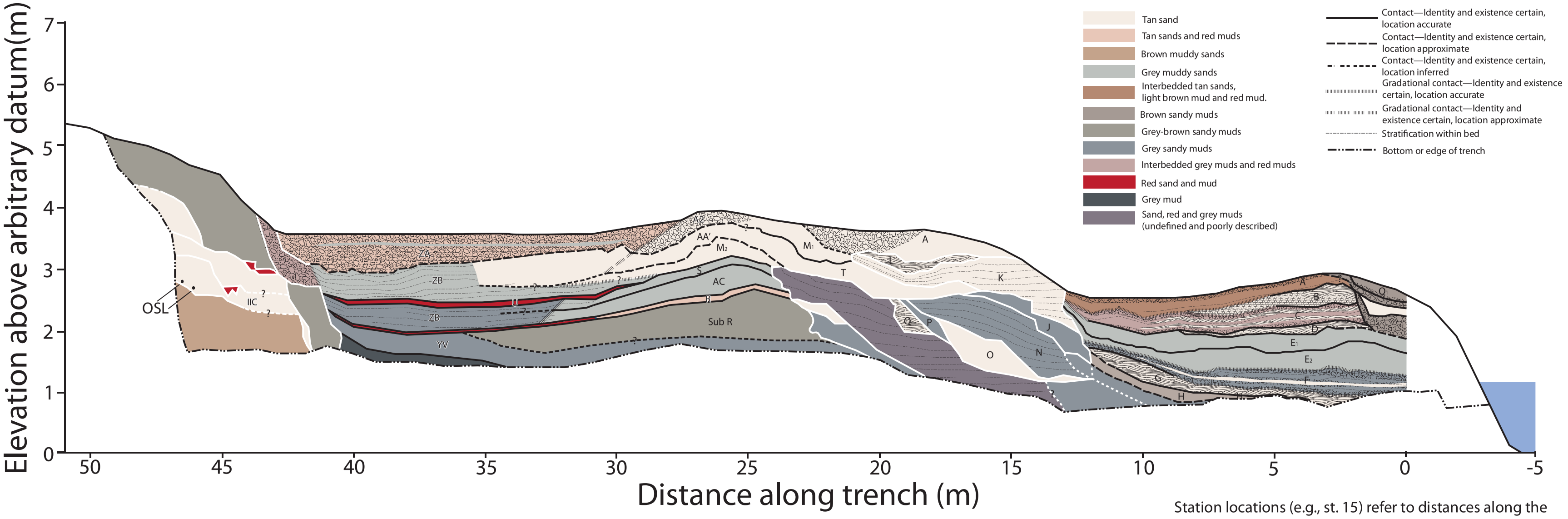
APPENDICES

APPENDIX A. SUPPLEMENTAL STRATIGRAPHIC AND SEDIMENTOLOGICAL DATA



Station locations (e.g., st. 15) refer to distances along the trench from station 0, at the offshore edge of the trench.

Description of stratigraphic units within the Hardscrabble trench

Floodplain Facies

A: Light brown blocky and crumbly mud and some very fine sand, organics present, faint horizontal beds of sand offshore from station 6 including 2 distinct sand layers near st. 5, discontinuous due to brecciation, no sand beds onshore from station 6, mostly mud st. 6-st.9. Some sand st. 9-12 but no bedding. Base of unit is a prominent red mud. Basal contact of A over B is wavy and sharp to diffuse. Basal contact of A over C is diffuse, includes root casts and rip up clasts (may be mud cracks).

B: Trough cross-laminated and laminated tan very fine sand grading onshore to muddy very fine sand; near st.3, lower half of unit is primarily horizontal laminations, upper half of unit is super critically climbing and trough cross-laminated ripples; near st. 4.5, may be evidence of multiple flood cycles evidenced by multiple sequences of horizontal laminations grading upward into ripples; ripples are symmetrical and asymmetrical (including upstream migrating ripples), muddy sand on shore from st. 5 has no ripples. Basal contact with C is sharp, irregular.

C: Alternating beds of grey mud that includes some red fines interbedded with very fine tan sand. Proportion of mud in unit increases onshore. Five distinct beds near st.6, three layers of grey sandy mud with sandy beds between; near st.12, unit is 3 layers with no sandy beds and large amounts of red mud are present. At least 2 brecciated beds in unit, at base and 5cm below top of unit. Trough cross-laminated ripples both onshore and offshore in sand beds at st. 3. Clay layers show evidence of cracking infilled with red muds. Basal contact st.3-st. 12 is abrupt, smooth; onshore of st. 12, contact is diffuse.

D: Trough cross-laminated tan very fine sand with organics in troughs primarily migrating onshore and downstream at st.3 grading onshore to laminated sand at st. 6. Basal contact over E1 is abrupt, smooth.

Q1: Brown fine sandy mud clearly separated and horizontally layered into at least 3 coarsening upward beds. Top of unit is a 5-7 cm bed of brown mud and organics. Upper boundary is ground surface, basal contact over Q2 is clear, slightly wavy, dipping offshore. Brecciation visible at base of Q1.

Between Q1/Q2: Lenticular bed of tan fine sands 2-3 cm thick, with abrupt, wavy upper contact and abrupt, wavy, conformable lower contact.

Q2: Brown, brecciated fining upward sandy mud with weakly visible horizontal layers. Abrupt, wavy, upper contact, basal contact over Q3 is clear, wavy.

Q3: Beds of trough cross-laminated coarsening upward tan sands migrating downstream above bed of light brown muddy sand. Lens of brown mud visible in tan sand, at least 4 horizontal beds visible in muddy sand. Contact between beds is sharp, wavy. Basal contact over Q4 is clear, smooth. Unit dips offshore, rising up in elevation onshore and pinching out at surface near station 1.5.

Q4: At least 2 sub-horizontal layers of brown sandy mud brecciated in part layered above a 2-3 cm thick layer of clean light tan sand and a layer of partly brecciated dark tan muddy sand. Beds in unit are coarsening upward. Unit dips offshore, possible on-lapping transgressive sequence of beds, truncates all units located onshore of Q4. Pinches out at ground surface near st. 2. Basal contact is abrupt, wavy.

S/AB2-4: Bed of sandy mud, coarsening upward into supercritically climbing ripples migrating offshore and downstream. Basal contact is abrupt, smooth. Offshore edge is sharply truncated, onshore edge is unknown.

U: Three beds of red sandy mud fining upward to red mud. Unit is 9 cm thick at st. 37, thinning offshore and pinching out at st. 30, thinning onshore and pinching out at st. 41 against IIC. Contact at top is abrupt, smooth, basal contact over ZC is abrupt, smooth.

ZC: Horizontally laminated grey-dark grey muds, with periodic 1-2 cm beds of red mud. Very similar to ZB, but contains a greater proportion of clay. No grading observed in beds, instead they alternate. Truncates against sands at st. 42, pinches out at st. 30, basal contact over U is abrupt, smooth.

YV: Horizontally laminated grey-dark grey muds, similar to ZC, but contains a greater proportion of clay and thicker layers including a 6-8 cm red mud layer. Basal contact unknown, below floor of trench.

Active Channel Facies

E1: Grey muddy very sand fining upward with faint horizontal laminations. Basal contact over E2 is abrupt, smooth, marked by a 2 cm bed of grey mud.

E2: Three horizontally laminated beds of featureless grey very fine muddy sand individually fining upward to mud. Basal contact over F is diffuse, smooth.

F: Beds of very fine sandy mud with 1 sand bed, fining laterally into beds of grey mud vertically interbedded with red mud. Single 20-cm thick sand layer extends from st.3-st.12. Rip up clasts and brecciation visible throughout in each mud bed. Basal contact over G is diffuse, smooth from st. 3-st.9, abrupt, smooth st. 9-st. 12.

G: Trough cross laminated tan/buff very fine sand primarily migrating onshore and downstream. There are two fining upward sequences. Basal contact over H is clear and smooth.

H: Brown-grey sandy mud, structureless, fining upward twice in layer. Basal contact over undefined lower unit is diffuse, but becomes more clear onshore.

Channel Margin

J: Abrupt upper and lower boundaries, composed of layered sands and muds, potentially coarsening upwards.

N: Unit with sharp base and top composed of well-defined sand and mud layers. Isolated bedforms and lenses and thin layers of red mud present. Bed is divided by 3D bedform of trough cross-laminated sand climbing onshore and downstream.

O: Trough cross-laminated very fine sand unit with sharp upper and unknown lower boundary, unit dips offshore, layers within unit are flat. Grades from red at bottom to grey on top.

P: Bounded sharply on top and at base and truncated sharply on shoreward side by O. generally coarsens upward from mud to very fine sand and silt; laminar bedding at base, critically onshore climbing ripple structures in middle, massive at top.

Large Flood

K: Tan unit with sharp top and base, composed of very fine sand and mud rhythmites, extending onshore beginning 13 meters shoreward of channel edge.

L: Tan unit with abrupt top and base composed of trough cross-laminated very fine sand with indistinct direction of climb.

M1: Tan unit with sharp upper boundary, composed of massive very fine sand; inclusions of clasts of red and grey clay.

M2/AA': Laminar tan very fine sand grading upward into supercritically climbing ripples moving onshore and downstream. Upper contact is diffuse, wavy, defined by material that was broken/brecciated in place. Unit is truncated on offshore side by erosional contact. Unit grades into ZA/ZB onshore near st. 30.

ZB: Horizontally laminated tan sandy muds and grey-dark grey muds, with periodic 1-2 cm beds of red mud. No grading observed in beds, instead they alternate. Truncates against sands at st. 42, pinches out at st. 30, basal contact over U is abrupt, smooth.

Valley Floor

IIC/OSL: Beds of fine sand to very fine sandy mud, well sorted and trough cross-laminated in parts. Truncated sharply on the offshore side by ZA, ZB, ZC and YV. Basal contact and shoreward contact unknown. Upper contact is a gradual transition into brecciated beds at surface.

Hardscrabble Trench sediment size distributions

LISST-Portable

Stratigraphic Unit	Station	Mean Size microns	Standard Deviation microns	D10 microns	D16 microns	D50 microns	D60 microns	D84 microns	D90 microns	D60/D10	Surface Area cm^2	Silt Ratio	Silt Volume µl/l	Total Concentration µl/l
C	0.7	11.681	21.56	2.565	4.507	12.298	15.146	28.635	36.828	5.905	516.532	0.977	254.824	260.706
C	3	41.169	83.521	8.888	12.396	41.096	64.234	148.821	182.238	7.227	280.017	0.638	231.561	362.899
F	3	43.209	94.048	7.287	11.137	47.392	73.942	168.678	206.363	10.148	519.334	0.605	364.362	602.303
A	3	46.494	92.255	8.881	12.59	53.925	83.78	165.926	201.678	9.434	313.408	0.573	241.147	420.624
G	3	56.197	26.452	32.747	37.765	58.028	63.619	82.737	91.978	1.943	127.834	0.768	321.863	419.356
C	3	63.403	62.251	24.52	31.072	64.67	76.968	125.745	153.564	3.139	131.185	0.589	250.564	425.471
B	3	64.812	33.252	34.614	40.195	66.952	74.352	97.424	109.192	2.148	94.367	0.617	225.654	365.896
B	3	64.866	38.837	32.56	37.481	67.56	75.89	102.973	116.353	2.331	99.456	0.596	223.508	375.313
E2	3	64.444	37.155	31.285	40.096	70.091	77.377	101.124	113.825	2.473	147.664	0.575	292.461	508.852
D	3	82.461	34.901	51.273	57.971	82.707	89.703	114.939	127.555	1.75	122.526	0.376	234.219	623.07
E1	3	81.138	52.248	24.641	38.894	99.131	110.336	142.577	156.855	4.478	81.063	0.319	97.83	307.12
H	8.7	34.026	67.496	6.044	9.011	40.393	58.162	117.195	142.604	9.623	191.301	0.685	131.1	191.405
C	9	10.83	35.884	0	2.839	10.746	13.566	29.132	42.05		471.998	0.95	196.144	206.503
C	9	13.483	34.151	2.593	4.933	13.939	17.387	35.033	46.933	6.705	501.892	0.954	259.446	272.015
F	9	23.735	52.257	5.671	7.969	23.518	31.457	76.189	101.99	5.547	183.856	0.838	130.718	155.963
E2	9	36.145	31.106	15.018	19.427	38.675	44.674	66.154	77.09	2.975	172.638	0.894	272.222	304.512
A	9	35.76	74.922	6.707	9.766	39.868	60.572	129.086	158.062	9.031	377.984	0.663	264.225	398.566
E1	9	44.487	36.377	18.519	24.417	48.554	55.677	80.547	93.213	3.006	226.543	0.807	383.913	475.517
H	9	44.376	49.717	15.053	20.499	49.72	58.925	92.413	110.582	3.914	115.258	0.745	156.344	209.899
G	9	80.479	32.974	51.044	58.091	82.014	88.558	111.831	121.619	1.735	154.089	0.388	289.268	745.3
C	10.7	9.139	12.347	0	2.583	10.121	12.487	22.452	28.115		496.898	0.998	202.44	202.765
C	10.7	16.897	44.656	2.731	5.223	16.062	22.064	61.524	86.662	8.079	345.72	0.877	179.287	204.448
F	10.7	21.301	40.679	5.25	7.542	22.496	29.227	60.599	79.348	5.567	352.453	0.891	247.128	277.476
J	15	39.112	47.237	14.881	19.148	39.917	48.145	82.87	102.769	3.235	355.48	0.808	488.702	604.852
J	15	41.044	34.475	19.056	23.022	41.054	47.665	72.464	85.64	2.501	465.473	0.855	867.762	1014.434
N	15	41.347	39.368	17.584	21.788	42.081	49.702	78.661	94.188	2.827	151.945	0.824	255.731	310.266
N	15	40.699	34.214	17.444	22.575	43.64	50.309	72.999	84.896	2.884	221.697	0.854	368.608	431.839
N	15	52.897	34.963	27.637	33.204	54.861	60.869	83.472	95.527	2.202	110.148	0.776	248.117	319.787
O	15	52.558	36.423	21.553	30.258	59.932	67.219	91.127	101.507	3.119	261.703	0.701	439.32	626.423
A	15	66.576	48.843	28.388	35.603	71.904	81.767	116.562	134.243	2.88	522.135	0.538	968.008	1799.702
A	15	70.415	50.296	31.018	38.099	74.9	84.904	120.988	139.369	2.737	357.337	0.507	687.42	1356.513
K	15	72.217	46.076	34.325	42.189	75.783	84.791	117.606	134.754	2.47	211.268	0.497	422.567	850.074
K	15	75.868	46.544	36.077	45.123	79.631	88.923	121.592	138.267	2.465	214.499	0.451	412.973	915.06
O	18	20.331	26.683	6.405	9.263	22.234	26.707	44.239	55.209	4.169	130.222	0.954	106.211	111.383
K	18	32.292	32.345	13.048	16.959	34.682	40.141	61.6	73.035	3.076	279.092	0.908	373.68	411.595
P	18	45.23	28.072	22.799	27.515	46.699	53.123	74.041	84.059	2.33	142.596	0.849	303.182	356.914
N	18	47.056	33.949	22.568	27.428	48.083	55.152	80.27	92.974	2.444	216.237	0.81	450.531	556.467
P	18	47.41	33.922	22.893	27.888	49.074	55.932	80.032	92.078	2.443	192.077	0.81	395.848	488.775
M1	18	51.496	43.479	22.378	28.156	53.859	61.83	92.378	108.379	2.763	423.488	0.732	817.462	1116.347
L	18	56.36	36.95	28.407	33.644	57.669	64.917	90.509	103.244	2.285	151.386	0.72	354.734	492.533
A	18	67.953	40.059	34.416	41.203	70.553	78.51	106.84	119.476	2.281	244.633	0.563	540.308	959.961
Q	19	60.137	33.218	32.767	38.38	62.254	69.037	92.244	102.883	2.107	121.658	0.685	284.037	414.949
M1	19	63.794	70.274	22.904	29.925	66.24	79.284	135.289	168.294	3.461	280.559	0.573	461.897	806.413
V	21.5	27.214	36.69	10.565	13.513	26.753	32.068	58.645	75.539	3.035	198.86	0.9	225.528	250.589
X	21.7	65.032	35.967	34.621	40.897	67.137	74.591	99.293	112.188	2.154	120.9	0.612	277.55	453.33
Y	25	36.459	31.147	13.707	18.775	41.107	47.734	69.692	80.559	3.482	290.632	0.877	407.991	465.447
SUBR	26	18.611	22.419	6.157	8.418	19.49	24.043	43.453	53.536	3.905	242.732	0.967	189.872	196.42
SUBR	26	21.313	35.374	7.217	9.805	20.971	25.549	50.292	68.778	3.54	303.357	0.914	251.748	275.316
S	26	40.937	30.34	19.61	23.762	41.713	47.888	69.796	81.106	2.442	152.398	0.875	293.765	335.839
R	26	46.817	32.192	20.973	27.043	50.998	57.817	81.037	91.922	2.757	202.832	0.798	379.055	474.857
M2/AA'	27	70.356	32.328	38.87	47.515	73.887	79.973	101.338	112.94	2.057	151.082	0.528	334.774	634.163
ZC	34	11.344	15.116	2.511	4.349	12.259	15.221	28.465	35.168	6.062	211.349	0.995	104.426	104.918
ZB	34	16.161	22.283	3.053	5.886	18.546	23.874	42.269	50.766	7.818	401.885	0.975	247.782	254.084
ZC	34	22.204	39.906	5.715	8.341	23.349	30.223	61.631	78.981	5.289	377.64	0.891	278.541	312.737
ZB	34	23.454	28.028	9.075	12.108	24.355	28.775	47.36	58.877	3.171	178.013	0.945	180.552	191.057
U	36	14.978	24.565	2.718	5.323	16.728	21.542	39.707	49.148	7.926	290.387	0.969	165.201	170.512
ZA	41	33.285	49.966	8.432	12.544	37.207	46.855	85.988	107.123	5.557	111.109	0.795	106.332	133.686
Z	42	53.882	36.737	24.612	32.349	59.05	66.329	91.106	102.541	2.695	151.835	0.709	279.955	394.645
IIC	47	46.938	26.534	24.517	30.199	49.565	55.192	73.617	82.868	2.251	140.398	0.853	308.449	361.585

Manually Sieved

Stratigraphic Unit	Station	<25 um (g)	>25 um (g)	>63 um (g)	>125 um (g)	>250 um (g)	>500 um (g)	>2000 um (g)	mass IN (g)	mass OUT (g)
OSL	45	0.9	35.4	194.1	303	25.3	0.1	0	561	558.8

Hardscrabble Trench sediment size distributions

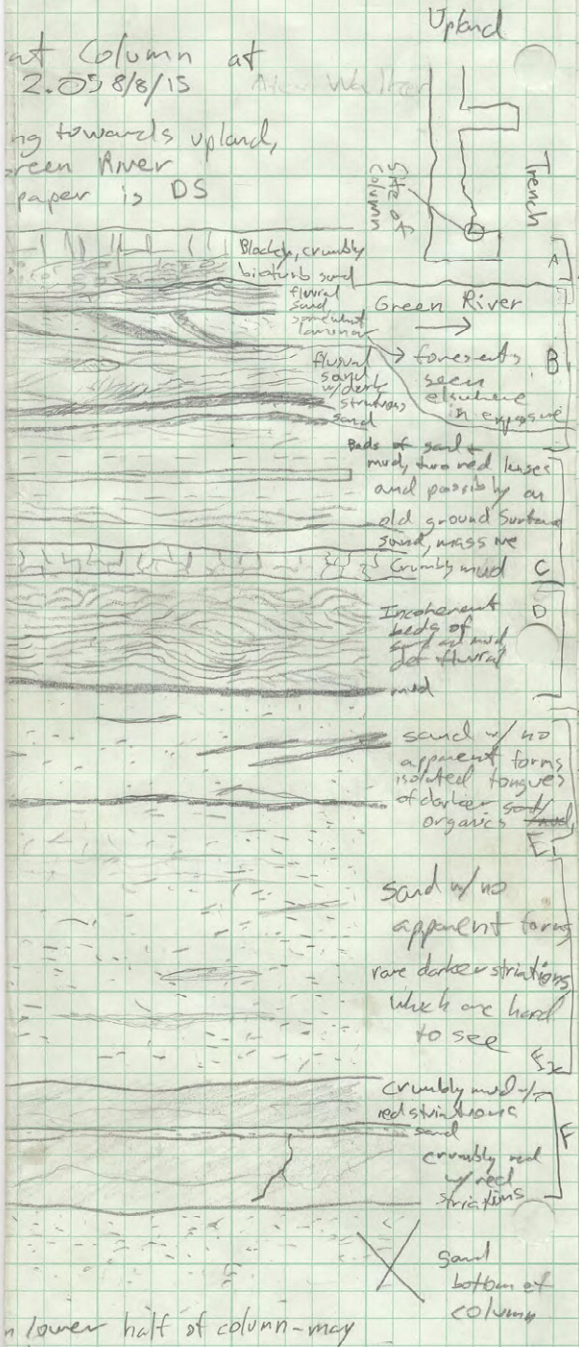
LISST-Portable

Stratigraphic Unit	Station	Volume concentration per size class (µl/l)																													
		2.06	2.43	2.87	3.39	4.01	4.73	5.59	6.6	7.79	9.2	10.86	12.83	15.15	17.89	21.12	24.95	29.46	34.79	41.08	48.51	57.29	67.65	79.89	94.34	111.41	131.56	155.36	183.47	216.66	255.85	302.13	356.79
C	0.7	19.537	8.156	5.324	3.589	3.654	7.005	11.931	13.99	15.394	17.321	18.976	20.276	21.369	17.84	16.143	14.014	11.944	9.161	6.956	5.244	3.807	2.755	1.874	1.476	1.133	0.806	0.536	0.279	0.13	0.047	0.021	0.018
C	3	6.347	2.731	1.813	1.248	1.29	2.514	4.541	6.014	7.069	8.815	11.19	14.132	17.395	18.143	18.565	18.082	17.311	16.402	14.122	13.086	13.412	13.825	15.049	16.706	18.897	19.772	19.358	15.927	12.066	7.529	5.18	4.367
F	3	16.904	6.907	4.409	2.873	2.81	5.234	8.932	10.823	12.183	14.226	16.524	19.065	21.911	23.035	24.439	25.008	25.994	26.624	23.887	22.44	22.496	22.215	23.222	25.58	29.312	32.14	34.076	30.917	26.014	17.775	13.06	11.269
A	3	7.874	3.287	2.142	1.442	1.469	2.875	5.209	6.82	7.964	9.813	12.21	15.06	18.13	18.296	18.4	17.621	16.703	15.583	13.621	13.024	13.983	15.415	18.024	21.106	24.771	26.652	26.277	21.965	17.131	11.379	8.536	7.844
G	3	0.305	0.112	0.065	0.037	0.032	0.061	0.135	0.253	0.353	0.549	0.892	1.413	2.11	3.476	5.231	7.952	13.645	28.6	39.488	55.517	77.361	71.311	55.512	30.817	14.687	5.67	2.248	0.834	0.367	0.155	0.088	0.079
C	3	0.054	0.027	0.02	0.017	0.022	0.058	0.167	0.403	0.61	1.075	2.051	3.794	6.342	9.053	12.093	15.461	19.437	29.211	29.557	31.95	39.579	39.828	41.781	36.102	31.355	23.616	17.901	12.443	8.756	5.42	3.955	3.336
B	3	0	0	0	0	0	0	0	0.002	0.004	0.013	0.06	0.26	0.891	2.2	4.016	6.71	10.048	23.855	24.826	30.234	51.735	55.774	64.356	42.147	26.581	12.072	5.594	2.439	1.135	0.474	0.272	0.198
B	3	0	0	0	0	0	0	0	0.002	0.006	0.022	0.106	0.48	1.654	3.523	5.991	9.312	12.43	26.473	25.298	28.516	46.214	49.509	59.834	42.661	30.649	16.002	8.497	4.17	2.109	0.932	0.548	0.374
E2	3	0.454	0.191	0.124	0.082	0.082	0.168	0.376	0.696	0.956	1.457	2.317	3.565	5.091	6.486	7.909	9.588	12.507	19.191	24.968	36.585	60.539	78.401	88.765	67.463	42.378	21.004	9.616	4.05	1.921	0.895	0.54	0.486
D	3	0	0	0	0	0	0	0	0	0	0	0.005	0.03	0.148	0.584	1.361	2.792	4.858	15.345	16.521	23.202	55.03	81.243	141.761	114.047	86.688	43.178	20.562	8.875	4.033	1.564	0.806	0.438
E1	3	0.381	0.124	0.067	0.035	0.03	0.063	0.16	0.345	0.523	0.914	1.726	3.198	5.386	7.013	7.389	7.188	6.609	6.573	6.293	7.653	11.787	17.702	28.561	38.783	49.476	47.721	32.106	13.453	4.115	1.086	0.388	0.271
H	8.7	5.991	2.677	1.813	1.269	1.297	2.359	3.822	4.418	4.843	5.459	6.082	6.707	7.365	7.235	7.401	7.448	7.743	8.136	8.047	8.491	9.556	10.337	11.153	11.363	11.057	9.642	7.688	5.1	3.222	1.723	1.063	0.899
C	9	22.442	8.458	5.151	3.181	3.037	5.819	10.075	11.658	12.738	14.025	14.667	14.706	14.556	11.236	9.86	8.395	7.235	5.546	4.422	3.549	2.761	2.221	1.737	1.638	1.595	1.537	1.449	1.114	0.778	0.417	0.258	0.242
C	9	20.389	7.858	4.862	3.068	2.988	5.803	10.27	12.452	13.965	16.075	18.019	19.666	21.15	18.391	17.229	15.529	13.961	11.526	9.066	7.101	5.409	4.007	2.842	2.323	1.957	1.628	1.42	1.087	0.807	0.484	0.342	0.344
F	9	5.154	2.285	1.549	1.093	1.143	2.174	3.706	4.536	5.115	6.014	7.08	8.267	9.509	9.328	9.343	9.052	8.757	8.353	7.36	6.821	6.606	6.159	5.628	5.118	4.537	3.69	2.866	1.921	1.238	0.687	0.45	0.424
E2	9	1.536	0.724	0.507	0.372	0.399	0.779	1.464	2.148	2.644	3.534	4.936	6.92	9.423	12.807	16.231	20.127	25.592	35.441	35.02	33.89	31.485	22.737	15.023	9.127	5.322	2.795	1.576	0.841	0.484	0.259	0.179	0.192
A	9	11.627	4.749	3.053	2.021	2.034	3.958	7.049	8.83	10.053	11.873	13.849	15.822	17.751	16.733	16.594	16.059	15.914	15.737	14.935	15.27	16.971	18.539	20.566	22.01	22.814	21.291	18.242	13.195	9.111	5.328	3.537	3.049
E1	9	2.695	1.1	0.693	0.442	0.421	0.791	1.496	2.203	2.739	3.679	5.107	7.069	9.508	12.971	16.543	20.936	28.277	42.553	47.913	54.396	60.909	52.089	40.187	26.374	15.955	8.436	4.603	2.365	1.344	0.721	0.495	0.506
H	9	2.076	0.84	0.527	0.334	0.316	0.582	1.049	1.447	1.751	2.275	3.05	4.102	5.387	6.908	8.262	9.633	11.732	15.412	16.346	18.309	21.328	20.461	18.055	13.613	9.572	6.03	3.92	2.428	1.641	1.013	0.754	0.745
G	9	0.25	0.072	0.034	0.015	0.01	0.017	0.038	0.08	0.122	0.212	0.396	0.72	1.208	2.148	3.105	4.336	6.697	12.436	17.358	29.263	63.084	108.316	168.525	147.982	99.093	47.503	19.396	7.146	3.093	1.328	0.741	0.578
C	10.7	24.977	8.845	5.163	3.026	2.795	5.439	9.799	11.802	13.171	14.863	15.906	16.222	16.226	12.348	10.785	9.091	7.678	5.574	3.974	2.601	1.418	0.678	0.245	0.097	0.031	0.008	0.002	0	0	0	0	0
C	10.7	14.187	5.613	3.527	2.262	2.21	4.198	7.211	8.495	9.381	10.552	11.46	12.066	12.562	10.799	10.204	9.434	8.956	8.12	7.268	6.792	6.497	6.162	5.699	5.44	4.942	4.047	2.951	1.697	0.905	0.403	0.218	0.19
E	10.7	11.444	4.696	3.018	1.99	1.981	3.766	6.542	8.061	9.138	10.771	12.637	14.68	16.883	17.059	17.565	17.502	17.586	17.386	15.258	13.766	12.611	10.736	8.782	7.198	5.7	4.086	2.852	1.721	1.005	0.492	0.291	0.272
J	15	6.278	2.245	1.298	0.744	0.661	1.258	2.457	3.687	4.674	6.455	9.29	13.448	18.98	26.876	33.827	40.159	48.421	60.699	55.091	51.48	50.433	42.121	34.77	27.068	20.806	14.386	10.241	6.614	4.418	2.548	1.774	1.644
J	15	2.447	0.868	0.498	0.283	0.253	0.515	1.184	2.261	3.215	5.178	8.935	15.319	24.661	39.252	53.446	68.772	89.291	126.931	116.293	108.599	104.929	80.645	59.907	40.162	26.027	14.765	8.759	4.816	2.84	1.487	0.981	0.915
N	15	1.187	0.506	0.328	0.216	0.211	0.402	0.785	1.246	1.613	2.309	3.517	5.416	8.043	12.233	16.095	20.05	25.079	33.793	31.66	30.522	30.606	25.226	20.075	14.376	9.927	6.046	3.767	2.153	1.296	0.695	0.46	0.428
N	15	2.683	1.087	0.681	0.431	0.407	0.759	1.429	2.112	2.639	3.578	5.047	7.138	9.831	14.067	18.381	23.484	31.491	46.311	48.381	50.443	51.392	40.173	28.536	17.918	10.612	5.589	3.148	1.688	1.012	0.566	0.405	0.419
N	15	0.453	0.191	0.121	0.076	0.07	0.127	0.247	0.407	0.536	0.78	1.203	1.864	2.788	4.657	6.654	9.471	14.48	26.169	32.816	41.352	51.166	44.52	34.13	20.824	11.709	5.755	3.059	1.616	0.98	0.589	0.461	0.515
O	15	3.767	1.43	0.86	0.518	0.475	0.895	1.72	2.522	3.128	4.151	5.587	7.381	9.426	11.598	13.97	16.895	22.524	33.9	43.15	59.043	84.318	92.096	85.495	58.286	33.535	15.907	7.36	3.176	1.593	0.774	0.485	0.457
A	15	2.236	0.672	0.341	0.166	0.131	0.265	0.667	1.415	2.126	3.635	6.564	11.456	18.381	27.706	36.976	46.915	63.019	94.796	102.836	122.356	171.356	199.216	234.585	213.504	176.781	115.865	69.348	35.941	19.831	9.864	6.016	4.734
A	15	0.353	0.119	0.067	0.037	0.034	0.079	0.233	0.589	0.945	1.765	3.536	6.766	11.591	17.589	24.052	31.528	42.52	67.896	73.147	88.019	125.839	148.709	179.9	165.793	140.778	95.687	59.661	32.349	18.185	9.098	5.5	4.149
K	15	0.181	0.062	0.034	0.019	0.017	0.038	0.107	0.263	0.418	0.773	1.539	2.934	5.027	7.921	11.151	15.2	21.741	37.512	43.544	56.159	85.183	103.356	125.858	112.665	91.053	58.172	33.833	17.16	9.16	4.425	2.611	1.957
K	15	0.093	0.031	0.017	0.009	0.008	0.02	0.062	0.171	0.287	0.572	1.249	2.605	4.795	7.731	10.992	14.836	20.816	35.426	40.382	51.636	82.855	105.613	140.338	130.143	110.205	71.037	41.258	20.652	10.839	5.136	3.018	2.231
O	18	3.798	1.485	0.921	0.58	0.558	1.062	1.908	2.499	2.948	3.698	4.749	6.138	7.833	9.125	9.933	10.088	9.895	9.312	7.014	5.325	4.048	2.845	1.917	1.367	0.956	0.613	0.388	0.203	0.1	0.039	0.019	0.016
K	18	5.008	1.838	1.087	0.643	0.59	1.143	2.239	3.334	4.198	5.738	8.128	11.516	15.857	21.433	26.661	31.771	38.624	48.94	43.949	39.029	34.067	24.146	16.021	10.247	6.374	3.608	2.202	1.274	0.799	0.453	0.327	0.35
P	18	0.607	0.22	0.126	0.071	0.06	0.113	0.243	0.454	0.644	1.038	1.81	3.159	5.187	9.018	13.003	17.911	25.585	41.456	42.871	45.29	48.906	38.86	28.062	16.466	8.776	3.872	1.744	0.723	0.334	0.145	0.084	0.079
N	18	0.718	0.264	0.154	0.089	0.079	0.156	0.36	0.712	1.03	1.695	3.004	5.275	8.647	14.415	20.389	27.61	38.383	60.816	61.769	64.774	70.597	58.798	46.235	30.498	18.885	9.981	5.437	2.716	1.472	0.708	0.43	0.371
P	18	1.05	0.381	0.219	0.123	0.104	0.192	0.398	0.701	0.968	1.507	2.53	4.286	6.92	11.979	16.957	22.954	32.177	50.914	53.592	58.108	65.09	54.808	42.353	27.03	16.002	8.139	4.325	2.189	1.232	0.653	0.447	0.447
M	18	2.341	0.86	0.505	0.295	0.268	0.536	1.192	2.171	3.002	4.633	7.529	12.028	18.093	26.769	35.569	45.898	61.97	94.401	101.017	113.509	134.085	125.127	109.918	80.36	54.793	32.381	19.578	11.132	6.966	3.99	2.82	2.612
L	18	0.016	0.006	0.004	0.003	0.003	0.008	0.028	0.089	0.158	0.343	0.842	2.002	4.147	7.367	11.058	15.845	22.467	41.408	45.163	52.68	70.826	66.2	60.258	39.367	24.677	12.632	6.853	3.572	2.043	1.075	0.737	0.656
A	18	0.072	0.023	0.012	0.006	0.006	0.013	0.043	0.129	0.224	0.472	1.095	2.427	4.703	8.119	12.081	17.286	25.752	48.547	57.027	74.644	116.813	134.946	153.615	120.391	85.348	47.092	24.914	11.872	6.189	2.942	1.779	1.381
Q	19	0.389	0.14	0.079	0.043	0.035	0.063	0.132	0.24	0.336	0.525	0.869	1.422	2.197	3.74	5.518	8.06	12.98	24.942	32.382	44.582	64.387	66.714	61.078	40.285	23.122	10.879	5.141	2.269	1.164	0.567	0.355	0.312
M	19	2.133	0.869	0.546	0.348	0.333	0.641	1.285	2.062	2.674	3.81	5.692	8.471	12.084	17.074	21.882	26.964	34.649	48.688	51.683	57.943	71.169	73.294	75.387	66.581	57.614	44.611	35.388	26.162	20.479	14.188	11.358	10.352
V	21.5	2.441	1.136	0.793	0.581	0.628	1.24	2.313	3.354	4.139	5.597	8.04	11.751	16.6	20.825	23.099	23.668	22.838	21.984	17.098	13.903	12.048	9.66	7.676	6.026	4.674	3.246	2.225	1.336	0.782	0.395	0.25	0.242
X	21.7	0.245	0.077	0.04	0.019	0.014	0.026	0.058	0.12	0.179	0.309	0.575	1.052	1.787	3.339	5.122	7.612	12.32	23.901	29.889	40.892	62.457	70.404	73.291	53.347	33.696	16.901	8.213	3.658	1.868	0.899	0.556	0.465
Y	25	5.529	2.084	1.257	0.764	0.717	1.392	2.671	3.799	4.641	6.049	7.999	10.451	13.328	16.75	20.695	25.425	33.422	47.661	50.396	52.63	52.842	40.909	28.183	17.179	9.569	4.62	2.304	1.059	0.543	0.259	0.161	0.16
SUBR	26	6.273	2.56	1.648	1.095	1.117	2.237	4.188	5.688	6.771	8.553	10.925	13.729	16.63	15.977	15.704	14.91	14.076	13.07	11.042	9.375	7.817	5.655	3.556	2.086	1.065	0.436	0.163	0.05	0.015	0.004	0.002	0.001
SUBR	26	7.375	2.86	1.775	1.125	1.109	2.241	4.368	6.28	7.725	10.223	13.87	18.609	23.929	24.314	24.062	22.394	20.072	17.304	13.335	10.713	9.1	7.516	6.21	5.409	4.641	3.542	2.493	1.415	0.726	0.301	0.151	0.129
S	26	0.739	0.294	0.181	0.112	0.104	0.203	0.436	0.785	1.083	1.68	2.794	4.646	7.309	11.765	16.278	21.444	28.79	42.739	41.12	39.601	38.474	28.555	19.844	12.123	7.057	3.582	1.93	0.982	0.545	0.278	0.184	0.183
R	26	1.985	0.733	0.43	0.25	0.222	0.419	0.849	1.373	1.796	2.576	3.842	5.676	8.053	11.684	15.407	19.851	27.274	41.892	46.658	54.13	64.502	58.504	46.894	29.566	16.372	7.517	3.455	1.48	0.726	0.34	0.207	0.194
M2	27	0.003	0	0	0	0	0.001	0.005	0.024	0.05	0.132	0.4	1.133	2.619	4.299	6.198	8.547	11.687	22.352	27.014	39.283	76.331	103.591	133.212	95.282	58.364	25.683	10.652	4.085	1.773	0.731	0.408	0.305
ZC	34	8.199	3.407	2.214	1.483	1.498	2.848	4.813	5.596	6.132	6.853	7.438	7.873	8.25	7.068	6.626	6	5.409	4.421	3.375	2.432	1.547	0.857	0.366	0.152	0.047	0.01	0.002	0	0	0	0	0
ZB	34	16.115	6.111	3.728	2.305	2.196	4.192	7.351	8.874	9.949	11.458	12.898	14.266	15.755	15.802	16.688	17.222	18.241	18.722	15.943	13.071	9.814	6.272	3.469	1.948	0.98	0.427	0.18	0.066	0.025	0.008	0.004	0.004
ZC	34	12.492	4.815	2.965	1.854	1.779	3.418	6.174	7.972	9.288	11.357	13.909	16.832	19.967	20.167	20.5	20.169	20.003	19.711	17.547	16.275	15.43	13.373	10.899	8.624	6.416	4.267	2.751	1.605	0.943	0.508	0.346	0.383
ZB	34	3.398	1.407	0.906	0.599	0.597	1.157	2.147	3.031	3.714	4.949	6.925	9.83	13.584	16.904	18.76	19.206	18.622	17.582	13.068	9.925	7.761	5.574	3.874	2.763	1.92	1.202	0.756	0.418	0.231	0.11	0.067	0.069
U	36	12.001	4.616	2.84	1.772	1.692	3.193	5.489	6.492	7.213	8.22	9.165	10.071	11.075	11.009	11.405	11.399	11.505	10.977	8.879	6.997	5.19	3.499	2.162	1.457	0.947	0.568	0.347	0.175	0.088	0.036	0.019	0.017
ZA	41	2.729	1.214	0.819	0.571	0.582	1.067	1.781	2.176	2.459	2.906	3.469	4.154	4.964	5.795	6.646	7.419	8.506	10.051	9.61	9.443	9.546	8.641	7.639	6.374	5.12	3.694	2.6	1.595	0.981	0.52	0.328	0.287
Z	42	1.725	0.68	0.416	0.254	0.231	0.419	0.781	1.146	1.426	1.91	2.621	3.556	4.683	6.421	8.277	10.699	15.155	24.44	30.718	40.752	55.109	56.686	50.745	34.678	20.61	10.336	5.142	2.374	1.252	0.63	0.402	0.37
IIC	47	0.652	0.275	0.176	0.114	0.109	0.209	0.424	0.706	0.928	1.34	2.024	3.024	4.326	6.648	9.399	13.3	20.448	36.666	44.172	52.197	58.649	45.546	30.476	16.288	7.81	3.167	1.372	0.568	0.276	0.129	0.082	0.083

Alex Walker

at Column at
2.05 8/8/15

ng towards upland,
reen River
paper is DS



n lower half of column - may
dry.

A - This could also represent the top of flood surface w/ mud interspersed w/ organics.
- clear contact, roots @ depth in unit, inclusions of rippled sand - some large, in unit.
(clear contact not seen w/ bioturb)

B ≈30 cm of sand sharply defined by clay

- Each clay layer represents a ground surface w/ a ground surface

- Ripple forms evident in package
- Sharp contact w/ lower layer

→ Bottom contact erosional

- Higher regime flow due to no ripple
fines upward
- ~~thought to~~ be upper plane bed regime
* Make sure the mud layer is described

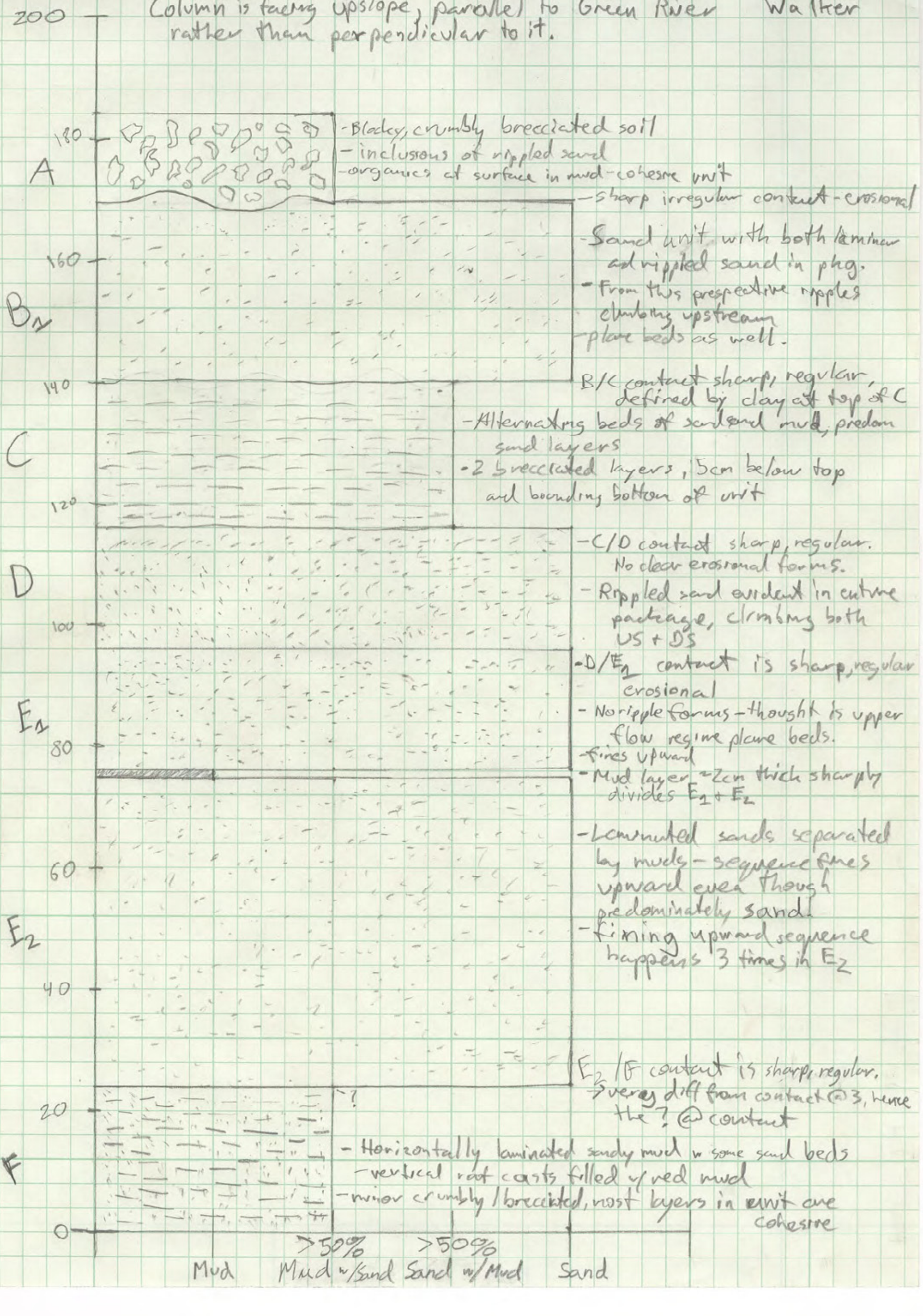
- Laminated sands separated by muds fines upward - 3+ sequences in unit. - Draw this
* photo this

>50% mud

F - Horizontally laminated ~~muds~~/sandy mud
- vertical red root casts filled w/ red mud

Station 2.0 Strat Column 8/19/15 Alex Walker

Column is facing upslope, parallel to Green River rather than perpendicular to it.



- Blocky, crumbly brecciated soil
- inclusions of rippled sand
- organics at surface in mud-cohesive unit

- sharp irregular contact - erosional

- Sand unit with both laminar and rippled sand in pkg.
- From this prespective ripples climbing upstream
- plane beds as well.

B/C contact sharp, regular, defined by clay at top of C

- Alternating beds of sand and mud, predom sand layers
- 2 brecciated layers, 5cm below top and bounding bottom of unit

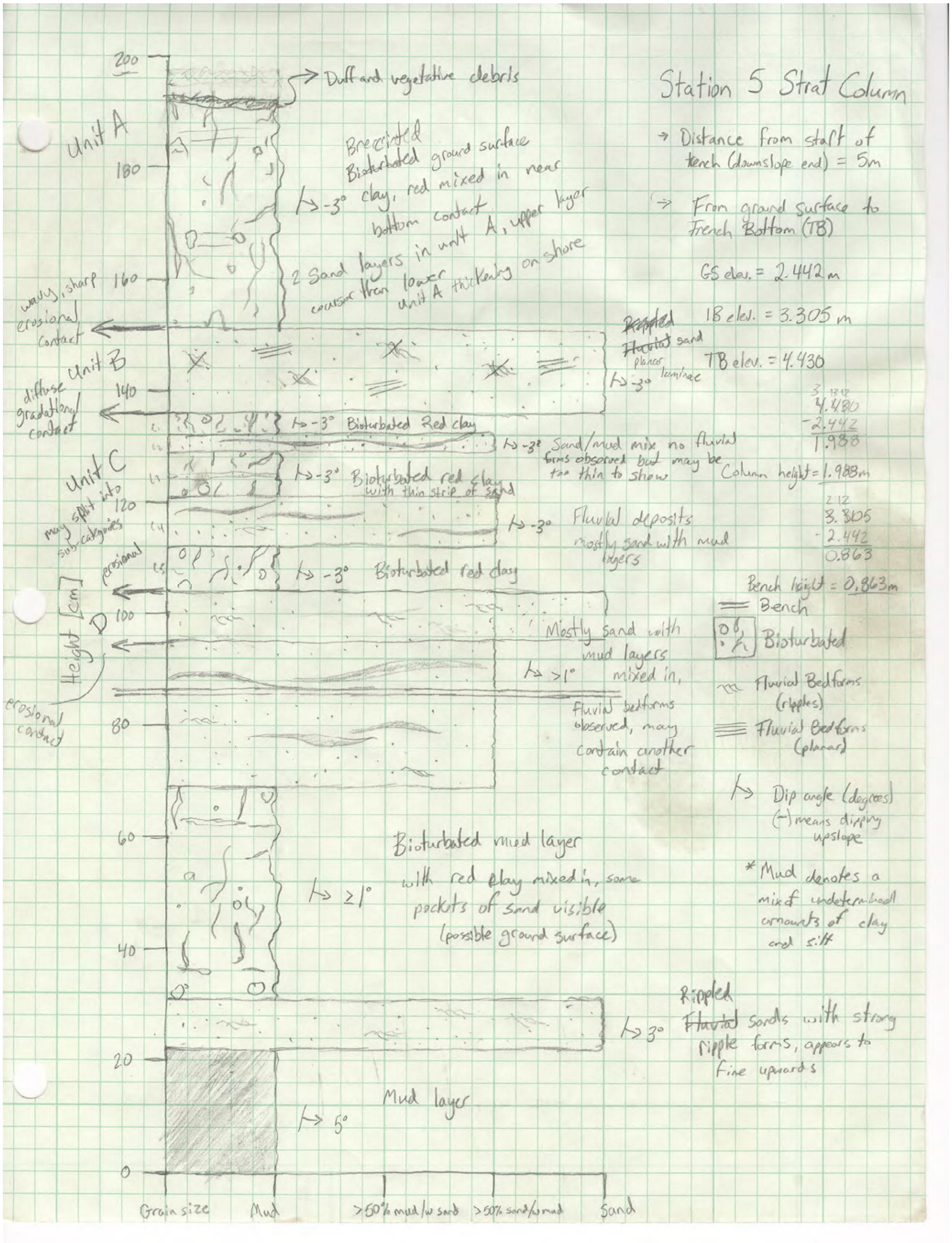
- C/D contact sharp, regular. No clear erosional forms.
- Rippled sand evident in entire package, climbing both US + DS

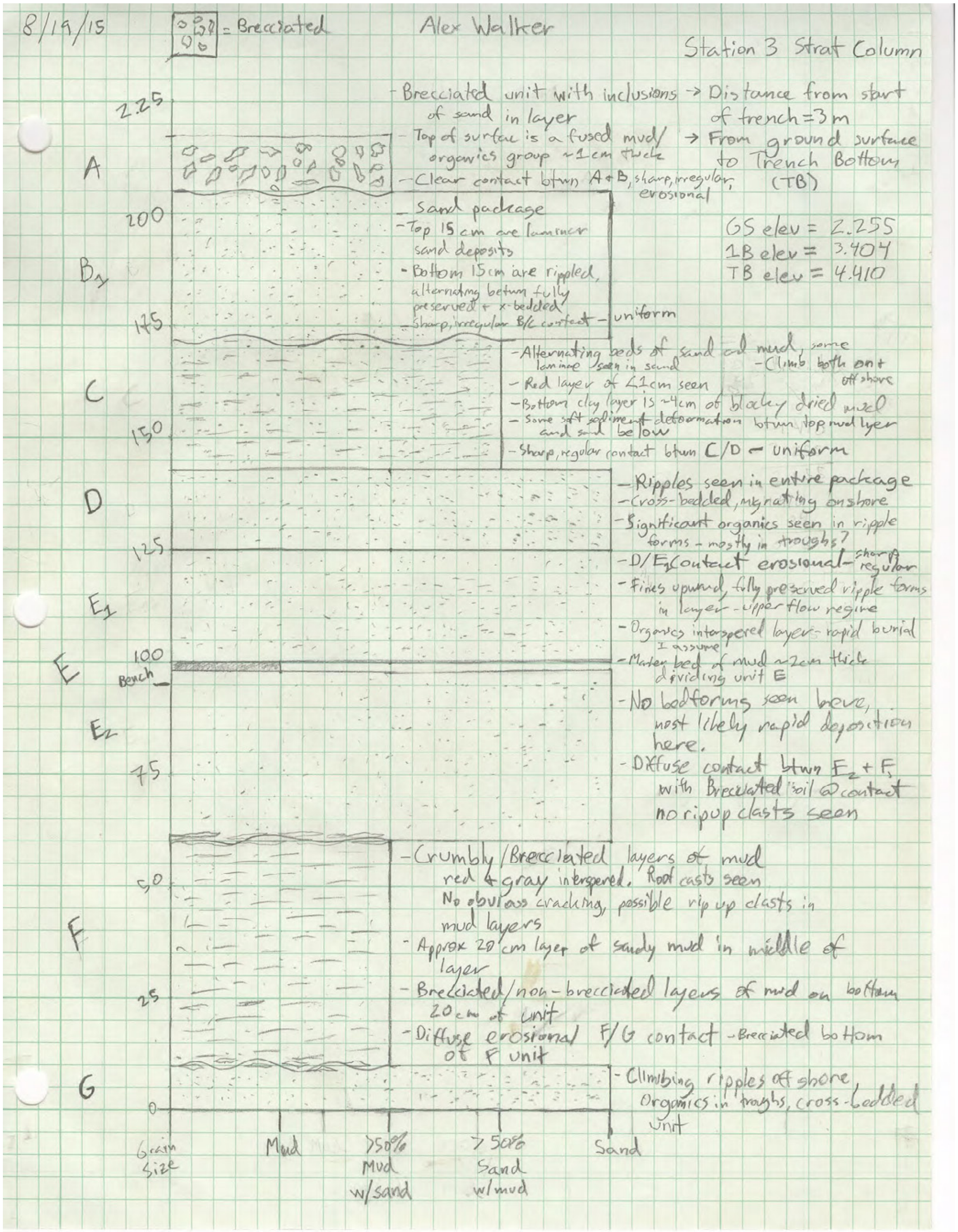
- D/E_1 contact is sharp, regular erosional
- No ripple forms - thought is upper flow regime plane beds.
- fines upward
- Mud layer ≈2cm thick sharply divides E_1 + E_2

- Laminated sands separated by muds - sequence fines upward even though predominately sand!
- fining upward sequence happens 3 times in E_2

E_2/F contact is sharp, regular.
→ very diff from contact @ 3, hence the ? @ contact

- Horizontally laminated sandy mud w some sand beds
- vertical root casts filled w/ red mud
- minor crumbly/brecciated, most layers in unit are cohesive


Station 5 Strat Column
→ Distance from start of bench (downslope end) = 5m
→ From ground surface to Trench Bottom (TB)
GS elev. = 2.442 m
BB elev. = 3.305 m
TB elev. = 4.430
3 1312
4.430
-2.442
1.988
Column height = 1.988m
2 12
3.305
-2.442
0.863
Bench height = 0.863m
Bench
Bioturbated
Fluvial Bedforms (ripples)
Fluvial Bedforms (planar)
Dip angle (degrees) (−) means dipping upslope
*Mud denotes a mix of undetermined amounts of clay and silt
200
180
160
140
120
100
80
60
40
20
0
Height [cm]
Duff and vegetative debris
Unit A
~~Brecciated~~
Bioturbated ground surface clay, red mixed in near bottom contact
-3°
2 Sand layers in unit A, upper layer coarser than lower unit A thickening on shore
wavy, sharp erosional contact
Unit B
~~Rippled~~ ~~Fluvial~~ sand planar laminae
-3°
diffuse gradational contact
Unit C
may split into subcategories
C1
C2
C3
C4
C5
-3° Bioturbated Red clay
-3° Sand/mud mix no fluvial forms observed but may be too thin to show
-3° Bioturbated red clay with thin strip of sand
-3° Fluvial deposits mostly sand with mud layers
-3° Bioturbated red clay
erosional
D
Mostly sand with mud layers mixed in, fluvial bedforms observed, may contain another contact
>1°
erosional contact
Bioturbated mud layer with red clay mixed in, some pockets of sand visible (possible ground surface)
≥1°
Rippled ~~Fluvial~~ sands with strong ripple forms, appears to fine upwards
3°
Mud layer
5°
Grain size
Mud
>50% mud/w sand
>50% sand/w mud
Sand



8/19/15

Alex Walker

Station 3 Strat Column

→ Distance from start of trench = 3 m

→ From ground surface to Trench Bottom (TB)

GS elev = 2.255
1B elev = 3.404
TB elev = 4.410

- Brecciated unit with inclusions of sand in layer
- Top of surface is a fused mud/organics group ~1cm thick
- Clear contact btwn A+B, sharp, irregular, erosional

- Sand package
- Top 15 cm are laminar sand deposits
- Bottom 15cm are rippled, alternating betwn fully preserved + x-bedded
- Sharp, irregular B/C contact – uniform

- Alternating beds of sand and mud, some laminae seen in sand – Climb both on + off shore
- Red layer of <1cm seen
- Bottom clay layer is ~4cm of blocky dried mud
- Some soft sediment deformation btwn top mud lyer and sand below
- Sharp, regular contact btwn C/D – uniform

- Ripples seen in entire package
- Cross-bedded, migrating onshore
- Significant organics seen in ripple forms – mostly in troughs?

- D/E1 Contact erosional – sharp regular
- Fines upward, fully preserved ripple forms in layer – upper flow regime
- Organics interspered layer – rapid burial I assume
- Marker bed of mud ~2cm thick dividing unit E

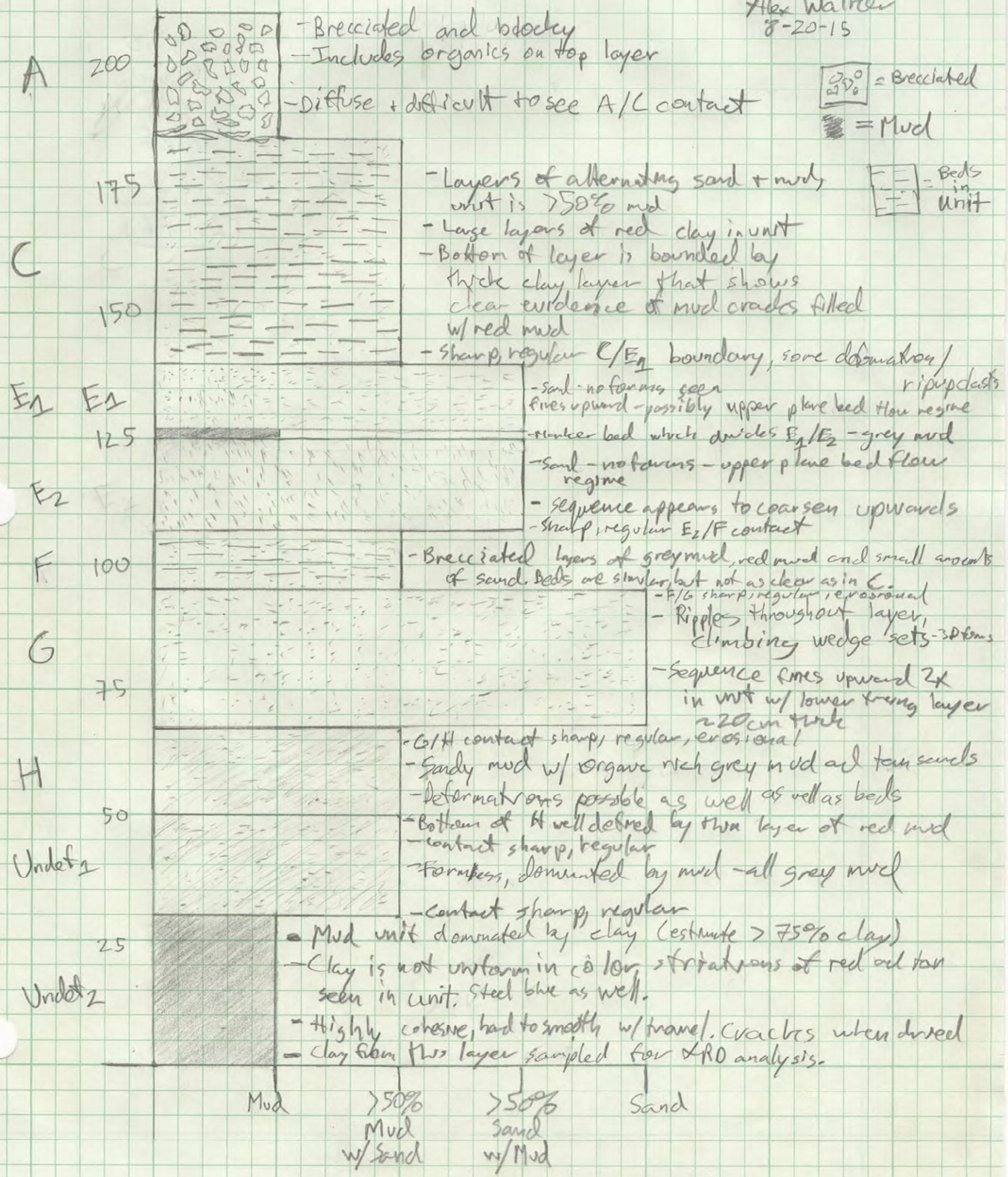
- No bedforms seen here, most likely rapid deposition here.
- Diffuse contact btwn E2 + F, with Brecciated soil @ contact no ripup clasts seen

- Crumbly/Brecciated layers of mud red + gray interspered. Root casts seen No obvious cracking, possible rip up clasts in mud layers
- Approx 20 cm layer of sandy mud in middle of layer
- Brecciated/non-brecciated layers of mud on bottom 20 cm of unit
- Diffuse erosional F/G contact – Brecciated bottom of F unit

- Climbing ripples off shore, Organics in troughs, cross-bedded unit

Station 9 Strat Column

Alex Walker
8-20-15



- Brecciated and blocky
- Includes organics on top layer
- Diffuse + difficult to see A/C contact

- Layers of alternating sand + mud, unit is >50% mud
- Large layers of red clay in unit
- Bottom of layer is bounded by thick clay layer that shows clear evidence of mud cracks filled w/ red mud
- Sharp, regular C/E_1 boundary, some deformation/ ripup clasts

- Sand - no forms seen fines upward - possibly upper plane bed flow regime
- Marker bed which divides E_1/E_2 - grey mud

- Sand - no forms - upper plane bed flow regime
- sequence appears to coarsen upwards
- Sharp, regular E_2/F contact

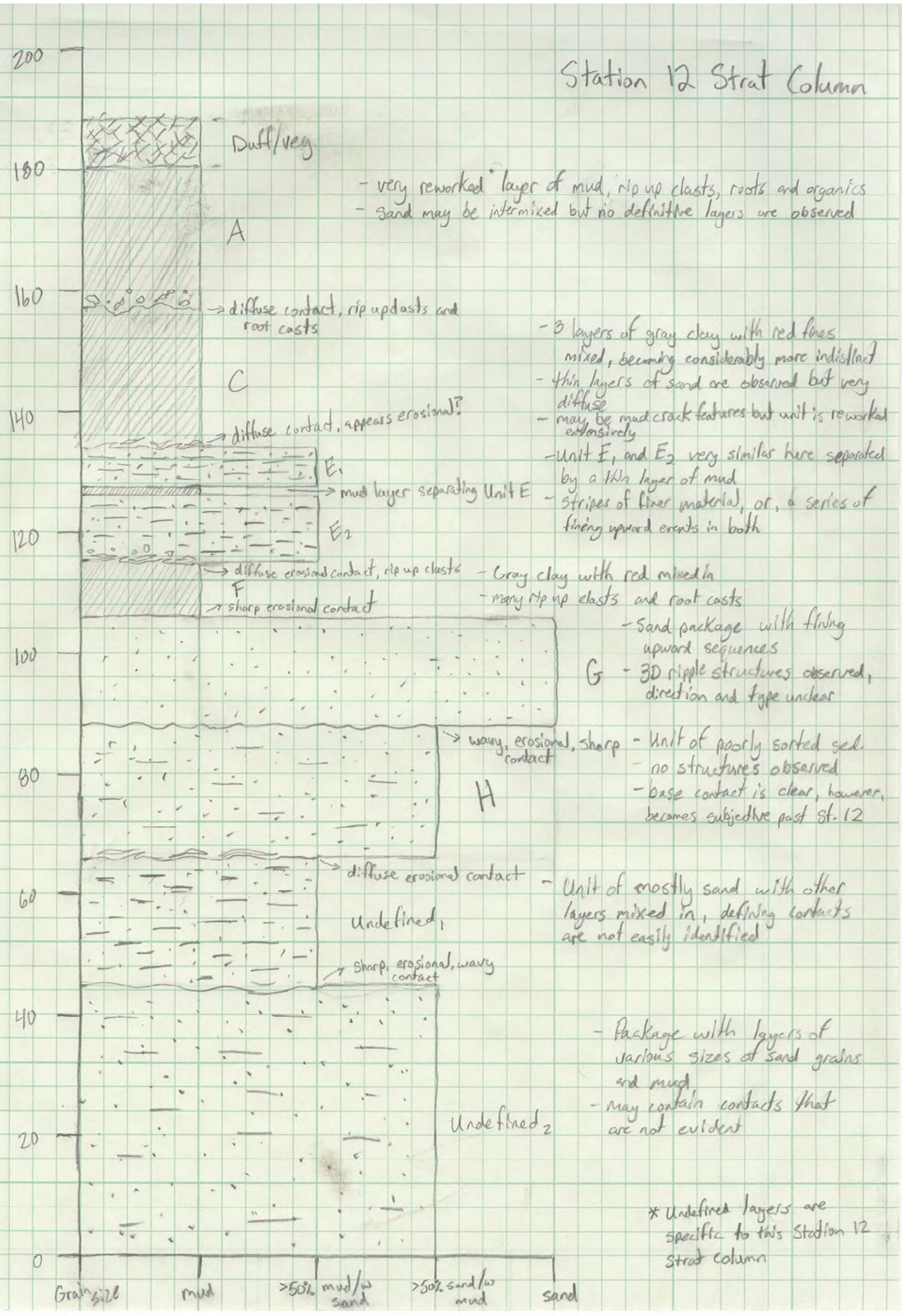
- Brecciated layers of grey mud, red mud and small amounts of sand. Beds are similar, but not as clear as in C.

- F/G sharp, regular, erosional
- Ripples throughout layer, climbing wedge sets - 3D forms
- Sequence fines upward 2x in unit w/ lower fining layer ≈20cm thick

- G/H contact sharp, regular, erosional
- Sandy mud w/ organic rich grey mud and tan sands
- Deformations possible as well as well as beds
- Bottom of H well defined by thin layer of red mud

- contact sharp, regular
- Formless, dominated by mud - all grey mud
- Contact sharp, regular

- Mud unit dominated by clay (estimate > 75% clay)
- Clay is not uniform in color, striations of red and tan seen in unit. Steel blue as well.
- Highly cohesive, had to smooth w/ trowel. Cracks when dried
- Clay from this layer sampled for XRD analysis.



Station 12 Strat Column

→ diffuse contact, rip upclasts and root casts

→ diffuse contact, appears erosional?

→ mud layer separating Unit E

→ diffuse erosional contact, rip up clasts

→ sharp erosional contact

→ wavy, erosional, sharp contact

→ diffuse erosional contact

→ Sharp, erosional, wavy contact

- very reworked* layer of mud, rip up clasts, roots and organics
- Sand may be intermixed but no definitive layers are observed

- 3 layers of gray clay with red fines mixed, becoming considerably more indistinct
- thin layers of sand are observed but very diffuse
- may be mud crack features but unit is reworked extensively

- Unit E_1 and E_2 very similar here separated by a thin layer of mud
- Stripes of finer material, or, a series of fining upward events in both

- Gray clay with red mixed in
- many rip up clasts and root casts

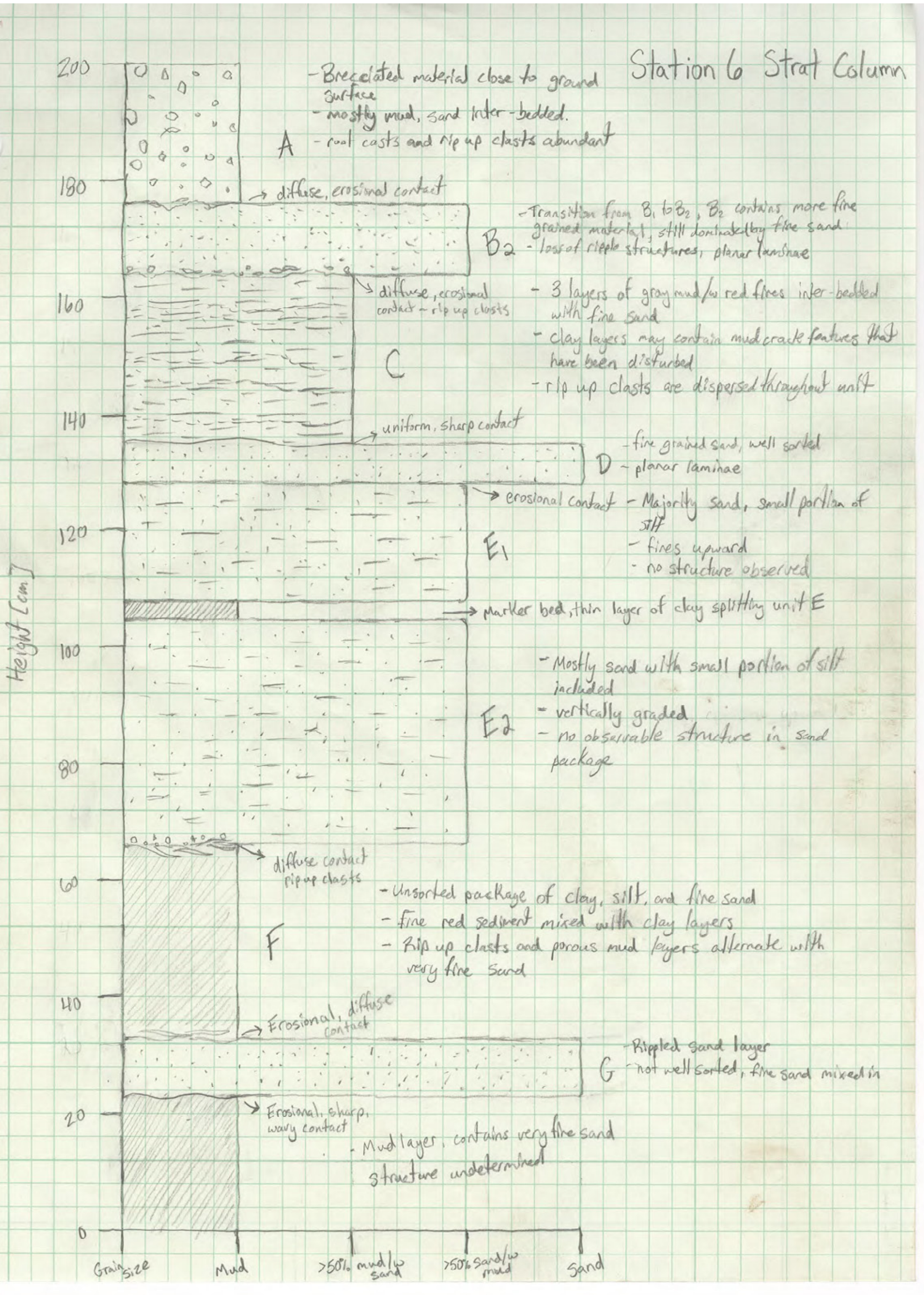
- Sand package with fining upward sequences
- 3D ripple structures observed, direction and type unclear

- Unit of poorly sorted sed.
- no structures observed
- base contact is clear, however, becomes subjective past St. 12

- Unit of mostly sand with other layers mixed in, defining contacts are not easily identified

- Package with layers of various sizes of sand grains and mud
- May contain contacts that are not evident

* Undefined layers are specific to this Station 12 Strat Column


Station 6 Strat Column
200
180
160
140
120
100
80
60
40
20
0
Height [cm]
A
-Brecclated material close to ground surface
- mostly mud, sand inter-bedded.
- root casts and rip up clasts abundant
→ diffuse, erosional contact
B2
-Transition from B1 to B2, B2 contains more fine grained material, still dominated by fine sand
- loss of ripple structures, planar laminae
→ diffuse, erosional contact ~ rip up clasts
C
- 3 layers of gray mud/w red fines inter-bedded with fine sand
- clay layers may contain mud crack features that have been disturbed
- rip up clasts are dispersed throughout unit
→ uniform, sharp contact
D
- fine grained sand, well sorted
- planar laminae
→ erosional contact
E1
- Majority sand, small portion of silt
- fines upward
- no structure observed
→ Marker bed, thin layer of clay splitting unit E
E2
- Mostly sand with small portion of silt included
- vertically graded
- no observable structure in sand package
→ diffuse contact rip up clasts
F
- Unsorted package of clay, silt, and fine sand
- fine red sediment mixed with clay layers
- Rip up clasts and porous mud layers alternate with very fine sand
→ Erosional, diffuse contact
G
-Rippled sand layer
- not well sorted, fine sand mixed in
→ Erosional, sharp, wavy contact
- Mud layer, contains very fine sand structure undetermined
Grain size
Mud
>50% mud/w sand
>50% sand/w mud
Sand

Station 11 Strat Column

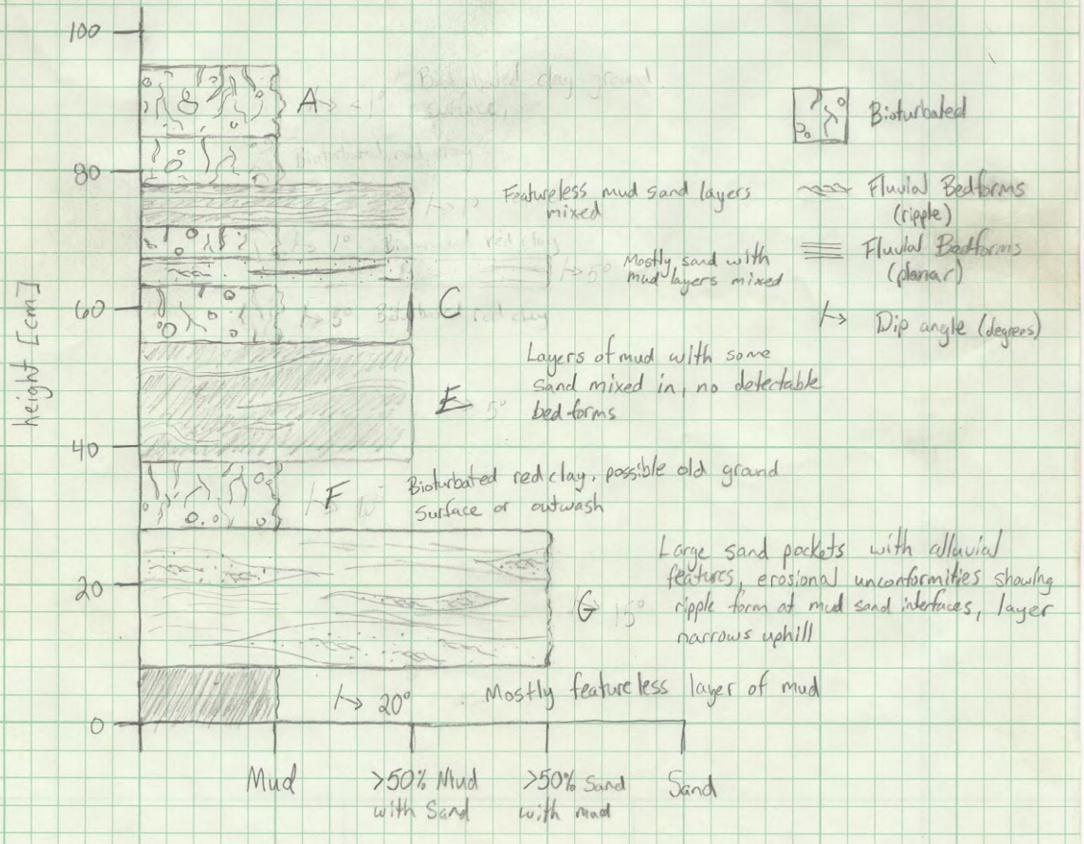
→ Distance from start of trench (downslope end) = 11m

→ Column includes layers from Bench to Ground Surface

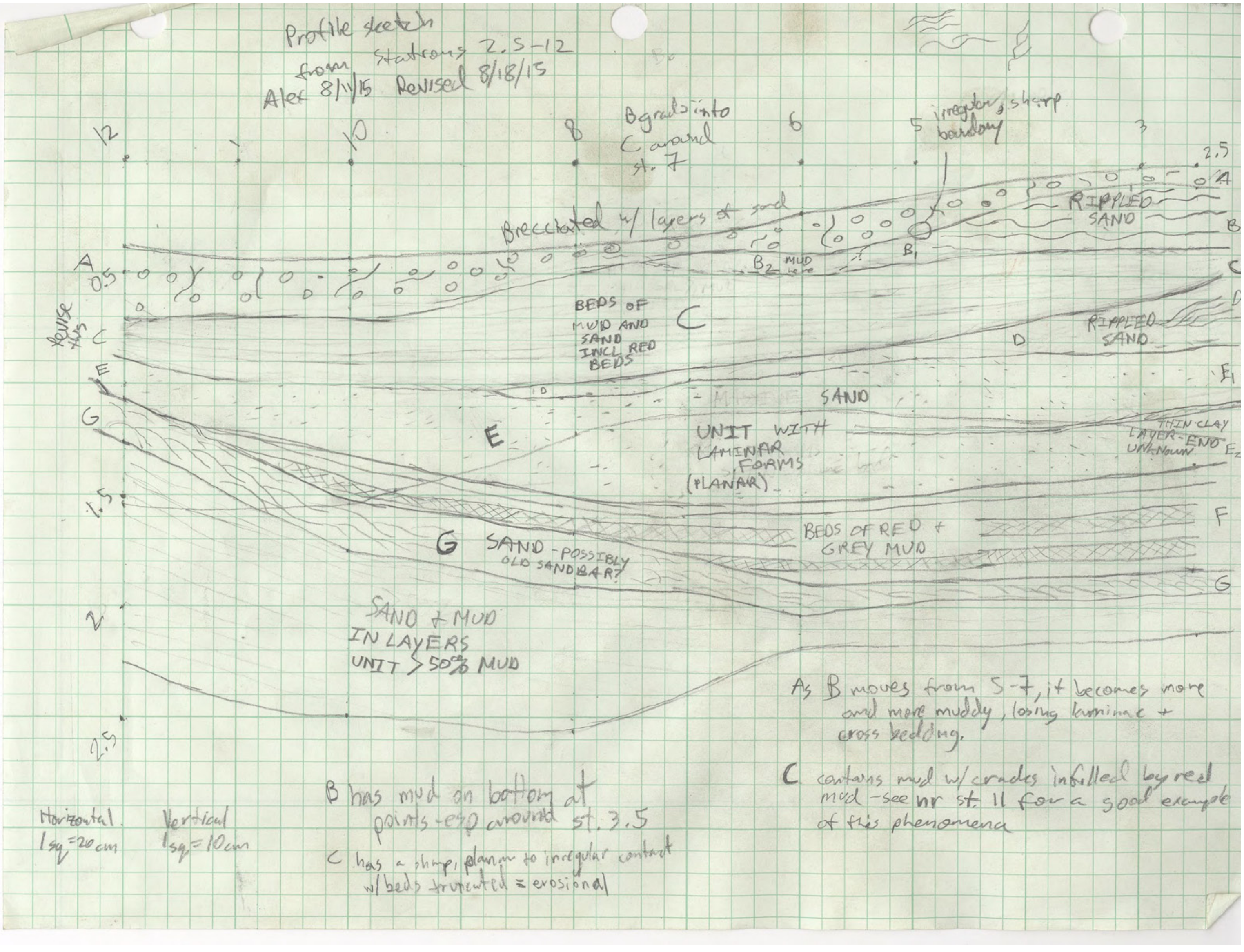
GS elev. = 2.644 m 1B elev. = 3.576 m
Column height = 0.932 m 932 cm

$$\begin{array}{r} 3.576 \\ -\ 2.644 \\ \hline 0.932 \end{array}$$

→ Mud denotes a mixture of undetermined amounts of silt and clay



Profile sketch
from Stations 2.5-12
Alex 8/11/15 Revised 8/18/15



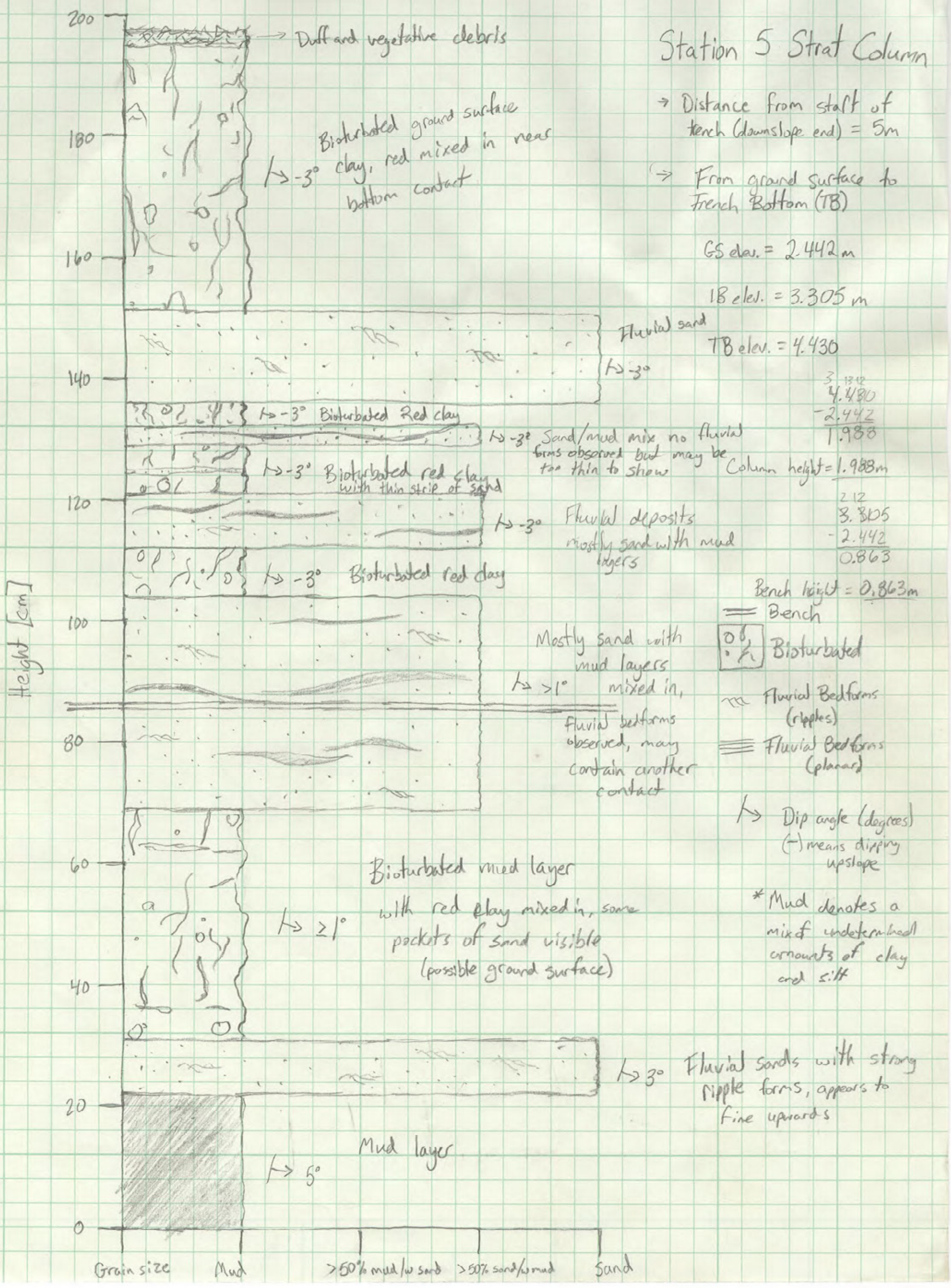
As B moves from 5-7, it becomes more and more muddy, losing laminae + cross bedding.

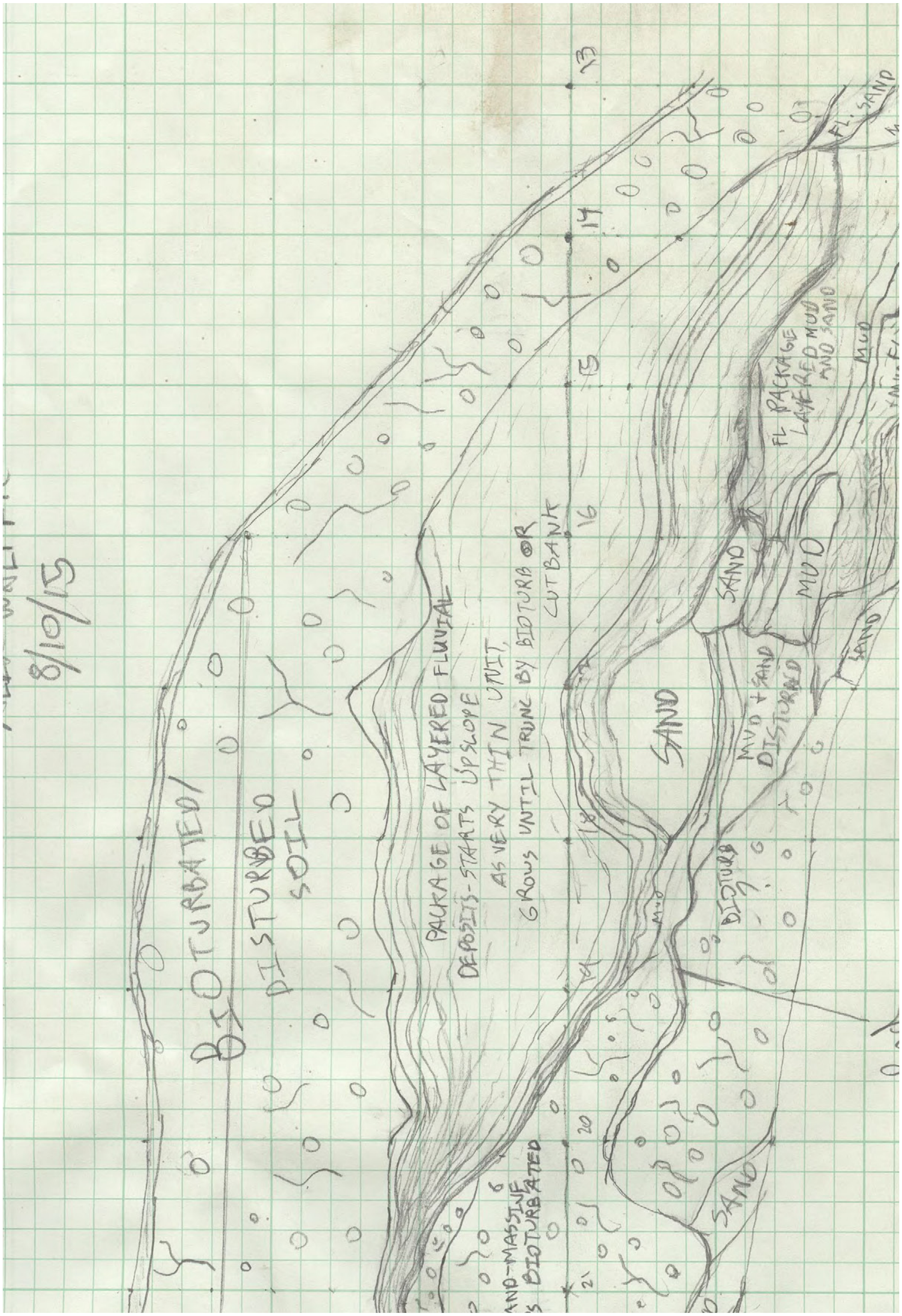
C contains mud w/ cracks infilled by red mud - see nr st. 11 for a good example of this phenomena

B has mud on bottom at points - esp around st. 3.5

C has a sharp, planar to irregular contact w/ beds truncated = erosional

Horizontal 1 sq = 20 cm
Vertical 1 sq = 10 cm


Station 5 Strat Column
→ Distance from start of tench (downslope end) = 5m
→ From ground surface to Trench Bottom (TB)
GS elev. = 2.442 m
IB elev. = 3.305 m
TB elev. = 4.430
3 1312
4.430
-2.442
1.988
Column height = 1.988m
2 12
3.305
-2.442
0.863
Bench height = 0.863m
Bench
Bioturbated
Fluvial Bedforms (ripples)
Fluvial Bedforms (planar)
Dip angle (degrees) (-) means dipping upslope
* Mud denotes a mix of undetermined amounts of clay and silt
200
180
160
140
120
100
80
60
40
20
0
Height [cm]
Duff and vegetative debris
Bioturbated ground surface clay, red mixed in near bottom contact
-3°
Fluvial sand
-3°
-3° Bioturbated Red clay
-3° Sand/mud mix no fluvial forms observed but may be too thin to show
-3° Bioturbated red clay with thin strip of sand
-3° Fluvial deposits mostly sand with mud layers
-3° Bioturbated red clay
Mostly sand with mud layers mixed in, fluvial bedforms observed, may contain another contact
>1°
Bioturbated mud layer with red clay mixed in, some pockets of sand visible (possible ground surface)
≥1°
3° Fluvial sands with strong ripple forms, appears to fine upwards
Mud layer
5°
Grain size
Mud
>50% mud/w sand
>50% sand/w mud
Sand


8/10/15
BIOTURBATED/ DISTURBED SOIL
PACKAGE OF LAYERED FLUVIAL DEPOSITS-STARTS UPSLOPE AS VERY THIN UNIT, GROWS UNTIL TRUNC BY BIOTURB OR CUTBANK
SAND
MUD + SAND DISTURBED
SAND
MUD
FL PACKAGE LAYERED MUD AND SAND
MUD
FL SAND
SAND
BIOTURB
MUD
SAND
SAND-MASSIVE
BIOTURBATED
13
14
15
16
19
20
21

= Boundary
Duff / Bioturb / Disturbed Soil
DRIED CLAY
SAND w/ MUD LENSES
SAND
SAND AND MUD
(much finer than the below sand package)
10
RED CLAY
MUD LAYER - GREY w/ Red in it
RED CLAY w/ GREY MUD intermingled
Red Clay w/ Grey Mud
SAND PACKAGE
MIXED GRAIN SIZES
(May be multiple floods)
SAND
SAND
Root Dist.
Dist.
MUD w/ RED ROOT CASTS
MUD w/ SAND LENSES
MUD w/ RED ROOT CASTS
12
SAND w/ COARSER LENSES
RED MUD / GREY MUD
SAND AND MUD INTERBEDDED
13

Station 11 Strat Column

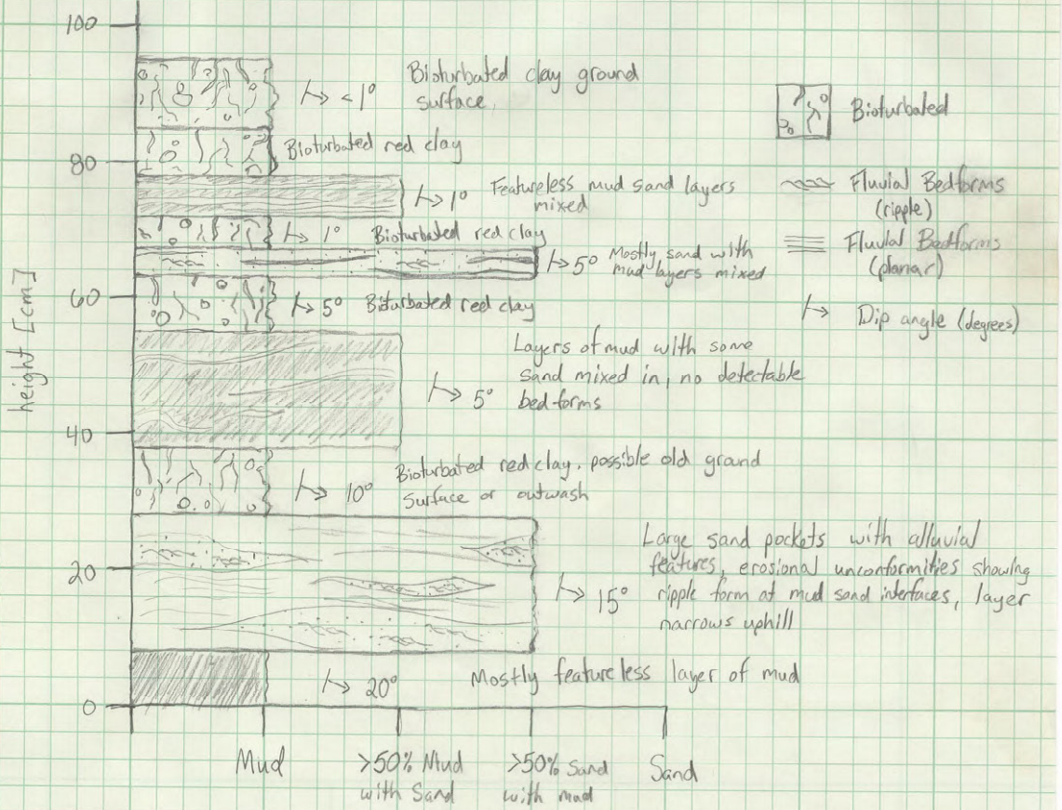
→ Distance from start of trench (downslope end) = 11m

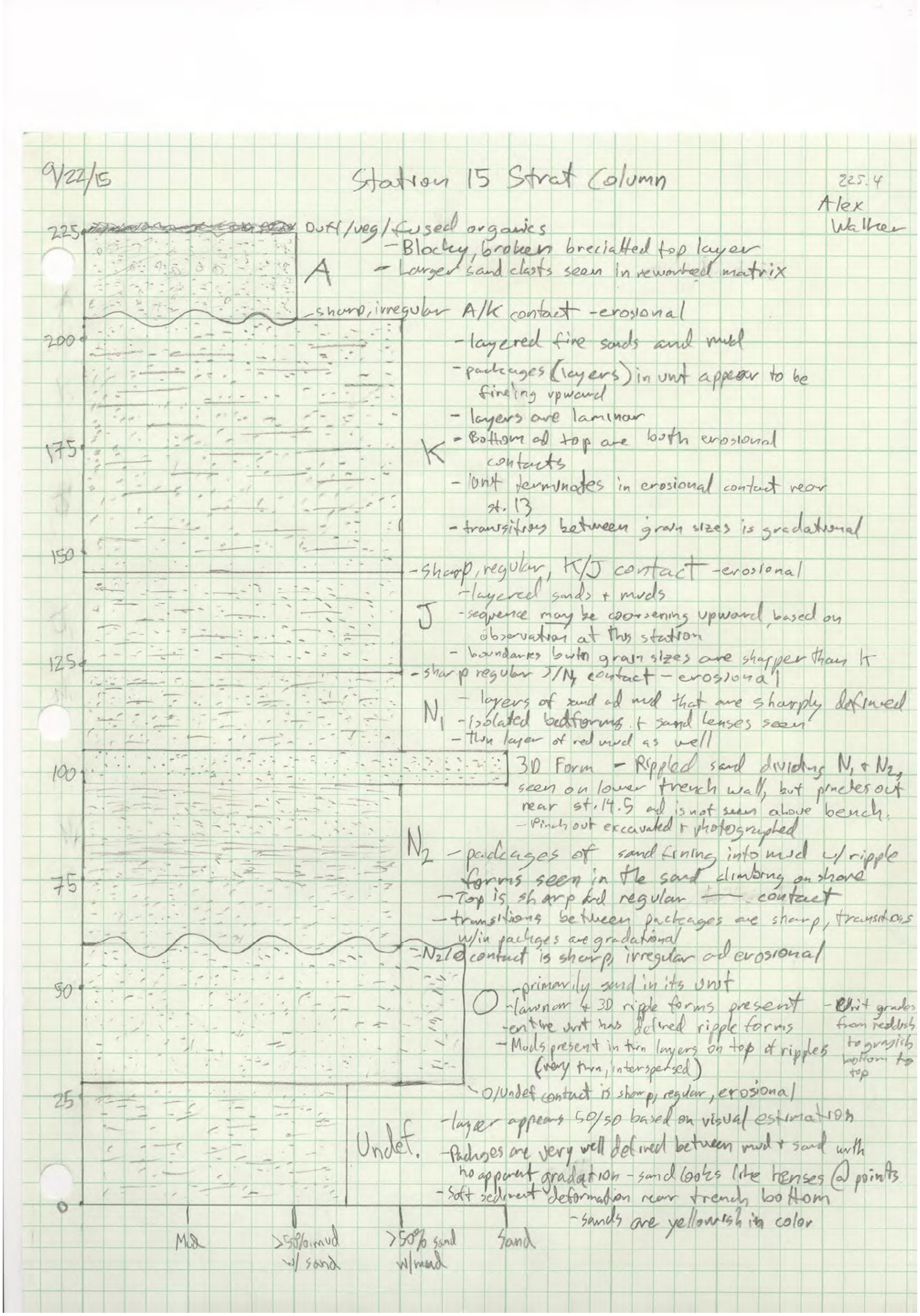
→ Column includes layers from Bench to Ground Surface

GS elev. = 2.644m 1B elev. = 3.576 m
Column height = 0.932m 932 cm

$$\begin{array}{r} 3.576 \\ -2.644 \\ \hline 0.932 \end{array}$$

→ Mud denotes a mixture of undetermined amounts of silt and clay





9/22/15

Station 15 Strat Column

225.4
Alex
Walker

Duff/veg/fused organics

A
- Blocky, broken breciatted top layer
- Larger sand clasts seen in reworked matrix

- sharp, irregular A/K contact - erosional

K
- layered fire sands and mud
- packages (layers) in unit appear to be fineing upward
- layers are laminar
- Bottom ad top are both erosional contacts
- Unit terminates in erosional contact near st. 13
- transitions between grain sizes is gradational

- Sharp, regular, K/J contact - erosional

J
- layered sands + muds
- sequence may be coarsening upward, based on observation at this station
- boundaries btwn grain sizes are sharper than K

- sharp regular J/N₁ contact - erosional

N₁
- layers of sand ad mud that are sharply defined
- isolated bedforms + sand lenses seen
- thin layer of red mud as well

3D Form - Rippled sand dividing N₁ + N₂, seen on lower trench wall, but pinches out near st. 14.5 ad is not seen above bench.
- Pinch out excavated + photographed

N₂
- packages of sand fining into mud w/ ripple forms seen in the sand climbing on shore
- Top is sharp and regular ~~—~~ contact
- transitions between packages are sharp, transitions w/in packages are gradational

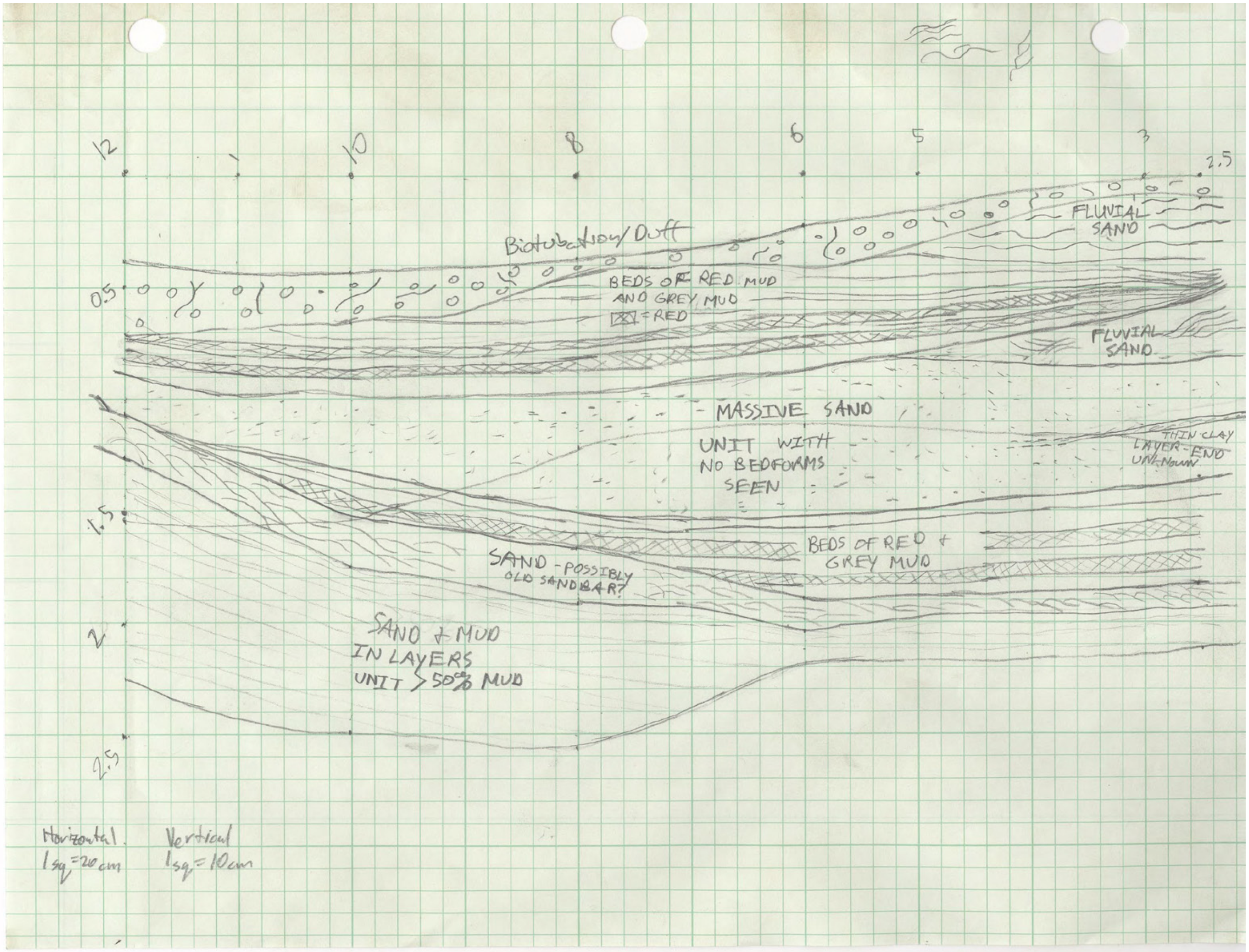
- N₂/O contact is sharp, irregular ad erosional

O
- primarily sand in its unit
- laminar + 3D ripple forms present
- entire unit has defined ripple forms
- Muds present in thin layers on top of ripples (very thin, interspersed)

- Unit grades from reddish to grayish bottom to top

- O/Undef contact is sharp, regular, erosional

Undef.
- layer appears 50/50 based on visual estimation
- Packages are very well defined between mud + sand with no apparent gradation - sand looks like lenses @ points
- Soft sediment deformation near trench bottom
- sands are yellowish in color


12
10
8
6
5
3
2,5
0.5
1.5
2
2.5
Biotubation/Duff
FLUVIAL SAND
BEDS OF RED MUD AND GREY MUD
☒ = RED
FLUVIAL SAND
MASSIVE SAND UNIT WITH NO BEDFORMS SEEN
THIN CLAY LAYER - END UNKNOWN
BEDS OF RED + GREY MUD
SAND - POSSIBLY OLD SANDBAR?
SAND + MUD IN LAYERS
UNIT > 50% MUD
Horizontal 1sq = 20cm
Vertical 1sq = 10cm

Station 18 Strat Column

Only depicts layers from Bench to Ground surface

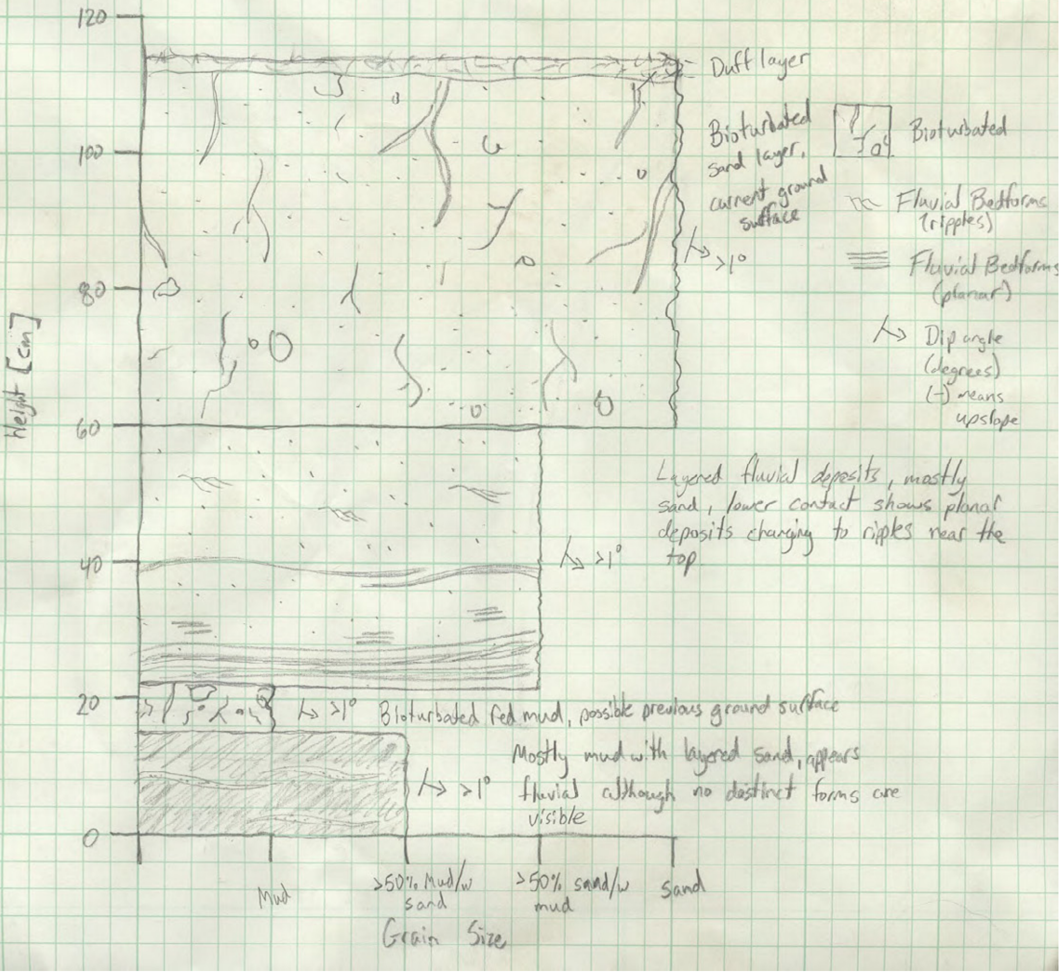
→ Distance from start of trench (downslope end) = 18m

GS elev. = 1.598 18 elev. = 2.740

Column Height = 1.142m

6 13
2.740
− 1.598
1.142

*Mud denotes a mix of undetermined amounts of clay and silt



Bioturbated sand layer, current ground surface

Layered fluvial deposits, mostly sand, lower contact shows planar deposits changing to ripples near the top.

Bioturbated red mud, possible previous ground surface

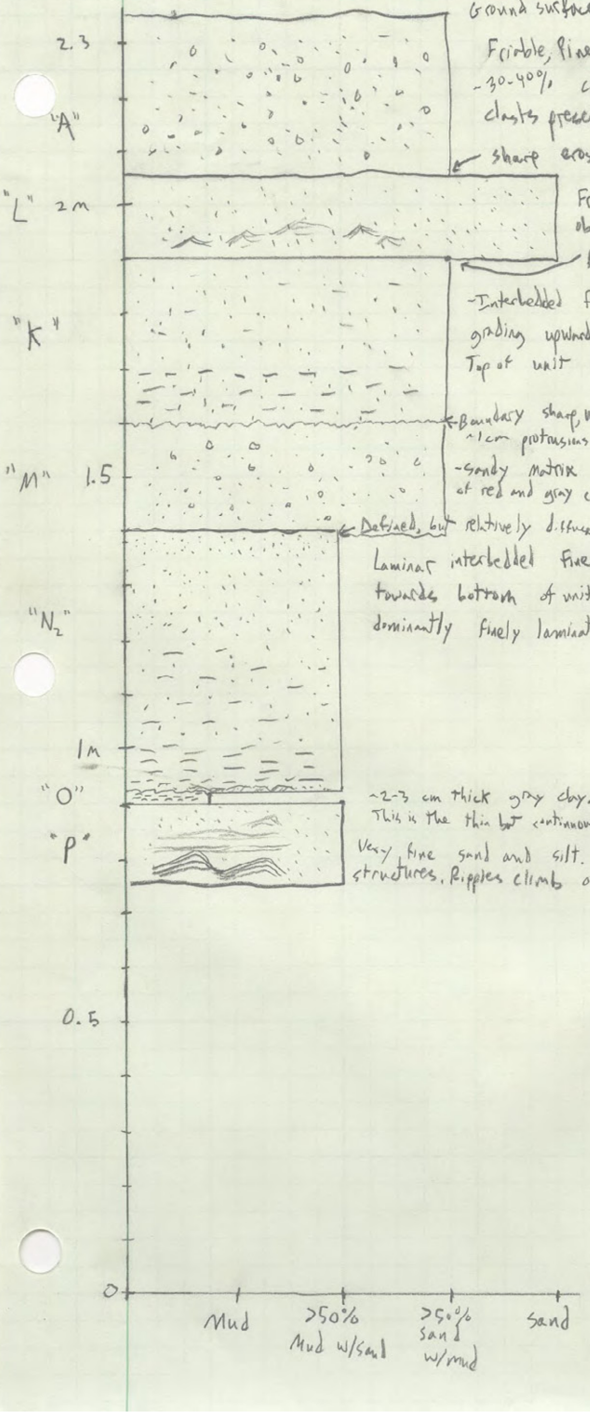
Mostly mud with layered sand, appears fluvial although no distinct forms are visible

Green River
Hardscrabble Trench

Station 18

9/22/15

Notes by
Angus Vaughan



Ground surface. Actually at 2.45 m

Friable, fine sand with no structure. Contains ~30-40% clasts of yellow/white sand. Some red clay clasts present towards top of unit. Blocky, brecciated

← sharp erosional contact

Friable, fine sand deposit. Ripple forms present, not obviously climbing in one direction

← Boundary well defined. Doesn't appear to be erosional

-Interbedded fine sand and clay. Bottom 10 cm dominantly clay, grading upwards into more sand, with some gray (silt/clay?) laminations. Top of unit quite cohesive

← Boundary sharp, well defined in some places, more diffuse in others. Boundary wavy ~1cm protrusions of "K" into top of "M"

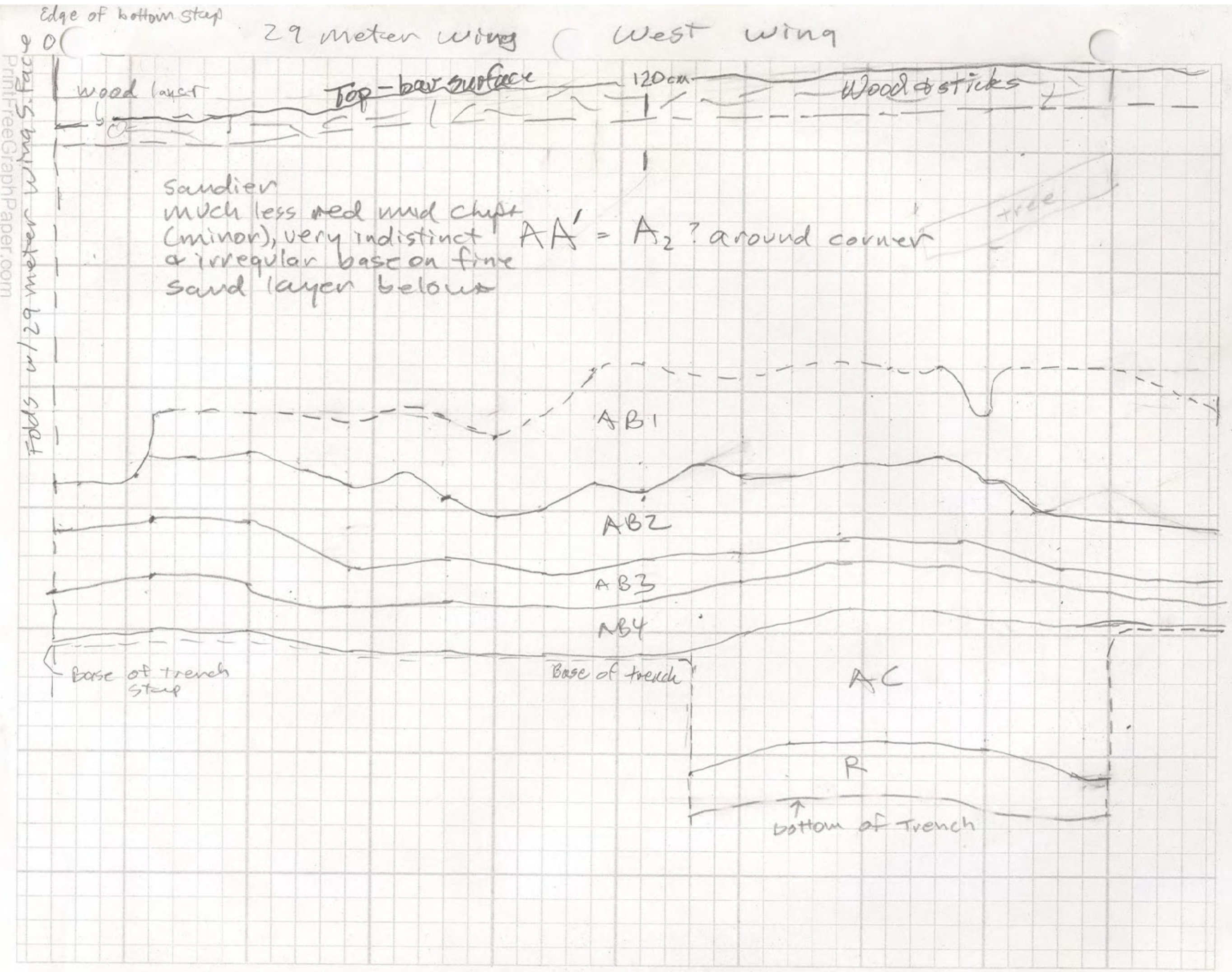
-Sandy matrix w/ little form (massive). ~10-20% clasts (subrounded to angular) of red and gray clay, max 1-2 cm diam. Unit contains ~ 3-5 cm thick red clay layer From stations 18-20

← Defined, but relatively diffuse boundary

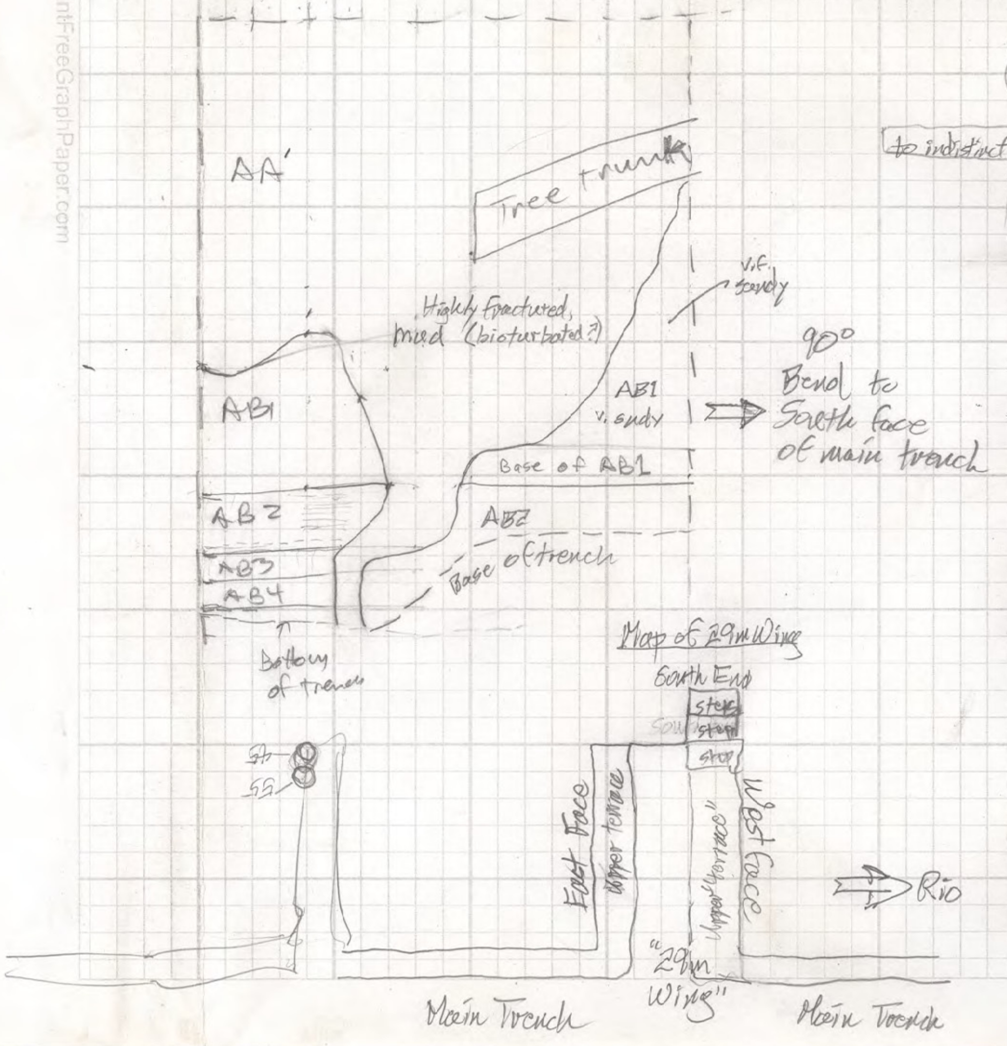
Laminar interbedded fine sand and silt/clay. Predominantly clay towards bottom of unit, grades upward into sand dominantly. Top ~15 cm dominantly finely laminated fine sand.

~2-3 cm thick gray clay. Sharp erosional contact below sharp but variably wavy contact above. This is the thin but continuous layer lying on top of "O". Contains few minor lenses of sand

Very fine sand and silt. Alternates between laminar bedding and ripple structures. Ripples climb offshore, critically. Package truncated sharply on shoreward side by "O"


Edge of bottom step
0
29 meter wing
West wing
Folds w/29 meter wing S face
wood layer
Top-bar surface
120cm
Wood & sticks
tree
sandier
much less red mud chips
(minor), very indistinct
& irregular base on fine
sand layer below
AA' = A2 ? around corner
AB1
AB2
AB3
AB4
Base of trench step
Base of trench
AC
R
bottom of Trench

29 meter wing West wall cont.



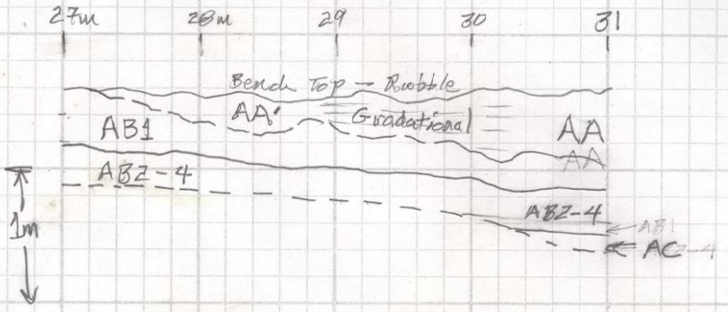
Notes:

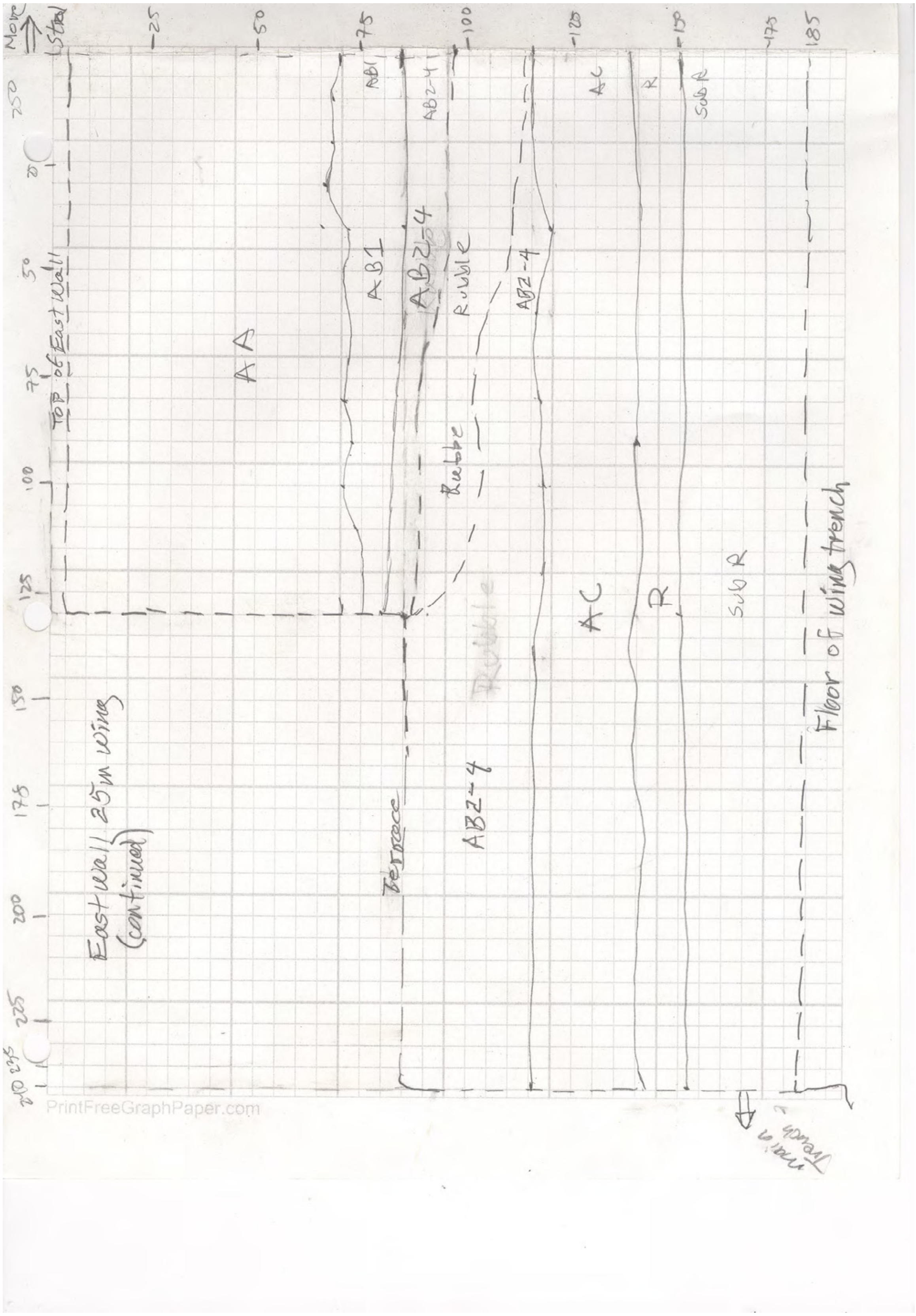
Unit AA – Uppmost unit of sequence. In south end of wing (29m) it is a distincly muddy unit w/ a sharp to indistinct base, irregular & possibly erosional. It contains discontinuous red-mud layers & mottles, some look like the fill root "burrows". Some sand lenses locally, but mostly mud & sndy mud (gry-brn) w/ lesser red mud.

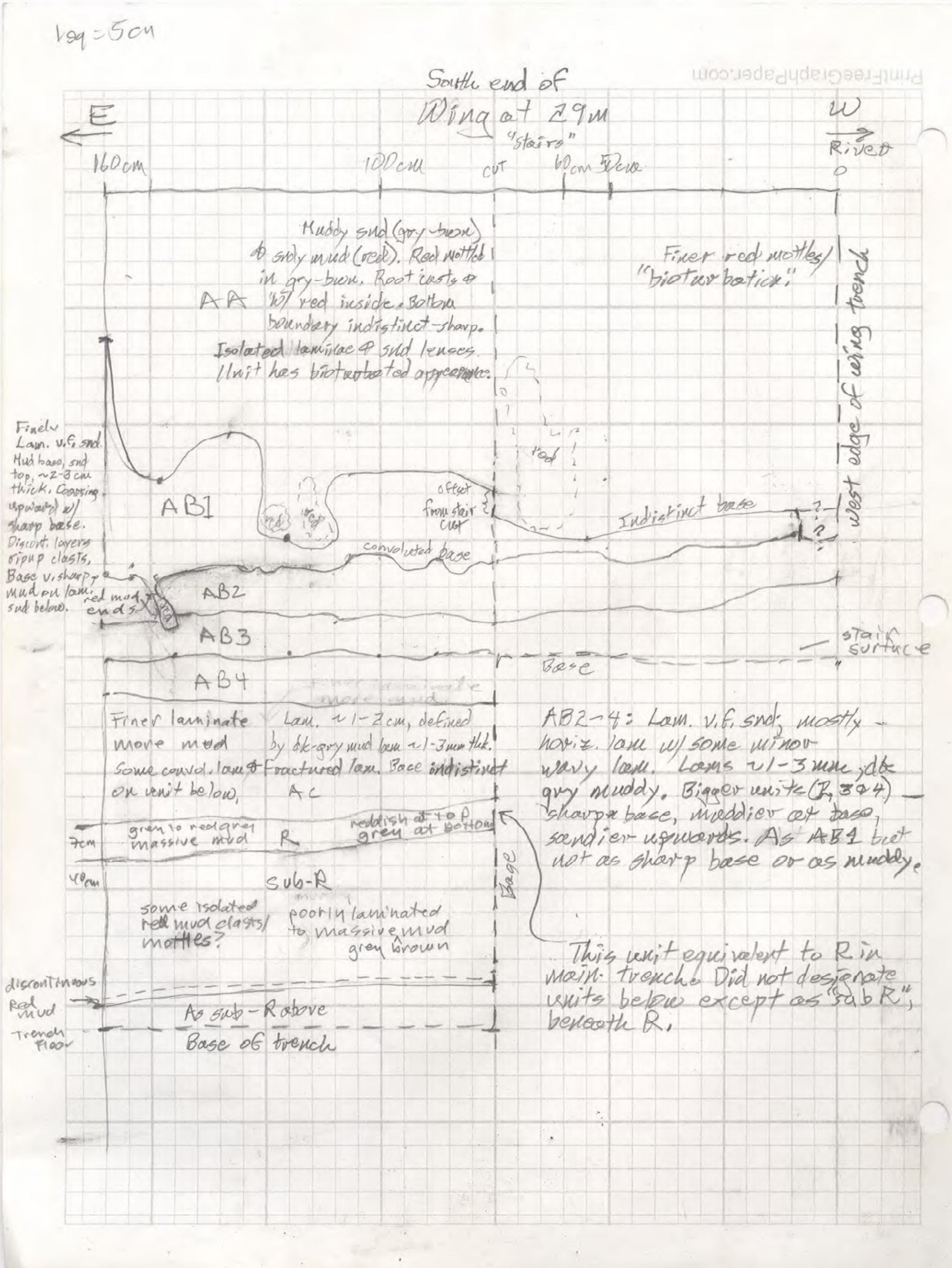
This unit changes in the W face of the wing trench. There it is sandier w/ much less red mud layers or chunks. So goes from "red-mud mottled unit to a lighter grey w/ small pieces of red mud & a brecciated/bioturbated texture. Base also becomes more irreg. & locally clearly eros. Some places near N end, at main trench, deep erosional cuts into lower units, w/ v. little red clasts. Mostly gry mud chips in cohesive (hard) gry mud–sndy mud matrix. East face has more red mud & more continuous, to more continuous layers. So, called w-face AA'. Change from red-dominated to gry dominated at w-edge of wing trench, on stairs, so not well "exposed". So, contact between AA & AA' not clear. May be erosional or may be gradational

North Face, Main Trench (Opposite 29m. wing

Sketch of relationship bet. AAprime + AA in south face of 29 m. wing
(how they Transform into each other)




Move ⇒ (Start)
25
50
75
100
120
150
175
185
250
50
75
100
125
150
175
200
225
235
240
Top of East Wall
East wall 25m wing (continued)
AA
AB1
AB2-4
Rubble
Rubble
Rubble
AB2-4
AB2-4
AC
AC
R
R
Sub R
Sub R
Terrace
Floor of wing trench
main trench ?
PrintFreeGraphPaper.com



1sq = 5cm

South end of Wing at 29m

Muddy snd (gry-brn) & sndy mud (red). Red mottled in gry-brn. Root casts & w/ red inside. Bottom boundary indistinct-sharp. Isolated laminae & snd lenses. Unit has bioturbated appearance.

Finer red mottles/ "bioturbation".

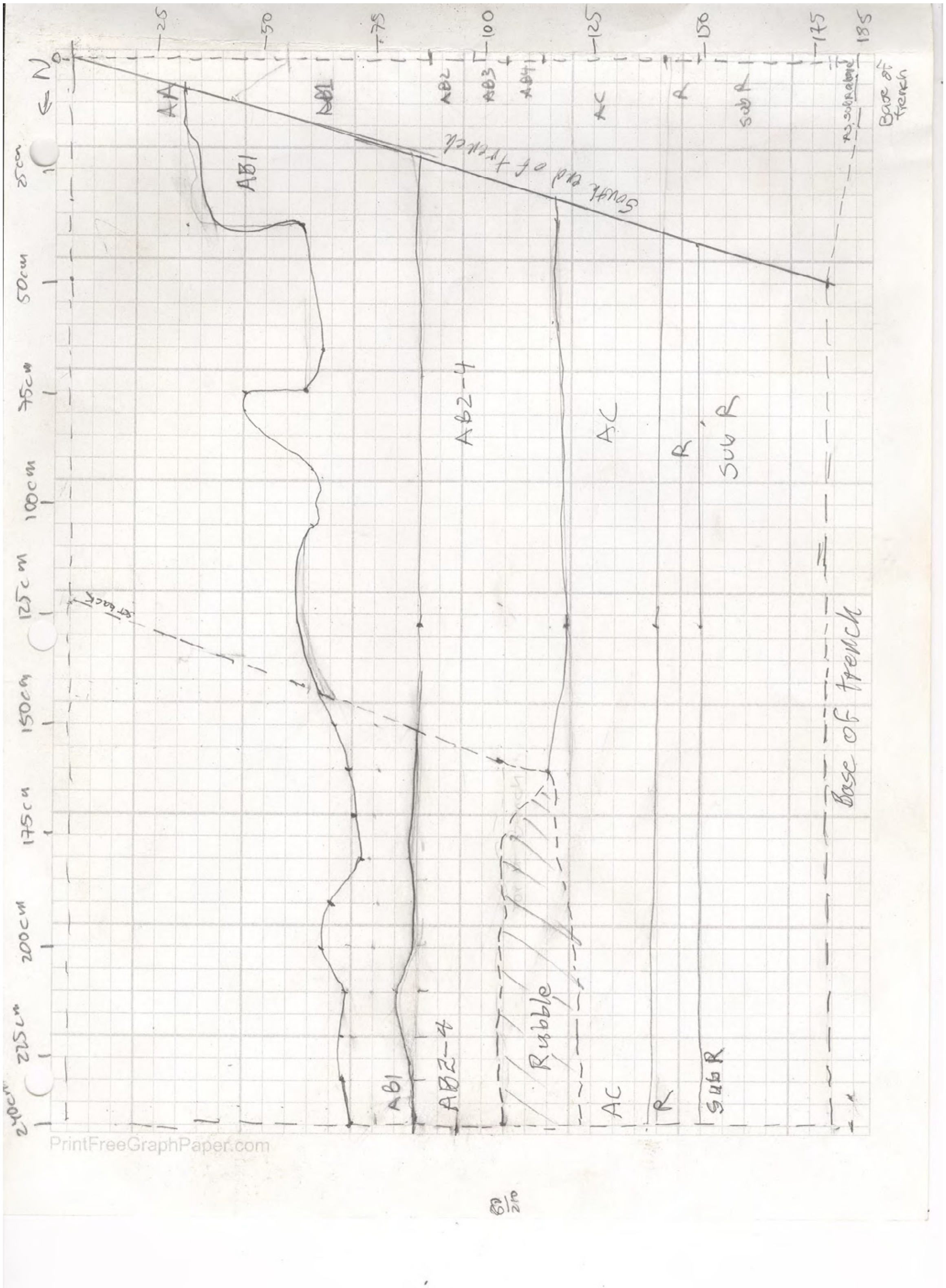
Finely Lam. v.f. snd. Mud base, snd top, ~2-3 cm thick. Coarsing upwards w/ sharp base. Discont. layers ripup clasts, Base v. sharp, mud on lam. snd below.

AB2-4: Lam. v.f. snd, mostly horiz. lam w/ some minor wavy lam. Lams ~1-3 mm, dk gry muddy. Bigger units (2, 3 & 4) sharp base, muddier at base, sandier upwards. As AB1 but not as sharp base or as muddy.

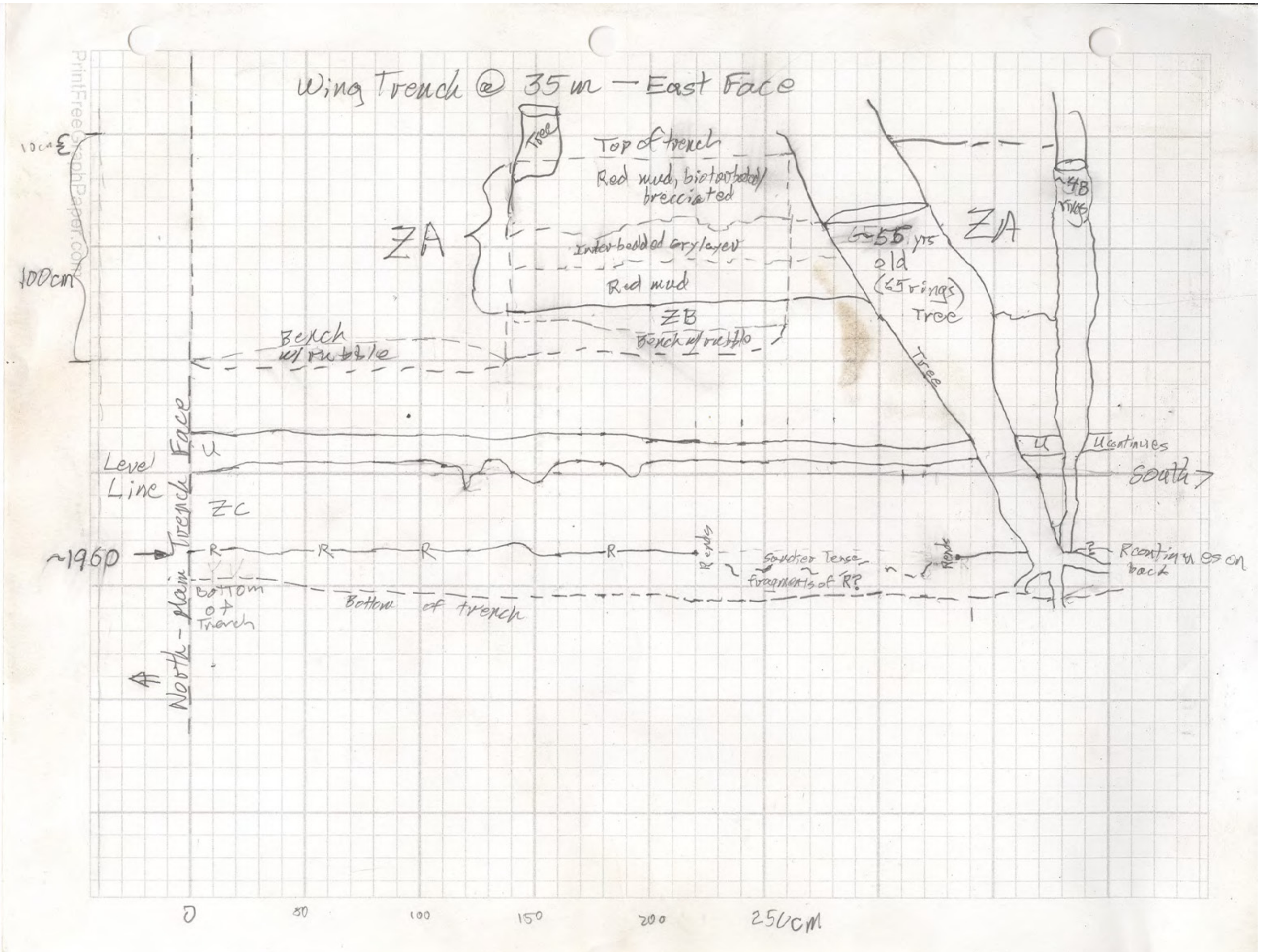
Finer laminate more mud

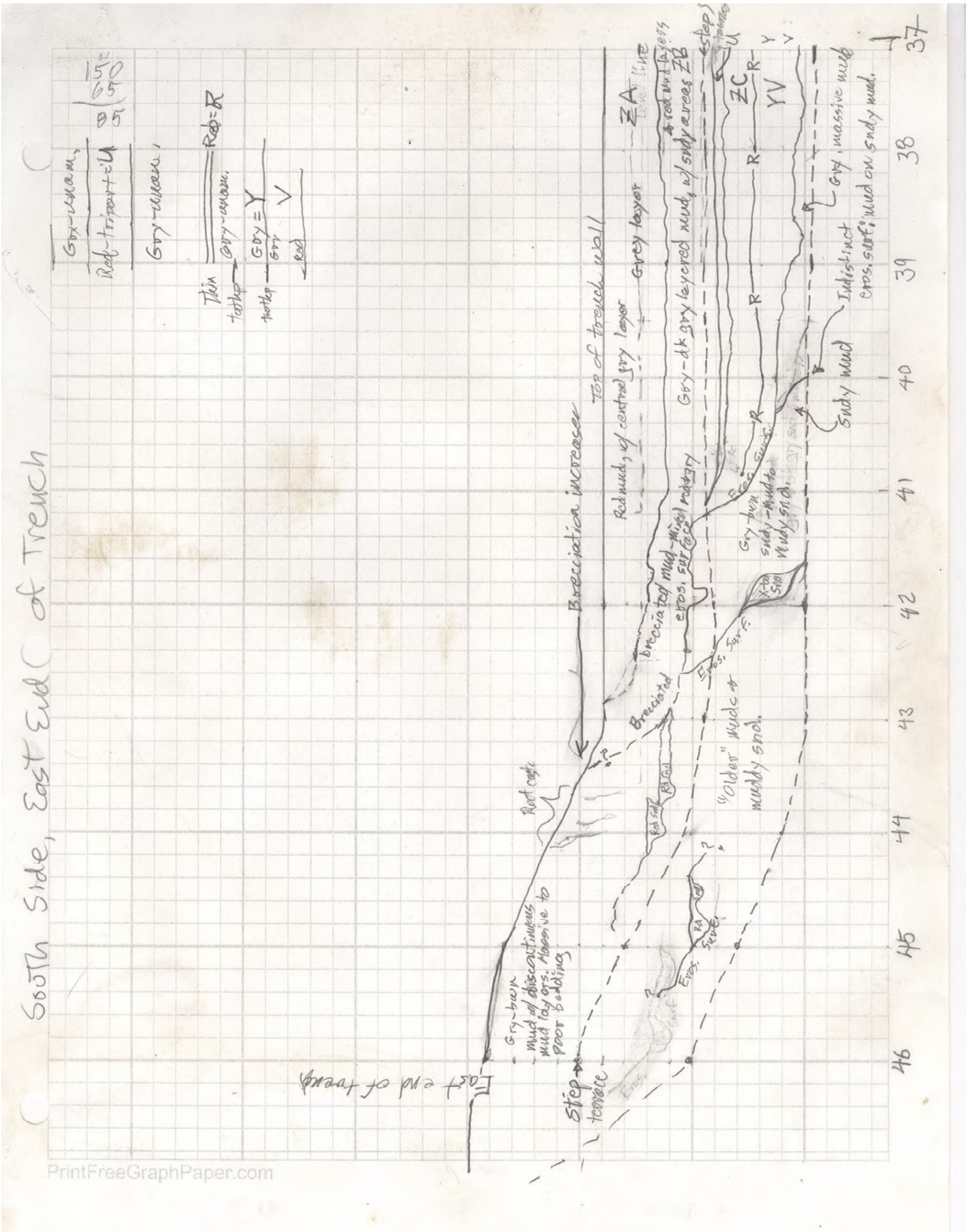
Lam. ~1-2 cm, defined by dk-gry mud lam ~1-3 mm thk. Some convol. lam & Fractured lam. Base indistinct on unit below.

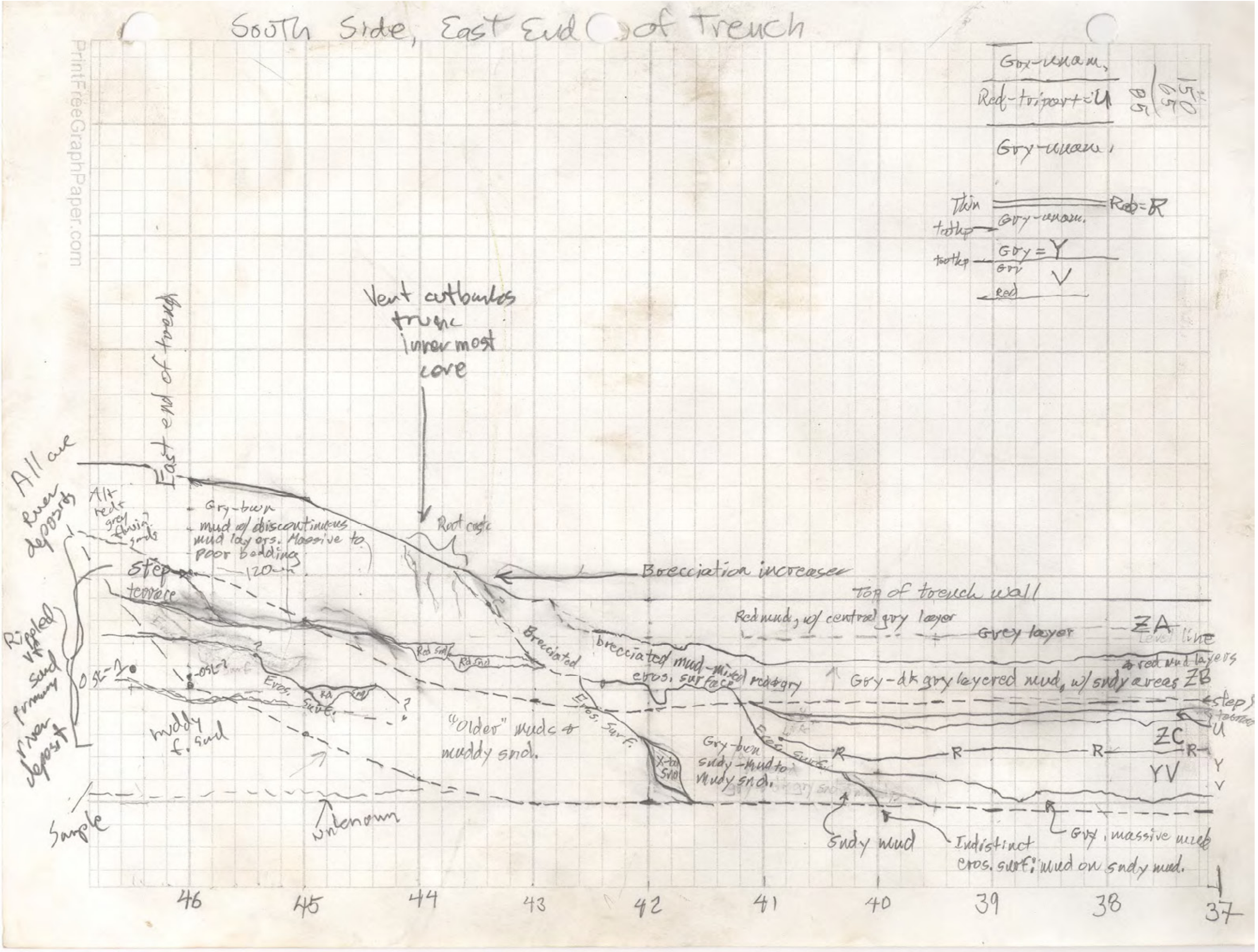
This unit equivalent to R in main trench. Did not designate units below except as "sub R", beneath R.



N
0
25
50
75
100
125
150
175
185
25cm
50cm
75cm
100cm
125cm
150cm
175cm
200cm
225cm
240cm
AA
AB1
AB2
AB3
AB4
AC
R
Sub R
Base of trench
South end of trench
AB2-4
Rubble
rock
Base of trench
PrintFreeGraphPaper.com

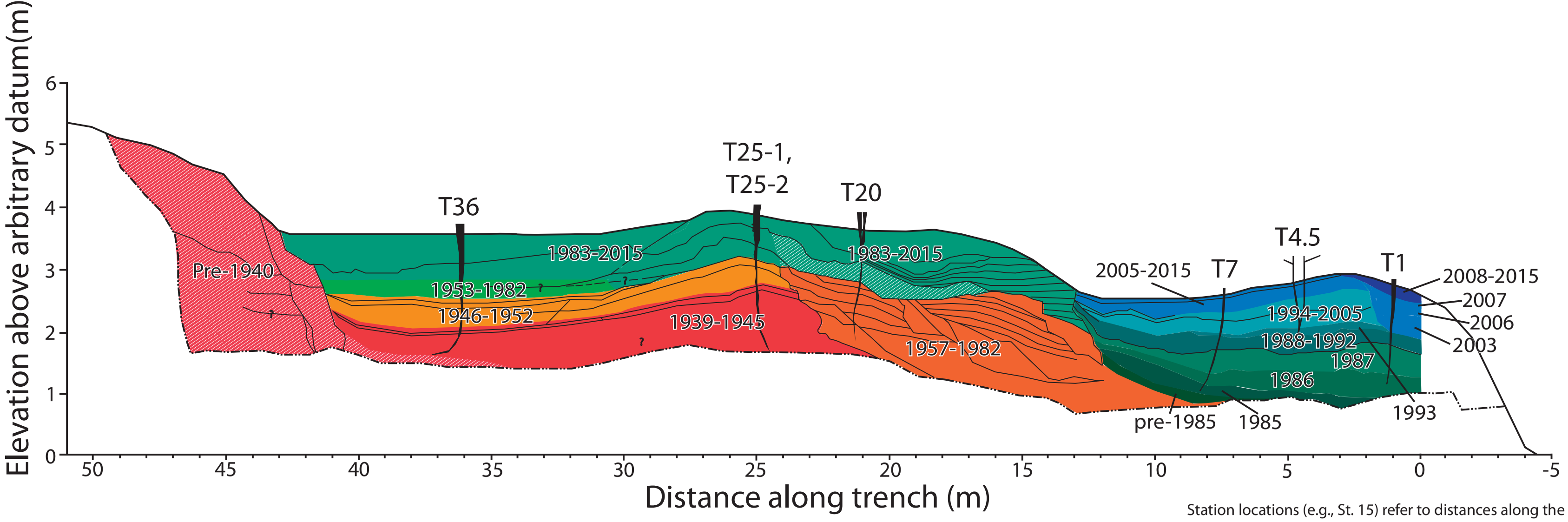

Wing Trench @ 35m — East Face
Tree
Top of trench
Red mud, bioturbated/ brecciated
Interbedded cry layer
Red mud
ZA
ZB
Bench w/ rubble
Bench w/ rubble
~55 yrs old (65 rings) Tree
ZA
~48 rings
Tree
10cm
100cm
U
Level Line
North - main trench face
ZC
~1960
R
R
R
R
R
R ends
Sandier Tense fragments of R?
R ends
R
? R continues on back
U
U continues
South
Bottom of trench
Bottom of trench
0
50
100
150
200
250cm


South Side, East End of Trench
Gry-cream,
Red transport = U
Gry-cream
Thin
Red = R
Gry-cream
Gry = Y
Gry V
Red
150
65
85
Top of trench wall
Brecciation increases
Top of central gry layer
Grey layer
ZA
Redmud, w/ central gry layer
Gry-dk gry layered mud, w/ sndy areas
ZB
Step
U
ZC
R
YV
Y
V
Gry, massive mud
Indistinct eros. surf: mud on sndy mud.
Sndy mud
Brecciated mud-mud eros. surface
Eros. Surf.
Gry-brn sndy-mud to muddy snd.
X-bd snd
Brecciated
"Older" mud & muddy snd.
Root casts
Gry-brwn mud w/ discontinuous mud lay ers. Massive to poor bedding
East end of trench
Step
terrace
37
38
39
40
41
42
43
44
45
46
PrintFreeGraphPaper.com

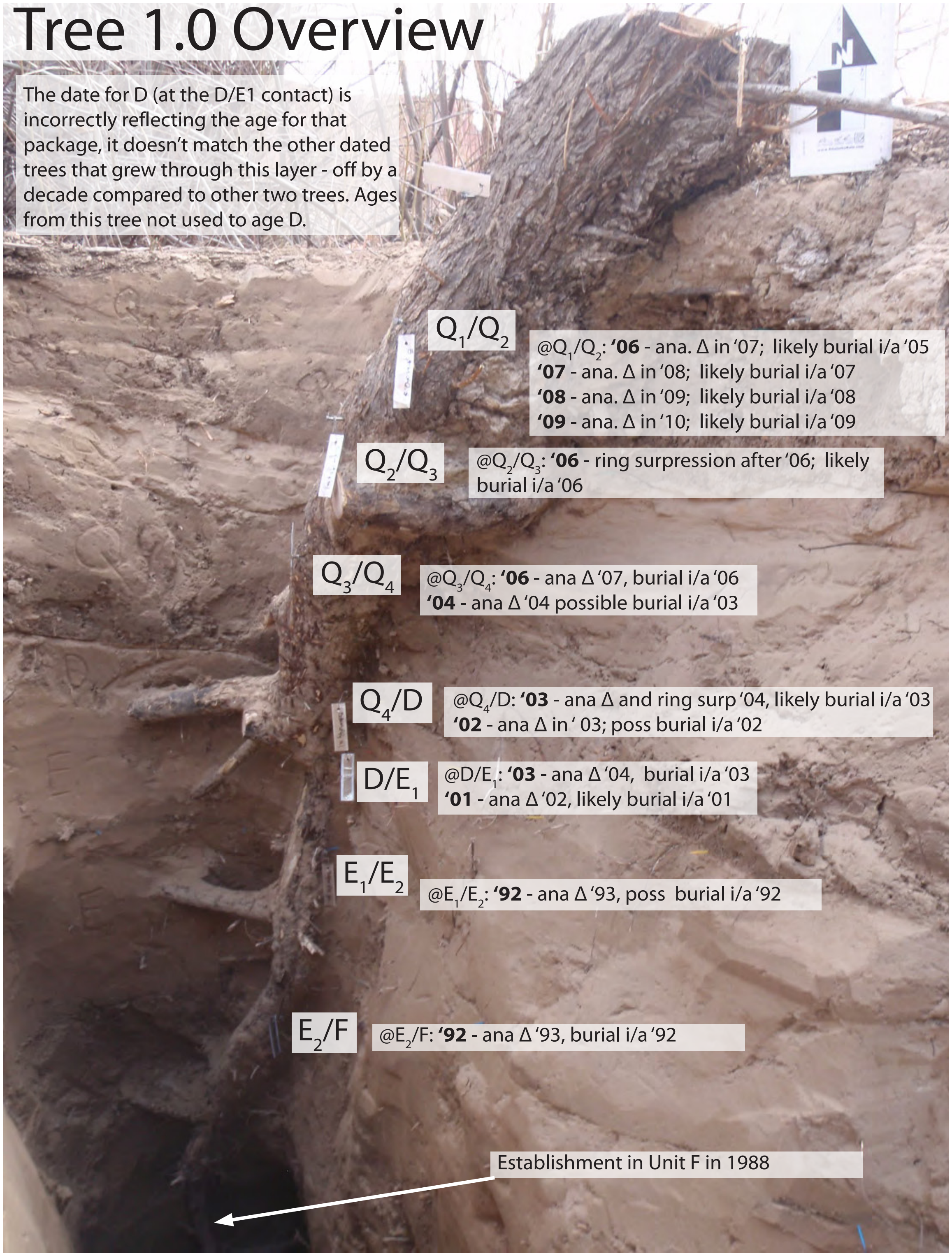

South Side, East End of Trench
Gry-unam,
Red-tripart=U
150
65
85
Gry-unam,
Thin
Red=R
tothp
Gry-unam.
Gry=Y
tothp
Gry
V
Red
Vent outbursts
trunc
innermost
core
East end of trench
All are
River
deposits
Alt
red+
grey
fluvial
snds
Gry-brn
mud w/ discontinuous
mud layers. Massive to
poor bedding
120
Root casts
Step
terrace
Brecciation increases
Top of trench wall
Red mud, w/ central gry layer
Grey layer
ZA
Level line
Brecciated
brecciated mud-mixed red+gry
eros. surface
& red mud layers
Gry-dk gry layered mud, w/ sndy areas
ZB
step
terrace
U
ZC
R
R
R
R
Y
YV
V
Red snd
Red snd
Rippled
vf
sand
primary
river
deposit
OSL-2
OSL-?
Eros.
Surf.
Rd
Snd
?
?
"Older" muds &
muddy snd.
Eros. Surf.
X-bd
Snd
Gry-brn
sndy-mud to
mudy snd.
Eros. Surf.
muddy
f. snd
Sample
unknown
Sndy mud
Indistinct
eros. surf; mud on sndy mud.
Gry, massive mud
46
45
44
43
42
41
40
39
38
37

APPENDIX B. DENDROGEOMORPHIC DATA

Tree locations in the trench and floodplain deposit ages



Station locations (e.g., St. 15) refer to distances along the trench from station 0, at the offshore edge of the trench.



Tree 1.0 Overview

The date for D (at the D/E1 contact) is incorrectly reflecting the age for that package, it doesn't match the other dated trees that grew through this layer - off by a decade compared to other two trees. Ages from this tree not used to age D.

@Q_1/Q_2: **'06** - ana. Δ in '07; likely burial i/a '05
'07 - ana. Δ in '08; likely burial i/a '07
'08 - ana. Δ in '09; likely burial i/a '08
'09 - ana. Δ in '10; likely burial i/a '09

@Q_2/Q_3: **'06** - ring surpression after '06; likely burial i/a '06

@Q_3/Q_4: **'06** - ana Δ '07, burial i/a '06
'04 - ana Δ '04 possible burial i/a '03

@Q_4/D: **'03** - ana Δ and ring surp '04, likely burial i/a '03
'02 - ana Δ in ' 03; poss burial i/a '02

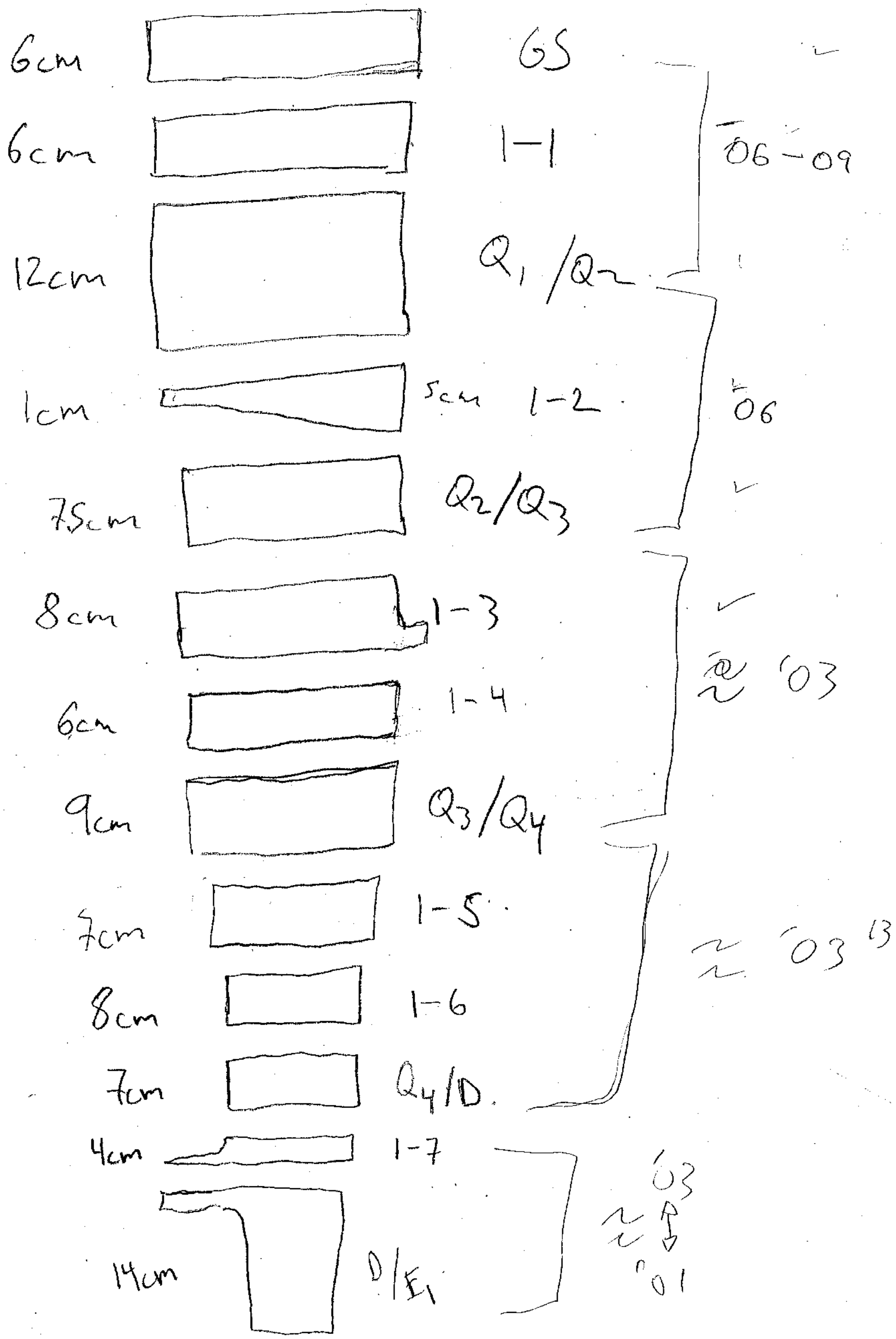
@D/E_1: **'03** - ana Δ '04, burial i/a '03
'01 - ana Δ '02, likely burial i/a '01

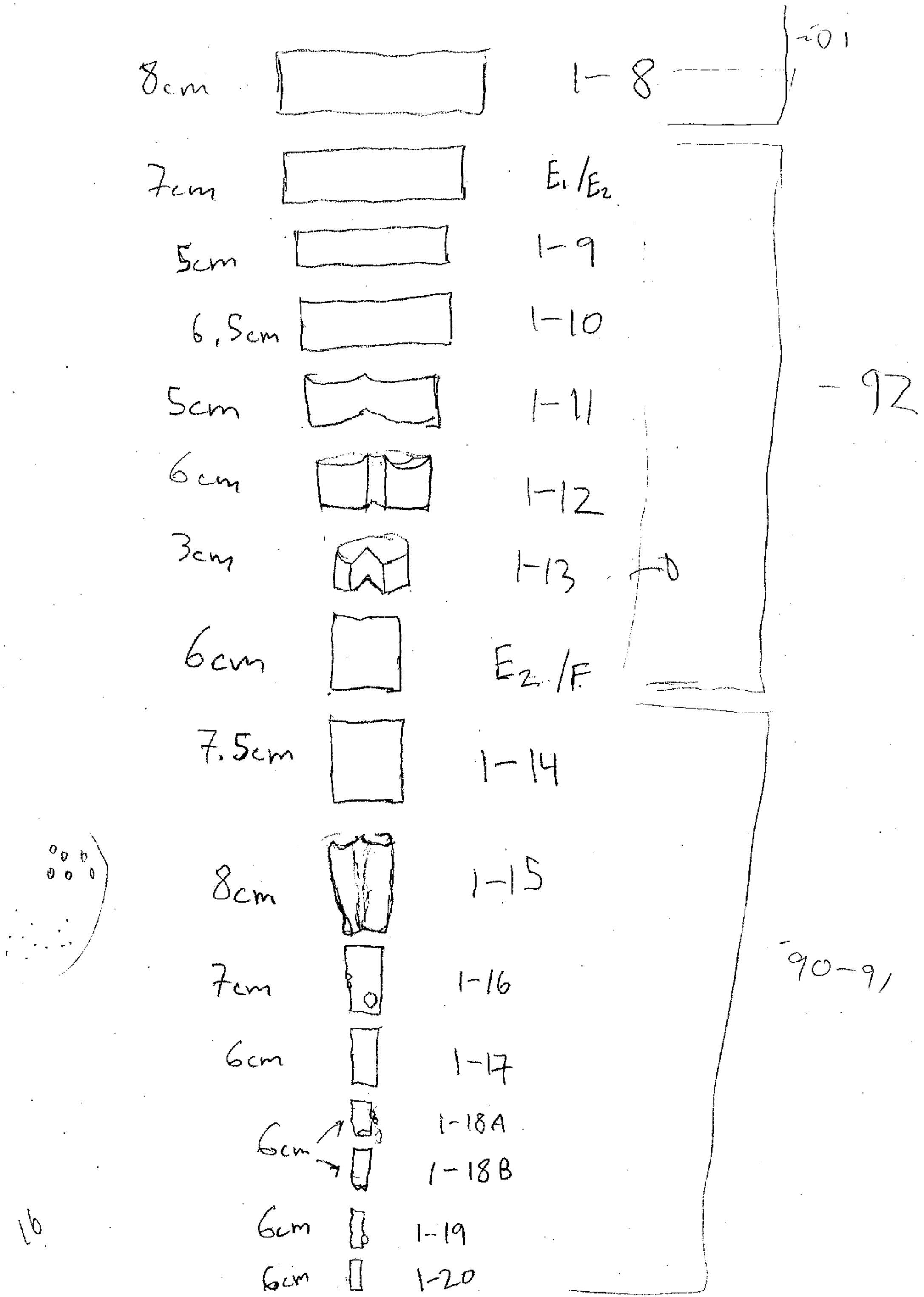
@E_1/E_2: **'92** - ana Δ '93, poss burial i/a '92

@E_2/F: **'92** - ana Δ '93, burial i/a '92

Establishment in Unit F in 1988

Tree stil stretch 45900




8cm
1-8
-01
7cm
E1/E2
5cm
1-9
6,5cm
1-10
5cm
1-11
-92
6cm
1-12
3cm
1-13
6cm
E2/F
7.5cm
1-14
8cm
1-15
7cm
1-16
90-91
6cm
1-17
6cm
1-18A
1-18B
6cm
1-19
6cm
1-20
10

Ring Reader: Alex Walker

Reading Date: 6/7/16

Site ID: Hardscrabble

Collection Date: cut June 2015

Removed April 2016

Tree ID: 1.0

Slab ID: G5

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes: ~~2011? on outer radius?~~

2015: outer most ring read

2012: rel large
2011: rel large
2010: rel small
2009: mid yr xyl band
2008: mid yr xyl band
2007: mid yr xyl band
2006:
2005:
2004: mid yr xyl band
2003:
2002: mid yr xyl band
2001: rel large
2000: rel large
1999:
1998:
1997: rel large
1996: faint mid yr xyl band
1995: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 6/7/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 1

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2015: outermost ring read

2012: rel large (is 2011 not also rel large?

2011: rel large

2010: rel small, mid yr xyl band

2009: rel large, mid yr xyl band ; ana Δ i/a 2010, poss burral i/a 2009

2008: mid yr xyl band

2007: rel large, mid yr xyl band

2006: rel large, ~~mid yr xylem band~~

2005: rel large

2004: rel large, mid yr xyl band

2003: ~~mid yr xyl band~~

2002: mid yr xyl band

2001: ~~is this possibly a mid yr xyl band?~~ ~~mid yr xyl band~~ rel large

2000: rel ~~large~~

1999: ~~rel large~~

1998:

1997: rel large

1996: mid yr, xyl band

1995: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 6/7/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 60

Slab ID: Q1/Q2

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

- A second stem w/ pith can be seen within the top of this slab

2014: outermost ring read
2013:
2012: rel large
2011: rel large
2010: rel small, mid yr xyl band
2009: mid yr xyl band
2008: mid yr xyl band
2007:
2006: rel large
2005: rel large
2004: mid yr xyl band
2003:
2002: mid yr xyl band
2001: rel large
2000: rel large
1998:
1997: rel large
1996: faint mid yr xyl band
1995: ⊙ w/ pith

} ana Δ in '07, '08, '09, or '10
likely burial i/a '06, '07, '08, or '09

SEE OTHER SHEET

Ring Reader: Alex Walker

Reading Date: 6/7/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.Q

Slab ID: Q1/Q2

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

-A second stem w/ pith can be seen within the top of this slab.

Wood anatomy change notes:

2014: outer most ring read

2012: rel large
2011: rel large
2010: rel small (about same size as '12)?
2009: rel large
2008: rel small
2007: rel large
2006: rel small
2005: rel large
2004: rel large
2003: rel large
2002: midyr xyl band
2001:
2000: mid yr xyl band, rel small compared to surrounding
1999: rel large
1998: rel large
1997:
1996:

1995: rel large
1994: rel large (mid year xyl?)
1993: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 6/7/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: Q_2/Q_3

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2014: outermost ring read
2012: rel large
2011: rel large
2010: rel small
2009: rel large, mid yr xyl band
2008: mid yr xyl band
2007: mid yr xyl band
2006: rel large ; ring suppression after '06 ; likely burial i/a '06
2005: rel large
2004: mid yr xyl band
2003:
2002: mid yr xyl band
2001: rel large
2000: rel large
1999:
1998: rel small
1997: rel large
1996: innermost ring read

possible
'95
'94
'93
'92 0

Ring Reader: Alex Walker
Reading Date: 6/7/2015
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 1.0
Slab ID: 2

Ring Counts/Notes:

I think that the stems switch from the previous slab to this one

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2014: outer most ring read

2012: rel large
2011: rel large
2010: rel small
2009: mid yr xyl band
2008: mid yr xyl band
2007: mid yr xyl band
2006: rel large Δ i/a 2007; poss burial i/a 2006
2005: rel large
2004: faint mid yr xyl band
2003: rel large
2002: mid yr xyl band
2001: rel large
2000: rel large
1999:
1998: mid yr xyl band
1997: rel large
1996:
1995: innermost ring read, rotted inside of this ring, 95 mostly rotted out no ⊙ seen
~~1994: inner most ring read, mostly rotted, no ⊙ seen~~

Ring Reader: Alex Walker

Reading Date: 6/7/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 3

Ring Counts/Notes:

—some of the radius show better evidence of burial than others, area near pencil lines seems to show burial the best

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2014: outer most ring read
2012: rel large
2011: rel large
2010: rel small
2009: midyr xyl band, ana Δ '10, possible burial i/a '09
2007: midyr xyl band. ;

2006: rel large ; ring supp. and ana Δ after '06; likely burial i/a '06
2005: rel large
2004: ~~rel small~~, midyr xyl band
2003 :
2002: midyr xyl band
2001: rel large
2000: rel large
1999: rel large
1998:
1996: Begin rot; damage sustained to stem i/a '95/'96

rot obscured
'95
'94
'93
'92 w/①

Ring Reader: Alex Walker

Reading Date: 6/7/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 4

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2010: Outer most ring read
2009: rel large
2008
2007: rel small
2006: rel large, ana Δ '07, likely burial i/a 06
2005: rel large
2004: mid yr xyl band
2003: ~~rel small, mid yr xyl band~~
2002: mid yr xyl band
2001: ~~mid yr xyl band~~ rel large
2000: rel large
1999:
1998:
1997: rel small
1996: indistinct on some portions of circumference
1994: mid yr xyl band [illegible]
[illegible]
[illegible]
1991: ⊙ w/ pith, mostly rotted
(or '91 [illegible])

Ring Reader: Alex Walker

Reading Date: 6/8/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 5

Ring Counts/Notes:

potential other stem on this slab

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2007: outer most ring read

2006: rel large, ana Δ '07, likely burial i/a '06

2005: rel large ~~+ ana Δ '06, poss. burial i/a '05~~

2004: mid yr xyl band

2003: Ana Δ in 2004; poss burial i/a 2003

2002: mid yr xyl band

2001: rel large

2000: rel large

1999:

1998:

1997:

1996: rel small

1995: rel small

1994: mid yr xyl band

1993: partially rotted

1992: partially rotted

1991: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 6/7/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: Q3/Q4

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2010: outer most ring read

2006: rel large →, ana Δ '07, ~~Likely~~ burial i/a '06

2005: rel large ; ~~ana Δ '06, poss burial i/a '05~~

2004: rel small comp to 06 + 05, faint mid yr xyl band

2003: rel large ; ana Δ '04; poss burial i/a '03

2002: mid yr xyl band

2001: rel large

2000: rel large

1999: ~~rel large~~

1998: rel small

1997: rel small, inner most ring read, rotted inside of this & hard to determine

~~1996: rel small~~

~~1995: inner most ring read~~

~~below this, ring are rotted and preliminary somewhat~~ unknown ~~and uncer~~tain

?
~~1994:~~
~~1993: rel large~~
~~1992: rel large~~
~~1991: rel large~~
~~1990: ⊕ w/pith~~

☆ Cut 6 in half ☆

Ring Reader: Alex Walker

Reading Date: 6/8/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 6 A

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2007: outermost ring read
2006: rel large
2005: rel large
2004: rel small, mid yr xyl band, ring suppression ~~ana Δ '05, pos burial i/a '04~~
2003: rel large, ana Δ '04, poss burial i/a '03
2002: mid yr xyl band
2001: rel large.
2000: rel large
1999: rel large
1998: rel large
1997: rel large
1996: rel small
1995: rel small
1994: rel small, mid yr xyl band
1993: ~~mid yr xyl band~~ rel large
1992 rel large
1991: ⊙ w/ pith

Ring reader: Alex Walker

Reading Date: 6/17/16

Site ID: Hardscrabble

Collection Date: cut 6/2015 removed 4/2016

Tree ID: 1.0

Slab ID: 6B

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2004: Outermost ring read
2003: ring surp + ana Δ '04, likely burial i/a '03
2002: mid yr xyl band; ana Δ in '03; possible burial i/a 2002
2001:
2000:
1999:
1998:
1997: rel large
1996: rel small
1995: rel small
1994: rel small, mid yr xyl band
1993: rel large
1992:
1991: ⊙ w/ pith

Ring Reader: Alex Walker

Site ID: Hard scrabble

Tree ID: 1.0

Reading Date: 6/9/16

Collection Date: June 2015

Slab ID: 7

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2004: outer most ring recd

2003: rel large, ana Δ + ring surp '04, burial i/a '03

2002: mid yr xyl band

2001: rel large

2000: rel large - mid yr xyl band

1998: rel large

1997: rel large

1996: rel small

1995: rel small

1994: mid yr xyl band → I think that this is 50/50 a new ring

1993: rel large comp to '94

1992: rel large

1991: ⊙ w/ pith

~~1990: mid yr xyl band~~

~~1989: ⊙ w/ pith~~

Ring Reader: Alex Walker

Reading Date: 6/8/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: Q4/1D

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2004: outer-most ring read

2003: rel large, anaΔ + ring surp '04, likely burial i/a '03

2002: mid yr xyl band; anaΔ in '03; poss burial i/a '02

2001: rel large

2000: rel large - mid yr xyl band?

1998

1997: rel large

1996: rel small

1995: rel small

1994: rel small, mid yr xyl band — possible new ring? looks like a false ring farther

1993: rel large comp to '94

1992: rel large

1991: ⊙ w/ pith

~~1990:~~

~~1989: ⊙ w/ pith~~

Rev A. Walker
6/15/16

Ring Reader: Bradley Collette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: P/E1 - A

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2004: Outer most ring read

2003: ana Δ '04, basal i/a '03

2002: mid yr xyl band

2001: rel large

2000: rel large mid yr xyl band

1999: , ~~mid yr xyl band, pinches out on t radius~~

1998:

1997:

1996: rel small

1995: rel small

1994: rel small, mid yr xyl band

1993: rel large comp to '94

1992: rel large comp to '94

1991: ① w/ pith

~~1990: mid xyl band on t radius~~

~~1989: ① w/ pith~~

Ring Reader: Alex Walker

Reading Date: 6/10/15

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1

Slab ID: D/E1-B

☆ - poss sand the bottom of this ☆

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2004: outermost ring read
2003: ~~outermost ring read~~ ana Δ + ring surp '04, burial i/a '03
2002: ~~outermost ring read~~
2001: ana Δ '02, possible burial i/a '01
2000: rel large, mid yr xyl band
1999: ~~mid yr xyl band~~, rel large
1998: rel large
1997:
1996: rel small
1995: rel small
1994: mid yr. xyl band
1993: relsmall comp to '95/'94
1992: mid yr xyl band
1991: ⊙ w/pith
~~1990: mid yr xyl band~~
~~1989: ⊙ w/pith large~~

Ring Reader: Alex Walter

Site ID: Hard scrabble

Tree ID: 1.0

Reading Date: 6/17/16

Collection Date: cut June 2015 removed Apr 2016

Slab ID: D/E$_1$ -C

Ring Counts/Notes:

File Name:

\# of radii measured

Series ID:

Wood anatomy change notes:

2004: Outermost ring read

2003: ring surp '04 burial i/a '03

2002: Not seeing the mid yr xyl spotted above

2001: ana Δ '02, likley burial i/a '01

2000:

1999: rel large

1998

1997:

1996: rel small comp to '97

1995: rel small

1994: rel small

1993: rel small, mid yr xyl band

1992: rel large

1990: ⊙ w/pith

Ring Reader: Bradley Collette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 8

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2004: Outer most ring read
2003: ~~aaa Δ + ring sur 04, burial i/a '03~~
2001: aaa Δ '02, likely burial i/a '01
2000: Rel. large, mid yr xyl band
1999: ~~mid yr xyl band - faint + decreasing~~ rel large
1998: ~~Rel. large~~
1997: ~~Rel small~~
1996: v. small, almost surp w/ '97
1995: Rel small ~~v. small, almost surp w/ '96~~
1994: Rel. Small
1993: Rel. large comp to '94/'95
1992: Rel. Small — ~~faint~~ mid yr xyl band ; poss aaa Δ '93 ; poss burial i/a '92
1991: Rel large on 1 radius, small on another aaa Δ '93; poss burial
1990: ⊙ w/ pith
~~1989: rel large~~
~~1988: ⊙ w/ pith~~

Ring Reader: Bradley Collette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: E1/E2

Ring Counts/Notes:

File Name:

\# of radii measured

Series ID:

Wood anatomy change notes:

~~2001: Outer most ring read~~
~~2000:~~
~~1999:~~
~~1998: Rel. Large~~
~~1997: Rel. Small~~
~~1996:~~
~~1995: Rel. Small~~
~~1994: Rel. Small~~
~~1993: Rel. Small~~

I don't think these can be easily determined

1992: outermost ring read
1990: Rel. small, mid yr xyl band
1989: rel large, mid yr xyl band on 1 radius
1988: ⊙ w/pith

I like this one better

2004: outermost ring read
2003: ~~[illegible] '04, burial i/a '03~~
2002:
2001: rel large, ~~[illegible] '02, poss burial '01~~
2000: rel large, mid yr xyl band
1999: rel large
1998:
1997:
1996: rel small
1995:
1994:
1993:
1992: mid yr xyl band
1991: and in '93; poss burial i/a '92
1990: ⊙ w/pith

Rev Alex W 6/10/16

Ring Reader: Bradley Gillette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 9

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~2001: Outermost ring read~~
~~2000:~~
~~1999:~~
~~1998: Rel. Large~~
~~1997: Rel Small~~
~~1996:~~
~~1995: Rel. Small~~
~~1994: Rel. Small~~
~~1993: Rel. Small~~

~~poss burial 94-99, ring surp and small, rings hard to define outside of '94~~

1994: ~~Rel. Small~~ outer most ring read, ring surp outside of this ring
1993: Rel. Large
1992: faint mid yr xyl band, rel small comp to '91 and '93; likely burial i/a '92
1991: rel large, ~~no xyl band seen~~
1990: ⊙ w/ pith

Review Alex W. 6/10/16

Ring Reader: Bradley Collette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 10

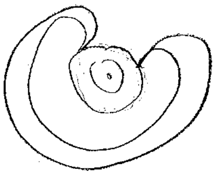
Slab ID: 10

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:



Wood anatomy change notes:

~~2001: Outer most ring read~~
~~2000:~~
~~1999:~~
~~1998: Rel. Large~~
~~1997:~~
~~1996:~~
~~1995: Rel. Small~~
~~1994: Rel. Small~~
~~1993: Rel. Small~~
1994: Outermost ring read, ring surp after this year, ~~poss burial 94-97,~~ ~~and Δ seen in '97?~~ ↳ ~~hard to read~~ in rings ~~years~~
1993: Rel. Large comp to '92
1992: rel small - still a faint mid yr xyl band; anaΔ '93; likely burial i/a '92
1991: rel large, faint mid yr xyl band on 1 radius; anaΔ '92; poss burial i/a '91
1990: ⊙ w/ pith

Ring reader: Alex Walker

Reading Date: 6/17/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 12-B

Ring Counts/Notes:

-Stems may switch here
↳ I actually think that the stems meet @ this slab

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1994: Outermost ring read

1993: rel small, ana Δ '94~~, likely burial i/a '93~~

1992: rel small, ~~ana Δ '93, likely burial i/a '92~~

↳ I think the burial event is i/a '92

1991: rel large, no wd yr xyl band seen

↳ innermost ring read, rotted inside of this point

↳ pith visible but rotted

[at least '88 ① can be inferred]

Ring Reader: Bradley Collette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 11

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Stem shows damage but pith is still visible, shows damage all the way to core.

Wood anatomy change notes:

~~2001: Outer most ring read~~
~~2000:~~
~~1999:~~
~~1998: Rel. Large~~
~~1997:~~
~~1996: Rel Large~~
~~1995: Rel. Small~~
~~1994: Rel. Small~~
~~1993: Rel. Small~~
1994: Outer most ring read, ring surp → ~~burial outside of this and Δ 1987, poss i/a 97??~~ ~~be skeptical of this~~
1993: rel small
1992: rel small, no xyl band seen; maΔ '93; likely burial i/a '92; also, damage incurred i/a '92
1991: rel large, faint xyl band mid yr; poss maΔ i/a '92; poss burial i/a '91
1990: ⊙ w/ pith

Rev

Ring Reader: Bradley Collette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 12 - A

Ring Counts/Notes:

File Name:

- Second stem seen here

# of radii measured

Series ID:

- pith gone

Wood anatomy change notes:

~~2001: Outer most ring read~~
~~2000: Rel. Small~~
~~1999:~~
~~1998: Rel. Large~~
~~1997: Rel. Large~~
~~1996: Rel. Small~~
~~1995: Rel. Small~~
~~1994: Rel. Small~~
~~1993: Rel. Small~~
1994: Outermost was read
1993: rel small, [anat Δ + ring surp '93, likely burial i/a '92]
1992: rel small
1991: rel large, mid yr xy band; ring supp. after '91; poss burial i/a '91
1990: ⊙, but pith is mostly gone - serious stem damage

Ring Reader: Bradley Collette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 13

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

→ still possible that stems switched in 12-A, 12-B, 13

→ stem damage, impacting pith and making it hard to read

Wood anatomy change notes:

~~1999: Outer Most Ring read~~
~~1998: Rel. Small~~
~~1997:~~
~~1996: Rel. Large~~
~~1995: Rel. Small~~
~~1994:~~

1994: Outermost ring read
1993: rel small, ~~ann Δ + ring supp '94~~
1992: rel small, mid yr xyl band-faint, ann Δ + ring supp '93 burial i/a '92
1991: rel large, faint mid yr xyl band ; poss burial i/a '91
1990: innermost ring read, mostly rotted, possible add'l ring added here, hard to see ⊙ w/pith

[at least '88 ⊙ can be inferred]

Reviewed Alex W.
6/10/16

Ring Reader: Bradley Collette

Reading Date: 6/9/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: E_2/F

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1999: Outer most ring read~~
~~1998:~~
~~1997: Rel. Large~~
~~1996: Rel. Large~~
~~1995: Rel. Small~~
~~1994:~~
~~1993: Rel. Small~~
~~1992: Rel. Small~~
~~1991: Inner most ring read, rotted out below this~~

1994: outer most ring read
1993: rel small
1992: rel small, ana Δ '93, burial i/a '92
1991: rel large, mid yr xyl band, inner most ring read
1990?: some wood visible, ⊙ rotted and gone
[poss ⊙ w/ pith @ 1998]

Ring Reader: Bradley Collette

Reading Date: 6/10/16

Site ID: Hard Scrabble

Collection Date: cut June 2015 removed Apr 2016

Tree ID: 1.0

Slab ID: 14

— poss add'l ring here or elongated center band

Ring Counts/Notes:

File Name:

\# of radii measured

Series ID:

Wood anatomy change notes:

1994: Outermost ring read

1993: rel small

1992: Rel. Small, ana Δ '93, burial i/a '92

1991: Rel. Large, mid yr xyl band; ring supp. in '92; poss burial i/a '91

1990? Innermost ring read, ⊙ rotted ad gone, ~20% of wood iside of '91 is visible, small amout of pith seen.

['88 ⊙ w/ pith]

Ring Reader: Bradley Collette

Reading Date: 6/10/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 15

Ring Counts/Notes: — Two other stems can be seen in this slab. They do not appear to extend downward

File Name:

# of radii measured

Series ID:

— substantial damage on this slab

Wood anatomy change notes: 1992: outermost ring read
1991: rel small
1990: rel small
1989: mid yr xyl band, rel large
1988: Innermost ring read, possibly another ring further in but the rot makes it hard to tell
⊙ rotted, totally gone

1994: outermost ring read — these pinch out on 1 radius
1993: rel small — these pinch out on 1 radius
1992: rel small, ~~mid yr xyl band~~, ana Δ'93, burial i/a '92

1991: innermost ring read, interior rotted, mid yr xyl band; ring supp in '92, likely burial i/a '91

1990? ~~Pith rotted + gone~~

'68 ⊙, possible pith visable

Ring Reader: Bradley Collette

Reading Date: 6/10/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 16

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1992: Outer most ring read.~~

~~1991: rel small, pinches out on 1 radius~~

~~1990: Rel. Small.~~

~~1989: Inner most ring read, too rotted further in to see any rings, mid yr xyl band~~

~~1988: (?) w/ pith, mostly rotted however~~

1992: outermost ring read

1991: rel large, mid yr xyl band, an a Δ '92, burial i/a '91

1990? some stemwood is visible, as well as pith, but the center is rotted ad cannot be read.

Ring Reader: Bradley Collette

Reading Date: 6/10/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 17

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1991: Outermost ring read~~
~~1990: Rel. Small~~
~~1989: possible mid yr xyl band, inner most ring read. Rot has removed any rings further in.~~

1992: outermost ring read

1991: rel large, mid yr xyl band, ~~inner most ring read~~ faint, ana Δ '92, burial i/a '91

1990: ~~appears to have mid yr xyl band~~

1989: ——→ ~~possible Θ w/pith~~, but interior is rotted and hard to read, 60-80% rotted

1988: Θ w/pith, but pith is unclear + hard to read.

Ring Reader: Bradley Collette

Reading Date: 6/10/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 18 A

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1992: Outer most ring read~~
~~1991:~~
~~1990: Rel. Small~~
~~1989: Rel. Large, mid year xyl band~~
~~1988: ⊙ w/ pith~~

1992: outer most ring read
1991: rel large, ~~ana Δ '92, burial i/a '91~~
1990: rel small, ana Δ '91, likely burial i/a '90, had to read 90/91 boundary on multiple radii
1989: rel large
1988: ⊙ w/ pith – ~~high uncertainty on # of years, possibly ± 1 year between 1990 & 1991.~~

Ring Reader: Bradley Lollette

Reading Date: 6/10/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1:0

Slab ID: 18 B

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1992: Outermost ring read~~
~~1991:~~
~~1990: Rel. Small~~
~~1989: Rel. Large~~
~~1988: ⊙ w/ pith~~

~~1989: poss wd yr xyl band, outermost~~
~~1988~~
~~1987: ⊙ w/pith~~

1992: outermost ring read
1991 anaΔ in '91; likely burial i/a '90; tiny ring in 1990
1989: rel large, ~~and Δ '90, burial i/a '89~~

1988: ⊙ w/pith

Ring Reader: Bradley Collette

Reading Date: 6/10/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 19

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1991: Outer most ring read
1990: Rel. Small
1989: Rel. large, mid year Xyl band
1988: ⊙ w/ pith

1991: Outermost ring read; tiny ~ merged with '91
1990-tiny [illegible], ana Δ 91, burial i/a '90
1989 mid yr xyl band
1988 ⊙ w/ pith

Ring Reader: Bradley Lollette

Reading Date: 6/10/16

Site ID: Hard Scrabble

Collection Date: June 2015

Tree ID: 1.0

Slab ID: 20

Ring Counts/Notes:

File Name:

# of radii measured

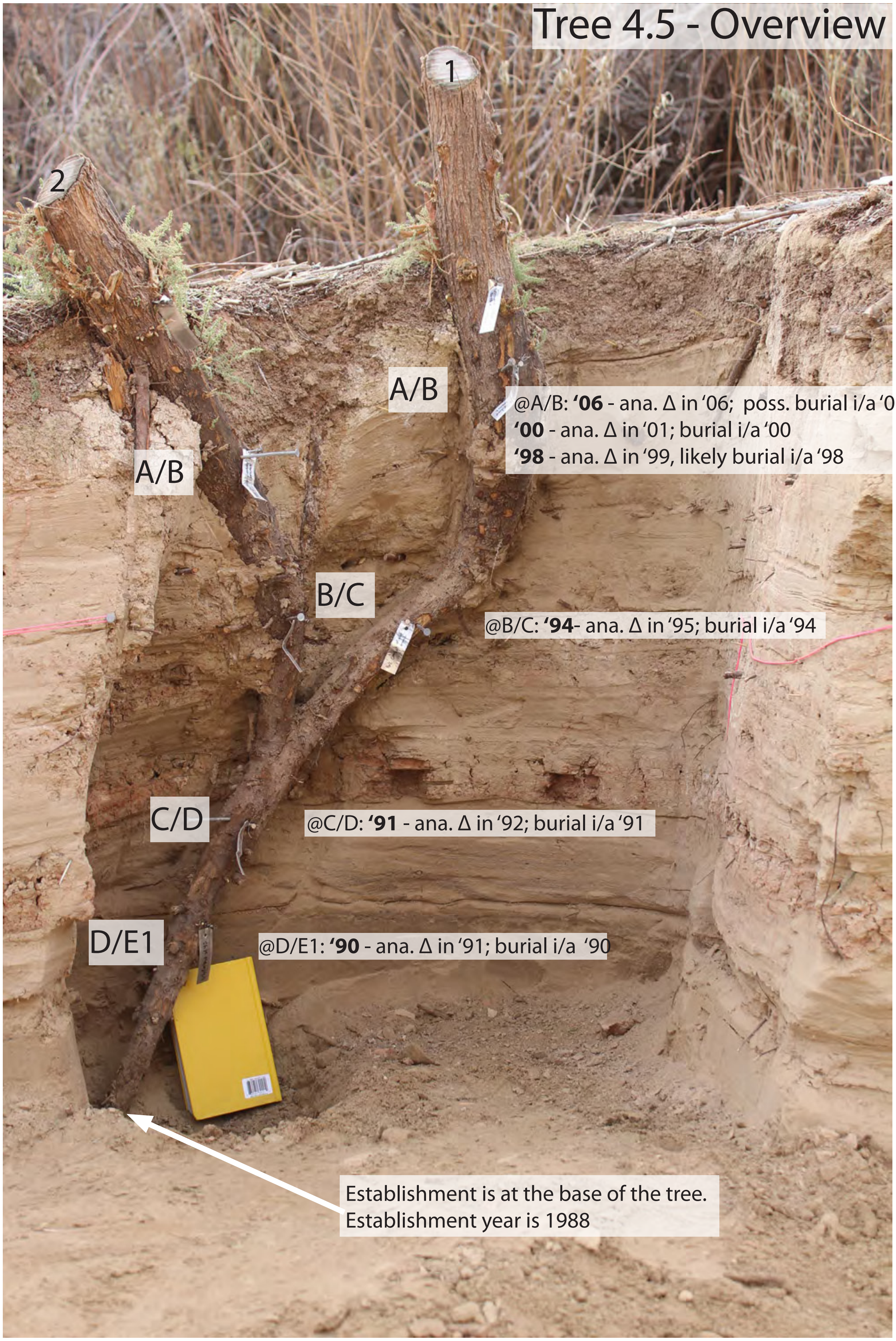
Series ID:

All root, germ/establish in Slab 19

Wood anatomy change notes:

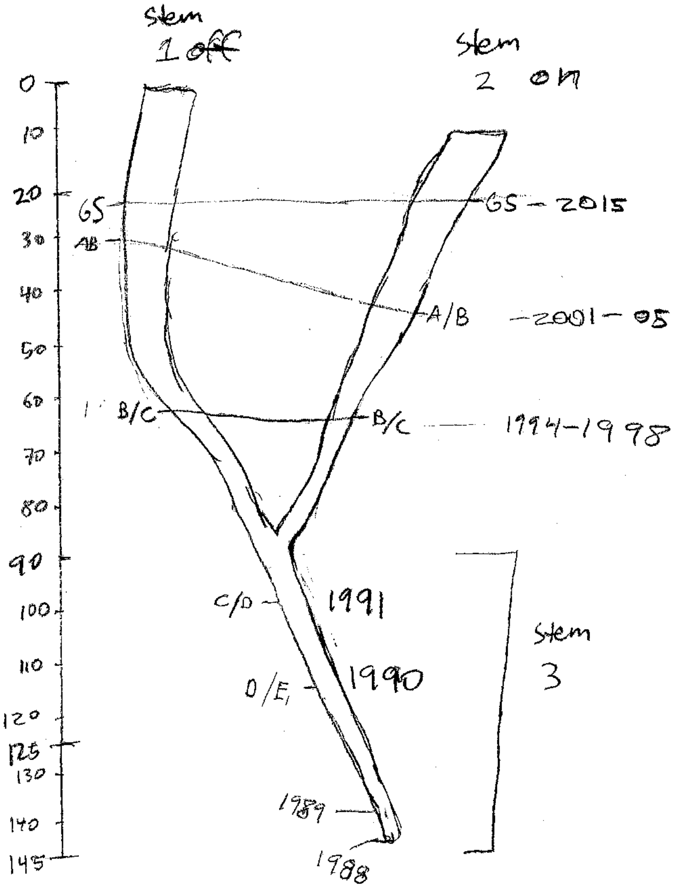
~~1991: Outer most ring read~~
~~1990: Rel. Small~~
~~1989: Mid year Xyl band~~
~~1988: Rel. Large, ⊙ w/ pith~~

1988 Establishment


Tree 4.5 - Overview
1
2
A/B
@A/B: **'06** - ana. Δ in '06; poss. burial i/a '05
'00 - ana. Δ in '01; burial i/a '00
'98 - ana. Δ in '99, likely burial i/a '98
A/B
B/C
@B/C: **'94**- ana. Δ in '95; burial i/a '94
C/D
@C/D: **'91** - ana. Δ in '92; burial i/a '91
D/E1
@D/E1: **'90** - ana. Δ in '91; burial i/a '90
Establishment is at the base of the tree.
Establishment year is 1988

CANY Hardscrabble Trench A. Walker (AEW) 1/25/16 ①

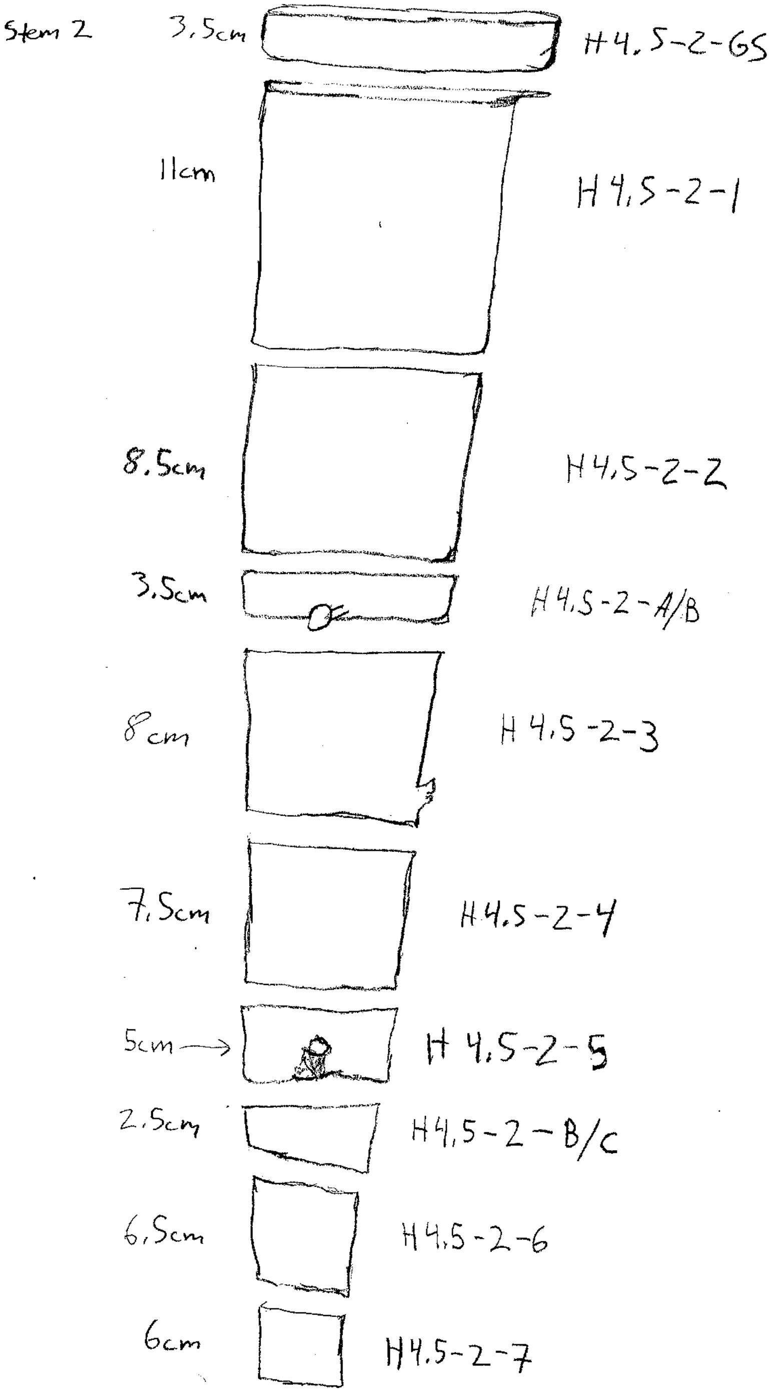
Tree 4.5



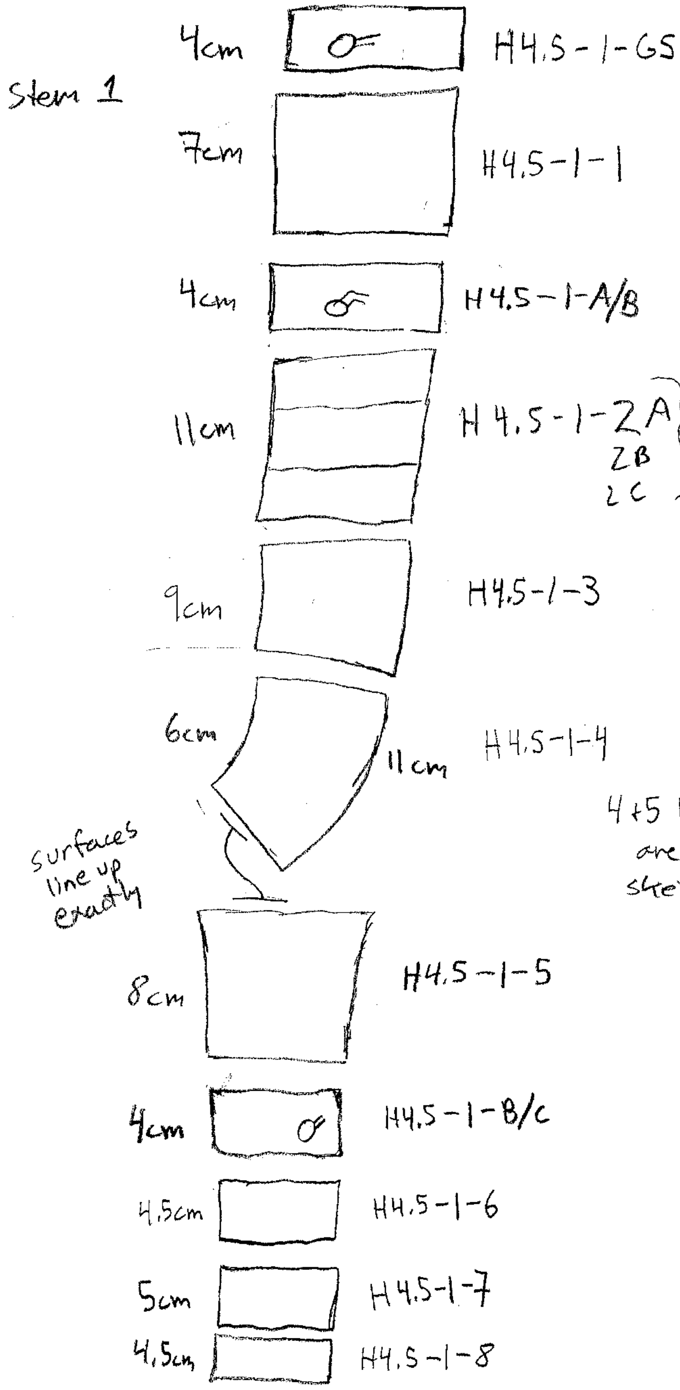
-Sketch is not oriented to ground surface – see notebook and field sketches for in-situ diagrams.

27
125

Tree 4.5 AEW 1/25/16 ②



Tree 4.5 AEW 1/25/16 ③

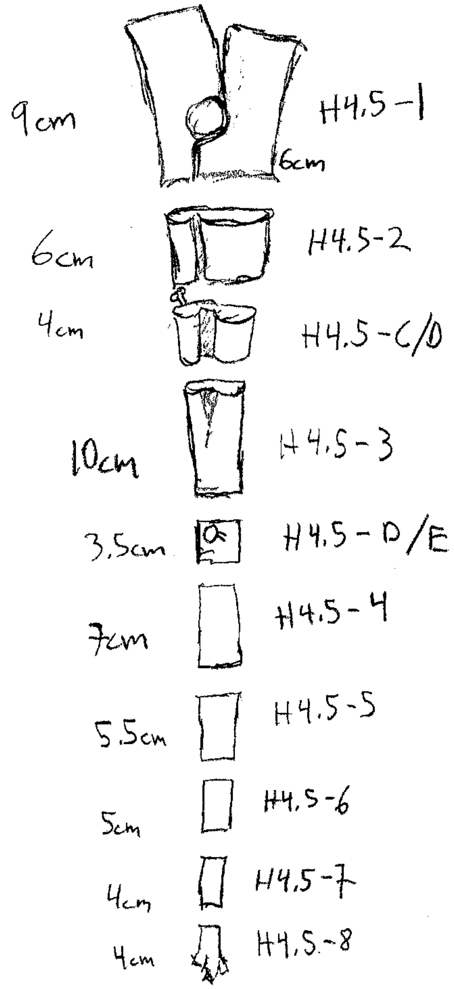


Split into 3 pieces

4+5 match up exactly, but are shifted to make sketch fit on paper.

Tree 4.5 AEW 1/25/16

④



Lower tree stems 1+2 combine at top of this sketch

Nail is on backside of sketch

JS

offshore

Ring reader: AEW

Reading Date: 1/29/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-1

Slab ID: H4.5-1-GS

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

JS 2015: partial band- only xylem present
JS 2013: ~~mid year band (false ring)~~ split into 2yrs - '12 + '13
2011: Rel large

2008: Midyear xylem band
JS 2004: rel small & pinches out, on 1 radius
1999-2000: Rel large

1996: Midyear xylem band
1995: Rel. small, midyear xylem band pinches out on 1 radius
1994: ⊙ w/ pith

JS

Ring reader: AEW

Site ID: Hardscrabble

Tree ID: 4.5-1

Reading Date: 1/29/16

Collection Date: June 2015

Slab ID: H4.5-1-1

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2015: Partial growth only

2011: Rel large

JS 2008: Midyear xylem band; small

JS 2004: small & pinches out on 1 radius

1999 + 2000: Rel large

1998: Rel small

1996: Midyear xylem band, rel large

1994: ⊙ w/ pith

Ring reader: AEW
Reading Date: 1/29/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 4.5-1
Slab ID: H4.5-1-A/B

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:
2015: Partial growth - only ~~xylem~~ xylem visible

2011: Rel large

2010: Midyear xylem band

2006-9': Rel small, '06; poss burial i/a 2006 - an Δ '06, poss burial i/a '05?
2006 ring supp after

JS 2002: ana Δ in 2003 and ring suppression beginning in 2003; likely burial i/a '02

1999 and 2000: Rel large

1998: Midyear xylem band

1997: Rel small

1996: Midyear xylem band, rel large

1995: Midyear xylem band

1994: 0 w/pith

Ring reader: AEW

Site ID: Hardscrabble

Tree ID: 4.5-1

Reading Date: 1/29/16

Collection Date: June 2015

Slab ID: H4.5-1-2A

Top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2011: Rel large, outermost ring read

2010: Midyear xylem band

2006-2010 Rel small- ring surpression; possible burial i/a 2006

JS 2002; and sm 2003; likely burial i/a 2002

1999 and 2000: Rel large

1998: Midyear xylem band

1997: Rel small

1996: Midyear xyl band

1995: Rel small, midyr xyl band

1994: 0 w/ pith

Ring reader: J.S.

Reading Date: 3/20/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-1

Slab ID: H4.5-1-2A Bottom

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Between the top and bottom of this slab, there is a stem switch. Above this (bottom) surface, the stem read here does not persist. ~~#~~ This bottom surface stem can be fairly confidently dated to 1994 with at least one additional inner ring w/ pith obscured by rot.

2006-2010 - ring surpression; possible burial

2004 - rel small

2000 - and Δ M 2001; pos burial i/a 2000

2000 - large

1999 - strange midyr xyl band

1998 - " " " "

1997: Rel small

1996: Rel large

1995: Rel small

1994 - rel large

(1993) - likely inner ring w/ pith; rot

Damage sustained in/befor '93 that may have killed this stem, leading to the resprout of the stem above this point, in 1994

Ring reader: AEW

Reading Date: 1/29/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: H4.5-1

Slab ID: H4.5-1-2B

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2011: Rel large

gap [2010: Midyear xylem band

2006-10: Rel small, indistinct, ring suppression; poss burial

JS very difficult to discern

↳ 2006: Outer most ring recvd

JS 2005: rel large

1999 + 2000: Rel large 2000: ana Δ in '01, likely burial in '00

1998: Midyr xyl band, strange midyr xylem band

1997: Rel small

1996: Midyr xyl band

1995: Rel small

JS 1994: large w/ stem damage

JS (1993) : inner portion contains pith and at least 1 year

AW ↳ possibly '91/'92

Ring reader: AEW

Site ID: Hardscrabble

Tree ID: 4.5-1

Reading Date: 1/29/16

Collection Date: June 2015

Slab ID: H4.5-1-2C

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2006-10: Ring Suppression; poss burial

2008: Outer most ring read, ring ~~suppression; poss burial~~

2000: Rel large ana Δ in '01, likely burial i/a '00

1999: Rel large, midyr xyl band

1998: Middle xylem band

1997: Rel small

1996; Rel large ~~, midyr xyl band~~

1995: Rel small

1994; Rel large

(1993) same rotten interior; possible '93 ⊙ w/pith
more than 1 year in
rot core

Ring reader: AEW

Reading Date: 1/29/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-1

Slab ID: H4.5-1-3

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2011: Rel large

~~2006-2010: Ring surpression, possible burial in/a 2005?~~

~~2006: Outermost ring read~~

JS ~~2005: Rel large, ring supp in '06, ana Δ '06, possible burial i/a '05~~

~~2003: ana Δ in '03, possible burial i/a '02~~

2000: Rel large, ana Δ in '01, likely burial in 00.

1999: Re large

1998: Rel large Midyr xyl band; ana Δ in 1999, poss burial i/a 1998

AW: skeptical

1997: Rel small

1996: Rel large

1995: Rel small

JS 1994: Rel large

1993 (rot)

1992 ⊙ w/ pith (rot)

Ring reader: Alex Walker

Site ID: Hardscrabble

Tree ID: 4.5-1

Reading Date: 3/23/16

Collection Date: June 2015

Slab ID: #4,5-1-4

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Outer rings extremely indistinct + hard to read
b/c root wood

~~2006 10? Ring suppression; poss burial in/a '05 ana Δ 06~~
~~2005: Outermost ring read, ana Δ '05 poss burial i/a '04~~
2002: Outermost ring read

2000: Rel large
1999: Rel large
1998: ana Δ '99, poss burial i/a 98
1997: Rel small
1996: Rel large
1995: Rel small, multiyr xylem band
1994: Rel. large
(1993): rot;
(1992) rot, ⊙ w/ pith } possibly more years than this in rotted core.

Ring reader: A Walker
Site ID: Hardscrabble
Tree ID: 4.5-1

Reading Date: 3/22/16
Collection Date: June 2015
Slab ID: H4.5-1-5

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:
Outer rings indistinct - root

2001: outermost ring read
2000: Rel large
1999: ~~Ana Δ in 2000, possible burial i/a '99~~, rel large

1998: ana Δ in '99, possible burial i/a '98
1997+1999: hard to read these rings
1996: Rel large
1995: Rel small
1994: Rel large
(1993) rot, ~~θ w/pith~~

L I think there are more years in the rot core, possibly back to 1990 or 1991.
LAW

~~(1992) rot~~

~~(1991) θ w/pith, rot~~

Ring reader: A. Walker

Site ID: Hardscrabble

Tree ID: 4.5-1

Reading Date: 3/24/16

Collection Date: June 2015

Slab ID: B/C

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Outer rings root wood

~~2000: outermost ring read, rel large~~

~~1999: Rel large~~

~~1996-1998: Ring suppression~~

1995: ~~ana Δ in '96 likely burial in/a '95~~
ana Δ in 95, likely burial i/a '94, ring sup

8/17/16
This looks like
it could be later,
even 1998, skeptical
on this ages
AW

1994: Rel large

(1993): ~~Visible on edge, mostly rotted~~

(1992): ~~Rot, ⊙ w/pith~~

too rotted to make
firm judgements
on these ages

Ring reader: A. Walker

Reading Date: 3/24/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-1

Slab ID: 6

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Outer rings root wood

1996: Outermost ring read

1995: Pel small

1994: Pel large, ana Δ + ring sup '95 likely burial '94

1993: Rotted on most radius

(1992): Rotted on most radius, pith appears visible, possible more rings - hard to tell if they are false or real, as there is a lot of rot in the interior

Ring reader: A. Walker

Site ID: Hardscrabble

Tree ID: 4.5-1

Reading Date: 3/24/16

Collection Date: June 2015

Slab ID: 7

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

outer rings → root wood

1994: Outer most ring read, rel large, ana Δ '95, likely burial in '94

1993: Rel small

1992:

1991:

1990: Possible false ring

1989:

1988: 0 w/pith

Ring reader: A. Walker
Reading Date: 3/24/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 4.5-1
Slab ID: 8

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:
Outer ring root

1994: Outer most ring read, rel large
ana Δ in '95, likely burial i/a '94
1993: Rel small
1992
1991: assymetrical width of year in slab, very large on l radius
1990
1989
1988: ⊙ w/ pith

false rings seen in slab 7 not apparent in slab 8,
1990 is actual growth year

onshore

Ring reader: AEW

Reading Date: 1/28/16

Reviewed J.S.

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-2

Slab ID: GS

Ring Counts/Notes:

File Name:

# of radii mea

Series ID:

Wood anatomy cha

The mid year band in 2013 is important b/c if its actually a ring, all inner dates are off by 1 year.
Can we build any case from weather/hydrology for this mid year band in 2013?

2015: Pinches ou

2013: ~~Midyear x~~,

2011: Rel large

2010: Midyear xylem band

2006-10: Rel small, ~~fmg suppression~~, poss burial

1999-00: Rel large

1996: Midyear xylem band

1995: Midyear xylem band

1994: Ow/pith, mid-yr xylem band

Ring reader: AEW

Reading Date: 1/28/16

Reviewed JS.

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-2

Slab ID: 1

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2015 Indistinct ~~years 4 in '14~~

2013 Mid~~year xylem band~~ split into '12 + '13

2011 Rel large

2010 Mid-late year xylem band

2009: Midyear xylem band

~~2007-10 Rel small~~ 2008: Midyear xylem band

2005 Midyear xylem band

2000: Rel large

1999 Rel large

1996 Midyear xylem band

1995 Mid year xylem band

1994 Midyear xylem band

1993 0 w/ pith

reviewed SJ.

Ring reader: AEW

Reading Date: 1/28/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-2

Slab ID: 2

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Outer layers indistinct

2011 Rel large "ring sup, and

2006-10: Rel Small, ana Δ in '06," possible burial i/a '05 - ring sup

2005: Midyear xylem band, medium size

2000: Rel large
1999: Rel large
1996: Midyear xylem band
1995: " " "
1993: ⊙ w/ pith

reviewed JS

Ring reader: AEW

Site ID: Hardscrabble

Tree ID: 4.5-2

AEW reviewed: 3/22/16

Reading Date: 1/28/16

Collection Date: June 2015

Slab ID: 3-Top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Outer rings indistinct

2012: ~~Rel large~~

2006-10: Rel small, ana Δ in '06, likely burial i/a '05

~~2006: Midyear xylem band~~

2001 : Ana change in 2001. Likely burial i/a '00

2000: Rel large

1999 Rel large

1998: Midyear xylem band

1997: Rel small

1996: Rel large

1995: Rel small

1994: Faint midyear xylem band

1993: 0 w/pith

reviewed JCS

Ring reader: AEW

Site ID: Hardscrabble

Tree ID: 4,5 - 2

Reading Date: 1/28/16

Collection Date: June 2015

Slab ID: A/B

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2007: outer most ring read

2006

2005: ana Δ in '06, likely burial in/a '05, ring sup, midyr xylem band

2002 ; checking (splitting) consistently to end of '01, beginning '02. Poss. burial in/after '01

1999-2000: Rl large

1998: Rel large

1997: Rel small

1996: Rel large

1995: Rel small

1994 : Midyear xylem band

1993: 0 w/ pith

Revised AEW 3/22/16

Ring reader: AEW
Reading Date: 1/28/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 4.5-2
Slab ID: 4

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Outer rings indistinct - unreadable

2005: outermost ring read (could be '06)
2003-05: Indistinct, hard to read
2001: ana Δ in $\overline{01}$, likely burial i/a $\overline{00}$
2000: rel large
1999: rel large
1998: Late year xylem band
1997: Rel small
1996: Rel large

1995: Rel small
1994: midyear xylem band, rel large
1993: 0 w/pith

reviewed by J.S.

Reviewed 3/22/16

Ring reader: AEW

Site ID: Hardscrabble

Tree ID: 4.5-2

Reading Date: 1/28/16

Collection Date: June 2015

Slab ID: 5

Ring Counts/Notes:

- Contact between btm 5 and top of B/C, cuts across a

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

outer most rings difficult to read

2006: outer most ring read

2001-06: Rel small, hard to define

2000: ana Δ in '01, ~~likely~~ burial in/a '00

1999+2000: rel large

1998: Midyear xylem band

1994: Midyear xylem band

1993: 0 w/pith; 1993 inner ring increased in diameter relative to the 1993 inner rings for above slab, as expected.

1995 & 1997: rel small

Ring reader: A. Walker

Site ID: Hardscrabble

Tree ID: 4.5-2

Reading Date: 3/25/16

Collection Date: June 2015

Slab ID:
B/c Bottom

Ring Counts/Notes:

File Name:

\# of radii measured:

Series ID:

Wood anatomy change notes:

2000: Outermost ring read
1999:
1998:
1996: ana Δ '97, likely i/a '96
1996: rel large
1995: rel small
1994: rel large
1993: midyear xylem band
1992:
1991: ⊙ w/ pith

Ring reader: A Walker

Site ID: Hardscrabble

Tree ID: 4.5-2

Reading Date: 3/23/16

Collection Date: June 2015

Slab ID: B/C

Top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

outer rings indistinct - root wood

2001: outermost ring read, 05

2000: Rel large, ana Δ in '01, ↑ burial i/a '00

1999: Rel large,

1997: Mid-yr xylem band, ana Δ in '98, likely burial in '97 8

1997: Rel small, ~~ana Δ in '98, poss burial in '97~~

1996: Rel large

1995: Rel small

1994: Rel large, midyear xylem band

(1993): Rel large

1992: Rel small, partially rotted

~~(1991): Rot, ⊙ w/ pith rotted increase relative to 4.5-2-5.~~

⊙ w/ pith somewhere below '92 in rotted area

some debate here → could be 1997

Ring reader: A. Walker

Reading Date: 3/23/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-2

Slab ID: 6

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

outer rings indistinct → root and ring surpression

2001: outer most ring read
2000: Rel large
1999: Rel large
1998: Faint mid-year xylem band, not visible on all radii
1997: Rel small
1996: Rel large,
1995: Rel small, ana Δ in '96, possible burial in '95 – This could be moved up to burial i/a 96 JS
1994: Mid year xylem band, Rel large
1993: Rel large
1992
1991: ⊙ w/pith

Ring reader: A. Walker

Reading Date: 3/23/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5-2

Slab ID: 7

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

outer rings - ~~ring surpression~~ root wood

~~2001: outer most ring read~~
~~2000: Rel large~~
~~1999: Rel large~~
~~1997-1998: Hard to define - ring surpression~~

~~1995: ana Δ in '96?~~ likely ~~possible burial in '95?~~ outer most ring read
1994: Rel large, midyear xylem band, ana Δ '95, likely burial '94
1993:
1992: ⊙
1991: ⊙ w/ pith

☆ This is the point where stems 1 + 2 meet and become a single branch ☆

Ring reader: A Walker

Reading Date: 3/24/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5

Slab ID: 1

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Stem 1

1991: Outer most ring read, rel large ana Δ '92, possible burial i/a '91 asymmetrical ring shape + width

1990: Asymmetrical, rel small

1989:

1988: ⊙ w/ pith

Stem 2

Outer rings root

1994: Outer most ring read midyear xylem band ana Δ '95 likely burial i/a '94

1993:

1992:

1991: ⊙ w/ pith

Ring reader: A. Walker
Site ID: Hard scrabble
Tree ID: 4.5

Reading Date: 3/24/16
Collection Date: June 2015
Slab ID: Stem 1
Bottom

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1991: Outer most ring read

1990: Asymmetrical in shape, rel large

1989: Assymmetrical, smaller, ~~possible~~ false ring

1988: ⊙ w/ pith

Ring reader: A. Walker

Site ID: Hardscrabble

Tree ID: 4.5

Reading Date: 3/24/16

Collection Date: June 2015

Slab ID: 2

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

There is some uncertainty here, as 1 + 2 do not match up exactly and don't show an easy to follow transition

Wood anatomy change notes:

outer rngs root wood

1993: outermost ring read, shows assymetrical growth, post damage

1992:

1991: ana Δ '92, burial i/a '91. midyear xylem band Damage apparent starting in '92

↳ Midyear xylem band, rel large, asymmetrical

1990: some asymmetry mid year xylem band

1989: dense wood w/ small pores

1988: ⊙ w/ pith

Ring reader: A Walter

Site ID: Hardscrabble

Tree ID: 4.5

Reading Date: 3/23/16

Collection Date: June 2015

Slab ID: 3

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

outer ring root

1992: outer ring read, partially rot

1991: rel large, midyr xylem band, ana Δ '92, burial i/a '91 part rot

1990: midyear xylem band, part rot

1989: slight asymmetry, part rot, dense wood, small pores

1988: ⊙ w/ pith, part rot

Ring reader: A. Walker

Site ID: Hardscrabble

Tree ID: 4.5

Reading Date: 3/25/16

Collection Date: June 2015

Slab ID: 4

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1991: Outer most ring read

1990: ana Δ '90, likely burial i/a 89, very small

1989: dense wood, small pores

1988: ⊙ w/pith

Ring reader: A Walker

Reading Date: 3/24/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4,5

Slab ID: C/P

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

outer rings root

1993: Outer most ring read, hard to define after this point

1992

1991: Ana Δ in '92 likely burial i/a '91, midyr band pinches out on 1 radius
↳ damage begins in '92

1990

1989: Midyr xylem band, small pores + dense wood

1988: ⊙ w/ pith

Ring reader: A. Walker
Site ID: Hardscrabble
Tree ID: 4.5

Reading Date: 3/25/16
Collection Date: June 2015
Slab ID: D/E_1

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1992: Outer ring read

1991: Asymmetrical shape

1990: ana Δ '91, likely burial i/a '90, much more symmetrical compared to '91 + '92

1989: Symmetrical, dense wood, small pores

1988: ⊙ w/ pith

Ring reader: A. Walker
Reading Date: 3/25/16
Site ID: Hardscrabble
Collection Date: June '15
Tree ID: 4,5
Slab ID: 5

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1991: Outermost ring read

1990: ~~Midyr xylem band~~ ana Δ in '90 likely burial i/a 89, pinches out on 1 radius
1989: dense wood, small pores
1988: ⊙ w/ pith

Ring reader: A. Walker
Site ID: Hardscrabble
Tree ID: 4.5

Reading Date: 3/25/16
Collection Date: June 2015
Slab ID: 6

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1991: outer most ring read

All rings are symmetrical in this slab

1990:

1989: ana Δ '90, likely burial i/a 89, dense wood, small pores

1988: ⊙ w/ pith

Ring reader: A. Walker

Reading Date: 3/25/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5

Slab ID: 7

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1990: outer ring read

1989: ana Δ '90, burial i/a '89

1988: ⊙ w/ pith

Ring reader: A. Walker

Reading Date: 3/25/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 4.5

Slab ID: 8

Ring Counts/Notes:

File Name:

\# of radii measured:

Series ID:

Wood anatomy change notes:

1990: outer ring read

1989: ana Δ 90 burial i/a '89

1988: ⊙ w/pith

Germination in 1988 at this slab

8/12/16
↳ doesn't appear possible w/r/t hydrology to have a burial in 1989, I would build a burial in '90 for this layer

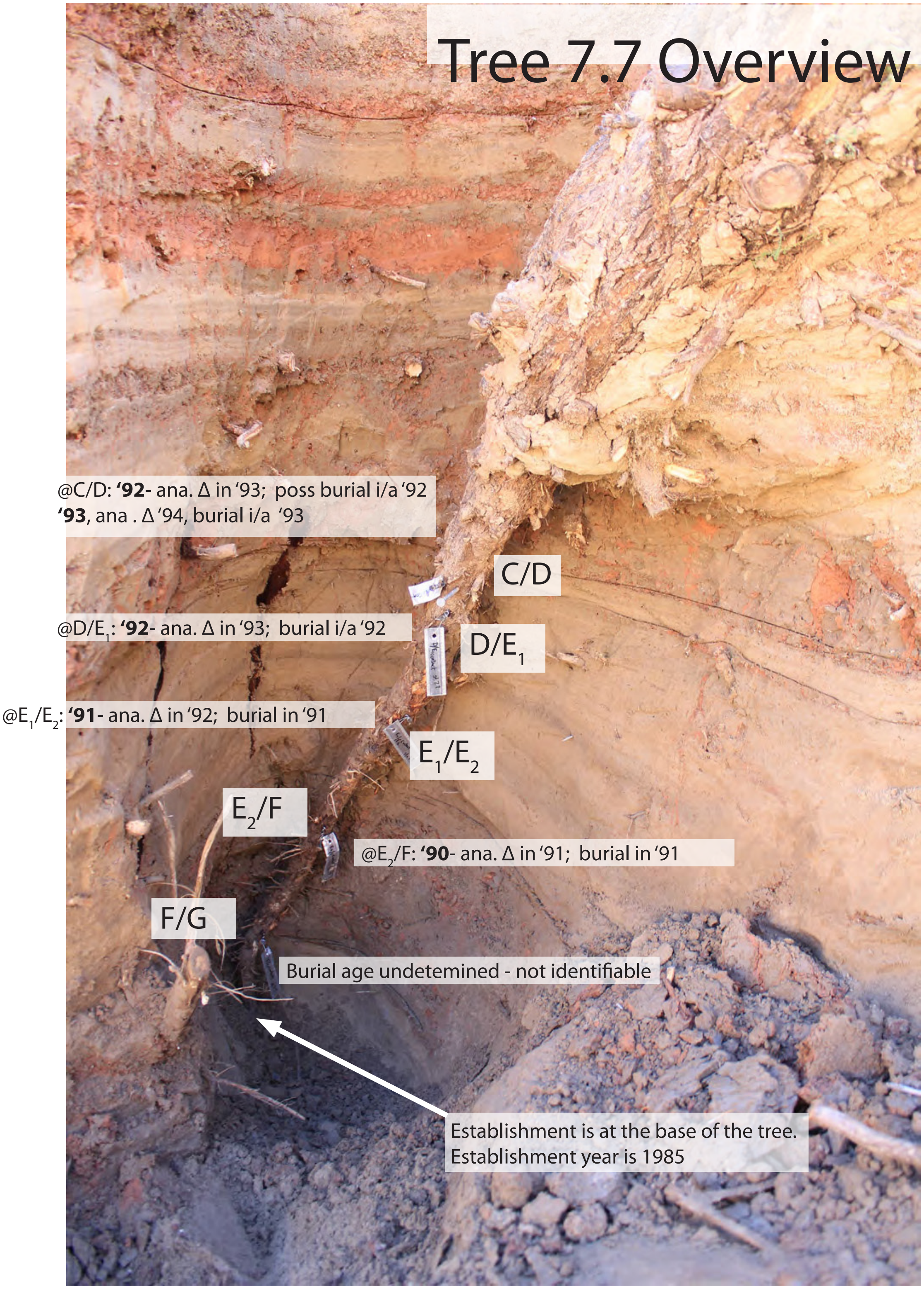
Tree 7.7 Overview

@A/B: **'05** - ana. Δ in '06; burial in '05

@B/C: **'05** - ana. Δ in '06; burial i/a '05 Based on notes and strat diagrams, B pinches out near tree, due to the uncertainty of the bed., I would not use the B contact for the dating.

@C/D: **'92**- ana. Δ in '93; poss burial i/a '92 **'93**, ana . Δ '94, burial i/a '93

See next page for detailed information on lower contacts

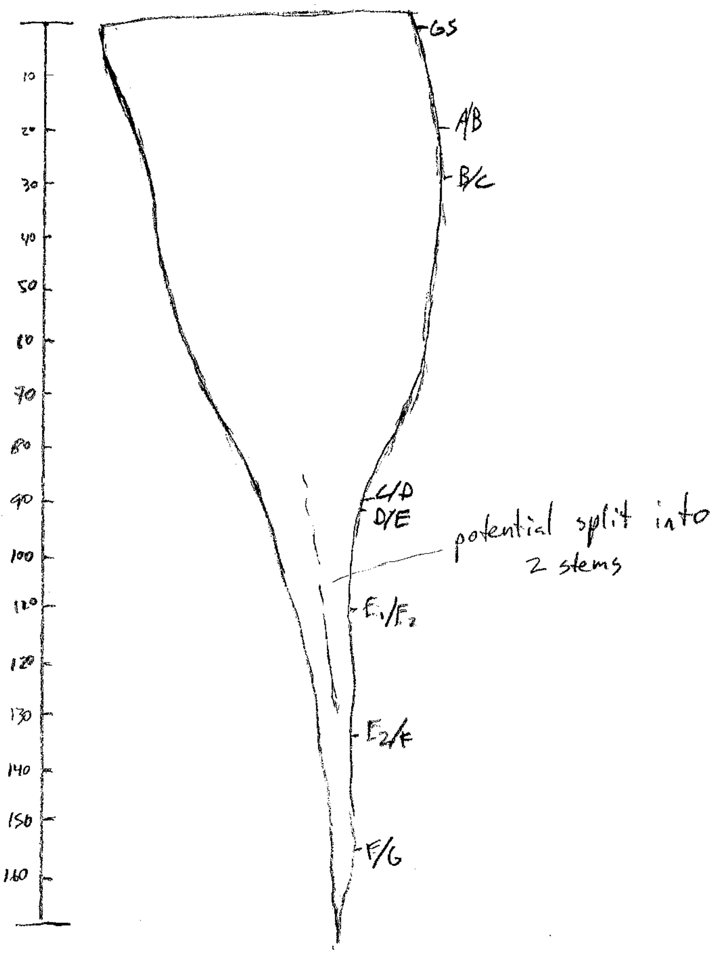

Tree 7.7 Overview
@C/D: **'92**- ana. Δ in '93; poss burial i/a '92
'93, ana . Δ '94, burial i/a '93
C/D
@D/E_1: **'92**- ana. Δ in '93; burial i/a '92
D/E_1
@E_1/E_2: **'91**- ana. Δ in '92; burial in '91
E_1/E_2
E_2/F
@E_2/F: **'90**- ana. Δ in '91; burial in '91
F/G
Burial age undetemined - not identifiable
Establishment is at the base of the tree.
Establishment year is 1985

1/25/16 CANY Hardscrabble trench AEW ①

Tree 7.7

~164cm

1 stem

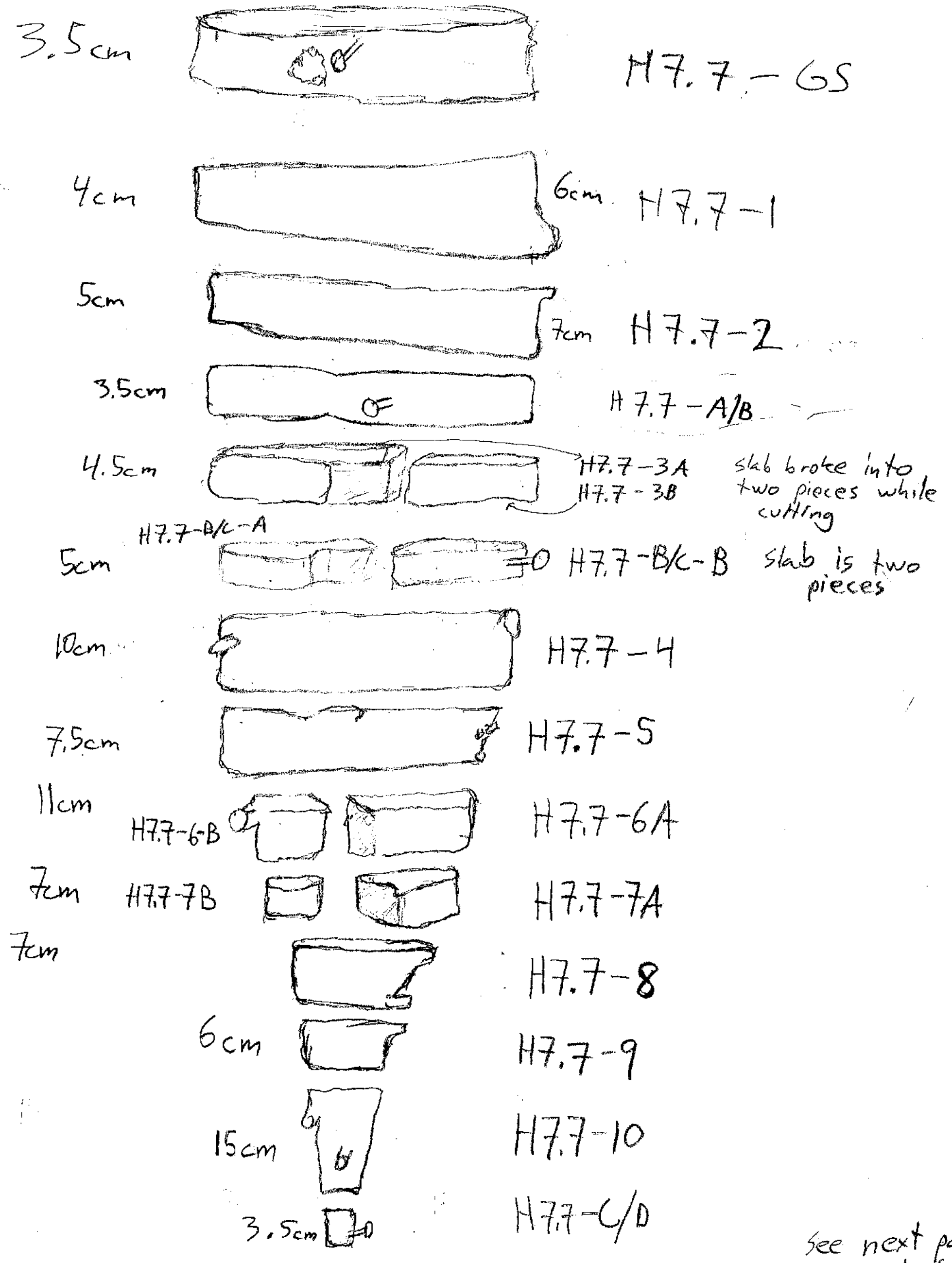


potential split into 2 stems

Tree 7.7 H = Hardscrabble

1/25/15
AEW

②



slab broke into two pieces while cutting

slab is two pieces

see next page for rest of tree

Tree 7.7 ③
Hardscrabble
1/25/15
AEW

4cm		H7.7-D/E_1	
6cm		H7.7-11	1 slab
5.5cm	H7.7-12A	H7.7-12B	2 slabs
4.5cm	H7.7-E_1/E_2A	H7.7-E_1/E_2B	2 slabs
8.5cm		H7.7-13	1 slab
11.5cm		H7.7-14	1 slab
5cm		H7.7-E_2/F	1 slab
6cm		H7.7-15	
5.5cm		H7.7-16	
5cm		H7.7-17	
3.5cm		H7.7-F/G	
5.5cm		H7.7-18	

Ring reader: AEW

Reading Date: 1/27/16

Site ID: Hardscrabble

Collection Date: December 2015

Tree ID: H7,7

Slab ID: GS
Bottom

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2015
2014 - large xylem, possible midyr xyl band

2011 rel large
2010 mid yr xylem band
2009 rel, small
2008 ~~mid yr xylem band~~

2006 midyr xyl band

2004 - rel large
2003 - rel large
2002 rel small (med?), mid yr xyl band
2001 - rel large
2000 - faint mid yr xyl band

1995 - mid yr xyl band, damage to tree in 1yr
1993 - midyr xyl band
1992 - rel small, pinches out on 1 radius
1991
1990 - 0 w/ pith

Ring reader: Alex Walker

Reading Date: 5/2/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: H 7.7

Slab ID: H7.7 -1 Top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Ring reader: JS/

Reading Date: 3/22/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: H7.7

Slab ID: H7.7-1
Bottom

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2015 - only xylem present
2013 - smaller xylem band (could be confused with a false ring)
2011 - large
2010 - midyear xylem band
2009 - rel small
2008 - ~~mid year xylem band~~
2002 - mid year xylem band, rel small
2001 - rel large
2000 - rel large
1999 - rel large
1996 - ~~possible damage to stem in this year~~
1993 - mid year xyl band
1992 - rel small,
1990 - ⊙ w/pith

Ring reader: Alex Walker
Site ID: Hardscrabble
Tree ID: 7.7
Reading Date: 5/2/15
Collection Date: June 2015
Slab ID: 2

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2011 - rel large
2010 - mid year xyl band
2009 - rel small, [illegible]
2008 - r [illegible] ~~; and Δ in 09? possible burial i/a 08?~~
2006 - [illegible]
2004 - [illegible]
2003 - rel [illegible]
2002 - rel small, midyr xyl band
2001 - rel large
2000 - rel large
1999 - rel large

1994 - r [illegible]
1993 - rel large, faint midyr xyl band
1990 - $\odot$ w/ pith

Ring reader: Alex Walker (JS)

Reading Date: 5/2/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: A/B

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2011 - rel large
2010 - midyr xyl band
2009 - rel small
2008 - ~~mid yr xyl band~~ ana Δ
2007 - ~~rel small~~,
2005 - ana Δ '06, burial i/a '05) ring supp after 2005,
2004 - rel large
2003 - rel large
2002 - rel small, midyr xyl band
2001 - rel large
2000 - rel large
1999 - rel large
1998 - faint mid yr xyl band
1996 + 1997: faint midyr xyl bands
1995 - rel large, mid yr xyl band

1993 - midyr xyl band, rel large
1992 + 1991 - rel small
1990 - ⊙ w/ pith, partial rot

Ring reader: Alex Walker

Reading Date: 5/2/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 3, A+B
Top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Ⓐ Wood anatomy change notes:

Slab 3 appears to have two stems on top, with only @ base + below slabs. The evidence points towards a switching of stems at this point. Year 1992 is a question mark - either a year or a false ring - currently unknown
↳ decided it was a year

2011 - rel large
2010 - mid year xyl band
2009 - rel small
2008 - ~~mid year xyl band ana Δ '09, poss burial i/a '08~~ 9/6/15
2007 - rel small
2005 - rel large, ana Δ in '06, like, burial i/a '05
2004 - rel large
2003 - rel large
2002 - rel small, mid year xyl band
2001 - rel large
2000 - rel large, faint midyr xyl band
1999 - rel large

1993 - mid yr xyl band, rel large

1990 - ⊙ w/pith, rotted and hard to tell which stem is ~~th~~ the one being followed

Ring reader: Alex Walker
Reading Date: 5/5/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 7.7
Slab ID: 3-Bottom

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Ⓐ Wood anatomy change notes:

2011 - rel large
2010 - mid yr xyl band
2009 - rel small
2008
2007
2006
2005 - ana Δ '06, burial i/a '05
2004 - rel large
2003 - rel large
2002 - rel small, midyr xyl band
2001 - rel large
2000 - rel large
1999 -
1998 -
1997 -
1996 -
1995 -
1994 -
1993 - midyr xyl band
1992 -
1991 - mostly rotted, innermost ring read

Ring reader: Alex Walker
Site ID: Hardscrabble
Tree ID: 7.7
Reading Date: 5/2/16
Collection Date: June 2015
Slab ID: 4 - top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

~~2011 - rel large~~
2010 - outermost ring read

2006 - ana Δ in '06; likely burial i/a '05

2002 - rel small, mid yr xyl band
2001 - rel large
2000 - rel large, mid yr xyl band
1999 - rel large

1993 - mid yr xyl band

1991 - inner most ring read, rotted inside of this

Ring reader: Alex Walker
Reading Date: 5/2/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 7.7
Slab ID: B/C - Top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Ⓐ Wood anatomy change notes:

2014 - outer most ring read

2011 - rel large
2010
2009 - rel small
2008 - ~~mid yr xyl band~~
2006 - rel small
2005 - ana Δ in '06, burial i/a '05, rel large
2004 - rel large
2003 - rel large
2002 - rel small, mid yr xyl band

2001 - rel large, mid yr xyl band (faint)
2000 - rel large
1999 - rel large
1998 - rel large
1996 ~~- faint~~ mid yr xyl band
1995 - rel large
1993 - mid yr xyl band
~~1992 - rel small~~
1991 - inner most ring red, everything older - rotted, rel small

Ring reader: Hardscrabble (SS)

Reading Date: 5/4/16

Site ID: Alex Walker

Collection Date: June 2015

Tree ID: 7.7

Slab ID: B/C -Bottom

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Ⓐ Wood anatomy change notes:

2011 - rel large
2010 - midyr xyl band
2009 - rel small

2005 - rel large, an Δ '06, burial i/a '05
2004
2003
2002 - rel small, midyr xyl band
2001 - rel large
2000 - rel large
1999 - rel large

1993 - midyr xyl band, rel large
1992 - innermost ring read, midyr xyl band, mostly rotted, inside of this point, inner rings are totally rotted

Ring reader: Alex Walter

Reading Date: 5/2/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 77

Slab ID: 5

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2009 - outermost ring read, indistinct after this - rootwood

2004 - ana Δ in '05, possible burial i/a '04 - I think this is 06/05 when compared to surrounding slabs

2002 - midyr xyl band, rel small

2001 - rel large

2000 - rel large

1999 - rel large

1998 - mid yr xyl band, rel large

1996 - rel small

1993 - mid yr xyl band

1992 - ~~mid yr xyl band~~

1991 - ~~inner most ring read, rotted inside~~

1990

1989 - inner most ring read, rotted inside

Ring reader: Alex Walker (JS)
Reading Date: 5/2/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 77
Slab ID: 64

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2009 - outermost ring read, somewhat distinct in newer years transitions to indistinct

2006 - ~~ana Δ '07, likely burial i/a '06~~

2005 - ana Δ '06, ~~pos~~ burial i/a '05

2002 - rel small, mid yr xyl band

2001 - rel large

2000 - rel large, mid yr xyl band

1999 - rel large

1998 - mid yr xyl band, rel large

1993 - mid yr xyl band, innermost ring read, rings are rotted out in earlier years

Invisible Cities (

Ring reader: Alex Walker (JS)

Reading Date: 5/2/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 7 – top

Ring Counts/Notes:

~~5/2 * 2006 onwards, xyl is wide + looks like root, xyl shrinks, but then begins to widen from '02 back to '95. A burial, then an excavation?~~

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

Ⓐ

2006 - outermost ring read

2005 - ana Δ in '06, li~~ke~~ly burial i/a '05

2002 - rel small, mid yr xyl band
2001 - rel large
2000 - rel large, mid yr xyl band
1999 - rel large
1998 - ~~mid yr xyl band~~

1996 - mid yr xyl band

~~1994 - ana Δ '95, possible burial i/a '94~~

This needs resanding to validate ana Δ observations JS

1993 - mid yr xyl band

1992 - narrow early yr xylem band for this annual growth ring. Distinctive

1990 - damage in/around 1990
1989 - incomplete ring; rot

Ring reader: Alex Walker (JS)
Reading Date: 5/4/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 7.7
Slab ID: 7- bottom

Ring Counts/Notes:

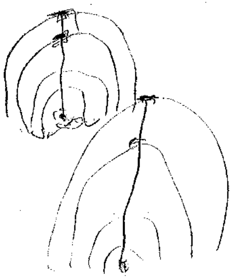
File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2006 - outer most ring read, indistinct beyond this point, ring surp.
2004 - rel large
2003 - rel large
2002 - rel small, midyear xyl band
2001 - rel large
2000 - rel large, mid yr xyl band
1998 - midyr xyl band



1993 - midyr xyl band, same width as 7-top, ana Δ '94, poss burial i/a '93
1992
1990 - innermost ring read, incomplete ring, rot; damage i/o around 1990
⊙ w/partial pith visible, either '87/'88, rings unclear due to rot

Ring reader: Alex Walker (JS)
Reading Date: 5/2/16

Site ID: Hardscrabble
Collection Date: June 2015

Tree ID: 7.7
Slab ID: 8-top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

2005 - outermost ring read

2004 - ~~faint~~, ~~anaΔ in '05, likely burial i/a '05~~ rel large

2003 - ~~fainter~~, rel large

2002 - rel small, mid yr xyl band, but fainter than above slab

2001 - rel large

2000 - rel large

1994 - ~~anaΔ '95, likely burial i/a '94~~

1993, mid yr xyl band; anaΔ '94, likely burial i/a '93

1992 - innermost ring read, inner core rotted beyond this point

1990 - damage i/around 1990

- possible goes to '87, but mostly conjecture post-'92

Ring reader: Alex Walker (JS)

Reading Date: 5/4/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 8-btm

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1995 - outermost ring read

1993 - mdyr xyl band, ana Δ '94, burial i/a '93
1992 - faint mdyr xyl band
1991
1990 - mdyr xyl band!, damage sustained M/ar around 1990
1989
1988
1987 - ⊙ w/pith, shows damge on 1 radius.

Ring reader: Alex Walker (JS)

Reading Date: 5/2/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 9

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1994 ~~outermost ring read~~, root beyond this point

1993 - midyr xyl band - outermost ring read
ana Δ 94, burial i/a '93

1992 - mdyr xyl band

1991 - pinches out on 1 radius

1990 - midyr xyl band

1989 - rel large

1988 -

1987 - ⊙ w/ pith - complete pith visible, but partial rot

Ring reader: Alex Walker (JS)
Reading Date: 5/3/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 77
Slab ID: 10

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

ana Δ '94, burial i/a '93
1993 - outer most ring read, root wood past 1994, midyr xyl band
1992 - sm midyr xyl band
1991 -
1990 - midyr xyl band
1989 - rel large
1988 -

1987 - ⊙ w/pith

Ring reader: Alex Walker (CJS)

Reading Date: 5/3/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: C/D

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1993- outermost ring read, ~~and Δ '94, burial i/a '93~~

1992- checking in layer - begins here + extends out and Δ '93, possible burial i/a '92

1991-

1990- mid yr xyl band

1989 -rel large

1988-

1987= innermost ring read, rotted inside of this point, possible ⊙ w/pith ~~right~~ in this ring layer.

Ring reader: Alex Walker (JS)
Reading Date: 5/3/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 77
Slab ID: D/E

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1992 - Outermost ring read, ana Δ '93, burial i/a '92
1991 -
1990 - midyr xyl band
1989 - rel large
1988 - innermost ring read
1987 - wood visible inside of 1988, pith not visible

[illegible]

Ring reader: Alex Walker (JS)

Reading Date: 5/3/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 11

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1993 - outermost ring read

1992 - ~~ana Δ '93, burial i/a '92~~ ana Δ '93; burial i/a '92

1991 - ~~ana Δ '92, burial i/a '91~~

1990 - mid yr xyl band, fainter than above

1989 - rel large

1988 - innermost ring read

1987 - rotted beyond this point, possible ⊙ w/pith in this year, no ring read ~~for~~ 1987

Ring reader: Alex Walker (JS)
Reading Date: 5/3/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 7.7
Slab ID: 12

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1993 - outer most ring read

1992 - ana Δ '93, burial i/a '92
1991 - ~~ana Δ '93, likely burial i/a '92~~
1990 - ~~ana Δ '92, burial i/a '91~~
midyr xyl band - faint band
1989
1988 - inner most ring read, rotted past this point, very little of the ring present

0 w/pith unknown

Ring reader: Alex Walker (CJJ)

Reading Date: 5/3/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: E_1/E_2

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Extremely rotted, hard to identify rings + ages due to high amount of rot

Wood anatomy change notes:

1992 - outer most ring read, ~~ana Δ '93 burial i/a '92~~

1991 - ana Δ '92, possible burial i/a '91

1990 - rel large, assymettrical

1989 - rel large, trunc by rot

1988 - innermost ring read

Ring reader: Alex Walker (JS)

Reading Date: 5/4/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 13

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1991 - outermost ring read, ana Δ '92, likely burial i/a '91

1990 - ~~ana Δ '91, likely burial i/a '90 could be '91/90~~

1989 -

1988 - innermost ring read, rotted in any older years inside of this point

Ring reader: Alex Walker (JS)

Reading Date: 5/4/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 14

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1992+ - all root wood

1991 - outermost ring read

1990 - ana Δ '91; possible burial i/a 90

1989 - innermost ring read

1988 - wood from this year, but no rings visible - rotted inside of this

these ana Δs are indistinct and complicated by severe damage sustained in the years surrounding

Ring reader: Alex Walker (JS)

Reading Date: 5/4/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: F2/F

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1991 + - root wood

1990 - outermost ring read, ana Δ '91, burial i/a '90

1989 - rel large, innermost ring read

1988 - wood from layer visible, but no rings to match layer identified

Ring reader: Alex Walther (JS)

Reading Date: 5/4/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 15

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1990 - outermost ring read, ana Δ '91, burial 1/a '90,

1989 - rel large, innermost ring read

1988 - wood visible, but no rings are seen past 1989,
tree is rotted past this point.

Ring reader: Alex Walker (JS)
Reading Date: 5/5/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 7.7
Slab ID: 16 – top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1990 – outermost ring read

1989 – rel large, mostly rxyl band, ana & '90 likely burial i/a $\bar{8}9$

1988 – pinches out on 1 radius

1987 – rel large

1986 – ⊙ w/pith

Ring reader: Alex Waller (JS)

Reading Date: 5/5/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: F/G

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1990 -

1989 - rel large, ana Δ '90, poss burial i/a '89

1988 - rel small, ring surp?

1987 - rel large anaΔ '88, ~~likely~~ poss burial i/a '87?

1986 - ⊙ w/pith

Ring reader: Alex Walker (JS)

Reading Date: 5/5/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 17—top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1990 – outermost ring read

1989 – rel large, midyr band on l axis, ana Δ'90, poss burial i/a '89

1988 – rel small, ring is shrinking (ring surp?)

1987 – rel large

1986 – ⊙ w/pith

Ring reader: Alex Walter (JS)

Site ID: Hardscrabble

Tree ID: 7.7

Reading Date: 5/5/16

Collection Date: June 2015

Slab ID: 18 - Top

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

ring surp? ana Δ '88, poss burial i/a '87

1988 - outer most ring read, indistinct/root beyond this point

1987 - rel large

1986 - ⊙ w/pith

Ring reader: Alex Walker (JS)

Reading Date: 5/5/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 7.7

Slab ID: 18-Bottom

Ring Counts/Notes:

File Name:

# of radii measured:

Series ID:

Wood anatomy change notes:

1988 – outermost ring read – hard to identify area Δ + burial date

1987 – rel large

1986 –

1985-⊙ w/ pith

Final slab from tree

Establishment in 1985 in this slab #7.7.18

Ring Reader: Adam Fisher

Reading Date: August 24, 2016

Site ID: Hard scrabble

Collection Date: June, 2015

Tree ID: 20-2

Slab ID: Ground surface

Reviewed AEW
10/24/16

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

-3 Possibly dead when collected. only tree to not have new shoots when collected. extensive rotting in stem

2009: Outermost ring read

1986 rel lrg, mid yr xyl band
1985 rel lrg
1984 rel small
1983 rel small, mid yr xyl band
1982 rel lrg
1981 rel large

1979: mid yr xyl band

1975 pith flecking

1957 - 0 w/pith

~~1990: distinct color change / rel large~~
~~1989: mid year xyl band~~

~~1987: Rel. small~~
~~1986 mid year xyl band~~

~~1983: Rel large~~
~~1982: mid yr xyl band~~
~~1981 Rel large~~
~~1980: mid year xyl band~~

~~1978: Pith flecking~~

~~1976: mid yr xyl band~~

~~1966: Rel small, damage apparent to tree in this year~~
~~1964-1969 rel small~~
~~1963 rel large~~
~~1962 rel large~~
~~1961 rel large~~
~~1960: 0 w/pith~~

Rev 10/26/16 AEW

Ring Reader: Adam F
Reading Date: August 24, 2016
Site ID: Hardscrabble
Collection Date: June, 2015
Tree ID: 20-2
Slab ID: 20-2-1

Outer trunk starting to rot

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2008: outermost ring

1987: color, v. distinct in this year

1986: rel large
1985 rel large
1984 rel small
1983 rel small, mid yr xyl band
1982 rel large
1981 rel large

1979 : mid yr xyl band

1977 : mid yr xyl band

1975: Pith flecking

1959: rel large
1958: rel. large
1957: 0 w/pith

~~1989~~
~~1988 Rel small~~
~~1987~~
~~1986 mid year xyl band~~
~~1985~~
~~1984 Rel small, mid year xyl band~~
~~1983~~
~~1982~~
~~1981 Rel small~~
~~1980 mid year xyl band~~
~~1979~~
~~1978 mid year xyl band~~
~~1977~~
~~1976 Rel small~~
~~1975~~
~~1974~~
~~1973~~
~~1972~~
~~1971~~
~~1970~~
~~1969 Rel large~~
~~1968~~
~~1967 Rel large~~
~~1966~~
~~1965 faint band~~
~~1964 Pith~~

Rev 10/26/16 AEW

Ring Reader: Adam Fisher

Reading Date: August 31, 2016

Site ID: Hardscrabble

Collection Date: June, 2015

Tree ID: 20 - 2

Slab ID: 20-2-2

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2008: outermost ring

1987: v. distinct color change

1986: rel large

1985: rel large

1984: rel small

1983: rel small, midyr xyl band

1982: rel large

1981 rel large

1979
1977 } midyr xyl band

1975: pith flecking

1961-1970: rel small

1957: rel large
1958: rel large
1957: ⊙ w/ pith } rotted but visible

~~1989 midyear xyl band~~
~~1988~~
~~1987 rel small, midyear xyl band~~
~~1986~~
~~1985~~
~~1984 rel small~~
~~1983 mid year xyl band~~
~~1982~~
~~1981~~
~~1980~~
~~1979~~
~~1978~~
~~1977~~
~~1976~~ } ~~small + tight~~
~~1975~~
~~1974~~
~~1973~~
~~1972~~
~~1971~~
~~1970 rel large~~
~~1969~~
~~1968 faint band~~
~~1967 Pith~~

Rev 10/26/16
AEW

Ring Reader: Adam Fowler

Reading Date: August 31, 2016

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 20-2

Slab ID: 20-2-3

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:
2006: outermost ring

1986 rel large
1985 rel large
1984 rel small
1983 rel small mid yr xyl band
1982 rel large
1981: rel large, sorta-same size approx as 1983 year
1979: mid yr xyl band
1977: mid yr xyl band
1975: pith flecking

1961-1970: v. small

1959: rel large
1958: rel large
1957: ⊙ w/ pith
rotted but visible

1989
1988 mid year xyl band
1987 rel large
~~1986 mid year xyl band, rel small~~
~~1985~~
~~1984~~
~~1983 rel small~~
~~1982 mid year xyl band~~
~~1981~~
~~1980~~
~~1979~~
~~1978~~
~~1977~~ small + tight
~~1976~~
~~1975~~
~~1974~~
~~1973~~
~~1972~~
~~1971~~
~~1970~~
~~1969~~
~~1968~~ Rot
~~1967~~
~~1966 Pith~~

Ring Reader: Alex Walker

Site ID: Hardscrabble

Tree ID: 20-2

Reading Date: 10/26/16

Collection Date: Cut June 2015 removed March 2016

Slab ID: 4

Ring Counts/Notes:

File Name:

\# of radii measured Outer trunk is rotted & hard to read

Series ID:

Wood anatomy change notes:

2003: outermost ring read

1986: rel large
1985: rel large
1984: rel small, lrg xyl
1983: rel small mid yr xyl band, faint → largeish on 1 radius
1982: rel large
1981: rel large

1979: mid yr xyl band

1977: faint mid yr xyl band

1975: pith flecking

1961-1970: compressed rings v. small

1959: innermost ring w/o rot

1958: rel large } rotted but
1957: ⊙ w/ pith } visible

Ring Reader: Alex Walker

Reading Date: 10/26/16

Site ID: Hardscrabble

Collection Date: Cut June 2015, removed March 2016

Tree ID: 20-2

Slab ID: 5

Ring Counts/Notes:

File Name:

Damage to tree in 1969, ± 2 years

# of radii measured

Series ID:

Wood anatomy change notes:

2003: outer most ring read

1993 - slight ana Δ - poss burial i/a 92?

1987 - large xyl - poss burial i/a 86?

1986 rel large
1985 rel large
1984 rel small, mostly xyl
1983 rel small
1982 rel large
1981 rel large

1979 - wd yr xyl band

1977 - wd yr xyl band

1975 - pith flecking

1973 - wd yr xyl band

1959: rel large

1958: rel large

1957: ⊙ w/pith, part rotted

Ring Reader: Alex Walker

Reading Date: 10/26/16

Site ID: Hardscrabble

Collection Date: Cut June 2015, removed March 2016

Tree ID: 20-2

Slab ID: A/K

Ring Counts/Notes:

File Name: Outer bark + stem rotted w/ indistinct edges + borders

# of radii measured

Series ID:

Wood anatomy change notes:

2003 outermost ring read

1986 rel large
1985 rel large
1984 rel small, mostly xyl
1983 rel small, mid yr xyl band, ana Δ '83, poss buried i/a '82
1982 rel large
1981 rel large

1979 mid yr xyl band

1977 mid yr xyl band

1975 pith flecking

1973 mid yr xyl band
1971 - damage to tree begins in this year, could be 1968-1971 hard to read
1959 rel large
1958 rel large
1957 ⊙ w/pith

Ring Reader: Alex Walker
Reading Date: 10/27/16
Site ID: Hardscrabble
Collection Date: Cut June 2016, removed March 2016
Tree ID: 20-2
Slab ID: 6

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1994 - Outermost ring read

1986 - rel large
1985 - rel large
1984 - rel small, mostly xyl
1983 - rel small, faint wdyr xyl band, ana Δ '83, likely burial i/a '82
1982 - rel large
1981 - rel large

1979 - wdyr xyl band
1977 - wdyr xyl band
1975 - pith flecking
1973 - wd yr xyl band

1959 - rel large

1958 - rel large

1957 - ⊙ w/pith

Ring Reader: Alex Walker

Reading Date: 10/27/16

Site ID: Hardscrabble

Collection Date: Cut June '15, removed Mar '16

Tree ID: 20-2

Slab ID: K/M

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1994 – Outermost ring read

1986 – vel large
1985 – vel large
1984 – vel small, mostly xyl,
1983 – vel small, ana Δ '84, likely burial i/a '83
1982 – vel large
1981 – vel large

1979 mid yr xyl band
1977 – mid yr xyl band

1975 – pith flecking
1973 – mid yr xyl band

1959 – vel large
1958 – vel large
1957 ⊙ w/pith

Ring Reader: Alex Walker

Reading Date: 10/27/16

Site ID: Hardscrabble

Collection Date: Cut 6/2015, removed 3/2016

Tree ID: 20-2

Slab ID: 7

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1994 Outermost ring read

1986 rel large
1985 rel large
1984 rel small, mostly xyl
1983 rel small mid yr xyl band
1982 rel large
1981 rel large

1979 - mid yr xyl band

1977 - mid yr xyl band

1975 - no pith flecking seen - it gone
1973 - mid yr xyl band

1959 - rel large
1958 - rel large
1957 - ⊙ w/pith

Ring Reader: Alex Walker

Reading Date: 10/27/16

Site ID: Hardscrabble

Collection Date: Cut 6/2015, removed 3/2016

Tree ID: 20-2

Slab ID: 8

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

- The anatomical change clearly begins in the 1983 growth year

Wood anatomy change notes:

No pith flecking in 1975

1984 - Outermost ring read

1983 - rel small, mid yr xyl band

1982 - rel large - ana Δ '83, burial i/a '82

1981 - rel large

1979 - mid yr xyl band

1977 - mid yr xyl band

1973 - mid yr xyl band

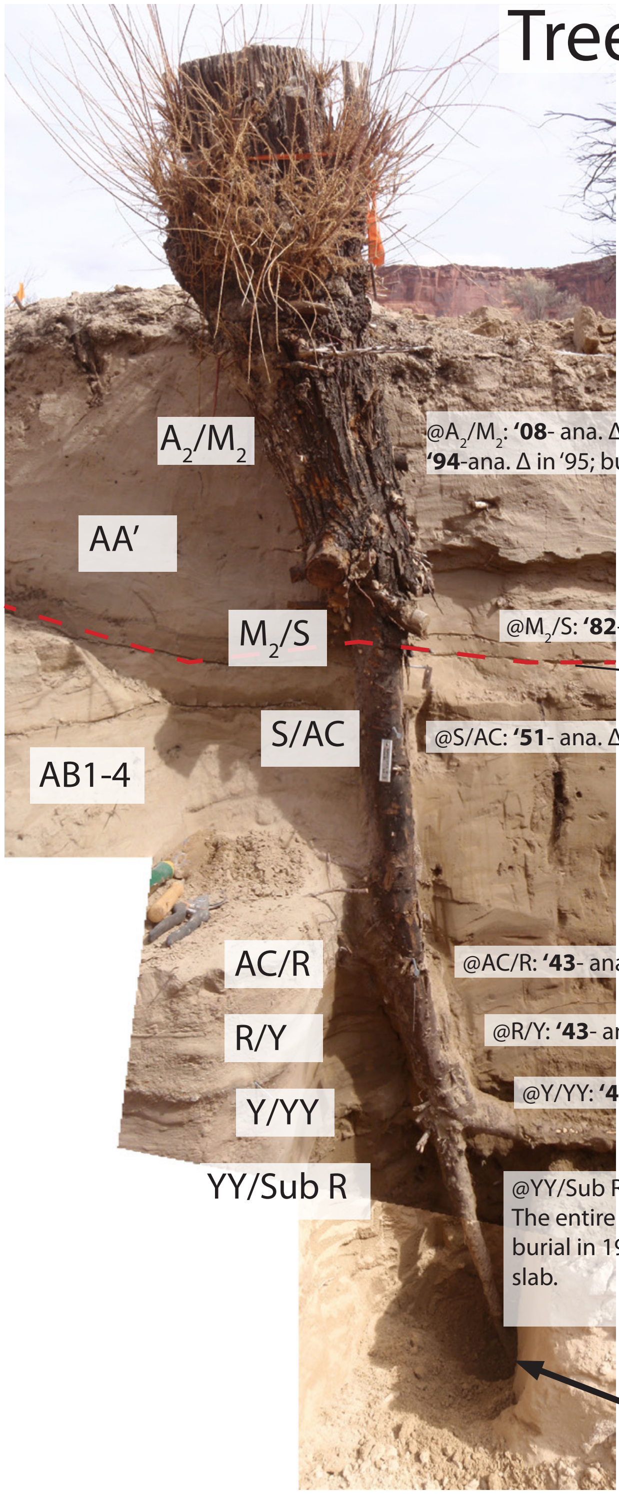
1959 - rel large

1958 - rel large

1957 - ⊙ w/ pith

Tree 25-1 Overview

Tree shows evidence of burial in 1951, then excavation in or before 1980, then reburial in or after 1982.



@A_2/M_2: **‘08**- ana. Δ in ‘09; likely burial in ‘08
‘94-ana. Δ in ‘95; burial in ‘94

@M_2/S: **‘82**- ana. Δ in ‘83; burial in or after ‘82

AB1-4/AA’
boundary
(unconformity)

@S/AC: **‘51**- ana. Δ in ‘52; burial in or after ‘51

@AC/R: **‘43**- ana. Δ in ‘44; burial in ‘43

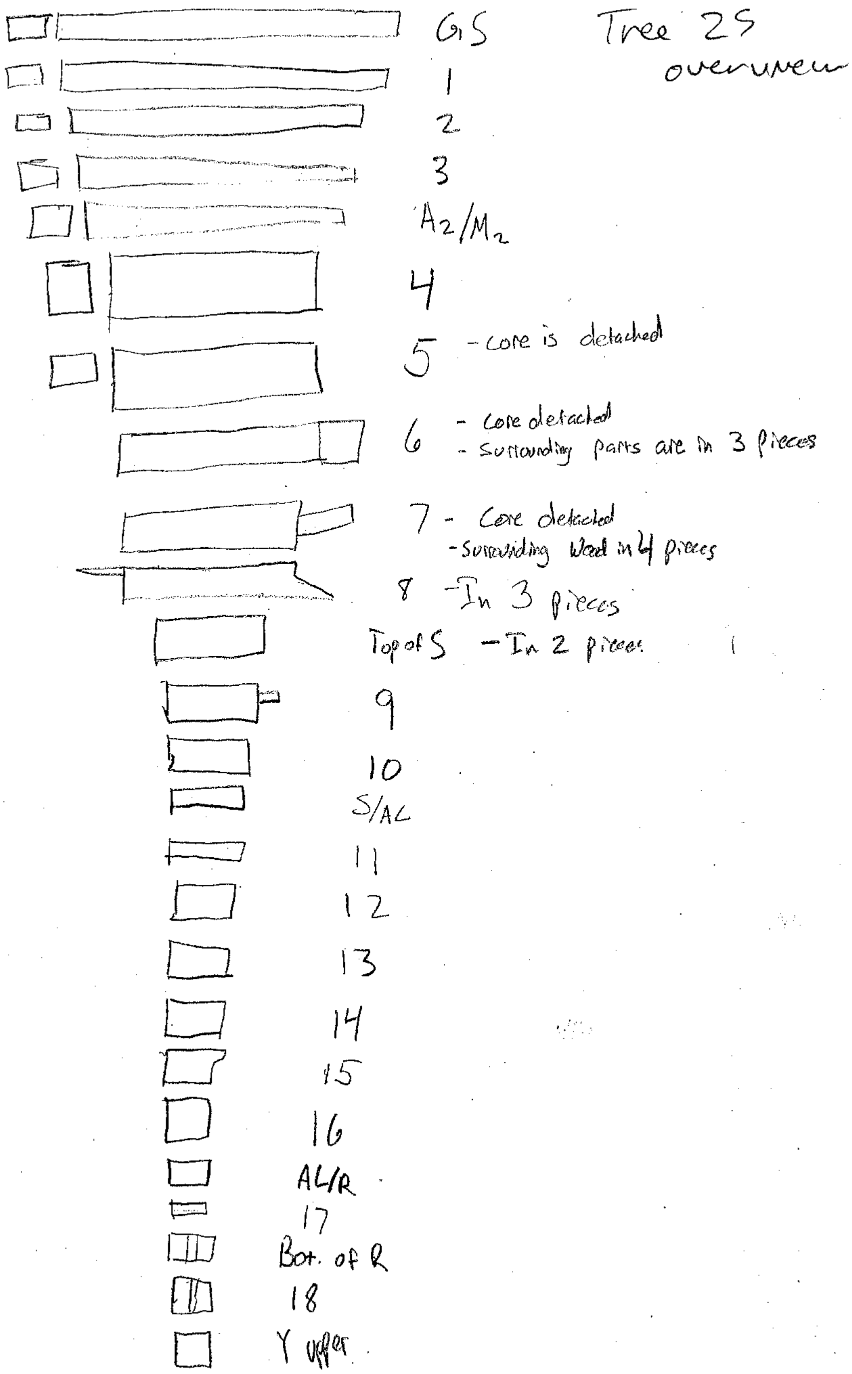
@R/Y: **‘43**- ana. Δ in ‘44; burial in ‘43

@Y/YY: **‘42**- ana. Δ in ‘43; burial in ‘42

@YY/Sub R: **‘41**- ana. Δ in ‘42; burial in ‘41
The entire package below this shows burial in 1941 - from YY lower to bottom slab.

Establishment in base at 1940 - base not obvious in bottom slab, establishment may be lower than tree removed. Confident in establishement year.

Tree 25
overview



5 - core is detached

6 - core detached
- surrounding parts are in 3 pieces

7 - Core detached
- surrounding Wood in 4 pieces

8 - In 3 pieces

Top of S - In 2 pieces

Ring Reader: Alex Walker

Reading Date: 9/15/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 25-1

Slab ID: 65 - Top

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2015: outermost ring read

2012: Small

2008: rel large
2007: rel large

1986: rel large
1985: rel large
1984: rel small
1983: rel small, weak yr xyl band
1982: rel large

1969: rel small

1957: rel small
1956: rel small
1955: rel small

1953: rel large

1945: rel large comp to surrounding

1943: innermost ring read
1942 wood visible inside of 1943
no pith seen

review
AW 7/14/16
JS 9/15/16

Ring Reader: Bradley Collette

Site ID: Hard Scrabble

Tree ID: 25 - 1

Reading Date: June 30, 2016

Collection Date: cut June 2015

Slab ID: GS - Btm excavated March 2016

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2016: Outermost ring read

2012: Small

2009: Rel. Small
2008: Rel large; ring supp after '08; poss burial i/n '08

1997: Mid year xyl band ?
1996: Midyr xyl band
1995: Mid year xyl band ??

1991: Rel large

1988: Rel Small
1987: Rel large
1986: Rel. large
1985: Rel large
1984: Rel small
1983: Mid. year xyl band, rel small
1982: Rel. large
1981: Rel large

1979: midyr xyl band
1978: Rel large
1977: midyr xyl band

1969: Rel. Small

1965: Rel. large
1964: Rel. Small

1962: Rel. large

1959: Rel. Small
1958: Rel. large
1957: Rel small
1956: Rel small
1955: Rel small

1953: Rel. large
1952: Rel small
1951: Rel small
some sort of physical transition here xyl widen and tone change - poss. burial here

1945: Rel. large
1944: Rel small
1943: Innermost ring read.

1942:

Review
JS 9/15/16

Ring Reader: Bradley Collette

Reading Date: June 30, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 1

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2016: Outermost ring read

2012: Small

2009: Rel small
2008: Rel large, ring supp after 08, poss burial i/a '08

1991: Rel. large
1990: Rel large

1986: Rel. large
1985: rel large
1984: rel small
1983: rel small
1982: rel large
1981: rel large

1978: Rel large
1977: mid yr xyl band

1969: rel small

1962: Rel large

1958: Rel large
1957: Rel. Small
1956: Rel. Small
1955: Rel. Small
1953: Rel. large
1952: Rel. Small ~~and Δ '53, poss burial i/a 52~~
1951: Rel small
1950:
1949: Rel. Large
1945: rel large
1944: Rel Small, Innermost ring read
1943: visible inside, but mostly rotted

Review
JS 9/16/16

Ring Reader: Bradley Collette

Reading Date: June 30, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 2

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2009: Outermost ring read likely
2008: Rel. Small Anat.Δ '09 ~~possible~~ burial '08, ring supp as well

1997: Rel. Small

1991: Rel large
1990: Rel large

1986: rel large
1985: rel large

1984: Rel. Small
1983: Mid year xyl band, rel small
1982: Rel. Large

1978: rel large
1977: Rel. Small, mid yr xyl band

1972: Rel. Large

1969: Rel. Small

1964: ~~Rel Small~~
1963: ~~Rel Small~~

1962: Rel large

1961: Rel. Small

1959: Rel Small
1958: Rel. Large
1957: Rel. Small
1956: Rel Small
1955: Rel. Small

1953: Rel. Large
1952: Rel. Small → Anat.Δ '53, poss. burial '62
1951: Rel Small
1945: rel large
1944: Rel. Small, Innermost ring read. Possibly another ring can be read further in but rot makes it hard to tell.
1943 visible inside

Review
JS 9/16/16

Ring Reader: Alex Walker

Reading Date: 7/15/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 25-1

Slab ID: 3

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

200[illegible]

2008 ring supp in '09; likely burial i/n '08

1994: ~~ana Δ 95, poss burial i/a '94~~

1991: rel large

1989: rel small

1986: rel large

1985: rel large

1984: rel small

1983: mid yr xyl band

1982: rel large

1977: mid yr xyl band

1970:) ana Δ from 69-70 xyl
1969: go from larger to smaller, poss excavation?

1959 \
1958) ring surp, these dates are inferred some what
1957 /

1952: ana Δ + ring surp '53 likely burial i/a '52

1951: rel small

1949: rel large

1945: rel large

1944: inner most ring read

Reviewe AW
8/2/16
9/16/16

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 4

Ring Counts/Notes:

File Name:

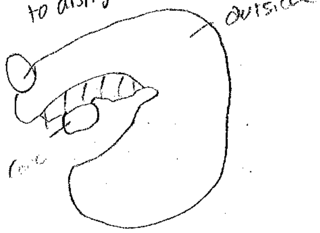
# of radii measured

Series ID:

Wood anatomy change notes:

Similar to A1/A2, there is a large band of xyl after '53 where it is tough/impossible to distinguish bands.

Core: 1953: Outermost ring read
1951: rel small ana Δ + ring surp 52 burial i/a 51
~~1951: Rel. Small~~
1949: Rel. large
✓ 1944: Innermost ring read



Outside: 1993.
2003: Outermost ring read
2002: Ring surp '03 poss burial i/a 02
1992:
1991: ana Δ'92, ~~likely~~ poss burial i/a '91 I don't see this... JS
1990:
1989:
1988:
1987: faint midyr xyl band?
1986: rel large
1985: Rel large
1984: Rel. small
1983: mid yr xyl band
1982: Rel. large, ana Δ '83, poss burial '82
1981: Rel. large
1980: Rel. large

1979:
1978:
1977:
1976:
1975:
1974: mid yr xyl band?
1973: mid yr xyl band?
1972:
1971:
1970: Innermost ring read, ana Δ inside of this to larger xyl, poss burial + excavation here

Ring Reader: Julian Scott

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date:

Tree ID: 25-1

Slab ID: A2/M2

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

'08: outermost ring read; Ring supp in '09; likely burial i/a '08
'84: rel small
'83; rel small w/ mid yr band; slight anad after '83, poss burial i/a '83
55-'69: compressed & rotten

'52; ring supp & anad after '52; likely burial i/a '52

This sequence of rings may indicate burial i/a '52 by a sediment package that was subsequently eroded in the late '60's or early '70s.

'51 rel small
'49 rel large

'43 innermost wood

Review
JS 9/16/16

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date:

Tree ID: 25-1

Slab ID: A2/M2

Ring Counts/Notes:

File Name:

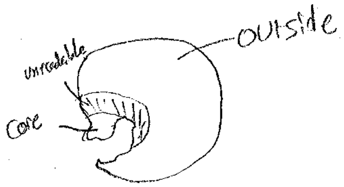
# of radii measured

Series ID:

Wood anatomy change notes:

Large Area of xyl between '54 band and next readable band. Tough/impossible to distinguish bands within this area

core! 1954: Outermost ring read
1953:
1952: ana Δ, ringsurp 53, burial i/a 52
1951: Rel. Small
1949: Rel. Large
1944: Rel. Small, Innermost ring read



1995: Outermost ring read
Outside! 1994: ~~ring surp 95, poss burial i/a 94~~
1991: rel small
1989: rel small
1988: Rel. Small
1987:
1986: rel large
1985: Rel large
1984: rel small
1983: relsmal midyr one laxis
1982: Rel Large
1981: Rel. Large
1980:

ring surp '83, poss burial i/a '82

1979:
1978
1977: midyr xyl band
1976: mid yr xyl band
1975: ~~mid yr xyl band~~
1974:
1973:
1972: Rel large
1971: Rel large
1970: Innermost ring read

Ring Reader: Julian Scott

Reading Date: 9/15/16

Site ID: Hardscrabble

Collection Date:

Tree ID: 25-1

Slab ID: 4

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

'84 Rel small

'83 Rel small w/ mid yr band

'82 ana Δ in '83 or '84, poss burial i/a '82 or '83

'70 - '82 Rel large ; (release from burial i/a '70); anatomy appears stem

'53 to '69 ; Rel small ; rng supp + ana Δ beginning in '53; burial i/a '52

'51 ; Rel small

'44 Inner most ring

Ring Reader: JS

Reading Date: 9/15/16

Site ID: Hardscrable

Collection Date:

Tree ID: 25-1

Slab ID: 5

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

'84 ana Δ in '84; burial i/a '83

'83 ring supp in '83; burial i/a '82 (likely '83)

'75 to '82 rel large; release from burial occured i/a '75

'53 to '74 Rel small; ring supp + Ana Δ & ring supp
likely due to burial i/a '52

'44 inner most ring read

Review 9/6/16

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 5

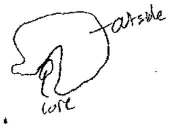
Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes: Slab is in 3 pieces. Core is detached from surrounding wood. Unable to read outward from where the core fits. Similar to previous slab (4, A2/A4).



Core:

1953: Outermost ring read

1951: Rel. Small Ana. Δ '52, burial i/a '51

~~1951: Rel. Small~~

~~1945: Rel. Large~~

1944: Innermost ring read, no pith seen

Outside:

~~2003: Outermost ring read~~

~~2002: ring surp '03, poss~~ burial i/a '02

~~1993: ana Δ '94, poss burial '93~~

1992:

~~1991: ana Δ '92, poss burial '91~~

1990:

1989:

~~1988: Rel. Small~~

1987:

1986:

1985:

1984: rel small, outermost ring read

1983: Rel Small, mid yr xyl band,

1982: rel large, ana Δ, ring surp '83, likely burial i/a '82

1981: rel large

1980: rel large, ana Δ and stem wood growth, smaller xyl, poss excavation i/b '79

↑ seems more like i/a '74, as evidenced by ringsupp release... ana Δ not clear to me

1979:

1978:

1977:

1974: innermost ring read, converts to larger xyl inside of this

Review
JS 9/16/16

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 6

Ring Counts/Notes:

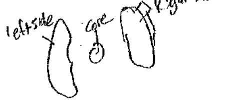
File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

Slab is in 4 pieces including the detached core. Tough/impossible to read bands on the pieces surrounding the core because of the lack of distinction between bands.



Core:

1953: Outtermost ring read

1951: Rel small, ana Δ '52, burial i/a '51

~~1951: Rel small~~

1948: Rel. Small

1945: Rel. Large

1943: Innermost ring read, but barely

Leftside:

1984: Outtermost ring read

1983: Rel. Small,

1982: Rel. Large, ana Δ + ring supp '83, burial i/a '82

1981: Rel. Large

1980: Innermost ring read, xyl grow bigger 1 side of this – likely excavation

1/6 '79

- Having trouble cross dating the cores from 5 to 6

Review
JS 9/16/17

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 7

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

Slab is in 5 pieces. Unable to read rings on the parts of the pieces immediately next to the core.

Can't read shaded parts

Core

1953: outermost ring read

1952: Rel. Small

1951: Rel small, ava Δ 52, burial i/c '51

1949: Rel. Small

1945: Rel. Large on l axis

1943: Innermost ring read

1942 visible inside of this, but mostly rolled

Outside:

1983 outtermost ring read

1982: rel large, ava Δ, burial i/a '82

1981: rel large

1980: rel large, innermost ring read, xyl much larger inside here, excavation i/b '79

Review
ß 9/16/17

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 8

Ring Counts/Notes:

File Name:

# of radii measured

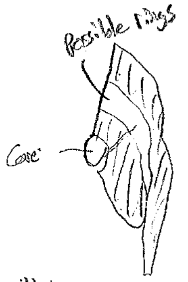
Series ID:

Wood anatomy change notes:

Slab 3 in 3 pieces. Core is actually attached, but rings are unable to be read in an area outside of 1952 ring.

Core:
1952: Outermost ring read
1951: Rel. Small; Ana. Δ in '62, ~~possible~~ burial '51
1950: Rel Small
1949: Rel Small
1945: Rel large
1942: Inner most ring read, no pith seen
1941: wood visable

Out side:
1983: outermost ring read
1982: rel large, ana Δ + ring sup '83, burial i/a '82
1981: inner most ring, sup inside, excavation i/6 '80



Possible:
1983: Outermost ring read
1982: Rel. Large
1981: Innermost ring read

How to be more certain dating these rings with few/no indicators.

Review
JS 9/16/17

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: Top of 5

Ring Counts/Notes:

File Name:

# of radii measured

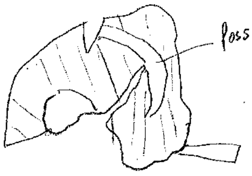
Series ID:

Wood anatomy change notes:

Slab is in 2 pieces. The second piece is a root that broke off with little value.

Just outside the core it's impossible to distinguish rings.

1953: Outermost ring read
1952: Rel. Small
1951: Ana. △ '52, possible burial '51
1950:
1949:
1948:
1947: Rel. Small
1946:
1945:
1944:
1943:
1942: Innermost ring read, Rel. Large



Possible: 1983: Outermost ring read
1982: Rel. Large
1981: Inner ring read, rel large

↳ V. likely, but extremely faint - not visible on multiple radii

↳ I do think this is an excavation and then burial that we are describing here

Review
JS 9/16/16

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 9

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1952: Outtermost ring read
1951: Ana. Δ '52, ~~[illegible]~~ burial y/a '51
1950:
1949: Rel. Small
1948: Rel. Small
1947: Rel. Small
1946:
1945: Rel. large

1942: rel large
1941: ⊙ w/ pith

Review
9/16/16

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: HardScrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 10

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1952: Outtermost ring read
1951: Ana. Δ '52, likely burial '51
1950: Rel. large
1949: Rel. Small
1947: Rel Small
1943: Rel. large
1942: Rel. Large
1941: ⊙ w/ pith

1952: Outtermost ring read
1951: Δ ana '52, burial i/a '51
1950: rel large
1949: rel small
1947: rel small
1943: rel large
1942: rel large
1941: ⊙ w/ pith

Review
9/16/16

Ring Reader: Bradley Collette

Reading Date: July 1, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: S/AC

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1952: Outtermost ring read
1951: Ann. Δ '52 ~~[illegible]~~ burial '51
1950:
1949: Rel Small
1948: Rel Small
1947: Rel Small
1946: Rel Small → 1943: rel large
1942: Rel large
1941: ⊕ W/ Pith

Review
JS 9/16/16

Ring Reader: Bradley Collette

Reading Date: July 5, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 11

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1952: Outtermost ring read
1951: Ana. Δ '52, likely burial '51
1950: rel large on this radius
1949: Rel. Small
1948: Rel. Small
1947: Rel Small
1945: Rel large, ann Δ '46, ring supp '47-49, poss burial i/a '45
1944: Rel. Small
1943:
1942: Rel large ; Mid year xyl band → possible adding a ring?
1941: ⊙ w/pith

JS
Review 9/6/16

Ring Reader: Bradley Collette

Reading Date: July 5, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 12

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1952: Outtermost ring read
1951: Ana Δ '52, ~~likely~~ burial '51.
1950:
1949: Rel small
1948: Rel small
1947: Rel small
1946: ring surp '47 & ana Δ in '47; likely burial i/a '46
1945: Rel large
1944
1943:
1942: Rel. large, faint mdyr xyl band
1941: ⊙ w/ pith

Review
JS 9/16/16

Ring Reader: Bradley Collette
Reading Date: July 5, 2016

Site ID: Hardscrabble
Collection Date: 2015

Tree ID: 25-1
Slab ID: 13

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1947: Outtermost ring read
1946: Rel. Small. Ana Δ '47, ~~likely~~ burial i/a '46
1945: Rel. large
1944:
1943:
1942: rel large, faint wdyr xyl band
1941: ⊙ w/pith

Ring Reader: Bradley Collette

Reading Date: July 5, 2016

Site ID: Hard Scrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 14

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1945: Outermost ring read
1944: Rel. small Ana. Δ '45, possible burial '44
1943:
1942: Rel large, mid year xyl band
1941: ⊙ W/ pith

1945: Outermost ring read
1944: Rel small, ana Δ + ring surp '45, burial i/a '44
1943: xyl size inc in '43, poss burial i/a '42
1942: rel large, faint midyr xyl band - poss add ring
1941: ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: July 5, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 15

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1945: Outermost ring read
1944: Rel. Small; Ana. Δ '45, ~~possible~~ burial '44
1943:
1942: Rel large, faint mid yr xyl band, ana Δ '43, poss burial i/a '42
1941: ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: July 5, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 16

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1943: Outter most ring read~~
~~1942: Ana. Δ '43, possible burial '42~~
~~1941: rel. Large~~
~~1940: ⊙ w/ pith~~

1944: Outermost ring read
1943: rel small
1942:
1941: rel large, midyr xyl band
1940: ⊙ w/pith

Ring Reader: Bradley Collette

Reading Date: July 5, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: AC/R

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1943: Outtermost ring read~~
~~1942: Ana. Δ '43; possible burial '42~~
~~1941: Rel Large; Mid year xyl band?~~
~~1940: ⊙ w/ pith~~

~~1944: Outermost ring read~~
~~1943: ana Δ '44, likely burial~~
~~i/a '43~~
~~1942: rel large~~
~~1941: ⊙ w/ pith~~

1943 : outermost
'42 : ring supp & anat in '43
likely burial i/a '42
'41 : Rel large & mid yr bnd
'40 ⊙ w/ pith & mid yr bnd

Ring Reader: Bradley Collette

Reading Date: July 5, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: Bot. of R

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1943: outtermost ring read~~
~~1942: Rel. Small, Ana. Δ '43, possible burial '42~~
~~1941: Rel. large, Mid year xyl. band?~~
~~1940: ⊙ W/ pith~~

1943: outermost ring read
1942: Rel small, ana Δ '43
burial i/a '42
1941: rel large
1940: ⊙ w/pith

Ring Reader: Bradley Collette

Reading Date: July 5, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: Y upper

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1943: Outermost ring read
1942: Rel. small; Ana △ '43, ~~possible~~ burial '42
1941: Rel. large
1940 ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: July 6, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: YY up

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1943: OUttermost ring read~~
~~1942: Rel. Large; Ana. Δ '43; possible burial '42.~~
~~1941: Rel. Small~~
~~1940: Rel. Large~~
~~1939: ⊙ w/ pith~~

1943: Outermost ring read, but only on 1 axis
1942: rel large
1941: rel large, ana Δ '42, likely burial i/a '41
1940: rel large
1939: rel small, O w/pith

Ring Reader: Bradley Collette

Reading Date: July 6, 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 20

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1942: Outtermost ring read~~
~~1941: Rel. Small; Ana. △ '42, possible burial '41~~
~~1940: Rel. Large~~
~~1939: ⊙ w/ pith~~

1991: outermost ring read
1940: rel large, ring surp '41, burial i/a '40
1939: ⊙ w/pith

Ring Reader: Bradley Gillette

Reading Date: 8-3-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 22

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outermost ring read, ana Δ '40, burial i/a '39

1939: O w/ pith ; ~~ana Δ '41, possible burial '40~~

Ring Reader: Bradley Collette

Reading Date: 8-3-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 23

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1941: Outtermost ring read

1940: Ana △ '41, burial in '40

1938: ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: 8-3-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 24

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outermost ring read, ana Δ outside of 40 - (41), burial i/a '40

1939: ① w/ pith, ~~Ana Δ '41, possible burial '40~~

Ring Reader: Bradley Collette

Reading Date: 8/3/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 26

25 is omitted due to labeling error - no 25 exists

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outtermost ring read; Ans △ outside '40, burial in '40 b/c ant. midyr xyl band

1939: ⊙ W/ pith

Ring Reader: Bradley Collette

Site ID: Hardscrabble

Tree ID: 25-1

Reading Date: 8/3/2016

Collection Date: 2015

Slab ID: 27

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1941: Outtermost ring read

1940: Ring supp. in '41, burial in '40

1939: ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: 8/31 2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 28

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outtermost ring read, Ann. Δ outside of '40, burial in '40

1939: ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: 8/3/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 29

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outtermost ring read; Not much change in '40, burial in '40

1939: O w/ pith

Ring Reader: Bradley Collette

Reading Date: 8/3/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 30

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outtermost ring read, 1 ring supp. outside of '40, burial in '40

1939: O w/ pith

Ring Reader: Bradley Collette

Reading Date: 8/3/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 31

Slab ID: 31

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outtermost ring read; Ann. Δ outside of '40, burial '40

1939: ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: 8/3/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 32

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outtermost ring read; appears to be little change in '40; likely burial in '40

1939: ① w/ pith

Ring Reader: Bradley Collette

Reading Date: 8/3/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 25-1

Slab ID: 33

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1940: Outtermost ring read, little change in '41, likely burial in '40

1939: ① w/ pith

Germinated at or below this slab
1939 +/- 2 yrs owing to unknown
location of transition to pith in stem

Ring Reader: Alec Walker

Site ID: Hardscrabble

Tree ID: Z5-2

Reading Date: 10/24/16

Collection Date: Cut June 2015, excavated March 2016

Slab ID: Above GS-Z

This slab + GS-1 both include a GS tag due to

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2016- outer most ring read
↳ hard to read outer rings due to partial conversions to root wood + rotting on outside

2009 - rel small
2008 - rel large
2007 - rel large

1986 - rel large
1985 - rel large, mid yr xyl band
1984 - rel small
1983 - rel small, mid yr xyl band
1982 - rel large
1981 - rel large

1975- pith flecking

1945- mdyr xyl band

1941- ① w/ pith

Ring Reader: Alex Walker
Reading Date: 10/24/16

Site ID: Hardscrabble
Collection Date: Cut June 2015, excavated March 2016

Tree ID: Z5-2
Slab ID: Above GS-Z

This slab + GS-1 both include a GS tag due to

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2016 - outer most ring read
↳ hard to read outer rings due to partial conversions to root wood + rotting on outside

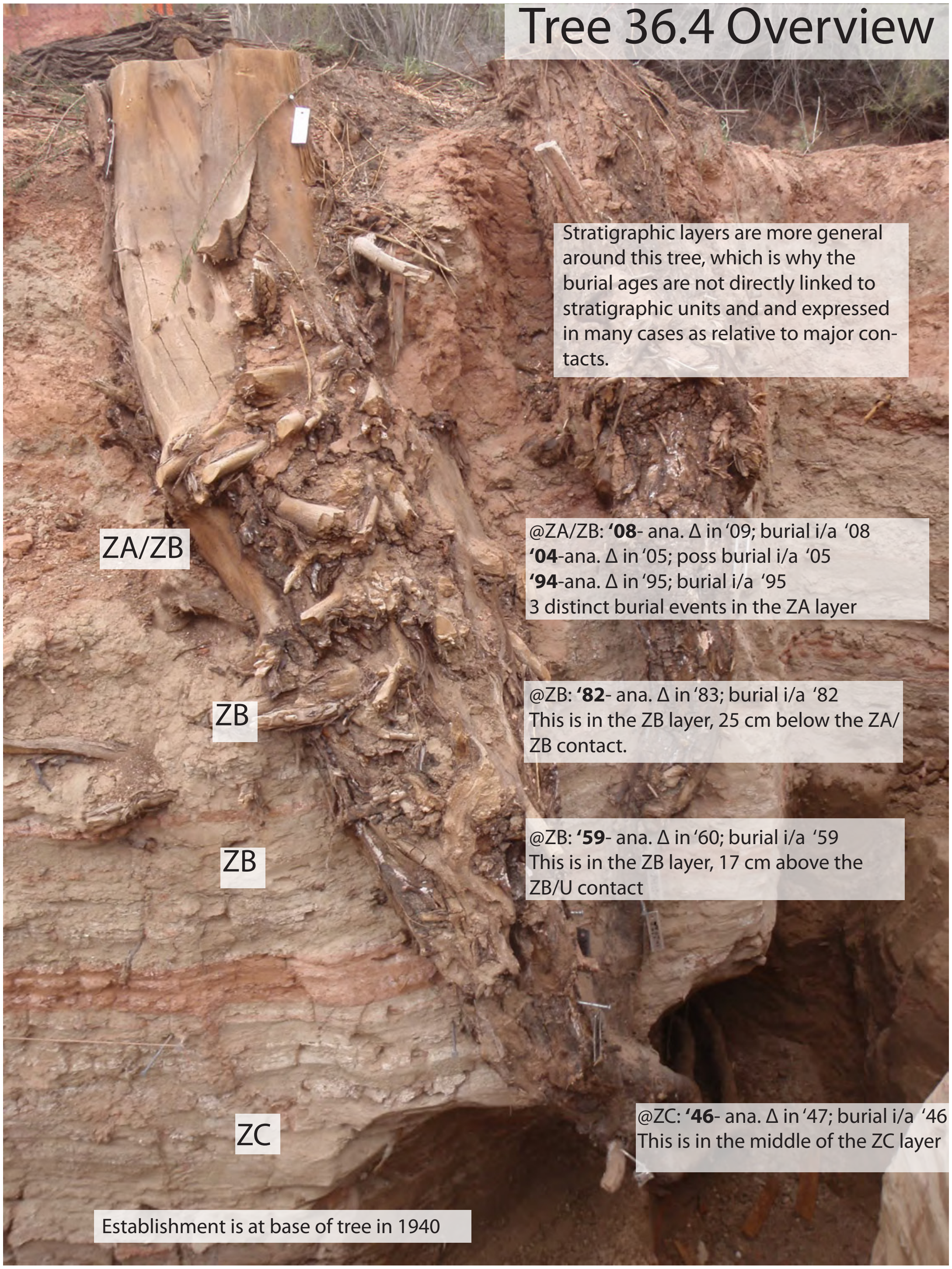
2009 - rel small
2008 - rel large
2007 - rel large

1986 - rel large
1985 - rel large, mid yr xyl band
1984 - rel small
1983 - rel small, mid yr xyl band
1982 - rel large
1981 - rel large

1975 - pith flecking

1945 - midyr xyl band

1941 - ① w/ pith



Tree 36.4 Overview

Stratigraphic layers are more general around this tree, which is why the burial ages are not directly linked to stratigraphic units and and expressed in many cases as relative to major contacts.

@ZA/ZB: **‘08**- ana. Δ in ‘09; burial i/a ‘08
‘04-ana. Δ in ‘05; poss burial i/a ‘05
‘94-ana. Δ in ‘95; burial i/a ‘95
3 distinct burial events in the ZA layer

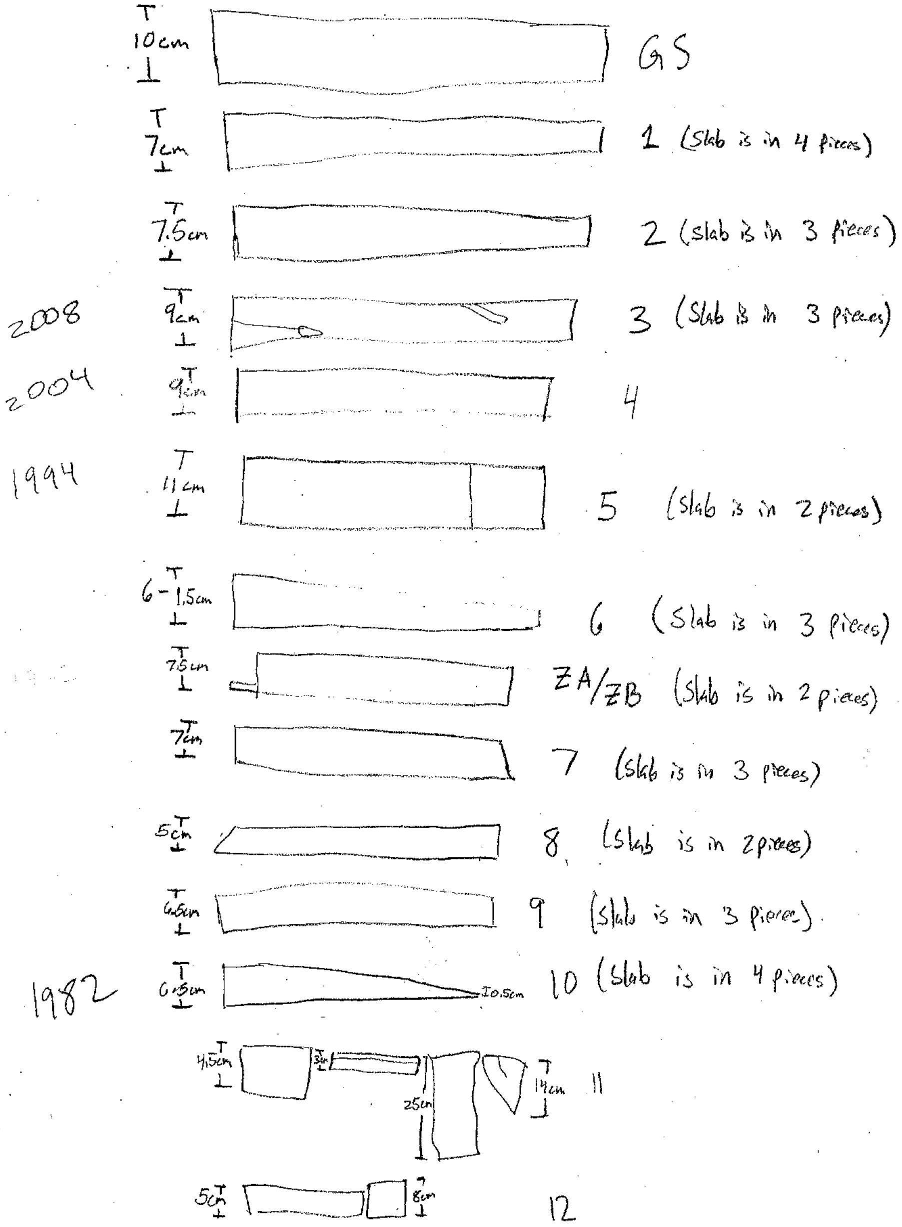
@ZB: **‘82**- ana. Δ in ‘83; burial i/a ‘82
This is in the ZB layer, 25 cm below the ZA/ZB contact.

@ZB: **‘59**- ana. Δ in ‘60; burial i/a ‘59
This is in the ZB layer, 17 cm above the ZB/U contact

@ZC: **‘46**- ana. Δ in ‘47; burial i/a ‘46
This is in the middle of the ZC layer

Establishment is at base of tree in 1940

Tree: 36.4


10cm
GS
7cm
1 (Slab is in 4 pieces)
7.5cm
2 (slab is in 3 pieces)
2008
9cm
3 (Slab is in 3 pieces)
2004
9cm
4
1994
11cm
5 (Slab is in 2 pieces)
6-1.5cm
6 (Slab is in 3 pieces)
7.5cm
ZA/ZB (Slab is in 2 pieces)
7cm
7 (Slab is in 3 pieces)
5cm
8 (Slab is in 2 pieces)
6.5cm
9 (Slab is in 3 pieces)
1982
6.5cm
10.5cm
10 (Slab is in 4 pieces)
4.5cm
3cm
25cm
14cm
11
5cm
8cm
12

Ring Reader:

Reading Date:

Site ID:

Collection Date:

Tree ID: 36.4

Slab ID:

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

✡ This applies to the following ring reading notes ✡

Compared to tree 25-1 and the hydrology, these slabs may be 4~~3~~ years older than originally thought - so a year would be -~~3~~4 years from actually recorded on notes

Ex: reads 1986, but is actually ~~1983~~ 1982 when comped to 25-1

-AEW 10/23/16

Ring Reader: Alex Walker

Reading Date: 10/23/16

Site ID: Hardscrabble

Collection Date: March 2016, cut June 2015

Tree ID: 36.4

Slab ID: 65

Ring Counts/Notes: Note: this is updated dating sequence with cross-dating to tree 25-1 based on 83/84 flood years. See cover note in this sequence as well for overall tree notes
—AEW 10/23/16

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

Exterior rotted

2011: Outermost ring read

1986: Rel large
1985: Rel large
1984: Rel sm, mid yr xyl band
1983: Rel small
1982: Rel large
1981: Rel large.

1975: Pith flecking, cracking on this radius

1954: Center w/pith

Ring Reader: Bradley Collette
Reading Date: 8/4/2016

Site ID: Hardscrabble
Collection Date: 2015

Tree ID: 36.4
Slab ID: GS

Ring Counts/Notes:

- Outer rings appeared rotted and so outer rings may be older that 2015 as read
-AW 10/23/16

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

2015: Outtermost ring read
2014:
2013:
A { 2012: Rel small
2011: Rel. Large, area Δ '12 poss burial i/a 11
2010: Rel. Large }
2009:
2008:
2007: Rel. Large
2006:
2005:
2004:
2003:
2002:
2001:
2000: Rel. Large
1999:
1998:
1997:
1996:
1995:
1994:
1993:
1992:
1991: Rel Small
1990:

1989:
1988: Rel. Small, midyr xyl band
1987: Rel. Small, lrg xyl
B { 1986: Rel. Small, faint midyr xyl band
1985: rel large
1984: rel lrg }
1983: rel large
1982:
1981: rel lrg
1980:
~~1978~~:
1979: splitting on 1 radius, compressed wood as well
1977: Rel. Small
1976: Rel. Large
1975: Rel. small
1974:
1973:
1973: Rel. Small
1971:
1970: Rel large
1969:
1968:
1968: Rel. Small
1967: Rel. Small
1966: rel lrg
1965: Rel. Small
1964: rel large
1962:
1961:
1961: faint mid yr xyl band

1959:
1959: Rel large ; Innermost ring read
1958: ~~Possibly there, inside is damaged and hard to tell~~ ⊙ w/pith visible, poss '56

Ring Reader: Bradley Collette

Reading Date: 8/4/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 1

Ring Counts/Notes:

File Name:

\# of radii measured

Series ID:

Wood anatomy change notes:

2012: Outermost ring read
2011: Ring Supp. '12, poss burial '11
2010: Rel. Large
2009:
2008: Mid year Xyl band?
2007: rel large
2006:
2005:
2004:
2003:
2002: Rel. Small
2001:
2000: Rel. Large ; mid year xyl band
1999: rel lrg
1998: rel lrg
1997: Rel Small
1996: rel lrg
1995: rel lrg
1994:
1993:
1992:
1991: Rel Small
1990:

1989:
1988: Rel. Small, mid yr xyl band
1987: Rel. Small
1986: Rel. Small ; Mid year Xyl band?
1985: Rel. large
1984: rel large
1983:
1982:
1981:
1980:
1979:
1978: splitting on this ring - wood looks like pith
1977: Rel. Small
1976: Rel. large
1975: Rel. Small
1974:
1973:
1972: Rel. Small
1971:
1970: rel large
1969:
1968: Rel large
1967: Rel. Small
1966 Rel. Small
1965: rel large
1964: Rel Small
1963:
1962:
1961:
1960:
1959:
1958: Rel large; Innermost ring read
1957: some partial pith visible, likely ⊙ w/pith

Ring Reader: Bradley Collette

Reading Date: 8/4/2016

Site ID: Hard Scrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 2

Ring Counts/Notes:

File Name:

\# of radii measured

Series ID:

Wood anatomy change notes:

2012: Outermost ring read
2011: Ann Δ+ ring surp '12, burial i/a '11
2008: rel small
2005:
2004:
2003:
2002: Rel. Small
2001:
2000: mid yr xyl band
1999:
1998:
1997:
1996: rel lrg
1995: rel lrg
1994: rel lrg
1993: rel lrg
1992:
1991: Rel. Small
1990:
1989:
1988: Rel Small, mid yr xyl band
1987: Rel small, mid yr xyl band
1986: Rel small, mid yr xyl band
1985: rel lrg
1984: rel lrg
1983:
1982:
1981: Rel large
1980: Rel lrg

1979:
1978: splitting on radius - pith wood
1977: Rel Small
1976: Rel large
1975: Rel Small
1974: Rel Small
1973:
1972: Rel Small
1971:
1970: Rel large
1969:
1968: Rel large
1967: Rel Small
1966: Rel Small
1965: Rel large
1964: Rel Small
1963: Rel small
1962: Rel small
1961:
1960:
1959:
1958: Rel. large
1957: ⊙ w/pith, part rotted

Reviewed AEW 8/9/16

Ring Reader: Bradley Collette

Reading Date: 8/4/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 3

Ring Counts/Notes:

-outer layers appear to be rotting

File Name:

# of radii measured

2012: outermost ring vessel

Series ID:

2011: ana Δ/ring surp 12, burial i/a '11

Wood anatomy change notes:

2008:
2007: ana Δ '08, poss. burial i/a '07
2006:
2005: ana Δ '06, poss burial i/a '05
2004:
2003:
2002: Rel. Small
2001:
2000: Mid year xyl band
1999:
1998:
1997:
1996:
1995: rel large
1994: rel large
1993:
1992:
1991: Rel. Small
1990:
1989:
1988: Rel. Small, mid yr xyl band
1987: Rel. small midyr xyl band
1986: Rel. Small mid yr xyl band
1985:
1984:
1983:
1982:
1981:
1980:

1979:
1978: splitting on radius - anatomy change
1977: Rel. Small
1976: Rel large
1975: Rel. Small
1974:
1973:
1972: Rel. Small
1971:
1970:
1969:
1968: rel large
1967: Rel. Small
1966: Rel small
1965: Rel. large
1964: Rel. Small
1963:
1962:
1961:
1960:
1959:
1958: Rel. Large;
1957: ⊙, partial pith visible

Ring Reader: Bradley Collette

Reading Date: 8/4/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 4

Ring Counts/Notes:

- can see out to 12 on 1 axis, so it may be
File Name: that 2012 is the outermost ring, but hard to
\# of radii measured see as a whole
2008: outermost ring read
Series ID: 2007: ana Δ/ring supp '08, poss burial i/a '07
Wood anatomy change notes: 2005 ana Δ '06, poss burial i/a '05

2000: mid yr xyl band
1999:
1998:
1997'
1996
1995; rel large
1994: rel large
1993: rel large
1992;
1991; Rel small, faint mid yr xyl band
1990;
1989.
1988: Rel. Small, mid yr xyl band
1987: Rel. Small, mid yr xyl band
1986; Rel. Small
1985: rel large
1984: rel large
1983:
1982;
1981:
1980;

1979;
- 1978: splitting @ ring, anatomy change
1977: Rel Small
1976: Rel. large, mid yr xyl band
1975: Rel. Small
1974;
1973:
1972: Rel. Small
1971:
1970:
1969: rel small
1968:
1967: Rel. Small
1966; Rel. Small
1965; rel large
1964; Rel. Small
1963: rel small
1962: rel small
1961:
1960;
1958: rel large
1957: 0 w/ pith visible
partial

Ring Reader: Bradley Collette

Reading Date: 8/5/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 5

Ring Counts/Notes: 2005: outer most ring read
2004: ana Δ '05, poss burial i/a '04

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1998: Outtermost ring read
1997: Ana Δ '98, burial '97; Rel. Small
1996:
1995:
1994:
1993: Rel. large
1992:
1991: Rel. Small
1990:
1989:
1988:
+ 1987: Rel. Small, mid yr xyl band
1986: Rel. Small,
1985: rel large, ana Δ 86, poss burial i/a '85
1984: rel large
1983:
1982:
1981: rel large
1980:
1979:
1978: Damage on ring in this year
1977: Rel. Small
1976: Rel. large
1975: Rel Small
1974:
1973:
1972: Rel. Small
1971:
1970:
1969:
1968:
1967: Rel. Small
1966: Rel. Small
1965:
1964: Rel. Small
1963:
1962:
1961:
1960: faint mid yr xyl band
1959:
1958
1957 ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: 8/9/2016

Site ID: HardScrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: II

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Damage begins in 1955

Wood anatomy change notes:

1977: Outermost ring read
1976: ana Δ 76, poss burial i/a 75
1975:
1974:
1973:
1972: Rel. Small, continues to surpress further down stem
1971:
1970:
1969: Rel. Small
1968: Rel. large
1967: Rel Small
1966: Rel Small
1965: Rel. large
1964: Rel. Small
1963:
1962 ana Δ 63, poss burial i/a 62
1961
1960:
1959:
1958
1957:
1956:
1955 wdyr xyl band, ana Δ 56, likely burial i/a 55
1954: msd yr xyl band
1953:
1952: Rel. Small

1951: Rel. Small
1950: Rel. small
1949:
1948: Innermost ring read
47 visible inside, no pith seen

Ring Reader: Bradley Collette

Reading Date: 8/5/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 6

Ring Counts/Notes:

- some checking and splitting on 1978 ring - def damage in that year

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

Hard to figure this out, I would eliminate these counted rings as we can't be sure -AEW

1999: Outermost ring read
~~1998: Ring supp. '99, possible burial in '98~~
~~1997:~~
~~1996:~~
~~1995:~~
~~1994:~~
~~1993: Rel large,~~
~~1992-1986: Area of large xyl. Individual rings can't be distinguished~~
1986: Outermost ring read
1985: Rel large; Ana △ '86 possible burial in '85
1984:
1983:
1982:
1981: rel large
1980:
1979:
1978: splitting + pith flecks no longer seen on this radius
1977: Rel. Small
1976: Rel. large
1975: Rel. Small
1974:
1973:
1972: Rel. Small
1971:
1970: rel large
1969:
1968:
1967: Rel. Small
1966: Rel Small
1965:
1964: Rel. Small
1963: rel small
1962: Rel. Small
1961:
1960:
1959:
1957: ⊙ w/ pith

Ring Reader: Bradley Collette

Reading Date: 8/4/2016

Site ID: Hard Scabble

Collection Date: 2015

Tree ID: 56.4

Slab ID: ZA/ZB Top

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~There's a portion of rings from the '90's that I am having trouble dating.~~

~~Possibly: 1999: Outtermost ring read~~

~~1998: Ann Δ '99, possible burial '98~~

~~1997:~~

~~1996~~

~~1995-1986: Large xyl which may indicate a burial in '85 followed by excavation '95 ?~~

1986: Outermost ring read

1985: rel large, ann Δ + ring surp 86, likely burial i/e '85

1984: rel large

1983:

1982: Rel. Small

1981: rel large

1980:

1979:

1978:

1977: Rel. Small

1976: Rel. large

1975: Rel Small

1974:

1973:

1972: Rel. Small

1971:

1970:

1969:

1968: rel large

1967: Rel. Small

1966: Rel. Small

1965: rel large

1964: Rel. Small

1963:

1962: rel small

1961:

1960: faint mid yr xyl band

1959:

1958:

1957: ⊙ w/pith

Reviewed ABW 8/15/16

Ring Reader: Bradley Collette

Reading Date: 8/10/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: ZA/ZB Bottom

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

∆ Switches stem at ZA/ZB slab between top and Botton of slab

+6 yrs

Wood anatomy change notes:

1992: Outtermost ring read
1991: Rel small
1988, 1987: Rel Small
1986: Rel small
1985: Rel. large, slight mm Δ 86, poss burial i/a 85
1984: Rel. large
1983:
1982: Rel. Small
1981: Rel large
1980:
1979:
1978:
1977: Rel. Small, mid xyl band
1976: Rel. large, mid yr xyl band
1975:
1974:
1973:
1972: Rel. Small
1971:
1970: Rel large
1969:
1968: Rel large
1967: Rel. Small
1966: Rel. Small
1965: Rel. large
1964: Rel. Small
1963:
1962:
1961:
1960: mid year xyl. band

1959: Rel large
1958: Rel large
1957:
1956:
1955:
1954:
1953:
1952: Rel. Small
1951: Rel. Small
1950: Rel. small
1949: Innermost ring read

+6 yrs = 1955

↳ Adds 8 years here - is this for real?
→ slab switch here

Ring Reader: Bradley Collette

Reading Date: 8/8/2016

Site ID: Hard Scrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 7

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

Maybe → 1996: outermost ring read
1994:
1993:
1992:
1991:
1990: Rel. Small
1989:
1988:
1987: More likely the outermost ring
1986: Mid year XYL band?
1985: Rel. large, also Δ 86, likely burial i/a 85
1984: Rel. large
1983: ~~Rel. Small~~
1982:
1981: Rel large, mid yr xyl band
1980
1979:
1978:
1977: Rel. Small
1976: Rel. large, mid yr xyl band
1975: ~~Rel. Small~~
1974:
1973: rel large
1972: Rel. Small
1971: Rel lrge
1970: Rel large

1969:
1968: Rel. large
1967: Rel. Small, ~~mid yr xyl band~~
1966: Rel. Small
1965: Rel. large
1964: Rel. Small
1963:
1962: splitting on radius at ring
1961:
1960: Mid year xyl. band'
1959:
1958:
1957:
1956:
1955:
1964: Innermost ring read

↳ center rings spotted in above slab not seen here, no pith seen

Ring Reader: Bradley Collette
Reading Date: 8/8/2016

Site ID: Hardscrabble
Collection Date: 2015

Tree ID: 36.4
Slab ID: 8

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1987: Outermost ring read
1985: Rel. large, ara Q + ring surp 86, burial i/a 85
1984: Rel. large
1983: Rel. Small
1982: Rel. small
1981: Rel large
1980:
1979:
1978:
1977: Rel. Small
1976: Rel. large
1975:
1974:
No longer rel. small, Possible mistake 1973:
1972: Rel. Small
1971
1970:
1969:
1968: Rel large
1967: Rel. Small
1966: Rel. Small
1965: Rel. large
1964: Rel. Small
1963:
1962: splitting on ring
1961:
1960: Mid year band ?

1958:
1957:
1956:
1955:
1954:
1953: Inner most ring read
~~1952: Rel. Small~~
~~1951: Innermost ring read~~

Ring Reader: Bradley Collette

Reading Date: 8/18/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 30.4

Slab ID: 9

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Damage to tree starting in 55/56 Impact apparent in those years → its 55

Wood anatomy change notes:

Visible on 1 radii somewhat dubious

1985: Outermost ring read, ana Δ 86, burial i/c '85
1984:
1983:
1982:
1981: Rel. Small
1980:
1979:
1978:
1977: Outermost ring read
1976:
1975: ana Δ + ring supp '76, poss burial i/c '75
1974:
1973:
1972: Rel. Small
1971: ana Δ 72 poss burial i/c 71
1970:
1969:
1968: Rel. large
1967: Rel. Small
1966: Rel. Small
1965: ~~Rel. large~~
1964: Rel. Small
1963:
1962:
1961: Mid yr xyl band
1960:

1959: Rel large
1958: Rel large
1957:
1956: Rel. Small
1955: Rel. Small
1954:
1953:
1952: Rel. Small
1951: Rel. Small
1950: Innermost ring read

* for clear 85 burial signature — weak on 11

Ring Reader: Bradley Collette

Reading Date: 8/8/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 10

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Damage to tree on radius beginning in '55

Wood anatomy change notes:

1978: Outermost ring read
1977: Rel. Small
1976: Rel. large, mid yr xyl band
1975: ann Δ 76, poss burial i/a 75
1974:
1973:
1972: Rel. Small
1971:
1970:
1969: Rel small
1968: Rel. Large
1967: Rel. Small
1966: Rel small
1965: Rel. Large
1964: Rel. small
1963:
1962: Ann Δ 63, poss burial i/a 62, mid yr xyl band here, but not seen further down on slabs
1961:
1960:

1959: Rel large
1958: Rel. large
1957:
1956: Rel small
1955: Rel small, ann Δ '56, poss burial i/a '55
1954: Mid year xyl. band
1953:
1952: Rel. Small
1951: Rel. Small
1950: Rel. Small
1949:
1948: Innermost ring read
'47 visible inside

Ring Reader: Bradley Collette

Reading Date: 8 /10/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 364

Slab ID: 12

Ring Counts/Notes:

- Extremely hard to figure out how the parts of 12 match up w/each other

File Name:

BC: Not confident on transition from 11→12

# of radii measured

-Unsure if ring dates were interpreted correctly from previous slab

Series ID:

↳ I think this interpretation is correct

—AEW
8/21/16

Wood anatomy change notes:

1963: Outermost ring read
1962: ana Δ + ring surp '63, likely burial i/a '62
1961:
1960:
1959:
1958:
1957:
1956: Rel. Small
1955: mid yr xyl band, ana Δ '56, likely burial i/a '55, damage to trunk starting in '55
1954: Mid year band
1953:
1952: Rel. Small
1951: Rel. Small
1950: Rel. Small
1949:
1948: Innermost ring read

47 visible inside, no pith seen

Ring Reader: Bradley Collette

Reading Date: 8/10/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: B -top

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1959: OUttermost ring read~~
~~1958:~~
~~1957:~~
~~1956: Rel. Small~~
~~1955:~~
~~1954:~~
~~1953:~~
~~1952: Rel. Small~~
~~1951: Rel. Small~~
~~1950:~~
~~1949:~~
~~1948: Innermost ring read~~

1963: Outermost ring read
1962:
1961:
1960:
1959: ana Δ in 60 + wng surp poss burial 1/a 59
1958: Rel large
1957:
1956: rel small
1955: mid yr xyl band
1954: mid yr xyl band
1953
1952: rel small
1951:
1950: Rel large
1949: Rel large
1948: Innermost ring read
1947 – ? Maybe visible
↳ At least 47 – maybe 46 visible inside here

Ring Reader: Alex Walker

Reading Date: 8/25/16

Site ID: Hardscrabble

Collection Date: 2015-June

Tree ID: 36.4

Slab ID: 13-base

Ring Counts/Notes:

File Name:

\# of radii measured

Series ID:

Wood anatomy change notes:

1960: outermost ring read, an Δ '60, likely burial i/a '59

1959

1958: Rel large

1957: rel small

1956: rel small

1955: mod yr xyl band, ring supp + ana Δ '56, poss burial '55

1954: no mod yr xyl band seen

1953:

1952:

1951:

1950:

1949:

1948: innermost ring read

1947 visible inside, possibly 1946 as well

Ring Reader: Bradley Collette

Reading Date: 8/10/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 14 - top

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

This is hard to track across slabs here - need to send base of 13

Wood anatomy change notes:

1956: outermost ring read
1955: rel large
1954: rel large
1953: rel small, ana Δ '54, poss burial 1/a 53
1952:
1951:
1950: rel small
1949:
1948:
1947: innermost ring read
1946 visible inside, but no pith seen

Ring Reader: Alex Walker

Reading Date: 8/25/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 14 - base

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1952: Outermost ring read, ana ll 152, poss burial i/a 51
1951
1950
1949: rel large
1948:
1947:
1946: innermost ring read
1945? possible ring in rot
possibly 44 in here below

Ring Reader: Bradley Collette

Reading Date: 8/10/2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 15

Ring Counts/Notes:

BC: Not confident in transition 14→15
- Unsure if ring dates were interpreted correctly

Sand base of 14

File Name:

# of radii measured

- These are a little shakey as only on 1 radius

Series ID:

Wood anatomy change notes:

1952: Outtermost ring read, anat Δ 52, likely burial i/a 51
1951 Rel. small
1950
1949
1948
1947
1946: Innermost ring read
1945 wside inside but no ring seen

Ring Reader: Bradley Collette

Reading Date: 8/10/2016

Site ID: Hard Scrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: Top of 4/2 B

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

counting switched axis, not confident with date
-BC

Wood anatomy change notes:

1952: Outermost ring read, pinching out on 1 radius - ann A 53/52, poss burial i/a 52/51
1951: Rel small
1950: Rel large
1949: Rel large
1948: Rel large, innermost ring read

1947 visible inside, no pith

Ring Reader: Bradley Collette

Reading Date: 8-11-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36-4

Slab ID: 16

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1953 - ~~outermost ring read → added a ring here, needs to be added further up~~

1952 - ana Δ '53, poss burial i/a '52
rel small, outermost ring read
also, ana Δ '52, poss burial i/a '51

1951: rel small
1950: Rel ~~small~~ large
1949: Rel large
1948: Mid year xyl band ← ~~mid yr xyl band~~, innermost ring read
1947 visible inside, no pith

Ring Reader: Bradley Collette

Reading Date: 8-11-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: Bottom of U/ZC

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1951: Outermost ring read, ring supp + ana Δ 51, likely burial 1/2 50

1950: Rel. Small

1949: rel large

1948: Mid year xyl band

1947: innermost ring read, rel large

1946: ⊙ w/ pits

Ring Reader: Bradley Gillette

Reading Date: 8-11-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 17

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1951: outermost ring read, ann Δ51, burial i/a 50

1950: Rel small

1949: rel large

1948: Mid year xyl band, rel. small

1947: Rel large

1946: O w/ pith

Ring Reader: Bradley Collette

Reading Date: 8-11-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 18

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1951: outermost ring read, ana Δ 51, bursal l/a 50

1950: rel. small

1949: rel large

1948: Mid year xyl band; rel. small

1947: rel large, faint yr xyl band

1946: 0 w/ pith

Ring Reader: Bradley Collette

Reading Date: 8-11-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 19

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Damage seen beginning in '51, more evidence for flooding in 1950

Wood anatomy change notes:

~~1453: Outtermost ring read~~
~~1952: Rel. Small~~
~~1451: Rel. Small~~
~~1950: Rel. Small~~
~~1949:~~
~~1948: Mid year band~~
~~1947: Innermost ring read, rotted out in the center~~

ana Δ '48, poss burial t/a '47, damage apparent to tree starting in '48

1951: Outermost ring read,
ana Δ '51, burial t/a 50

1950: Rel small

1949: Rel ~~large~~ small

1948: Rel small, no mid yr xyl band,
ana Δ '49, poss burial t/a 48

1947: Rel large, also poss burial here

1946: Rel large on 1 radius

1945: Rel large, innermost ring read

1944 visible inside but no pith seen

Ring Reader: Bradley Collette

Reading Date: 8-11-2016

Site ID: Hardscrabble

Collection Date: 2015

Tree ID: 36.4

Slab ID: 20

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

~~1952: OUttermost ring read~~
~~1951: Rel. Small~~
~~1950: Rel. Small~~
~~1949:~~
~~1948: Mid year xyl band?~~
~~1947: ⊙ w/ pith~~

1950: Outermost ring read, ana Δ '50, likely burial i/a '49

1949: Rel small

1948: Rel small

1947: Rel large, ana Δ '48, likely burial i/a 47

1946: Rel large on 1 radius

1945: Rel large, but shrinks on other radius'

1944: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 8/26/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 21

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1950: outermost ring read

1949: Rel small

1948: Rel small

1947: Rel large, and '48, likely burial i/a '47

1946: Rel large, compresses on other radius, faint midyr xyl band

1945: faint mid yr xyl band

1944: Rel small

1943: ⊙ w/pith

Ring Reader: Alex Walker

Reading Date: 8/26/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 22

Ring Counts/Notes:

-This is where two trunks combine, still unclear if these trunks are 1 or 2 trees. Also, at this point, tree takes a 40-50° angle offshore into wall of side trench. Below this tree dives at a lower rates than above, where it is vertical through the sediments.

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1948: Outermost ring read

1947: Rel large, ana Δ/ring surp '48, burial i/a '47

1946: Rel medium

1945: mid yr xyl band

1944: Rel small

1943: ⊙ w/pith

Ring Reader: Alex Walker

Reading Date: 8/26/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 23 -A

Ring Counts/Notes:

File Name:

# of radii measured

Series ID: Rings compress on certain radius

Wood anatomy change notes:

1948: Outermost ring read

1947: rel large, ana Δ '48, burial i/a '47

1946: rel large

1945: mid yr xyl band

1944: rel small

1943: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 8/26/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 23-B

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1948: outermost ring read

1947:
1946: ana Δ '47, poss burial i/a '46, wd yr xyl band
1945: no wd yr xyl band seen
1944: rel small
1943: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 8/26/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 24

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

This mid yr band looks a lot like an added ring, but I can't find evidence for the adding of a year by looking at the surrounding slabs - the size of center isn't changing + the dimensions of the rings is smaller on surrounding ~~rings~~ slabs

1948: Outermost ring read
1947
1946: strong mid yr xyl band, ana Δ '47, likely burial i/a '46
1945: Damage seen in this layer
1944: rel small → same as above + below in width
1943: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 8/30/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 25

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1947: outermost ring read

1946: rel small, no mid yr xyl band seen, ana Δ '47, likely buried i/a '46

1945:

1944: rel small

1943: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 8/30/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 26

Ring Counts/Notes:

File Name:

\# of radii measured

Series ID:

Wood anatomy change notes:

1946: Outermost ring read

1945: ana Δ '46, poss burial i/a '45

1944: rel small

1943: ⊙ w/ pith

Ring Reader: Alex Walker

Reading Date: 8/30/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 27

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1946: Outermost ring read ana Δ '46, likely burial i/a '45
1945: clear here, becomes more faint farther down
1944: rel small
1943: 0 w/ pith

Ring Reader: Alex Walker

Site ID: Hardscrabble

Tree ID: 36.4

Reading Date: 8/30/16

Collection Date: June 2015

Slab ID: 28

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1946: Outermost ring read
1945: rel small, ana Δ '46, burial i/a '45 - faint ring
1944: rel small
1943: ⊙ w/pith

Ring Reader: Alex Walker

Reading Date: 8/30/16

Site ID: Hardscrabble

Collection Date: June 2015

Tree ID: 36.4

Slab ID: 29

Ring Counts/Notes:

File Name:

\# of radii measured

Series ID:

Wood anatomy change notes:

1946: outer most rings vessel

1945: and 46, burial 1/a '45 - faint ring

1944: rel small

1943: ⊙ w/ pith

Ring Reader: Alex Walker
Reading Date: 8/30/16
Site ID: Hardscrabble
Collection Date: June 2015
Tree ID: 36.4
Slab ID: 30

Ring Counts/Notes:

File Name:

# of radii measured

Series ID:

Wood anatomy change notes:

1946: Outermost ring read
1945: if this is a ring, it is really faint, and Δ '46, burial i/a '45
1944: rel small
1943: ⊙ w/pith

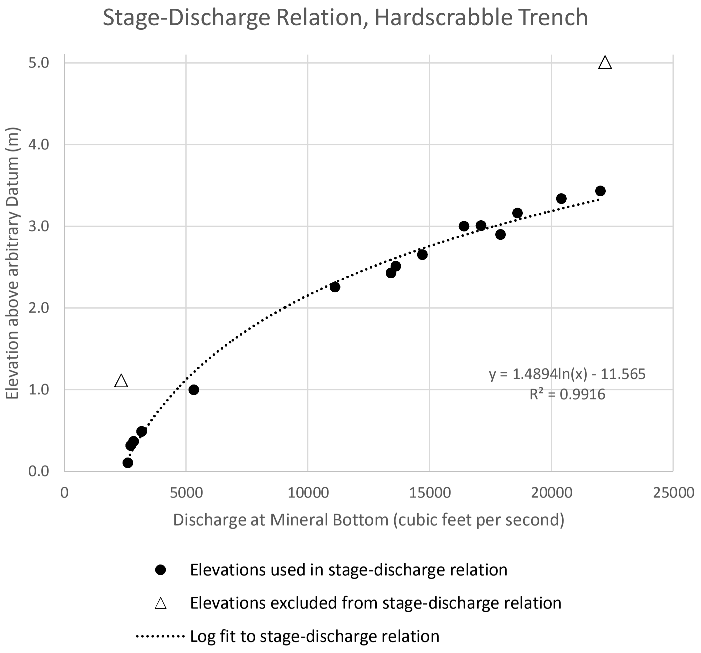
establishment in 1943 in this slab

10/23/16:
w/ 4 yr older adj,
establishment in 1939
-AEW

APPENDIX C. DATA USED TO COMPUTE STAGE-DISCHARGE RELATION AT HARDSCRABBLE BOTTOM

Date	Elevation Above Arbitrary Datum (m)	Discharge at Mineral Bottom (ft^3/s)	Gage Height at Mineral Bottom (ft)	Notes
9/20/2015	1.111	2340	6.71	Not used in relation
6/15/2016	5.009	22200	17.56	Not used in relation
8/8/2015	0.105	2600	6.84	
8/10/2015	0.317	2710	7.00	
3/14/2016	0.489	3160	7.46	
4/8/2016	0.369	2830	7.09	
5/12/2016	2.514	13600	14.28	
5/19/2016	2.654	14700	14.76	
5/26/2016	3.004	16400	15.44	
6/3/2016	2.259	11100	13.07	
6/6/2016	3.009	17100	15.71	
6/7/2016	3.164	18600	16.29	
6/9/2016	3.339	20400	16.92	
6/13/2016	3.434	22000	17.48	
6/22/2016	2.899	17900	15.75	
6/30/2016	2.429	13400	13.96	
7/12/2016	0.999	5310	9.45	

Water surface elevations were collected immediately off shore of the trench at a range of discharges. Elevations were all adjusted to the same arbitrary datum and plotted against discharges from Mineral Bottom (USGS 09328920). I then fit a logarithmic trendline to the data to produce a stage-discharge relation. Two values were excluded from the relation. For both of the excluded values, the elevations recorded were substantially higher than



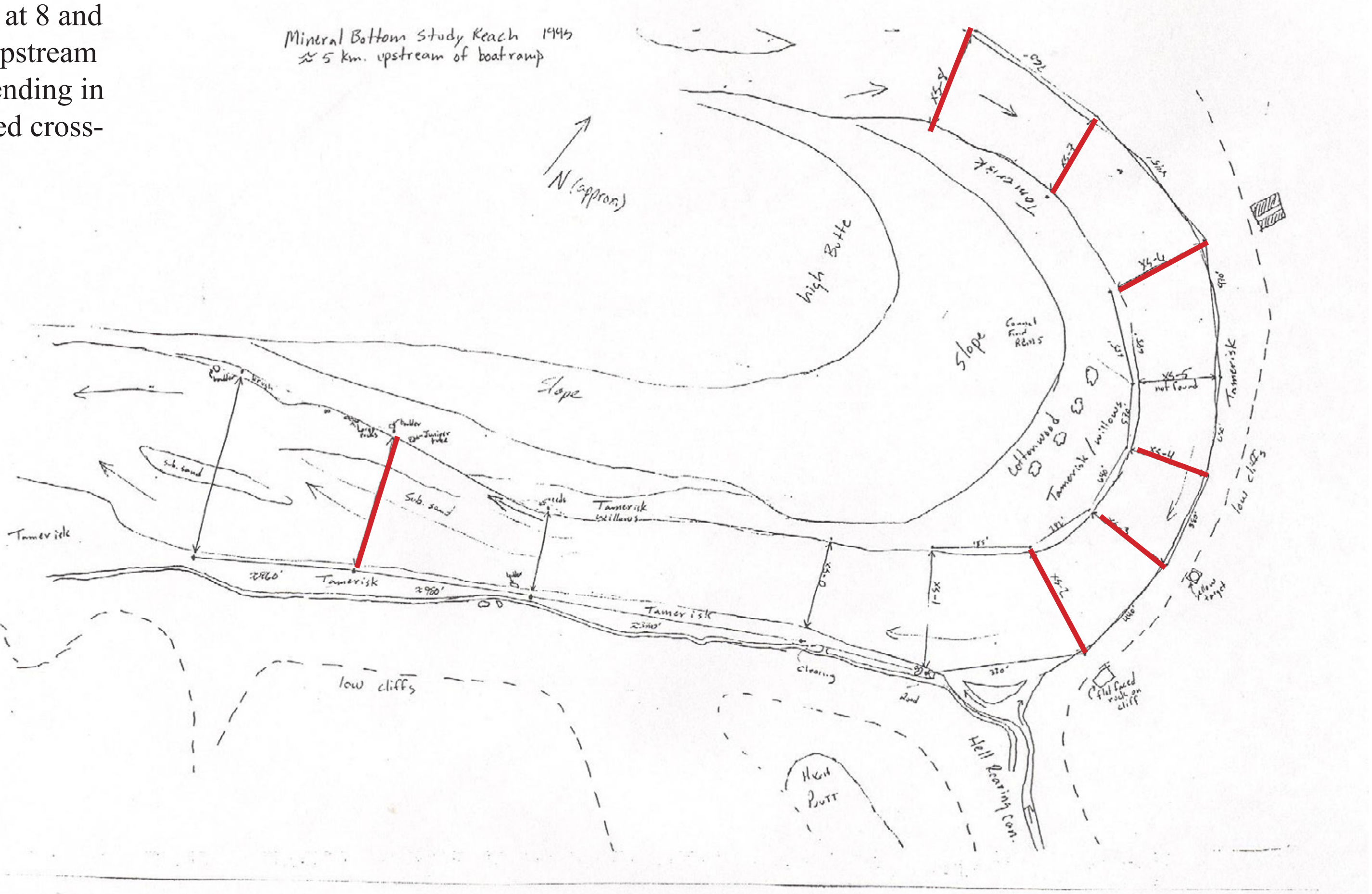
APPENDIX D. CROSS-SECTION SURVEY DATA FROM HELL ROARING CANYON, MAY 2015

Cross-sections were marked at Hell Roaring Canyon by fence posts on both the left and right banks by previous surveys in 1995 and 1996. Some of the posts were eroded away between 1996 and 2015. Of the 12 cross-sections marked on a 1995 sketch of the study reach, 11 were resurveyed and 1 (XS5) wasn’t found. In 2015, we were able to find the left and right benchmarks for 7 cross-sections, and we resurveyed inside of the channel using an Odom CV-100 echo sounder with a 200 kHz transducer. On the banks, the surveys were done by a Trimble RTK-GPS. Positioning was by RTK GNSS survey with a local base station using the coordinate system UTM Zone 12N, North American Datum of 1983 (EPSG 26912).

All collected RTK points were used to build cross-sections. Multiple sonar tracks were collected at each cross-section, resulting in thousands of points. I sub-sampled the raw sonar data to a density of 1 point per meter along an ideal cross-section line between benchmarks. For each cross-section, the ideal cross-section distance is the desired location for each sonar reading and the actual distance is the location on the cross-section of the sub-sampled reading. The 2015 Z values were then adjusted relative to the 1996 elevation of the left pin so the 2015 elevations could be compared to the surveys from the mids-1990s.

Red highlighted cross-sections were resurveyed in 2015. Cross-section numbering starts at 8 and decreases from upstream to downstream, ending in -3. The resurveyed cross-sections were:

XS8
XS7
XS6
XS4
XS3
XS2
XS-2



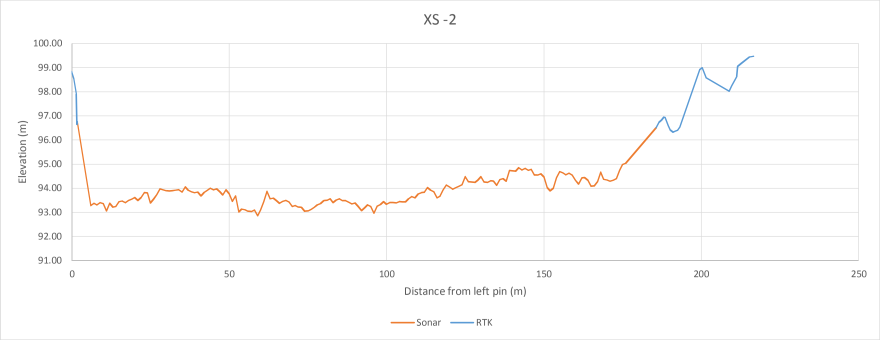
XS -2

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.06	4267484.05	587400.30	98.82	1183.72
Right Pin	216.53	4267622.37	587233.92	99.51	1184.34

We have this listed as XS -3 in our notes, but it is actually XS -2

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-3.16	4267481.60	587402.78	1183.79	98.89
-2.44	4267482.45	587402.22	1183.77	98.88
-1.26	4267483.42	587401.32	1183.85	98.96
-0.04	4267484.04	587400.38	1183.72	98.83
0.61	4267484.71	587399.88	1183.44	98.54
1.45	4267485.53	587399.23	1182.79	97.90
1.69	4267485.96	587399.05	1181.53	96.64
1.77	4267485.89	587398.98	1181.65	96.75
185.63	4267605.42	587257.67	1181.41	96.51
186.57	4267606.12	587256.95	1181.63	96.74
187.41	4267606.87	587256.30	1181.72	96.82
188.05	4267607.34	587255.81	1181.84	96.95
188.53	4267607.69	587255.44	1181.82	96.93
189.52	4267607.99	587254.68	1181.48	96.59
190.11	4267608.13	587254.23	1181.30	96.41
191.09	4267608.36	587253.48	1181.22	96.33
191.64	4267608.51	587253.05	1181.25	96.36
192.47	4267608.98	587252.41	1181.30	96.40
193.23	4267609.45	587251.83	1181.42	96.53
199.50	4267613.23	587247.01	1183.80	98.91
200.35	4267612.64	587246.36	1183.89	99.00
201.40	4267613.39	587245.55	1183.51	98.62
201.49	4267613.28	587245.48	1183.47	98.58
208.84	4267617.83	587239.83	1182.92	98.03
209.67	4267618.25	587239.19	1183.14	98.25
211.29	4267619.38	587237.95	1183.52	98.63
211.61	4267619.50	587237.70	1183.96	99.06
212.73	4267619.93	587236.84	1184.07	99.17
215.39	4267621.81	587234.80	1184.34	99.45
216.62	4267622.35	587233.85	1184.37	99.47



Sonar Data at 1m points

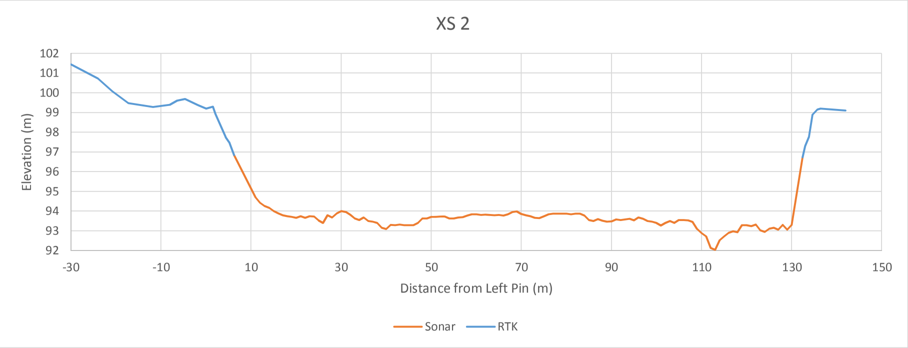
Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
1.77	1.77	4267485.89	587398.98	1181.65	96.75	63.00	62.99	4267526.81	587350.84	1178.45	93.56	121.00	120.99	4267564.92	587305.21	1178.85	93.96
6.06	6.06	4267490.38	587395.62	1178.17	93.28	64.00	63.98	4267527.28	587350.06	1178.48	93.59	122.00	121.99	4267565.51	587304.42	1178.92	94.03
7.00	6.99	4267490.88	587394.89	1178.27	93.38	65.00	64.99	4267527.75	587349.26	1178.37	93.48	123.00	123.00	4267566.38	587303.63	1178.97	94.08
8.00	7.99	4267491.10	587394.10	1178.20	93.31	66.00	66.00	4267528.24	587348.47	1178.27	93.38	124.00	123.99	4267567.29	587302.85	1179.04	94.15
9.00	9.00	4267491.85	587393.31	1178.30	93.41	67.00	66.99	4267529.16	587347.69	1178.35	93.46	125.00	124.99	4267566.90	587302.06	1179.37	94.48
10.00	9.99	4267492.32	587392.53	1178.25	93.36	68.00	67.98	4267529.32	587346.91	1178.39	93.50	126.00	125.99	4267568.66	587301.28	1179.16	94.27
11.00	10.99	4267494.51	587391.74	1177.95	93.06	69.00	69.00	4267529.72	587346.11	1178.32	93.43	127.00	126.98	4267568.83	587300.50	1179.15	94.26
12.00	12.00	4267493.88	587390.95	1178.27	93.38	70.00	69.99	4267531.20	587345.33	1178.13	93.24	128.00	127.99	4267568.95	587299.70	1179.13	94.24
13.00	12.99	4267494.70	587390.17	1178.11	93.22	71.00	70.98	4267531.02	587344.55	1178.17	93.28	129.00	129.00	4267569.69	587298.91	1179.23	94.34
14.00	13.99	4267494.35	587389.38	1178.13	93.24	72.00	72.00	4267532.03	587343.75	1178.11	93.22	130.00	129.99	4267570.50	587298.13	1179.37	94.48
15.00	14.99	4267495.37	587388.60	1178.34	93.45	73.00	72.99	4267532.72	587342.97	1178.09	93.20	131.00	130.99	4267571.85	587297.34	1179.15	94.26
16.00	15.99	4267496.04	587387.81	1178.36	93.47	74.00	73.99	4267533.44	587342.18	1177.94	93.05	132.00	132.00	4267571.81	587296.55	1179.13	94.24
17.00	16.98	4267496.41	587387.03	1178.29	93.40	75.00	74.97	4267533.54	587341.41	1177.95	93.06	133.00	132.98	4267572.40	587295.78	1179.20	94.31
18.00	18.00	4267496.93	587386.23	1178.39	93.50	76.00	75.98	4267534.37	587340.62	1178.01	93.12	134.00	133.99	4267573.65	587294.98	1179.18	94.29
19.00	18.99	4267497.60	587385.45	1178.44	93.55	77.00	76.99	4267534.94	587339.82	1178.09	93.20	135.00	135.00	4267573.52	587294.19	1179.01	94.12
20.00	19.99	4267498.28	587384.66	1178.51	93.62	78.00	77.99	4267535.84	587339.04	1178.20	93.31	136.00	135.99	4267574.06	587293.41	1179.25	94.36
21.00	21.00	4267498.30	587383.87	1178.39	93.50	79.00	78.99	4267536.41	587338.25	1178.26	93.37	137.00	136.99	4267574.57	587292.62	1179.29	94.40
22.00	21.96	4267498.70	587383.11	1178.51	93.62	80.00	79.99	4267537.29	587337.46	1178.38	93.49	138.00	138.00	4267575.10	587291.83	1179.18	94.29
23.00	22.98	4267501.01	587382.31	1178.70	93.81	81.00	81.00	4267538.24	587336.67	1178.39	93.50	139.00	138.99	4267576.24	587291.05	1179.62	94.73
24.00	23.99	4267501.20	587381.52	1178.69	93.80	82.00	81.99	4267538.32	587335.89	1178.46	93.57	140.00	139.99	4267576.74	587290.26	1179.61	94.72
25.00	24.99	4267487.35	587380.73	1178.28	93.39	83.00	82.99	4267539.69	587335.10	1178.30	93.41	141.00	141.00	4267577.65	587289.47	1179.59	94.70
26.00	25.99	4267491.17	587379.94	1178.44	93.55	84.00	83.99	4267540.27	587334.32	1178.40	93.51	142.00	141.99	4267578.62	587288.69	1179.74	94.85
27.00	26.99	4267502.90	587379.16	1178.63	93.74	85.00	84.98	4267539.87	587333.54	1178.46	93.57	143.00	142.99	4267578.65	587287.90	1179.65	94.76
28.00	27.96	4267503.78	587378.39	1178.87	93.98	86.00	85.98	4267541.27	587332.75	1178.38	93.49	144.00	144.00	4267579.69	587287.11	1179.71	94.82
29.00	28.99	4267504.64	587377.58	1178.82	93.93	87.00	87.00	4267541.89	587331.95	1178.37	93.48	145.00	144.96	4267579.79	587286.35	1179.64	94.75
30.00	29.99	4267505.22	587376.80	1178.79	93.90	88.00	87.96	4267542.64	587331.19	1178.31	93.42	146.00	145.98	4267580.74	587285.55	1179.68	94.79
31.00	30.99	4267505.76	587376.01	1178.77	93.88	89.00	88.99	4267543.38	587330.38	1178.24	93.35	147.00	146.99	4267581.47	587284.76	1179.44	94.55
32.00	31.98	4267506.11	587375.23	1178.79	93.90	90.00	89.97	4267543.26	587329.61	1178.28	93.39	148.00	147.99	4267581.71	587283.97	1179.44	94.55
33.00	33.00	4267507.09	587374.43	1178.81	93.92	91.00	90.99	4267544.84	587328.81	1178.14	93.25	149.00	148.99	4267582.92	587283.18	1179.49	94.60
34.00	33.99	4267507.69	587373.65	1178.83	93.94	92.00	91.98	4267544.52	587328.03	1177.96	93.07	150.00	150.00	4267583.29	587282.39	1179.36	94.47
35.00	34.98	4267507.49	587372.87	1178.73	93.84	93.00	93.00	4267544.90	587327.23	1178.08	93.19	151.00	150.98	4267584.00	587281.62	1178.92	94.03
36.00	35.97	4267508.40	587372.09	1178.95	94.06	94.00	93.99	4267545.57	587326.45	1178.20	93.31	152.00	151.97	4267584.59	587280.84	1178.78	93.89
37.00	36.99	4267509.19	587371.29	1178.81	93.92	95.00	94.99	4267547.18	587325.66	1178.14	93.25	153.00	153.00	4267585.18	587280.03	1178.89	94.00
38.00	37.98	4267510.38	587370.51	1178.75	93.86	96.00	96.00	4267546.75	587324.87	1177.85	92.96	154.00	153.99	4267585.73	587279.25	1179.33	94.44
39.00	39.00	4267510.83	587369.71	1178.70	93.81	97.00	96.99	4267547.51	587324.09	1178.15	93.26	155.00	154.98	4267586.74	587278.47	1179.58	94.69
40.00	39.98	4267512.16	587368.94	1178.73	93.84	98.00	97.99	4267548.34	587323.30	1178.22	93.33	156.00	156.00	4267587.46	587277.67	1179.53	94.64
41.00	40.97	4267512.83	587368.16	1178.57	93.68	99.00	99.00	4267550.52	587322.51	1178.34	93.45	157.00	156.99	4267588.73	587276.89	1179.45	94.56
42.00	41.99	4267513.42	587367.36	1178.72	93.83	100.00	99.99	4267551.32	587321.73	1178.23	93.34	158.00	157.99	4267588.81	587276.10	1179.51	94.62
43.00	42.98	4267513.95	587366.58	1178.80	93.91	101.00	100.99	4267552.09	587320.94	1178.30	93.41	159.00	159.00	4267589.16	587275.31	1179.44	94.55
44.00	43.99	4267512.48	587365.78	1178.89	94.00	102.00	102.00	4267553.04	587320.15	1178.29	93.40	160.00	159.98	4267590.13	587274.54	1179.22	94.33
45.00	45.00	4267513.11	587364.99	1178.82	93.93	103.00	102.99	4267552.09	587319.37	1178.28	93.39	161.00	160.98	4267590.30	587273.75	1179.06	94.17
46.00	45.98	4267515.57	587364.22	1178.86	93.97	104.00	103.99	4267553.67	587318.58	1178.33	93.44	162.00	161.99	4267591.64	587272.96	1179.32	94.43
47.00	46.99	4267516.46	587363.42	1178.74	93.85	105.00	105.00	4267554.05	587317.79	1178.32	93.43	163.00	162.99	4267592.28	587272.17	1179.33	94.44
48.00	48.00	4267517.31	587362.63	1178.61	93.72	106.00	105.99	4267553.99	587317.01	1178.32	93.43	164.00	163.99	4267591.88	587271.38	1179.22	94.33
49.00	48.99	4267517.59	587361.85	1178.83	93.94	107.00	106.99	4267555.58	587316.22	1178.46	93.57	165.00	165.00	4267593.70	587270.59	1178.97	94.08
50.00	49.97	4267518.74	587361.08	1178.66	93.77	108.00	107.99	4267555.56	587315.44	1178.55	93.66	166.00	165.99	4267594.04	587269.81	1178.99	94.10
51.00	51.00	4267519.41	587360.27	1178.35	93.46	109.00	108.98	4267555.83	587314.66	1178.49	93.60	167.00	166.98	4267594.12	587269.03	1179.16	94.27
52.00	51.99	4267517.95	587359.49	1178.57	93.68	110.00	109.98	4267558.10	587313.87	1178.65	93.76	168.00	168.00	4267594.87	587268.23	1179.56	94.67
53.00	52.99	4267520.61	587358.70	1177.91	93.02	111.00	110.99	4267557.93	587313.08	1178.71	93.82	169.00	168.98	4267595.74	587267.46	1179.27	94.38
54.00	54.00	4267521.11	587357.91	1178.03	93.14	112.00	111.98	4267559.40	587312.30	1178.72	93.83	170.00	169.99	4267596.07	587266.66	1179.24	94.35
55.00	54.99	4267521.56	587357.13	1178.00	93.11	113.00	112.98	4267559.63	587311.51	1178.92	94.03	171.00	170.99	4267596.70	587265.88	1179.18	94.29
56.00	55.98	4267521.63	587356.35	1177.93	93.04	114.00	113.99	4267560.42	587310.72	1178.81	93.92	172.00	171.98	4267596.62	587265.10	1179.22	94.33
57.00	56.99	4267522.37	587355.56	1177.92	93.03	115.00	114.98	4267560.80	587309.94	1178.75	93.86	173.00	172.99	4267597.96	587264.30	1179.29	94.40
58.00	57.96	4267522.98	587354.79	1177.99	93.10	116.00	115.99	4267561.33	587309.14	1178.50	93.61	174.00	174.00	4267598.56	587263.51	1179.63	94.74
59.00	58.99	4267523.79	587353.98	1177.75	92.86	117.00	117.00	4267562.12	587308.35	1178.56	93.67	175.00	174.99	4267597.16	587262.73	1179.88	94.99
60.00	60.00	4267524.49	587353.19	1177.99	93.10	118.00	117.99	4267562.71	587307.57	1178.83	93.94	176.00	175.83	4267599.59	587262.07	1179.93	95.04
61.00	60.99	4267525.32	587352.41	1178.34	93.45	119.00	118.98	4267563.51	587306.79	1179.02	94.13	185.63	185.63	4267605.42	587257.67	1181.41	96.51
62.00	61.99	4267525.74	587351.62	1178.76	93.87	120.00	120.00	4267564.28	587305.99	1178.94	94.05						

XS 2

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.03	4268967.02	588202.56	99.21	1184.12
Right Pin	135.65	4268921.59	588074.86	99.15	1184.21

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-29.94	4269000.05	588230.78	1186.35	101.44
-24.03	4268996.51	588225.21	1185.64	100.73
-20.80	4268993.61	588222.17	1184.99	100.08
-17.26	4268989.91	588218.84	1184.40	99.48
-11.74	4268986.05	588213.64	1184.19	99.28
-8.02	4268979.20	588210.14	1184.30	99.39
-6.37	4268973.18	588208.58	1184.53	99.62
-4.68	4268970.99	588206.99	1184.60	99.69
-1.84	4268967.96	588204.32	1184.30	99.39
0.03	4268967.02	588202.56	1184.12	99.21
1.51	4268964.87	588201.17	1184.20	99.29
2.08	4268964.36	588200.63	1183.85	98.93
4.35	4268962.07	588198.49	1182.67	97.76
5.17	4268961.76	588197.72	1182.41	97.50
6.23	4268961.32	588196.72	1181.76	96.85
132.43	4268922.67	588077.90	1181.79	96.74
132.96	4268922.38	588077.39	1182.35	97.30
133.80	4268922.31	588076.60	1182.83	97.77
134.64	4268921.98	588075.81	1183.95	98.90
135.65	4268921.59	588074.86	1184.21	99.15
136.41	4268921.41	588074.15	1184.26	99.20
141.97	4268916.76	588068.92	1184.16	99.10



Sonar Data at 1m points

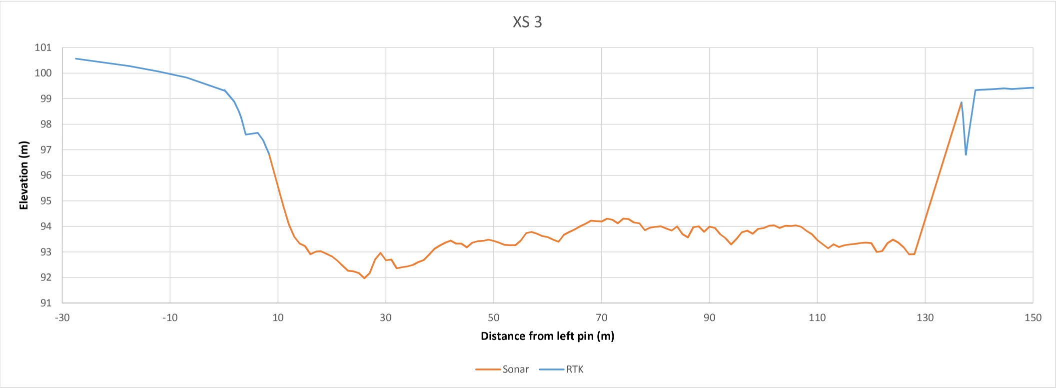
Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
6.23	6.23	4268961.32	588196.72	1181.76	96.85	71.00	70.98	4268943.75	588135.76	1178.71	93.80
11.00	10.99	4268964.38	588192.24	1179.62	94.71	72.00	71.96	4268943.68	588134.83	1178.66	93.75
12.00	12.00	4268964.21	588191.29	1179.34	94.43	73.00	72.98	4268942.83	588133.87	1178.57	93.66
13.00	13.00	4268964.26	588190.35	1179.17	94.26	74.00	73.98	4268942.45	588132.93	1178.56	93.65
14.00	13.99	4268964.24	588189.42	1179.08	94.17	75.00	74.97	4268942.20	588132.00	1178.66	93.75
15.00	14.97	4268963.77	588188.49	1178.92	94.01	76.00	75.99	4268941.92	588131.04	1178.76	93.85
16.00	15.99	4268962.37	588187.53	1178.80	93.89	77.00	76.99	4268941.65	588130.10	1178.78	93.87
17.00	16.99	4268962.63	588186.59	1178.70	93.79	78.00	78.00	4268941.14	588129.15	1178.78	93.87
18.00	18.00	4268961.87	588185.64	1178.65	93.74	79.00	78.98	4268941.31	588128.22	1178.78	93.87
19.00	18.99	4268960.71	588184.71	1178.62	93.71	80.00	79.99	4268940.68	588127.27	1178.78	93.87
20.00	19.98	4268961.52	588183.78	1178.57	93.66	81.00	80.99	4268940.15	588126.33	1178.76	93.85
21.00	20.98	4268961.13	588182.83	1178.66	93.75	82.00	81.98	4268939.74	588125.40	1178.78	93.87
22.00	21.99	4268960.57	588181.88	1178.58	93.67	83.00	83.00	4268939.52	588124.44	1178.78	93.87
23.00	22.99	4268959.59	588180.94	1178.66	93.75	84.00	84.00	4268939.28	588123.50	1178.69	93.78
24.00	23.98	4268959.60	588180.01	1178.64	93.73	85.00	84.98	4268939.03	588122.57	1178.47	93.56
25.00	25.00	4268959.22	588179.05	1178.44	93.53	86.00	85.98	4268938.27	588121.63	1178.42	93.51
26.00	26.00	4268959.37	588178.11	1178.32	93.41	87.00	86.99	4268938.11	588120.68	1178.51	93.60
27.00	26.97	4268958.76	588177.19	1178.71	93.80	88.00	87.99	4268938.13	588119.74	1178.43	93.52
28.00	27.99	4268958.64	588176.23	1178.60	93.69	89.00	89.00	4268937.75	588118.79	1178.38	93.47
29.00	28.99	4268958.07	588175.29	1178.80	93.89	90.00	89.99	4268937.00	588117.86	1178.40	93.49
30.00	29.99	4268958.16	588174.35	1178.91	94.00	91.00	90.94	4268936.92	588116.96	1178.49	93.58
31.00	30.96	4268957.69	588173.44	1178.87	93.96	92.00	91.98	4268936.39	588115.98	1178.46	93.55
32.00	32.00	4268956.82	588172.46	1178.73	93.82	93.00	92.97	4268936.38	588115.05	1178.49	93.58
33.00	32.97	4268956.86	588171.54	1178.55	93.64	94.00	93.99	4268935.74	588114.09	1178.52	93.61
34.00	33.97	4268956.33	588170.60	1178.47	93.56	95.00	95.00	4268935.78	588113.14	1178.44	93.53
35.00	34.98	4268955.52	588169.65	1178.60	93.69	96.00	96.00	4268935.54	588112.20	1178.60	93.69
36.00	35.99	4268955.03	588168.70	1178.42	93.51	97.00	96.98	4268934.67	588111.28	1178.52	93.61
37.00	36.98	4268955.76	588167.77	1178.38	93.47	98.00	97.97	4268934.49	588110.34	1178.42	93.51
38.00	37.99	4268955.45	588166.82	1178.31	93.40	99.00	98.99	4268934.19	588109.38	1178.38	93.47
39.00	38.99	4268955.04	588165.88	1178.08	93.17	100.00	99.98	4268933.88	588108.45	1178.31	93.40
40.00	40.00	4268953.94	588164.93	1178.01	93.10	101.00	100.99	4268933.68	588107.50	1178.18	93.27
41.00	40.99	4268953.50	588163.99	1178.22	93.31	102.00	101.97	4268932.79	588106.58	1178.31	93.40
42.00	41.99	4268953.78	588163.05	1178.21	93.30	103.00	102.99	4268932.41	588105.62	1178.41	93.50
43.00	42.99	4268953.55	588162.11	1178.24	93.33	104.00	103.97	4268932.81	588104.69	1178.31	93.40
44.00	43.99	4268953.18	588161.17	1178.21	93.30	105.00	104.99	4268932.21	588103.73	1178.47	93.56
45.00	44.98	4268952.89	588160.24	1178.21	93.30	106.00	105.99	4268931.69	588102.79	1178.47	93.56
46.00	46.00	4268952.56	588159.28	1178.21	93.30	107.00	106.99	4268931.63	588101.85	1178.45	93.54
47.00	46.98	4268952.12	588158.35	1178.31	93.40	108.00	108.00	4268931.18	588100.90	1178.36	93.45
48.00	47.98	4268951.69	588157.41	1178.54	93.63	109.00	108.99	4268930.68	588099.97	1178.01	93.10
49.00	48.97	4268951.20	588156.48	1178.55	93.64	110.00	110.00	4268930.30	588099.02	1177.79	92.88
50.00	49.98	4268950.63	588155.53	1178.62	93.71	111.00	110.98	4268930.35	588098.09	1177.64	92.73
51.00	51.00	4268950.17	588154.57	1178.63	93.72	112.00	111.98	4268929.99	588097.15	1177.05	92.14
52.00	52.00	4268949.86	588153.63	1178.64	93.73	113.00	112.99	4268929.71	588096.20	1176.95	92.04
53.00	52.99	4268949.41	588152.69	1178.64	93.73	114.00	113.99	4268928.43	588095.26	1177.44	92.53
54.00	53.97	4268949.48	588151.77	1178.54	93.63	115.00	114.99	4268928.81	588094.32	1177.63	92.72
55.00	54.98	4268949.19	588150.82	1178.54	93.63	116.00	116.00	4268927.69	588093.37	1177.82	92.91
56.00	55.99	4268948.30	588149.87	1178.60	93.69	117.00	117.00	4268927.91	588092.43	1177.89	92.98
57.00	57.00	4268948.08	588148.92	1178.61	93.70	118.00	117.99	4268927.49	588091.49	1177.85	92.94
58.00	57.99	4268947.92	588147.99	1178.69	93.78	119.00	118.99	4268927.27	588090.55	1178.20	93.29
59.00	59.00	4268947.81	588147.04	1178.75	93.84	120.00	119.99	4268926.82	588089.61	1178.20	93.29
60.00	59.99	4268947.37	588146.10	1178.76	93.85	121.00	120.99	4268926.58	588088.67	1178.15	93.24
61.00	60.99	4268947.41	588145.16	1178.72	93.81	122.00	122.00	4268926.22	588087.72	1178.23	93.32
62.00	61.99	4268946.92	588144.22	1178.74	93.83	123.00	123.00	4268925.60	588086.78	1177.95	93.04
63.00	63.00	4268946.66	588143.27	1178.72	93.81	124.00	123.99	4268925.40	588085.84	1177.86	92.95
64.00	64.00	4268946.09	588142.33	1178.70	93.79	125.00	124.99	4268924.99	588084.90	1178.03	93.12
65.00	64.98	4268945.52	588141.41	1178.73	93.82	126.00	125.99	4268924.21	588083.96	1178.07	93.16
66.00	65.99	4268945.04	588140.45	1178.69	93.78	127.00	127.00	4268924.21	588083.01	1177.98	93.07
67.00	66.98	4268944.86	588139.52	1178.76	93.85	128.00	127.99	4268924.47	588082.08	1178.22	93.31
68.00	67.97	4268944.42	588138.59	1178.87	93.96	129.00	129.00	4268924.52	588081.13	1177.97	93.06
69.00	68.99	4268944.13	588137.63	1178.90	93.99	130.00	129.17	4268924.58	588080.97	1178.22	93.31
70.00	70.00	4268944.01	588136.68	1178.77	93.86	132.43	132.43	4268922.67	588077.90	1181.79	96.74

XS 3

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.10	4269071.47	588153.10	99.39	1184.36
Right Pin	136.84	4268996.13	588039.07	99.10	1184.05

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-27.48	4269084.14	588176.10	1185.54	100.57
-17.58	4269079.31	588167.84	1185.26	100.28
-12.31	4269076.90	588163.45	1185.05	100.07
-6.93	4269074.57	588158.97	1184.80	99.83
0.10	4269071.49	588153.10	1184.29	99.32
0.11	4269071.49	588153.09	1184.32	99.34
0.11	4269071.48	588153.09	1184.31	99.33
1.88	4269070.76	588151.62	1183.87	98.89
2.75	4269070.50	588150.89	1183.48	98.51
3.18	4269070.25	588150.53	1183.23	98.25
4.02	4269069.87	588149.83	1182.57	97.60
6.23	4269069.54	588147.99	1182.64	97.67
7.24	4269068.87	588147.15	1182.35	97.37
7.71	4269068.78	588146.75	1182.11	97.14
8.32	4269068.64	588146.24	1181.82	96.84
136.72	4268997.23	588039.17	1183.84	98.86
136.94	4268998.06	588038.99	1183.43	98.46
137.53	4268999.75	588038.50	1181.78	96.81
137.94	4268999.44	588038.16	1182.39	97.42
139.28	4268994.52	588037.03	1184.31	99.33
140.14	4268993.70	588036.32	1184.32	99.35
142.48	4268992.08	588034.37	1184.35	99.37
144.65	4268990.69	588032.56	1184.38	99.40
146.10	4268989.62	588031.35	1184.35	99.38
149.74	4268987.74	588028.32	1184.41	99.43
153.81	4268986.84	588024.92	1184.37	99.40
158.87	4268982.97	588020.70	1184.26	99.29
162.42	4268980.91	588017.74	1183.94	98.97



Sonar Data at 1m points

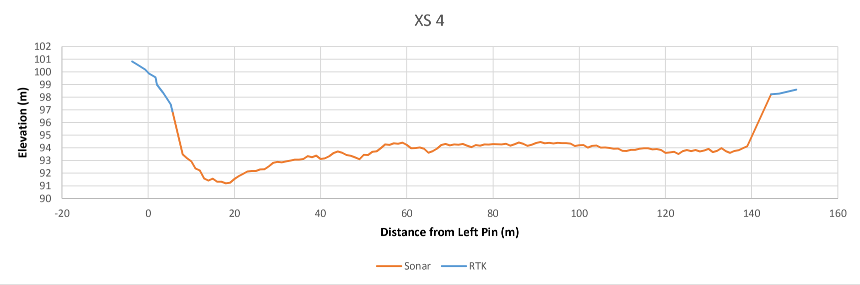
Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
8.32	8.32	4268961.32	588146.24	1181.82	96.84	69.00	68.97	4269033.91	588095.67	1179.18	94.21	128.00	127.29	4269001.31	588047.04	1177.89	92.92
11.00	10.99	4269067.03	588144.02	1179.77	94.80	70.00	69.99	4269033.44	588094.82	1179.17	94.20	136.72	136.72	4268997.23	588039.17	1183.84	98.86
12.00	12.00	4269066.38	588143.18	1179.06	94.09	71.00	71.00	4269032.40	588093.98	1179.28	94.31						
13.00	12.99	4269065.62	588142.35	1178.57	93.60	72.00	71.99	4269032.28	588093.15	1179.24	94.27						
14.00	14.00	4269065.43	588141.51	1178.31	93.34	73.00	73.00	4269031.44	588092.31	1179.10	94.13						
15.00	15.00	4269064.73	588140.68	1178.21	93.24	74.00	73.99	4269031.17	588091.48	1179.28	94.31						
16.00	15.99	4269065.27	588139.85	1177.89	92.92	75.00	74.98	4269030.64	588090.66	1179.26	94.29						
17.00	17.00	4269064.07	588139.01	1177.99	93.02	76.00	76.00	4269029.63	588089.81	1179.13	94.16						
18.00	17.99	4269062.28	588138.18	1178.00	93.03	77.00	76.99	4269029.49	588088.98	1179.10	94.13						
19.00	18.99	4269061.88	588137.35	1177.90	92.93	78.00	77.99	4269028.66	588088.15	1178.83	93.86						
20.00	20.00	4269061.40	588136.51	1177.80	92.83	79.00	79.00	4269027.99	588087.31	1178.93	93.96						
21.00	20.99	4269060.94	588135.68	1177.64	92.67	80.00	79.99	4269027.49	588086.48	1178.96	93.99						
22.00	22.00	4269060.35	588134.84	1177.43	92.46	81.00	81.00	4269027.06	588085.64	1178.98	94.01						
23.00	22.99	4269059.81	588134.01	1177.24	92.27	82.00	81.98	4269026.60	588084.82	1178.89	93.92						
24.00	23.99	4269059.33	588133.18	1177.22	92.25	83.00	82.98	4269026.11	588083.99	1178.82	93.85						
25.00	24.98	4269058.09	588132.35	1177.15	92.18	84.00	83.98	4269025.74	588083.15	1178.98	94.01						
26.00	25.98	4269058.61	588131.52	1176.95	91.98	85.00	84.98	4269025.12	588082.32	1178.67	93.70						
27.00	26.99	4269058.07	588130.68	1177.15	92.18	86.00	85.99	4269024.59	588081.48	1178.55	93.58						
28.00	27.99	4269056.72	588129.84	1177.68	92.71	87.00	86.99	4269023.91	588080.64	1178.95	93.98						
29.00	28.98	4269055.99	588129.02	1177.94	92.97	88.00	87.99	4269023.19	588079.81	1178.98	94.01						
30.00	29.98	4269055.54	588128.18	1177.65	92.68	89.00	89.00	4269022.52	588078.97	1178.77	93.80						
31.00	30.99	4269055.18	588127.34	1177.68	92.71	90.00	89.98	4269022.24	588078.15	1178.97	94.00						
32.00	32.00	4269054.47	588126.50	1177.34	92.37	91.00	91.00	4269021.75	588077.30	1178.92	93.95						
33.00	32.99	4269053.50	588125.67	1177.38	92.41	92.00	91.99	4269020.78	588076.47	1178.67	93.70						
34.00	33.98	4269053.12	588124.85	1177.41	92.44	93.00	92.99	4269020.63	588075.64	1178.51	93.54						
35.00	35.00	4269052.67	588124.00	1177.47	92.50	94.00	94.00	4269019.99	588074.80	1178.27	93.30						
36.00	35.99	4269052.09	588123.17	1177.58	92.61	95.00	94.99	4269019.13	588073.97	1178.49	93.52						
37.00	36.98	4269051.66	588122.35	1177.66	92.69	96.00	95.99	4269018.51	588073.14	1178.75	93.78						
38.00	38.00	4269051.13	588121.50	1177.87	92.90	97.00	96.97	4269017.93	588072.32	1178.81	93.84						
39.00	38.99	4269050.24	588120.67	1178.10	93.13	98.00	97.98	4269017.43	588071.48	1178.69	93.72						
40.00	40.00	4269050.13	588119.83	1178.23	93.26	99.00	98.99	4269016.94	588070.64	1178.88	93.91						
41.00	40.99	4269049.62	588119.00	1178.34	93.37	100.00	99.98	4269016.47	588069.81	1178.91	93.94						
42.00	41.99	4269048.88	588118.17	1178.42	93.45	101.00	101.00	4269015.90	588068.96	1179.00	94.03						
43.00	43.00	4269048.47	588117.33	1178.30	93.33	102.00	101.97	4269015.25	588068.15	1179.02	94.05						
44.00	43.97	4269047.77	588116.52	1178.30	93.33	103.00	102.97	4269014.59	588067.32	1178.92	93.95						
45.00	45.00	4269048.51	588115.66	1178.16	93.19	104.00	104.00	4269014.05	588066.46	1179.00	94.03						
46.00	45.98	4269046.57	588114.84	1178.34	93.37	105.00	104.98	4269013.70	588065.64	1178.99	94.02						
47.00	46.97	4269046.16	588114.02	1178.40	93.43	106.00	105.99	4269013.24	588064.80	1179.02	94.05						
48.00	47.98	4269046.64	588113.17	1178.41	93.44	107.00	106.98	4269012.33	588063.97	1178.96	93.99						
49.00	48.99	4269044.46	588112.33	1178.46	93.49	108.00	107.99	4269011.84	588063.13	1178.80	93.83						
50.00	49.99	4269044.30	588111.50	1178.41	93.44	109.00	109.00	4269011.55	588062.29	1178.67	93.70						
51.00	50.98	4269043.83	588110.67	1178.34	93.37	110.00	109.99	4269010.91	588061.46	1178.44	93.47						
52.00	51.97	4269043.25	588109.85	1178.25	93.28	111.00	110.99	4269010.27	588060.63	1178.28	93.31						
53.00	53.00	4269042.60	588108.99	1178.24	93.27	112.00	111.97	4269009.74	588059.81	1178.12	93.15						
54.00	53.99	4269042.14	588108.16	1178.24	93.27	113.00	112.99	4269008.84	588058.96	1178.28	93.31						
55.00	54.99	4269041.54	588107.33	1178.42	93.45	114.00	114.00	4269008.65	588058.12	1178.17	93.20						
56.00	55.99	4269040.93	588106.49	1178.72	93.75	115.00	114.99	4269007.94	588057.29	1178.24	93.27						
57.00	56.99	4269041.14	588105.66	1178.76	93.79	116.00	115.99	4269007.53	588056.46	1178.27	93.30						
58.00	57.99	4269039.55	588104.83	1178.69	93.72	117.00	117.00	4269006.57	588055.62	1178.29	93.32						
59.00	58.99	4269039.62	588103.99	1178.60	93.63	118.00	117.99	4269006.52	588054.79	1178.33	93.36						
60.00	59.99	4269038.25	588103.16	1178.56	93.59	119.00	118.98	4269005.63	588053.97	1178.34	93.37						
61.00	61.00	4269038.43	588102.32	1178.46	93.49	120.00	119.99	4269005.32	588053.12	1178.32	93.35						
62.00	61.98	4269037.99	588101.50	1178.38	93.41	121.00	120.98	4269004.95	588052.30	1177.98	93.01						
63.00	63.00	4269037.17	588100.65	1178.65	93.68	122.00	122.00	4269004.17	588051.45	1178.01	93.04						
64.00	63.99	4269036.37	588099.82	1178.76	93.79	123.00	122.99	4269003.92	588050.62	1178.32	93.35						
65.00	64.99	4269035.58	588098.99	1178.86	93.89	124.00	123.99	4269003.52	588049.79	1178.46	93.49						
66.00	65.98	4269035.57	588098.16	1178.98	94.01	125.00	125.00	4269002.26	588048.95	1178.35	93.38						
67.00	66.98	4269034.48	588097.33	1179.08	94.11	126.00	125.99	4269001.70	588048.12	1178.16	93.19						
68.00	68.00	4269033.93	588096.48	1179.20	94.23	127.00	126.99	4269001.11	588047.29	1177.88	92.91						

XS 4

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.07	4269204.07	588069.35	99.91	1184.84
Right Pin	146.36	4269127.11	587947.50	98.93	1183.21

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-3.71	4269205.73	588072.51	1185.76	100.82
-2.20	4269205.05	588071.25	1185.43	100.50
-0.69	4269204.45	588069.99	1185.11	100.17
0.07	4269204.07	588069.35	1184.84	99.91
0.10	4269204.08	588069.33	1184.82	99.88
1.71	4269203.39	588067.99	1184.50	99.56
2.05	4269203.17	588067.71	1183.92	98.99
3.32	4269202.57	588066.65	1183.35	98.41
3.32	4269202.56	588066.65	1183.35	98.41
3.32	4269202.56	588066.64	1183.35	98.42
4.50	4269201.97	588065.67	1182.76	97.83
5.23	4269201.71	588065.06	1182.36	97.43
5.65	4269201.30	588064.71	1181.81	96.87
144.52	4269127.54	587949.03	1183.16	98.23
146.36	4269127.11	587947.50	1183.21	98.28
150.35	4269125.48	587944.17	1183.53	98.59



Sonar Data at 1m points

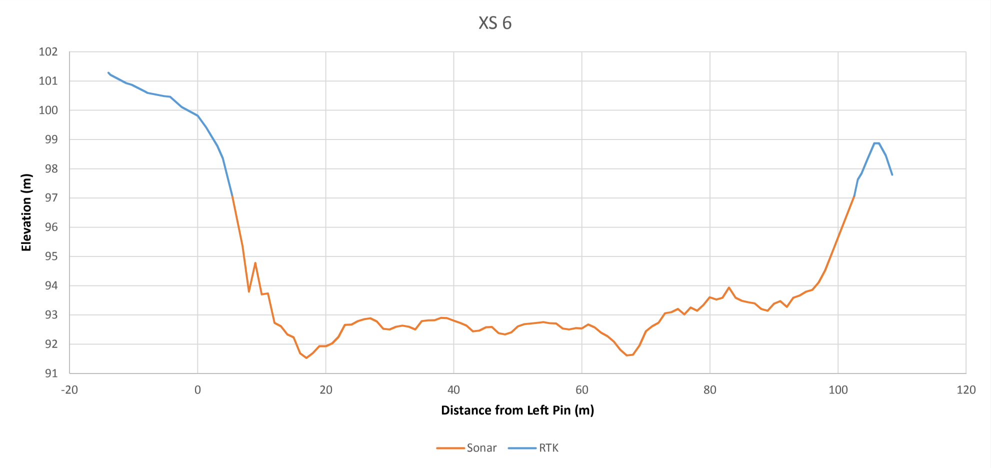
Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
5.65	5.65	4269201.30	588064.71	1181.81	96.87	65.00	65.00	4269170.26	588015.27	1178.55	93.61	123.00	122.99	4269139.87	587966.96	1178.45	93.51
8.00	8.00	4269200.75	588062.75	1178.41	93.47	66.00	65.99	4269169.90	588014.44	1178.68	93.74	124.00	123.99	4269138.87	587966.13	1178.68	93.74
9.00	9.00	4269200.55	588061.92	1178.10	93.16	67.00	66.98	4269169.62	588013.62	1178.88	93.94	125.00	124.99	4269138.18	587965.30	1178.76	93.82
10.00	9.99	4269200.54	588061.09	1177.87	92.93	68.00	67.99	4269168.80	588012.78	1179.16	94.22	126.00	125.98	4269137.70	587964.47	1178.68	93.74
11.00	10.99	4269199.38	588060.26	1177.30	92.36	69.00	68.98	4269168.03	588011.95	1179.24	94.30	127.00	126.99	4269137.31	587963.63	1178.77	93.83
12.00	12.00	4269199.58	588059.42	1177.15	92.21	70.00	69.99	4269167.84	588011.11	1179.13	94.19	128.00	128.00	4269137.01	587962.79	1178.65	93.71
13.00	12.99	4269198.88	588058.59	1176.51	91.57	71.00	70.99	4269167.08	588010.28	1179.20	94.26	129.00	129.00	4269136.14	587961.96	1178.73	93.79
14.00	13.99	4269198.43	588057.76	1176.35	91.41	72.00	72.00	4269166.96	588009.44	1179.18	94.24	130.00	129.99	4269135.78	587961.13	1178.85	93.91
15.00	15.00	4269197.67	588056.92	1176.50	91.56	73.00	72.99	4269165.73	588008.61	1179.25	94.31	131.00	130.99	4269135.21	587960.30	1178.60	93.66
16.00	15.99	4269195.67	588056.09	1176.26	91.32	74.00	73.98	4269165.11	588007.79	1179.11	94.17	132.00	132.00	4269134.67	587959.46	1178.70	93.76
17.00	16.99	4269196.10	588055.26	1176.26	91.32	75.00	75.00	4269164.85	588006.94	1178.99	94.05	133.00	132.99	4269133.56	587958.63	1178.91	93.97
18.00	17.99	4269194.90	588054.43	1176.13	91.19	76.00	75.98	4269164.44	588006.12	1179.15	94.21	134.00	133.99	4269133.66	587957.80	1178.68	93.74
19.00	18.97	4269194.18	588053.61	1176.19	91.25	77.00	76.99	4269163.89	588005.28	1179.10	94.16	135.00	135.00	4269132.99	587956.96	1178.53	93.59
20.00	19.99	4269194.25	588052.76	1176.48	91.54	78.00	78.00	4269163.45	588004.44	1179.20	94.26	136.00	135.98	4269132.72	587956.14	1178.69	93.75
21.00	20.98	4269193.61	588051.94	1176.70	91.76	79.00	78.98	4269162.89	588003.62	1179.19	94.25	137.00	136.99	4269131.44	587955.30	1178.75	93.81
22.00	21.99	4269192.99	588051.10	1176.88	91.94	80.00	79.99	4269162.30	588002.78	1179.23	94.29	138.00	137.98	4269131.82	587954.48	1178.92	93.98
23.00	22.99	4269193.24	588050.26	1177.07	92.13	81.00	80.99	4269161.68	588001.95	1179.22	94.28	139.00	138.29	4269131.74	587954.22	1179.05	94.11
24.00	23.99	4269191.98	588049.43	1177.11	92.17	82.00	82.00	4269161.66	588001.11	1179.21	94.27	144.52	144.52	4269127.54	587949.03	1183.16	98.23
25.00	25.00	4269192.33	588048.59	1177.11	92.17	83.00	82.98	4269160.75	588000.29	1179.26	94.32						
26.00	25.99	4269191.34	588047.76	1177.23	92.29	84.00	83.99	4269160.32	587999.45	1179.10	94.16						
27.00	26.99	4269190.62	588046.93	1177.25	92.31	85.00	85.00	4269159.67	587998.61	1179.22	94.28						
28.00	28.00	4269190.02	588046.09	1177.48	92.54	86.00	85.99	4269158.99	587997.78	1179.36	94.42						
29.00	29.00	4269189.44	588045.26	1177.75	92.81	87.00	86.99	4269158.56	587996.95	1179.26	94.32						
30.00	29.99	4269189.13	588044.43	1177.83	92.89	88.00	88.00	4269158.22	587996.11	1179.09	94.15						
31.00	30.99	4269188.54	588043.60	1177.79	92.85	89.00	88.97	4269157.66	587995.30	1179.18	94.24						
32.00	32.00	4269188.06	588042.76	1177.86	92.92	90.00	89.99	4269157.19	587994.45	1179.32	94.38						
33.00	32.97	4269187.19	588041.95	1177.93	92.99	91.00	90.95	4269156.29	587993.65	1179.39	94.45						
34.00	33.99	4269186.74	588041.10	1178.01	93.07	92.00	92.00	4269155.79	587992.78	1179.29	94.35						
35.00	34.97	4269186.90	588040.28	1178.00	93.06	93.00	92.99	4269155.48	587991.95	1179.33	94.39						
36.00	35.96	4269185.86	588039.46	1178.06	93.12	94.00	93.99	4269155.22	587991.12	1179.28	94.34						
37.00	36.99	4269185.20	588038.60	1178.28	93.34	95.00	94.99	4269154.41	587990.29	1179.33	94.39						
38.00	38.00	4269185.34	588037.76	1178.20	93.26	96.00	95.99	4269153.71	587989.45	1179.31	94.37						
39.00	39.00	4269184.74	588036.93	1178.32	93.38	97.00	96.99	4269153.48	587988.62	1179.31	94.37						
40.00	39.97	4269183.78	588036.12	1178.05	93.11	98.00	98.00	4269153.53	587987.78	1179.27	94.33						
41.00	40.99	4269183.33	588035.27	1178.11	93.17	99.00	99.00	4269152.52	587986.95	1179.08	94.14						
42.00	41.99	4269183.18	588034.44	1178.27	93.33	100.00	99.98	4269151.59	587986.13	1179.14	94.20						
43.00	42.99	4269182.29	588033.60	1178.52	93.58	101.00	100.98	4269151.38	587985.30	1179.16	94.22						
44.00	43.99	4269181.79	588032.77	1178.65	93.71	102.00	102.00	4269150.36	587984.45	1178.95	94.01						
45.00	45.00	4269181.18	588031.93	1178.55	93.61	103.00	102.99	4269150.06	587983.62	1179.09	94.15						
46.00	45.99	4269180.80	588031.10	1178.37	93.43	104.00	103.99	4269149.63	587982.79	1179.12	94.18						
47.00	46.99	4269179.74	588030.27	1178.31	93.37	105.00	105.00	4269149.30	587981.95	1178.95	94.01						
48.00	48.00	4269179.43	588029.43	1178.18	93.24	106.00	105.99	4269148.44	587981.12	1178.97	94.03						
49.00	48.97	4269179.03	588028.62	1178.03	93.09	107.00	106.99	4269147.84	587980.29	1178.93	93.99						
50.00	49.98	4269178.45	588027.78	1178.39	93.45	108.00	108.00	4269147.42	587979.45	1178.87	93.93						
51.00	50.99	4269177.78	588026.94	1178.37	93.43	109.00	109.00	4269146.94	587978.62	1178.88	93.94						
52.00	52.00	4269177.57	588026.10	1178.63	93.69	110.00	109.99	4269146.30	587977.79	1178.70	93.76						
53.00	52.99	4269177.11	588025.27	1178.66	93.72	111.00	110.98	4269146.29	587976.97	1178.69	93.75						
54.00	53.99	4269176.59	588024.44	1178.92	93.98	112.00	112.00	4269145.07	587976.12	1178.78	93.84						
55.00	55.00	4269175.99	588023.60	1179.20	94.26	113.00	112.98	4269144.53	587975.30	1178.78	93.84						
56.00	55.99	4269175.34	588022.77	1179.17	94.23	114.00	113.99	4269144.06	587974.46	1178.86	93.92						
57.00	56.98	4269174.65	588021.95	1179.29	94.35	115.00	114.99	4269143.74	587973.63	1178.90	93.96						
58.00	58.00	4269174.63	588021.10	1179.26	94.32	116.00	115.99	4269143.25	587972.79	1178.90	93.96						
59.00	59.00	4269173.65	588020.27	1179.34	94.40	117.00	116.99	4269142.77	587971.96	1178.82	93.88						
60.00	59.99	4269173.11	588019.44	1179.17	94.23	118.00	117.98	4269141.82	587971.14	1178.84	93.90						
61.00	60.99	4269172.45	588018.61	1178.90	93.96	119.00	119.00	4269141.59	587970.29	1178.77	93.83						
62.00	62.00	4269172.29	588017.77	1178.91	93.97	120.00	119.98	4269140.98	587969.47	1178.53	93.59						
63.00	62.99	4269171.87	588016.94	1178.97	94.03	121.00	120.98	4269140.74	587968.64	1178.58	93.64						
64.00	63.99	4269171.05	588016.11	1178.87	93.93	122.00	122.00	4269139.97	587967.79	1178.63	93.69						

XS 6

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.10	4269434.54	587730.41	99.70	1184.53
Right most point	0.00	4269333.69	587690.48		1182.62

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-13.93	4269447.59	587735.61	1186.11	101.28
-13.64	4269447.32	587735.81	1186.04	101.21
-11.17	4269445.02	587734.59	1185.75	100.93
-10.31	4269444.22	587734.09	1185.70	100.87
-8.27	4269442.32	587733.32	1185.47	100.65
-7.83	4269441.92	587733.95	1185.42	100.60
-5.25	4269439.52	587732.31	1185.31	100.48
-4.31	4269438.64	587732.11	1185.29	100.46
-2.51	4269436.96	587731.20	1184.94	100.11
0.00	4269434.63	587730.40	1184.64	99.81
1.32	4269433.39	587729.69	1184.24	99.42
3.07	4269431.77	587729.20	1183.61	98.78
3.93	4269430.97	587728.66	1183.18	98.36
5.38	4269429.62	587728.21	1181.93	97.10
102.53	4269339.21	587692.16	1181.89	97.07
103.09	4269338.69	587692.10	1182.46	97.63
103.68	4269338.14	587691.85	1182.67	97.84
104.62	4269337.27	587691.66	1183.15	98.33
105.67	4269336.29	587691.48	1183.69	98.87
106.41	4269335.60	587691.43	1183.70	98.87
107.46	4269334.63	587691.25	1183.28	98.45
108.46	4269333.69	587690.48	1182.62	97.80



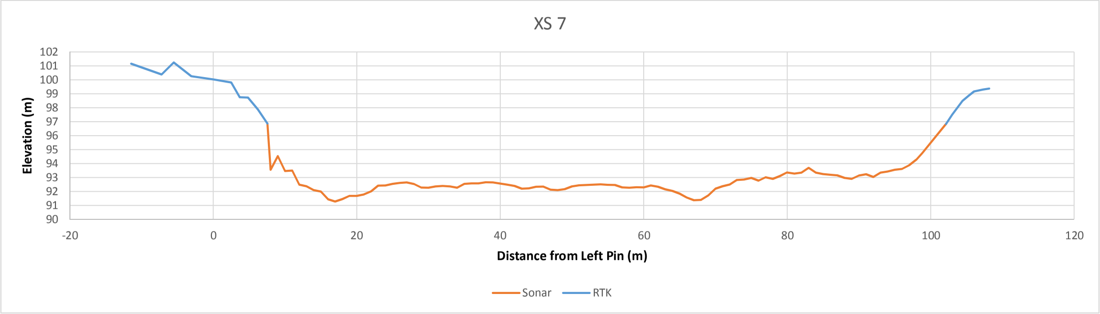
Sonar Data at 1m points

Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
5.38	5.38	4269429.62	587728.21	1181.93	97.10	56.00	55.99	4269425.02	587476.51	1177.53	92.71
7.01	7.01	4269428.10	587727.45	1180.19	95.37	57.00	56.99	4269424.02	587476.31	1177.36	92.54
8.00	7.99	4269472.92	587478.35	1178.62	93.80	58.00	58.00	4269423.01	587476.69	1177.33	92.51
9.00	9.00	4269471.92	587475.85	1179.60	94.78	59.00	58.99	4269422.02	587476.68	1177.37	92.55
10.00	10.00	4269470.92	587477.71	1178.53	93.71	60.00	59.99	4269421.02	587476.84	1177.36	92.54
11.00	10.99	4269469.93	587477.12	1178.56	93.74	61.00	60.99	4269420.02	587476.81	1177.50	92.68
12.00	11.99	4269468.93	587476.21	1177.55	92.73	62.00	62.00	4269419.02	587476.33	1177.40	92.58
13.00	12.99	4269467.93	587475.66	1177.44	92.62	63.00	62.99	4269418.03	587476.73	1177.22	92.40
14.00	14.00	4269466.93	587476.41	1177.16	92.34	64.00	63.99	4269417.03	587476.57	1177.10	92.28
15.00	14.99	4269465.94	587476.24	1177.06	92.24	65.00	64.99	4269416.03	587476.55	1176.91	92.09
16.00	16.00	4269464.93	587476.31	1176.51	91.69	66.00	65.98	4269415.04	587476.54	1176.63	91.81
17.00	16.99	4269463.94	587476.17	1176.35	91.53	67.00	67.00	4269414.03	587476.24	1176.44	91.62
18.00	17.99	4269462.94	587475.86	1176.52	91.70	68.00	67.98	4269413.05	587476.40	1176.46	91.64
19.00	18.98	4269461.96	587476.38	1176.75	91.93	69.00	68.99	4269412.04	587476.38	1176.78	91.96
20.00	20.00	4269460.94	587476.21	1176.75	91.93	70.00	69.99	4269411.04	587476.65	1177.27	92.45
21.00	21.00	4269459.94	587476.17	1176.85	92.03	71.00	70.98	4269410.05	587476.64	1177.44	92.62
22.00	21.99	4269458.95	587476.04	1177.07	92.25	72.00	71.99	4269409.05	587476.32	1177.56	92.74
23.00	22.99	4269457.95	587476.46	1177.48	92.66	73.00	72.98	4269408.06	587476.99	1177.88	93.06
24.00	23.99	4269456.95	587476.22	1177.49	92.67	74.00	73.98	4269407.06	587476.74	1177.92	93.10
25.00	25.00	4269455.95	587476.57	1177.61	92.79	75.00	74.99	4269406.05	587476.59	1178.03	93.21
26.00	26.00	4269454.95	587476.33	1177.68	92.86	76.00	75.99	4269405.05	587476.59	1177.84	93.02
27.00	26.96	4269453.99	587475.96	1177.71	92.89	77.00	76.98	4269404.06	587476.84	1178.08	93.26
28.00	27.99	4269452.96	587476.17	1177.60	92.78	78.00	78.00	4269403.05	587476.85	1177.97	93.15
29.00	28.98	4269451.97	587476.16	1177.35	92.53	79.00	79.00	4269402.05	587476.67	1178.17	93.35
30.00	29.99	4269450.97	587476.42	1177.33	92.51	80.00	79.94	4269401.11	587477.17	1178.43	93.61
31.00	30.98	4269449.98	587476.96	1177.42	92.60	81.00	80.99	4269400.06	587476.64	1178.35	93.53
32.00	31.98	4269448.98	587476.62	1177.46	92.64	82.00	81.97	4269399.08	587476.81	1178.41	93.59
33.00	32.99	4269447.97	587476.09	1177.42	92.60	83.00	82.98	4269398.08	587476.66	1178.76	93.94
34.00	33.98	4269446.98	587476.66	1177.33	92.51	84.00	84.00	4269397.06	587476.80	1178.41	93.59
35.00	34.99	4269445.98	587476.38	1177.61	92.79	85.00	84.99	4269396.07	587476.82	1178.31	93.49
36.00	36.00	4269444.97	587476.33	1177.64	92.82	86.00	85.96	4269395.10	587476.87	1178.26	93.44
37.00	36.97	4269444.00	587476.00	1177.64	92.82	87.00	86.98	4269394.08	587477.52	1178.22	93.40
38.00	37.97	4269443.00	587476.68	1177.72	92.90	88.00	88.00	4269393.07	587476.92	1178.03	93.21
39.00	38.99	4269441.98	587475.96	1177.71	92.89	89.00	89.00	4269392.07	587476.77	1177.97	93.15
40.00	40.00	4269440.98	587476.69	1177.63	92.81	90.00	90.00	4269391.07	587476.76	1178.21	93.39
41.00	41.00	4269439.98	587476.27	1177.55	92.73	91.00	90.99	4269390.08	587476.55	1178.30	93.48
42.00	42.00	4269438.98	587476.33	1177.46	92.64	92.00	91.99	4269389.08	587476.46	1178.10	93.28
43.00	42.99	4269437.99	587476.66	1177.26	92.44	93.00	93.00	4269388.08	587476.35	1178.41	93.59
44.00	43.98	4269437.00	587476.64	1177.29	92.47	94.00	94.00	4269387.08	587476.65	1178.49	93.67
45.00	44.98	4269436.00	587476.29	1177.40	92.58	95.00	95.00	4269386.08	587476.98	1178.62	93.80
46.00	45.98	4269435.01	587476.21	1177.41	92.59	96.00	95.99	4269385.09	587477.46	1178.68	93.86
47.00	46.98	4269434.01	587476.19	1177.20	92.38	97.00	96.99	4269384.09	587477.69	1178.94	94.12
48.00	47.99	4269433.00	587476.65	1177.16	92.34	98.00	97.99	4269383.09	587476.89	1179.35	94.53
49.00	48.98	4269432.01	587476.52	1177.23	92.41	99.00	98.83	4269382.26	587475.90	1179.82	95.00
50.00	49.98	4269431.01	587476.55	1177.43	92.61	102.53	102.53	4269339.21	587692.16	1181.89	97.07
51.00	51.00	4269430.00	587476.51	1177.51	92.69						
52.00	52.00	4269429.00	587476.42	1177.53	92.71						
53.00	52.98	4269428.02	587476.48	1177.55	92.73						
54.00	53.99	4269427.01	587476.56	1177.58	92.76						
55.00	54.96	4269426.04	587476.37	1177.54	92.72						

XS 7		Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
	Left Pin	0.02	4269480.88	587475.94	100.12	1185.18
	Right Pin	107.21	4269373.89	587476.50	99.52	1184.36

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-11.44	4269492.32	587477.18	1186.22	101.16
-7.20	4269488.08	587475.80	1185.45	100.39
-5.52	4269486.41	587475.73	1186.31	101.25
-3.06	4269483.95	587475.93	1185.32	100.26
0.02	4269480.88	587475.92	1185.09	100.03
2.50	4269478.40	587476.50	1184.88	99.82
3.67	4269477.23	587476.41	1183.81	98.75
4.84	4269476.07	587476.31	1183.80	98.73
6.23	4269474.68	587476.35	1182.95	97.89
7.54	4269473.37	587476.31	1181.93	96.87
102.14	4269378.96	587476.45	1181.89	96.83
103.01	4269378.09	587476.72	1182.58	97.51
104.40	4269376.70	587476.80	1183.54	98.48
105.34	4269375.76	587476.66	1183.95	98.89
106.03	4269375.07	587476.55	1184.23	99.17
107.29	4269373.82	587476.61	1184.37	99.31
108.15	4269372.95	587476.67	1184.44	99.38



Sonar Data at 1m points

Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
7.54	7.54	4269473.37	587476.31	1181.93	96.87
8.00	7.99	4269472.92	587478.35	1178.62	93.56
9.00	9.00	4269471.92	587475.85	1179.60	94.54
10.00	10.00	4269470.92	587477.71	1178.53	93.47
11.00	10.99	4269469.93	587477.12	1178.56	93.50
12.00	11.99	4269468.93	587476.21	1177.55	92.49
13.00	12.99	4269467.93	587475.66	1177.44	92.38
14.00	14.00	4269466.93	587476.41	1177.16	92.10
15.00	14.99	4269465.94	587476.24	1177.06	92.00
16.00	16.00	4269464.93	587476.31	1176.51	91.45
17.00	16.99	4269463.94	587476.17	1176.35	91.29
18.00	17.99	4269462.94	587475.86	1176.52	91.46
19.00	18.98	4269461.96	587476.38	1176.75	91.69
20.00	20.00	4269460.94	587476.21	1176.75	91.69
21.00	21.00	4269459.94	587476.17	1176.85	91.79
22.00	21.99	4269458.95	587476.04	1177.07	92.01
23.00	22.99	4269457.95	587476.46	1177.48	92.42
24.00	23.99	4269456.95	587476.22	1177.49	92.43
25.00	25.00	4269455.95	587476.57	1177.61	92.55
26.00	26.00	4269454.95	587476.33	1177.68	92.62
27.00	26.96	4269453.99	587475.96	1177.71	92.65
28.00	27.99	4269452.96	587476.17	1177.60	92.54
29.00	28.98	4269451.97	587476.16	1177.35	92.29
30.00	29.99	4269450.97	587476.42	1177.33	92.27
31.00	30.98	4269449.98	587476.96	1177.42	92.36
32.00	31.98	4269448.98	587476.62	1177.46	92.40
33.00	32.99	4269447.97	587476.09	1177.42	92.36
34.00	33.98	4269446.98	587476.66	1177.33	92.27
35.00	34.99	4269445.98	587476.38	1177.61	92.55
36.00	36.00	4269444.97	587476.33	1177.64	92.58
37.00	36.97	4269444.00	587476.00	1177.64	92.58
38.00	37.97	4269443.00	587476.68	1177.72	92.66
39.00	38.99	4269441.98	587475.96	1177.71	92.65
40.00	40.00	4269440.98	587476.69	1177.63	92.57
41.00	41.00	4269439.98	587476.27	1177.55	92.49
42.00	42.00	4269438.98	587476.33	1177.46	92.40
43.00	42.99	4269437.99	587476.66	1177.26	92.20
44.00	43.98	4269437.00	587476.64	1177.29	92.23
45.00	44.98	4269436.00	587476.29	1177.40	92.34
46.00	45.98	4269435.01	587476.21	1177.41	92.35
47.00	46.98	4269434.01	587476.19	1177.20	92.14
48.00	47.99	4269433.00	587476.65	1177.16	92.10
49.00	48.98	4269432.01	587476.52	1177.23	92.17
50.00	49.98	4269431.01	587476.55	1177.43	92.37
51.00	51.00	4269430.00	587476.51	1177.51	92.45
52.00	52.00	4269429.00	587476.42	1177.53	92.47
53.00	52.98	4269428.02	587476.48	1177.55	92.49
54.00	53.99	4269427.01	587476.56	1177.58	92.52
55.00	54.96	4269426.04	587476.37	1177.54	92.48
56.00	55.99	4269425.02	587476.51	1177.53	92.47
57.00	56.99	4269424.02	587476.31	1177.36	92.30
58.00	58.00	4269423.01	587476.69	1177.33	92.27
59.00	58.99	4269422.02	587476.68	1177.37	92.31
60.00	59.99	4269421.02	587476.84	1177.36	92.30
61.00	60.99	4269420.02	587476.81	1177.50	92.44
70.00	69.99	4269411.04	587476.65	1177.27	92.21
71.00	70.98	4269410.05	587476.64	1177.44	92.38
72.00	71.99	4269409.05	587476.32	1177.56	92.50
73.00	72.98	4269408.06	587476.99	1177.88	92.82
74.00	73.98	4269407.06	587476.74	1177.92	92.86
75.00	74.99	4269406.05	587476.59	1178.03	92.97
76.00	75.99	4269405.05	587476.59	1177.84	92.78
77.00	76.98	4269404.06	587476.84	1178.08	93.02
78.00	78.00	4269403.05	587476.85	1177.97	92.91
79.00	79.00	4269402.05	587476.67	1178.17	93.11
80.00	79.94	4269401.11	587477.17	1178.43	93.37
81.00	80.99	4269400.06	587476.64	1178.35	93.29
82.00	81.97	4269399.08	587476.81	1178.41	93.35
83.00	82.98	4269398.08	587476.66	1178.76	93.70
84.00	84.00	4269397.06	587476.80	1178.41	93.35
85.00	84.99	4269396.07	587476.82	1178.31	93.25
86.00	85.96	4269395.10	587476.87	1178.26	93.20
87.00	86.98	4269394.08	587477.52	1178.22	93.16
88.00	88.00	4269393.07	587476.92	1178.03	92.97
89.00	89.00	4269392.07	587476.77	1177.97	92.91
90.00	90.00	4269391.07	587476.76	1178.21	93.15
91.00	90.99	4269390.08	587476.55	1178.30	93.24
92.00	91.99	4269389.08	587476.46	1178.10	93.04
93.00	93.00	4269388.08	587476.35	1178.41	93.35
94.00	94.00	4269387.08	587476.65	1178.49	93.43
95.00	95.00	4269386.08	587476.98	1178.62	93.56
96.00	95.99	4269385.09	587477.46	1178.68	93.62
97.00	96.99	4269384.09	587477.69	1178.94	93.88
98.00	97.99	4269383.09	587476.89	1179.35	94.29
99.00	98.83	4269382.26	587475.90	1179.82	94.76
	102.14	4269378.96	587476.45	1181.89	96.83

XS 8		Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
	Left Pin	0.04	4269432.69	587230.89	99.58	1184.62
	Right most point	0.00	4269283.18	587293.90		1184.20

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
0.08	4269432.65	587230.76	1184.58	99.54
0.10	4269432.63	587230.77	1184.59	99.54
1.80	4269431.06	587231.08	1184.25	99.21
4.25	4269428.81	587230.94	1184.22	99.18
5.59	4269427.57	587230.88	1184.42	99.38
7.08	4269426.20	587231.15	1184.16	99.11
9.11	4269424.33	587231.18	1183.78	98.73
9.97	4269423.54	587231.32	1183.11	98.06
10.57	4269422.98	587231.62	1183.01	97.96
10.83	4269422.74	587231.60	1182.78	97.74
11.31	4269422.30	587231.60	1182.71	97.66
12.42	4269421.28	587231.31	1182.11	97.06
149.87	4269294.59	587288.37	1181.98	96.94
150.50	4269294.01	587289.03	1182.63	97.58
152.45	4269292.21	587287.02	1182.41	97.36
152.88	4269291.81	587287.56	1182.59	97.55
153.71	4269291.05	587288.17	1182.70	97.66
154.43	4269290.38	587288.68	1184.57	99.52
156.54	4269288.43	587290.33	1184.29	99.24
157.41	4269287.64	587290.84	1184.19	99.14
162.24	4269283.18	587293.90	1184.20	99.16

Sonar Data at 1m points

Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
12.42	12.42	4269421.28	587231.31	1182.11	97.06	72.00	71.98	4269366.38	587255.33	1180.67	95.63	148.00	147.49	4269296.78	587281.62	1178.24	93.20
13.66	13.66	4269420.13	587236.01	1178.89	93.85	73.00	73.00	4269365.44	587255.79	1180.58	95.54	149.87	149.87	4269294.59	587288.37	1181.98	96.94
14.00	14.00	4269419.82	587236.02	1179.49	94.45	74.00	74.00	4269364.52	587256.13	1180.52	95.48						
15.00	14.99	4269418.91	587235.58	1178.78	93.74	75.00	74.99	4269363.60	587256.54	1180.36	95.32						
16.00	16.00	4269417.98	587236.39	1179.44	94.40	76.00	75.98	4269362.69	587256.79	1180.08	95.04						
17.00	16.99	4269417.06	587236.86	1179.20	94.16	77.00	76.98	4269361.77	587256.99	1180.05	95.01						
18.00	17.97	4269416.16	587237.38	1179.31	94.27	78.00	78.00	4269360.83	587257.25	1179.85	94.81						
18.00	18.97	4269415.24	587237.67	1179.36	94.32	79.00	78.98	4269359.93	587258.14	1179.53	94.49						
20.00	19.97	4269414.32	587237.78	1179.39	94.35	80.00	79.97	4269359.01	587258.50	1179.52	94.48						
21.00	21.00	4269413.37	587238.00	1179.51	94.47	81.00	80.97	4269358.09	587258.46	1179.31	94.27						
22.00	21.98	4269412.46	587238.34	1179.71	94.67	82.00	81.98	4269357.16	587258.99	1178.93	93.89						
23.00	22.98	4269411.54	587238.83	1179.74	94.70	83.00	82.97	4269356.25	587259.52	1179.03	93.99						
24.00	23.97	4269410.63	587239.43	1179.81	94.77	84.00	84.00	4269355.30	587259.98	1178.95	93.91						
25.00	24.97	4269409.71	587239.91	1179.68	94.64	85.00	84.99	4269354.39	587260.35	1178.85	93.81						
26.00	26.00	4269408.76	587240.13	1179.67	94.63	86.00	86.00	4269353.46	587260.63	1178.95	93.91						
27.00	26.99	4269407.85	587240.51	1179.73	94.69	87.00	86.96	4269352.57	587260.96	1178.95	93.91						
28.00	27.98	4269406.93	587240.88	1179.78	94.74	88.00	87.97	4269351.64	587260.96	1178.81	93.77						
29.00	28.99	4269406.00	587240.78	1179.54	94.50	89.00	88.99	4269350.70	587261.49	1178.85	93.81						
30.00	29.98	4269405.09	587241.11	1179.42	94.38	90.00	89.99	4269349.78	587262.13	1178.73	93.69						
31.00	30.99	4269404.16	587241.55	1179.77	94.73	91.00	90.95	4269348.89	587262.82	1178.62	93.58						
32.00	32.00	4269403.23	587242.20	1179.80	94.76	92.00	91.95	4269347.97	587263.05	1178.54	93.50						
33.00	32.99	4269402.32	587242.50	1179.52	94.48	93.00	92.98	4269347.02	587263.29	1178.30	93.26						
34.00	33.97	4269401.41	587242.89	1179.22	94.18	94.00	93.98	4269346.10	587263.61	1178.20	93.16						
35.00	34.97	4269400.49	587243.26	1179.06	94.02	95.00	94.97	4269345.19	587264.83	1178.56	93.52						
36.00	35.95	4269399.59	587243.48	1179.19	94.15	96.00	95.98	4269344.26	587264.28	1178.56	93.52						
37.00	36.98	4269398.64	587243.64	1179.49	94.45	97.00	97.00	4269343.32	587264.57	1178.45	93.41						
38.00	37.99	4269397.71	587243.87	1179.67	94.63	98.00	97.99	4269342.40	587265.37	1178.53	93.49						
39.00	38.99	4269396.79	587244.18	1179.88	94.84	99.00	98.95	4269341.52	587264.95	1178.54	93.50						
40.00	39.97	4269395.88	587244.84	1180.03	94.99	100.00	99.96	4269340.59	587265.67	1178.18	93.14						
41.00	40.98	4269394.95	587245.19	1180.06	95.02	101.00	100.98	4269339.65	587265.83	1178.09	93.05						
42.00	41.97	4269394.04	587245.33	1179.97	94.93	102.00	102.00	4269338.71	587265.98	1177.88	92.84						
43.00	43.00	4269393.09	587245.69	1179.91	94.87	103.00	102.97	4269337.81	587266.53	1178.05	93.01						
44.00	44.00	4269392.17	587246.24	1179.85	94.81	120.00	119.98	4269322.14	587272.22	1177.67	92.63						
45.00	44.98	4269391.26	587246.30	1179.89	94.85	121.00	120.97	4269321.22	587272.48	1177.63	92.59						
46.00	45.99	4269390.33	587246.68	1179.95	94.91	122.00	121.98	4269320.29	587272.78	1177.55	92.51						
47.00	46.98	4269389.42	587247.12	1179.80	94.76	123.00	122.99	4269319.36	587273.23	1177.48	92.44						
48.00	47.99	4269388.49	587247.69	1179.58	94.54	124.00	123.98	4269318.45	587273.73	1177.48	92.44						
49.00	48.98	4269387.58	587247.90	1179.69	94.65	125.00	125.00	4269317.51	587273.39	1177.30	92.26						
50.00	50.00	4269386.64	587248.66	1179.87	94.83	126.00	126.00	4269316.59	587274.33	1177.04	92.00						
51.00	50.98	4269385.73	587248.85	1179.83	94.79	127.00	126.97	4269315.69	587274.41	1177.07	92.03						
52.00	51.97	4269384.82	587248.92	1179.67	94.63	128.00	127.99	4269314.75	587274.65	1177.32	92.28						
53.00	52.96	4269383.91	587249.18	1179.90	94.86	129.00	128.99	4269313.83	587274.97	1177.22	92.18						
54.00	53.98	4269382.97	587249.36	1180.03	94.99	130.00	129.97	4269312.93	587275.45	1177.14	92.10						
55.00	55.00	4269382.03	587249.75	1179.96	94.92	131.00	131.00	4269311.98	587275.58	1177.06	92.02						
56.00	55.98	4269381.13	587250.20	1180.11	95.07	132.00	131.97	4269311.08	587276.03	1177.01	91.97						
57.00	56.97	4269380.21	587250.72	1179.94	94.90	133.00	132.97	4269310.16	587276.43	1176.89	91.85						
58.00	57.98	4269379.28	587251.15	1180.25	95.21	134.00	133.98	4269309.23	587276.26	1176.79	91.75						
59.00	58.96	4269378.38	587251.51	1180.24	95.20	135.00	134.95	4269308.34	587276.94	1176.89	91.85						
60.00	59.96	4269377.46	587251.79	1180.46	95.42	136.00	135.99	4269307.38	587277.24	1177.13	92.09						
61.00	60.98	4269376.52	587251.97	1180.32	95.28	137.00	137.00	4269306.45	587277.67	1177.22	92.18						
62.00	61.99	4269375.59	587252.49	1180.42	95.38	138.00	137.97	4269305.55	587278.34	1177.32	92.28						
63.00	62.97	4269374.68	587252.21	1180.49	95.45	139.00	138.98	4269304.62	587278.81	1177.31	92.27						
64.00	63.99	4269373.74	587252.43	1180.60	95.56	140.00	139.97	4269303.71	587279.14	1177.32	92.28						
65.00	64.99	4269372.82	587253.50	1180.52	95.48	141.00	140.99	4269302.77	587278.70	1177.48	92.44						
66.00	65.99	4269371.90	587253.72	1180.53	95.49	142.00	141.99	4269301.85	587279.77	1178.23	93.19						
67.00	66.97	4269371.00	587253.47	1180.52	95.48	143.00	143.00	4269300.92	587279.33	1178.58	93.54						
68.00	68.00	4269370.05	587254.18	1180.62	95.58	144.00	144.00	4269300.00	587279.66	1178.48	93.44						
69.00	68.98	4269369.14	587254.33	1180.62	95.58	145.00	144.99	4269299.08	587279.84	1178.32	93.28						
70.00	69.97	4269368.23	587254.69	1180.59	95.55	146.00	145.98	4269298.17	587280.75	1178.12	93.08						
71.00	70.98	4269367.30	587255.24	1180.65	95.61	147.00	146.98	4269297.25	587281.13	1177.99	92.95						

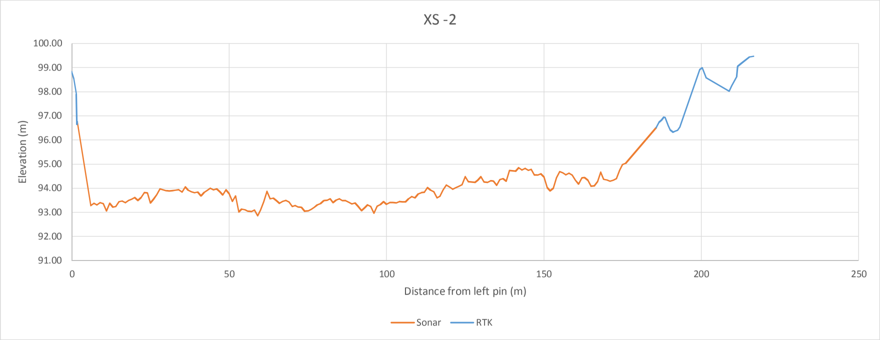
XS -2

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.06	4267484.05	587400.30	98.82	1183.72
Right Pin	216.53	4267622.37	587233.92	99.51	1184.34

We have this listed as XS -3 in our notes, but it is actually XS -2

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-3.16	4267481.60	587402.78	1183.79	98.89
-2.44	4267482.45	587402.22	1183.77	98.88
-1.26	4267483.42	587401.32	1183.85	98.96
-0.04	4267484.04	587400.38	1183.72	98.83
0.61	4267484.71	587399.88	1183.44	98.54
1.45	4267485.53	587399.23	1182.79	97.90
1.69	4267485.96	587399.05	1181.53	96.64
1.77	4267485.89	587398.98	1181.65	96.75
185.63	4267605.42	587257.67	1181.41	96.51
186.57	4267606.12	587256.95	1181.63	96.74
187.41	4267606.87	587256.30	1181.72	96.82
188.05	4267607.34	587255.81	1181.84	96.95
188.53	4267607.69	587255.44	1181.82	96.93
189.52	4267607.99	587254.68	1181.48	96.59
190.11	4267608.13	587254.23	1181.30	96.41
191.09	4267608.36	587253.48	1181.22	96.33
191.64	4267608.51	587253.05	1181.25	96.36
192.47	4267608.98	587252.41	1181.30	96.40
193.23	4267609.45	587251.83	1181.42	96.53
199.50	4267613.23	587247.01	1183.80	98.91
200.35	4267612.64	587246.36	1183.89	99.00
201.40	4267613.39	587245.55	1183.51	98.62
201.49	4267613.28	587245.48	1183.47	98.58
208.84	4267617.83	587239.83	1182.92	98.03
209.67	4267618.25	587239.19	1183.14	98.25
211.29	4267619.38	587237.95	1183.52	98.63
211.61	4267619.50	587237.70	1183.96	99.06
212.73	4267619.93	587236.84	1184.07	99.17
215.39	4267621.81	587234.80	1184.34	99.45
216.62	4267622.35	587233.85	1184.37	99.47



Sonar Data at 1m points

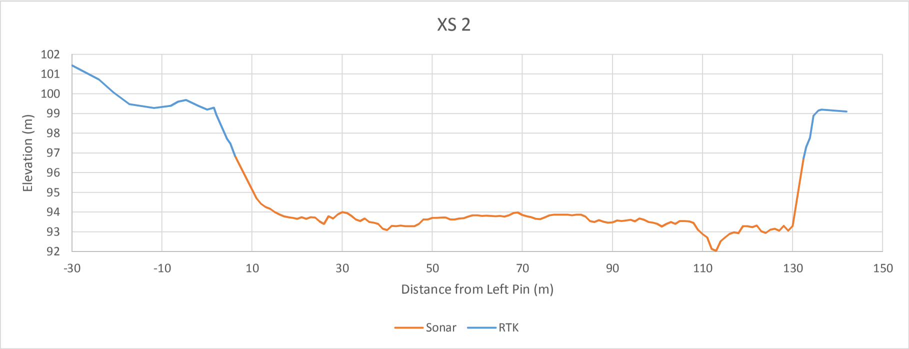
Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
1.77	1.77	4267485.89	587398.98	1181.65	96.75	63.00	62.99	4267526.81	587350.84	1178.45	93.56	121.00	120.99	4267564.92	587305.21	1178.85	93.96
6.06	6.06	4267490.38	587395.62	1178.17	93.28	64.00	63.98	4267527.28	587350.06	1178.48	93.59	122.00	121.99	4267565.51	587304.42	1178.92	94.03
7.00	6.99	4267490.88	587394.89	1178.27	93.38	65.00	64.99	4267527.75	587349.26	1178.37	93.48	123.00	123.00	4267566.38	587303.63	1178.97	94.08
8.00	7.99	4267491.10	587394.10	1178.20	93.31	66.00	66.00	4267528.24	587348.47	1178.27	93.38	124.00	123.99	4267567.29	587302.85	1179.04	94.15
9.00	9.00	4267491.85	587393.31	1178.30	93.41	67.00	66.99	4267529.16	587347.69	1178.35	93.46	125.00	124.99	4267566.90	587302.06	1179.37	94.48
10.00	9.99	4267492.32	587392.53	1178.25	93.36	68.00	67.98	4267529.32	587346.91	1178.39	93.50	126.00	125.99	4267568.66	587301.28	1179.16	94.27
11.00	10.99	4267494.51	587391.74	1177.95	93.06	69.00	69.00	4267529.72	587346.11	1178.32	93.43	127.00	126.98	4267568.83	587300.50	1179.15	94.26
12.00	12.00	4267493.88	587390.95	1178.27	93.38	70.00	69.99	4267531.20	587345.33	1178.13	93.24	128.00	127.99	4267568.95	587299.70	1179.13	94.24
13.00	12.99	4267494.70	587390.17	1178.11	93.22	71.00	70.98	4267531.02	587344.55	1178.17	93.28	129.00	129.00	4267569.69	587298.91	1179.23	94.34
14.00	13.99	4267494.35	587389.38	1178.13	93.24	72.00	72.00	4267532.03	587343.75	1178.11	93.22	130.00	129.99	4267570.50	587298.13	1179.37	94.48
15.00	14.99	4267495.37	587388.60	1178.34	93.45	73.00	72.99	4267532.72	587342.97	1178.09	93.20	131.00	130.99	4267571.85	587297.34	1179.15	94.26
16.00	15.99	4267496.04	587387.81	1178.36	93.47	74.00	73.99	4267533.44	587342.18	1177.94	93.05	132.00	132.00	4267571.81	587296.55	1179.13	94.24
17.00	16.98	4267496.41	587387.03	1178.29	93.40	75.00	74.97	4267533.54	587341.41	1177.95	93.06	133.00	132.98	4267572.40	587295.78	1179.20	94.31
18.00	18.00	4267496.93	587386.23	1178.39	93.50	76.00	75.98	4267534.37	587340.62	1178.01	93.12	134.00	133.99	4267573.65	587294.98	1179.18	94.29
19.00	18.99	4267497.60	587385.45	1178.44	93.55	77.00	76.99	4267534.94	587339.82	1178.09	93.20	135.00	135.00	4267573.52	587294.19	1179.01	94.12
20.00	19.99	4267498.28	587384.66	1178.51	93.62	78.00	77.99	4267535.84	587339.04	1178.20	93.31	136.00	135.99	4267574.06	587293.41	1179.25	94.36
21.00	21.00	4267498.30	587383.87	1178.39	93.50	79.00	78.99	4267536.41	587338.25	1178.26	93.37	137.00	136.99	4267574.57	587292.62	1179.29	94.40
22.00	21.96	4267498.70	587383.11	1178.51	93.62	80.00	79.99	4267537.29	587337.46	1178.38	93.49	138.00	138.00	4267575.10	587291.83	1179.18	94.29
23.00	22.98	4267501.01	587382.31	1178.70	93.81	81.00	81.00	4267538.24	587336.67	1178.39	93.50	139.00	138.99	4267576.24	587291.05	1179.62	94.73
24.00	23.99	4267501.20	587381.52	1178.69	93.80	82.00	81.99	4267538.32	587335.89	1178.46	93.57	140.00	139.99	4267576.74	587290.26	1179.61	94.72
25.00	24.99	4267487.35	587380.73	1178.28	93.39	83.00	82.99	4267539.69	587335.10	1178.30	93.41	141.00	141.00	4267577.65	587289.47	1179.59	94.70
26.00	25.99	4267491.17	587379.94	1178.44	93.55	84.00	83.99	4267540.27	587334.32	1178.40	93.51	142.00	141.99	4267578.62	587288.69	1179.74	94.85
27.00	26.99	4267502.90	587379.16	1178.63	93.74	85.00	84.98	4267539.87	587333.54	1178.46	93.57	143.00	142.99	4267578.65	587287.90	1179.65	94.76
28.00	27.96	4267503.78	587378.39	1178.87	93.98	86.00	85.98	4267541.27	587332.75	1178.38	93.49	144.00	144.00	4267579.69	587287.11	1179.71	94.82
29.00	28.99	4267504.64	587377.58	1178.82	93.93	87.00	87.00	4267541.89	587331.95	1178.37	93.48	145.00	144.96	4267579.79	587286.35	1179.64	94.75
30.00	29.99	4267505.22	587376.80	1178.79	93.90	88.00	87.96	4267542.64	587331.19	1178.31	93.42	146.00	145.98	4267580.74	587285.55	1179.68	94.79
31.00	30.99	4267505.76	587376.01	1178.77	93.88	89.00	88.99	4267543.38	587330.38	1178.24	93.35	147.00	146.99	4267581.47	587284.76	1179.44	94.55
32.00	31.98	4267506.11	587375.23	1178.79	93.90	90.00	89.97	4267543.26	587329.61	1178.28	93.39	148.00	147.99	4267581.71	587283.97	1179.44	94.55
33.00	33.00	4267507.09	587374.43	1178.81	93.92	91.00	90.99	4267544.84	587328.81	1178.14	93.25	149.00	148.99	4267582.92	587283.18	1179.49	94.60
34.00	33.99	4267507.69	587373.65	1178.83	93.94	92.00	91.98	4267544.52	587328.03	1177.96	93.07	150.00	150.00	4267583.29	587282.39	1179.36	94.47
35.00	34.98	4267507.49	587372.87	1178.73	93.84	93.00	93.00	4267544.90	587327.23	1178.08	93.19	151.00	150.98	4267584.00	587281.62	1178.92	94.03
36.00	35.97	4267508.40	587372.09	1178.95	94.06	94.00	93.99	4267545.57	587326.45	1178.20	93.31	152.00	151.97	4267584.59	587280.84	1178.78	93.89
37.00	36.99	4267509.19	587371.29	1178.81	93.92	95.00	94.99	4267547.18	587325.66	1178.14	93.25	153.00	153.00	4267585.18	587280.03	1178.89	94.00
38.00	37.98	4267510.38	587370.51	1178.75	93.86	96.00	96.00	4267546.75	587324.87	1177.85	92.96	154.00	153.99	4267585.73	587279.25	1179.33	94.44
39.00	39.00	4267510.83	587369.71	1178.70	93.81	97.00	96.99	4267547.51	587324.09	1178.15	93.26	155.00	154.98	4267586.74	587278.47	1179.58	94.69
40.00	39.98	4267512.16	587368.94	1178.73	93.84	98.00	97.99	4267548.34	587323.30	1178.22	93.33	156.00	156.00	4267587.46	587277.67	1179.53	94.64
41.00	40.97	4267512.83	587368.16	1178.57	93.68	99.00	99.00	4267550.52	587322.51	1178.34	93.45	157.00	156.99	4267588.73	587276.89	1179.45	94.56
42.00	41.99	4267513.42	587367.36	1178.72	93.83	100.00	99.99	4267551.32	587321.73	1178.23	93.34	158.00	157.99	4267588.81	587276.10	1179.51	94.62
43.00	42.98	4267513.95	587366.58	1178.80	93.91	101.00	100.99	4267552.09	587320.94	1178.30	93.41	159.00	159.00	4267589.16	587275.31	1179.44	94.55
44.00	43.99	4267512.48	587365.78	1178.89	94.00	102.00	102.00	4267553.04	587320.15	1178.29	93.40	160.00	159.98	4267590.13	587274.54	1179.22	94.33
45.00	45.00	4267513.11	587364.99	1178.82	93.93	103.00	102.99	4267552.09	587319.37	1178.28	93.39	161.00	160.98	4267590.30	587273.75	1179.06	94.17
46.00	45.98	4267515.57	587364.22	1178.86	93.97	104.00	103.99	4267553.67	587318.58	1178.33	93.44	162.00	161.99	4267591.64	587272.96	1179.32	94.43
47.00	46.99	4267516.46	587363.42	1178.74	93.85	105.00	105.00	4267554.05	587317.79	1178.32	93.43	163.00	162.99	4267592.28	587272.17	1179.33	94.44
48.00	48.00	4267517.31	587362.63	1178.61	93.72	106.00	105.99	4267553.99	587317.01	1178.32	93.43	164.00	163.99	4267591.88	587271.38	1179.22	94.33
49.00	48.99	4267517.59	587361.85	1178.83	93.94	107.00	106.99	4267555.58	587316.22	1178.46	93.57	165.00	165.00	4267593.70	587270.59	1178.97	94.08
50.00	49.97	4267518.74	587361.08	1178.66	93.77	108.00	107.99	4267555.56	587315.44	1178.55	93.66	166.00	165.99	4267594.04	587269.81	1178.99	94.10
51.00	51.00	4267519.41	587360.27	1178.35	93.46	109.00	108.98	4267555.83	587314.66	1178.49	93.60	167.00	166.98	4267594.12	587269.03	1179.16	94.27
52.00	51.99	4267517.95	587359.49	1178.57	93.68	110.00	109.98	4267558.10	587313.87	1178.65	93.76	168.00	168.00	4267594.87	587268.23	1179.56	94.67
53.00	52.99	4267520.61	587358.70	1177.91	93.02	111.00	110.99	4267557.93	587313.08	1178.71	93.82	169.00	168.98	4267595.74	587267.46	1179.27	94.38
54.00	54.00	4267521.11	587357.91	1178.03	93.14	112.00	111.98	4267559.40	587312.30	1178.72	93.83	170.00	169.99	4267596.07	587266.66	1179.24	94.35
55.00	54.99	4267521.56	587357.13	1178.00	93.11	113.00	112.98	4267559.63	587311.51	1178.92	94.03	171.00	170.99	4267596.70	587265.88	1179.18	94.29
56.00	55.98	4267521.63	587356.35	1177.93	93.04	114.00	113.99	4267560.42	587310.72	1178.81	93.92	172.00	171.98	4267596.62	587265.10	1179.22	94.33
57.00	56.99	4267522.37	587355.56	1177.92	93.03	115.00	114.98	4267560.80	587309.94	1178.75	93.86	173.00	172.99	4267597.96	587264.30	1179.29	94.40
58.00	57.96	4267522.98	587354.79	1177.99	93.10	116.00	115.99	4267561.33	587309.14	1178.50	93.61	174.00	174.00	4267598.56	587263.51	1179.63	94.74
59.00	58.99	4267523.79	587353.98	1177.75	92.86	117.00	117.00	4267562.12	587308.35	1178.56	93.67	175.00	174.99	4267597.16	587262.73	1179.88	94.99
60.00	60.00	4267524.49	587353.19	1177.99	93.10	118.00	117.99	4267562.71	587307.57	1178.83	93.94	176.00	175.83	4267599.59	587262.07	1179.93	95.04
61.00	60.99	4267525.32	587352.41	1178.34	93.45	119.00	118.98	4267563.51	587306.79	1179.02	94.13	185.63	185.63	4267605.42	587257.67	1181.41	96.51
62.00	61.99	4267525.74	587351.62	1178.76	93.87	120.00	120.00	4267564.28	587305.99	1178.94	94.05						

XS 2

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.03	4268967.02	588202.56	99.21	1184.12
Right Pin	135.65	4268921.59	588074.86	99.15	1184.21

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-29.94	4269000.05	588230.78	1186.35	101.44
-24.03	4268996.51	588225.21	1185.64	100.73
-20.80	4268993.61	588222.17	1184.99	100.08
-17.26	4268989.91	588218.84	1184.40	99.48
-11.74	4268986.05	588213.64	1184.19	99.28
-8.02	4268979.20	588210.14	1184.30	99.39
-6.37	4268973.18	588208.58	1184.53	99.62
-4.68	4268970.99	588206.99	1184.60	99.69
-1.84	4268967.96	588204.32	1184.30	99.39
0.03	4268967.02	588202.56	1184.12	99.21
1.51	4268964.87	588201.17	1184.20	99.29
2.08	4268964.36	588200.63	1183.85	98.93
4.35	4268962.07	588198.49	1182.67	97.76
5.17	4268961.76	588197.72	1182.41	97.50
6.23	4268961.32	588196.72	1181.76	96.85
132.43	4268922.67	588077.90	1181.79	96.74
132.96	4268922.38	588077.39	1182.35	97.30
133.80	4268922.31	588076.60	1182.83	97.77
134.64	4268921.98	588075.81	1183.95	98.90
135.65	4268921.59	588074.86	1184.21	99.15
136.41	4268921.41	588074.15	1184.26	99.20
141.97	4268916.76	588068.92	1184.16	99.10



Sonar Data at 1m points

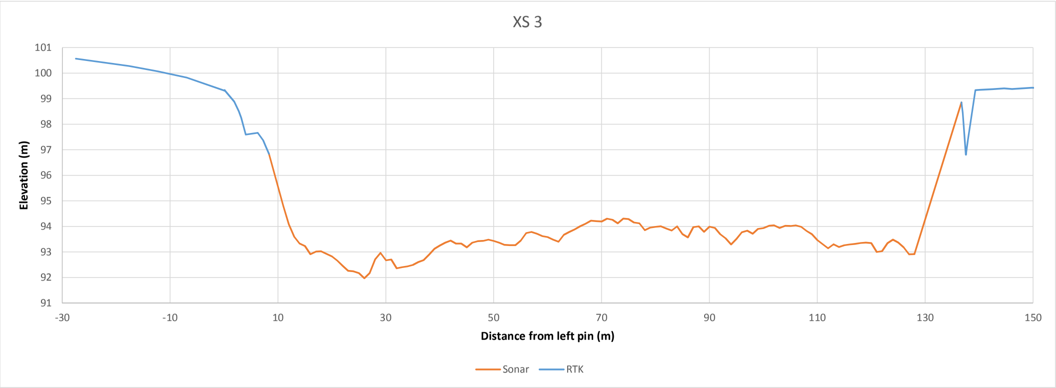
Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
6.23	6.23	4268961.32	588196.72	1181.76	96.85	71.00	70.98	4268943.75	588135.76	1178.71	93.80
11.00	10.99	4268964.38	588192.24	1179.62	94.71	72.00	71.96	4268943.68	588134.83	1178.66	93.75
12.00	12.00	4268964.21	588191.29	1179.34	94.43	73.00	72.98	4268942.83	588133.87	1178.57	93.66
13.00	13.00	4268964.26	588190.35	1179.17	94.26	74.00	73.98	4268942.45	588132.93	1178.56	93.65
14.00	13.99	4268964.24	588189.42	1179.08	94.17	75.00	74.97	4268942.20	588132.00	1178.66	93.75
15.00	14.97	4268963.77	588188.49	1178.92	94.01	76.00	75.99	4268941.92	588131.04	1178.76	93.85
16.00	15.99	4268962.37	588187.53	1178.80	93.89	77.00	76.99	4268941.65	588130.10	1178.78	93.87
17.00	16.99	4268962.63	588186.59	1178.70	93.79	78.00	78.00	4268941.14	588129.15	1178.78	93.87
18.00	18.00	4268961.87	588185.64	1178.65	93.74	79.00	78.98	4268941.31	588128.22	1178.78	93.87
19.00	18.99	4268960.71	588184.71	1178.62	93.71	80.00	79.99	4268940.68	588127.27	1178.78	93.87
20.00	19.98	4268961.52	588183.78	1178.57	93.66	81.00	80.99	4268940.15	588126.33	1178.76	93.85
21.00	20.98	4268961.13	588182.83	1178.66	93.75	82.00	81.98	4268939.74	588125.40	1178.78	93.87
22.00	21.99	4268960.57	588181.88	1178.58	93.67	83.00	83.00	4268939.52	588124.44	1178.78	93.87
23.00	22.99	4268959.59	588180.94	1178.66	93.75	84.00	84.00	4268939.28	588123.50	1178.69	93.78
24.00	23.98	4268959.60	588180.01	1178.64	93.73	85.00	84.98	4268939.03	588122.57	1178.47	93.56
25.00	25.00	4268959.22	588179.05	1178.44	93.53	86.00	85.98	4268938.27	588121.63	1178.42	93.51
26.00	26.00	4268959.37	588178.11	1178.32	93.41	87.00	86.99	4268938.11	588120.68	1178.51	93.60
27.00	26.97	4268958.76	588177.19	1178.71	93.80	88.00	87.99	4268938.13	588119.74	1178.43	93.52
28.00	27.99	4268958.64	588176.23	1178.60	93.69	89.00	89.00	4268937.75	588118.79	1178.38	93.47
29.00	28.99	4268958.07	588175.29	1178.80	93.89	90.00	89.99	4268937.00	588117.86	1178.40	93.49
30.00	29.99	4268958.16	588174.35	1178.91	94.00	91.00	90.94	4268936.92	588116.96	1178.49	93.58
31.00	30.96	4268957.69	588173.44	1178.87	93.96	92.00	91.98	4268936.39	588115.98	1178.46	93.55
32.00	32.00	4268956.82	588172.46	1178.73	93.82	93.00	92.97	4268936.38	588115.05	1178.49	93.58
33.00	32.97	4268956.86	588171.54	1178.55	93.64	94.00	93.99	4268935.74	588114.09	1178.52	93.61
34.00	33.97	4268956.33	588170.60	1178.47	93.56	95.00	95.00	4268935.78	588113.14	1178.44	93.53
35.00	34.98	4268955.52	588169.65	1178.60	93.69	96.00	96.00	4268935.54	588112.20	1178.60	93.69
36.00	35.99	4268955.03	588168.70	1178.42	93.51	97.00	96.98	4268934.67	588111.28	1178.52	93.61
37.00	36.98	4268955.76	588167.77	1178.38	93.47	98.00	97.97	4268934.49	588110.34	1178.42	93.51
38.00	37.99	4268955.45	588166.82	1178.31	93.40	99.00	98.99	4268934.19	588109.38	1178.38	93.47
39.00	38.99	4268955.04	588165.88	1178.08	93.17	100.00	99.98	4268933.88	588108.45	1178.31	93.40
40.00	40.00	4268953.94	588164.93	1178.01	93.10	101.00	100.99	4268933.68	588107.50	1178.18	93.27
41.00	40.99	4268953.50	588163.99	1178.22	93.31	102.00	101.97	4268932.79	588106.58	1178.31	93.40
42.00	41.99	4268953.78	588163.05	1178.21	93.30	103.00	102.99	4268932.41	588105.62	1178.41	93.50
43.00	42.99	4268953.55	588162.11	1178.24	93.33	104.00	103.97	4268932.81	588104.69	1178.31	93.40
44.00	43.99	4268953.18	588161.17	1178.21	93.30	105.00	104.99	4268932.21	588103.73	1178.47	93.56
45.00	44.98	4268952.89	588160.24	1178.21	93.30	106.00	105.99	4268931.69	588102.79	1178.47	93.56
46.00	46.00	4268952.56	588159.28	1178.21	93.30	107.00	106.99	4268931.63	588101.85	1178.45	93.54
47.00	46.98	4268952.12	588158.35	1178.31	93.40	108.00	108.00	4268931.18	588100.90	1178.36	93.45
48.00	47.98	4268951.69	588157.41	1178.54	93.63	109.00	108.99	4268930.68	588099.97	1178.01	93.10
49.00	48.97	4268951.20	588156.48	1178.55	93.64	110.00	110.00	4268930.30	588099.02	1177.79	92.88
50.00	49.98	4268950.63	588155.53	1178.62	93.71	111.00	110.98	4268930.35	588098.09	1177.64	92.73
51.00	51.00	4268950.17	588154.57	1178.63	93.72	112.00	111.98	4268929.99	588097.15	1177.05	92.14
52.00	52.00	4268949.86	588153.63	1178.64	93.73	113.00	112.99	4268929.71	588096.20	1176.95	92.04
53.00	52.99	4268949.41	588152.69	1178.64	93.73	114.00	113.99	4268928.43	588095.26	1177.44	92.53
54.00	53.97	4268949.48	588151.77	1178.54	93.63	115.00	114.99	4268928.81	588094.32	1177.63	92.72
55.00	54.98	4268949.19	588150.82	1178.54	93.63	116.00	116.00	4268927.69	588093.37	1177.82	92.91
56.00	55.99	4268948.30	588149.87	1178.60	93.69	117.00	117.00	4268927.91	588092.43	1177.89	92.98
57.00	57.00	4268948.08	588148.92	1178.61	93.70	118.00	117.99	4268927.49	588091.49	1177.85	92.94
58.00	57.99	4268947.92	588147.99	1178.69	93.78	119.00	118.99	4268927.27	588090.55	1178.20	93.29
59.00	59.00	4268947.81	588147.04	1178.75	93.84	120.00	119.99	4268926.82	588089.61	1178.20	93.29
60.00	59.99	4268947.37	588146.10	1178.76	93.85	121.00	120.99	4268926.58	588088.67	1178.15	93.24
61.00	60.99	4268947.41	588145.16	1178.72	93.81	122.00	122.00	4268926.22	588087.72	1178.23	93.32
62.00	61.99	4268946.92	588144.22	1178.74	93.83	123.00	123.00	4268925.60	588086.78	1177.95	93.04
63.00	63.00	4268946.66	588143.27	1178.72	93.81	124.00	123.99	4268925.40	588085.84	1177.86	92.95
64.00	64.00	4268946.09	588142.33	1178.70	93.79	125.00	124.99	4268924.99	588084.90	1178.03	93.12
65.00	64.98	4268945.52	588141.41	1178.73	93.82	126.00	125.99	4268924.21	588083.96	1178.07	93.16
66.00	65.99	4268945.04	588140.45	1178.69	93.78	127.00	127.00	4268924.21	588083.01	1177.98	93.07
67.00	66.98	4268944.86	588139.52	1178.76	93.85	128.00	127.99	4268924.47	588082.08	1178.22	93.31
68.00	67.97	4268944.42	588138.59	1178.87	93.96	129.00	129.00	4268924.52	588081.13	1177.97	93.06
69.00	68.99	4268944.13	588137.63	1178.90	93.99	130.00	129.17	4268924.58	588080.97	1178.22	93.31
70.00	70.00	4268944.01	588136.68	1178.77	93.86	132.43	132.43	4268922.67	588077.90	1181.79	96.74

XS 3

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.10	4269071.47	588153.10	99.39	1184.36
Right Pin	136.84	4268996.13	588039.07	99.10	1184.05

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-27.48	4269084.14	588176.10	1185.54	100.57
-17.58	4269079.31	588167.84	1185.26	100.28
-12.31	4269076.90	588163.45	1185.05	100.07
-6.93	4269074.57	588158.97	1184.80	99.83
0.10	4269071.49	588153.10	1184.29	99.32
0.11	4269071.49	588153.09	1184.32	99.34
0.11	4269071.48	588153.09	1184.31	99.33
1.88	4269070.76	588151.62	1183.87	98.89
2.75	4269070.50	588150.89	1183.48	98.51
3.18	4269070.25	588150.53	1183.23	98.25
4.02	4269069.87	588149.83	1182.57	97.60
6.23	4269069.54	588147.99	1182.64	97.67
7.24	4269068.87	588147.15	1182.35	97.37
7.71	4269068.78	588146.75	1182.11	97.14
8.32	4269068.64	588146.24	1181.82	96.84
136.72	4268997.23	588039.17	1183.84	98.86
136.94	4268998.06	588038.99	1183.43	98.46
137.53	4268999.75	588038.50	1181.78	96.81
137.94	4268999.44	588038.16	1182.39	97.42
139.28	4268994.52	588037.03	1184.31	99.33
140.14	4268993.70	588036.32	1184.32	99.35
142.48	4268992.08	588034.37	1184.35	99.37
144.65	4268990.69	588032.56	1184.38	99.40
146.10	4268989.62	588031.35	1184.35	99.38
149.74	4268987.74	588028.32	1184.41	99.43
153.81	4268986.84	588024.92	1184.37	99.40
158.87	4268982.97	588020.70	1184.26	99.29
162.42	4268980.91	588017.74	1183.94	98.97



Sonar Data at 1m points

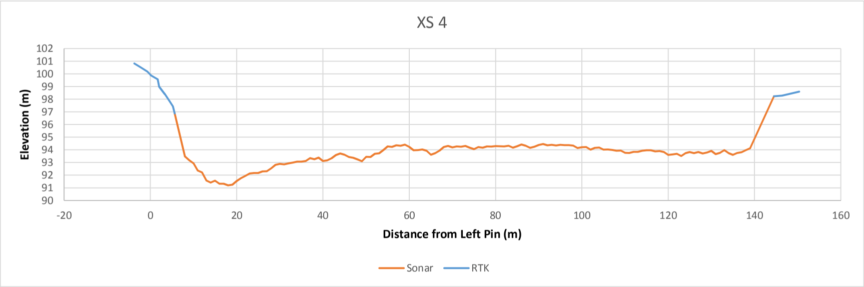
Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
8.32	8.32	4268961.32	588146.24	1181.82	96.84	69.00	68.97	4269033.91	588095.67	1179.18	94.21	128.00	127.29	4269001.31	588047.04	1177.89	92.92
11.00	10.99	4269067.03	588144.02	1179.77	94.80	70.00	69.99	4269033.44	588094.82	1179.17	94.20	136.72	136.72	4268997.23	588039.17	1183.84	98.86
12.00	12.00	4269066.38	588143.18	1179.06	94.09	71.00	71.00	4269032.40	588093.98	1179.28	94.31						
13.00	12.99	4269065.62	588142.35	1178.57	93.60	72.00	71.99	4269032.28	588093.15	1179.24	94.27						
14.00	14.00	4269065.43	588141.51	1178.31	93.34	73.00	73.00	4269031.44	588092.31	1179.10	94.13						
15.00	15.00	4269064.73	588140.68	1178.21	93.24	74.00	73.99	4269031.17	588091.48	1179.28	94.31						
16.00	15.99	4269065.27	588139.85	1177.89	92.92	75.00	74.98	4269030.64	588090.66	1179.26	94.29						
17.00	17.00	4269064.07	588139.01	1177.99	93.02	76.00	76.00	4269029.63	588089.81	1179.13	94.16						
18.00	17.99	4269062.28	588138.18	1178.00	93.03	77.00	76.99	4269029.49	588088.98	1179.10	94.13						
19.00	18.99	4269061.88	588137.35	1177.90	92.93	78.00	77.99	4269028.66	588088.15	1178.83	93.86						
20.00	20.00	4269061.40	588136.51	1177.80	92.83	79.00	79.00	4269027.99	588087.31	1178.93	93.96						
21.00	20.99	4269060.94	588135.68	1177.64	92.67	80.00	79.99	4269027.49	588086.48	1178.96	93.99						
22.00	22.00	4269060.35	588134.84	1177.43	92.46	81.00	81.00	4269027.06	588085.64	1178.98	94.01						
23.00	22.99	4269059.81	588134.01	1177.24	92.27	82.00	81.98	4269026.60	588084.82	1178.89	93.92						
24.00	23.99	4269059.33	588133.18	1177.22	92.25	83.00	82.98	4269026.11	588083.99	1178.82	93.85						
25.00	24.98	4269058.09	588132.35	1177.15	92.18	84.00	83.98	4269025.74	588083.15	1178.98	94.01						
26.00	25.98	4269058.61	588131.52	1176.95	91.98	85.00	84.98	4269025.12	588082.32	1178.67	93.70						
27.00	26.99	4269058.07	588130.68	1177.15	92.18	86.00	85.99	4269024.59	588081.48	1178.55	93.58						
28.00	27.99	4269056.72	588129.84	1177.68	92.71	87.00	86.99	4269023.91	588080.64	1178.95	93.98						
29.00	28.98	4269055.99	588129.02	1177.94	92.97	88.00	87.99	4269023.19	588079.81	1178.98	94.01						
30.00	29.98	4269055.54	588128.18	1177.65	92.68	89.00	89.00	4269022.52	588078.97	1178.77	93.80						
31.00	30.99	4269055.18	588127.34	1177.68	92.71	90.00	89.98	4269022.24	588078.15	1178.97	94.00						
32.00	32.00	4269054.47	588126.50	1177.34	92.37	91.00	91.00	4269021.75	588077.30	1178.92	93.95						
33.00	32.99	4269053.50	588125.67	1177.38	92.41	92.00	91.99	4269020.78	588076.47	1178.67	93.70						
34.00	33.98	4269053.12	588124.85	1177.41	92.44	93.00	92.99	4269020.63	588075.64	1178.51	93.54						
35.00	35.00	4269052.67	588124.00	1177.47	92.50	94.00	94.00	4269019.99	588074.80	1178.27	93.30						
36.00	35.99	4269052.09	588123.17	1177.58	92.61	95.00	94.99	4269019.13	588073.97	1178.49	93.52						
37.00	36.98	4269051.66	588122.35	1177.66	92.69	96.00	95.99	4269018.51	588073.14	1178.75	93.78						
38.00	38.00	4269051.13	588121.50	1177.87	92.90	97.00	96.97	4269017.93	588072.32	1178.81	93.84						
39.00	38.99	4269050.24	588120.67	1178.10	93.13	98.00	97.98	4269017.43	588071.48	1178.69	93.72						
40.00	40.00	4269050.13	588119.83	1178.23	93.26	99.00	98.99	4269016.94	588070.64	1178.88	93.91						
41.00	40.99	4269049.62	588119.00	1178.34	93.37	100.00	99.98	4269016.47	588069.81	1178.91	93.94						
42.00	41.99	4269048.88	588118.17	1178.42	93.45	101.00	101.00	4269015.90	588068.96	1179.00	94.03						
43.00	43.00	4269048.47	588117.33	1178.30	93.33	102.00	101.97	4269015.25	588068.15	1179.02	94.05						
44.00	43.97	4269047.77	588116.52	1178.30	93.33	103.00	102.97	4269014.59	588067.32	1178.92	93.95						
45.00	45.00	4269048.51	588115.66	1178.16	93.19	104.00	104.00	4269014.05	588066.46	1179.00	94.03						
46.00	45.98	4269046.57	588114.84	1178.34	93.37	105.00	104.98	4269013.70	588065.64	1178.99	94.02						
47.00	46.97	4269046.16	588114.02	1178.40	93.43	106.00	105.99	4269013.24	588064.80	1179.02	94.05						
48.00	47.98	4269046.64	588113.17	1178.41	93.44	107.00	106.98	4269012.33	588063.97	1178.96	93.99						
49.00	48.99	4269044.46	588112.33	1178.46	93.49	108.00	107.99	4269011.84	588063.13	1178.80	93.83						
50.00	49.99	4269044.30	588111.50	1178.41	93.44	109.00	109.00	4269011.55	588062.29	1178.67	93.70						
51.00	50.98	4269043.83	588110.67	1178.34	93.37	110.00	109.99	4269010.91	588061.46	1178.44	93.47						
52.00	51.97	4269043.25	588109.85	1178.25	93.28	111.00	110.99	4269010.27	588060.63	1178.28	93.31						
53.00	53.00	4269042.60	588108.99	1178.24	93.27	112.00	111.97	4269009.74	588059.81	1178.12	93.15						
54.00	53.99	4269042.14	588108.16	1178.24	93.27	113.00	112.99	4269008.84	588058.96	1178.28	93.31						
55.00	54.99	4269041.54	588107.33	1178.42	93.45	114.00	114.00	4269008.65	588058.12	1178.17	93.20						
56.00	55.99	4269040.93	588106.49	1178.72	93.75	115.00	114.99	4269007.94	588057.29	1178.24	93.27						
57.00	56.99	4269041.14	588105.66	1178.76	93.79	116.00	115.99	4269007.53	588056.46	1178.27	93.30						
58.00	57.99	4269039.55	588104.83	1178.69	93.72	117.00	117.00	4269006.57	588055.62	1178.29	93.32						
59.00	58.99	4269039.62	588103.99	1178.60	93.63	118.00	117.99	4269006.52	588054.79	1178.33	93.36						
60.00	59.99	4269038.25	588103.16	1178.56	93.59	119.00	118.98	4269005.63	588053.97	1178.34	93.37						
61.00	61.00	4269038.43	588102.32	1178.46	93.49	120.00	119.99	4269005.32	588053.12	1178.32	93.35						
62.00	61.98	4269037.99	588101.50	1178.38	93.41	121.00	120.98	4269004.95	588052.30	1177.98	93.01						
63.00	63.00	4269037.17	588100.65	1178.65	93.68	122.00	122.00	4269004.17	588051.45	1178.01	93.04						
64.00	63.99	4269036.37	588099.82	1178.76	93.79	123.00	122.99	4269003.92	588050.62	1178.32	93.35						
65.00	64.99	4269035.58	588098.99	1178.86	93.89	124.00	123.99	4269003.52	588049.79	1178.46	93.49						
66.00	65.98	4269035.57	588098.16	1178.98	94.01	125.00	125.00	4269002.26	588048.95	1178.35	93.38						
67.00	66.98	4269034.48	588097.33	1179.08	94.11	126.00	125.99	4269001.70	588048.12	1178.16	93.19						
68.00	68.00	4269033.93	588096.48	1179.20	94.23	127.00	126.99	4269001.11	588047.29	1177.88	92.91						

XS 4

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.07	4269204.07	588069.35	99.91	1184.84
Right Pin	146.36	4269127.11	587947.50	98.93	1183.21

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-3.71	4269205.73	588072.51	1185.76	100.82
-2.20	4269205.05	588071.25	1185.43	100.50
-0.69	4269204.45	588069.99	1185.11	100.17
0.07	4269204.07	588069.35	1184.84	99.91
0.10	4269204.08	588069.33	1184.82	99.88
1.71	4269203.39	588067.99	1184.50	99.56
2.05	4269203.17	588067.71	1183.92	98.99
3.32	4269202.57	588066.65	1183.35	98.41
3.32	4269202.56	588066.65	1183.35	98.41
3.32	4269202.56	588066.64	1183.35	98.42
4.50	4269201.97	588065.67	1182.76	97.83
5.23	4269201.71	588065.06	1182.36	97.43
5.65	4269201.30	588064.71	1181.81	96.87
144.52	4269127.54	587949.03	1183.16	98.23
146.36	4269127.11	587947.50	1183.21	98.28
150.35	4269125.48	587944.17	1183.53	98.59



Sonar Data at 1m points

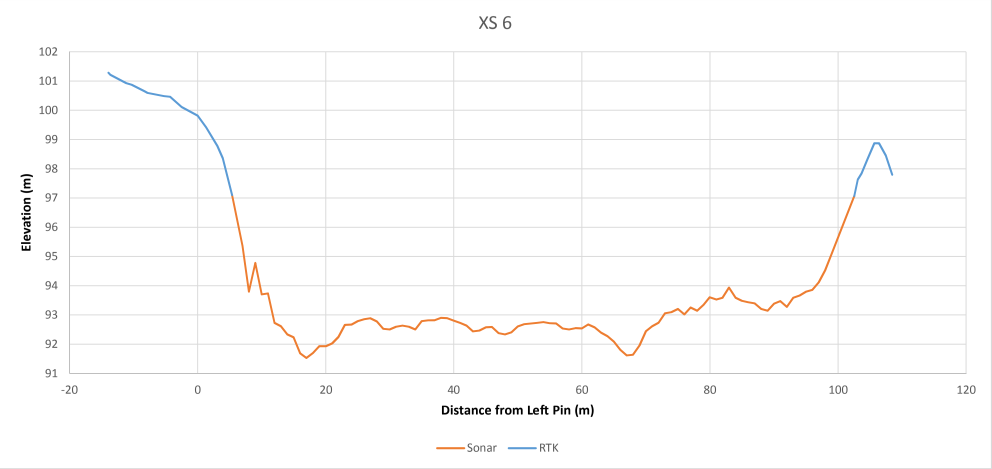
Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
5.65	5.65	4269201.30	588064.71	1181.81	96.87	65.00	65.00	4269170.26	588015.27	1178.55	93.61	123.00	122.99	4269139.87	587966.96	1178.45	93.51
8.00	8.00	4269200.75	588062.75	1178.41	93.47	66.00	65.99	4269169.90	588014.44	1178.68	93.74	124.00	123.99	4269138.87	587966.13	1178.68	93.74
9.00	9.00	4269200.55	588061.92	1178.10	93.16	67.00	66.98	4269169.62	588013.62	1178.88	93.94	125.00	124.99	4269138.18	587965.30	1178.76	93.82
10.00	9.99	4269200.54	588061.09	1177.87	92.93	68.00	67.99	4269168.80	588012.78	1179.16	94.22	126.00	125.98	4269137.70	587964.47	1178.68	93.74
11.00	10.99	4269199.38	588060.26	1177.30	92.36	69.00	68.98	4269168.03	588011.95	1179.24	94.30	127.00	126.99	4269137.31	587963.63	1178.77	93.83
12.00	12.00	4269199.58	588059.42	1177.15	92.21	70.00	69.99	4269167.84	588011.11	1179.13	94.19	128.00	128.00	4269137.01	587962.79	1178.65	93.71
13.00	12.99	4269198.88	588058.59	1176.51	91.57	71.00	70.99	4269167.08	588010.28	1179.20	94.26	129.00	129.00	4269136.14	587961.96	1178.73	93.79
14.00	13.99	4269198.43	588057.76	1176.35	91.41	72.00	72.00	4269166.96	588009.44	1179.18	94.24	130.00	129.99	4269135.78	587961.13	1178.85	93.91
15.00	15.00	4269197.67	588056.92	1176.50	91.56	73.00	72.99	4269165.73	588008.61	1179.25	94.31	131.00	130.99	4269135.21	587960.30	1178.60	93.66
16.00	15.99	4269195.67	588056.09	1176.26	91.32	74.00	73.98	4269165.11	588007.79	1179.11	94.17	132.00	132.00	4269134.67	587959.46	1178.70	93.76
17.00	16.99	4269196.10	588055.26	1176.26	91.32	75.00	75.00	4269164.85	588006.94	1178.99	94.05	133.00	132.99	4269133.56	587958.63	1178.91	93.97
18.00	17.99	4269194.90	588054.43	1176.13	91.19	76.00	75.98	4269164.44	588006.12	1179.15	94.21	134.00	133.99	4269133.66	587957.80	1178.68	93.74
19.00	18.97	4269194.18	588053.61	1176.19	91.25	77.00	76.99	4269163.89	588005.28	1179.10	94.16	135.00	135.00	4269132.99	587956.96	1178.53	93.59
20.00	19.99	4269194.25	588052.76	1176.48	91.54	78.00	78.00	4269163.45	588004.44	1179.20	94.26	136.00	135.98	4269132.72	587956.14	1178.69	93.75
21.00	20.98	4269193.61	588051.94	1176.70	91.76	79.00	78.98	4269162.89	588003.62	1179.19	94.25	137.00	136.99	4269131.44	587955.30	1178.75	93.81
22.00	21.99	4269192.99	588051.10	1176.88	91.94	80.00	79.99	4269162.30	588002.78	1179.23	94.29	138.00	137.98	4269131.82	587954.48	1178.92	93.98
23.00	22.99	4269193.24	588050.26	1177.07	92.13	81.00	80.99	4269161.68	588001.95	1179.22	94.28	139.00	138.29	4269131.74	587954.22	1179.05	94.11
24.00	23.99	4269191.98	588049.43	1177.11	92.17	82.00	82.00	4269161.66	588001.11	1179.21	94.27	144.52	144.52	4269127.54	587949.03	1183.16	98.23
25.00	25.00	4269192.33	588048.59	1177.11	92.17	83.00	82.98	4269160.75	588000.29	1179.26	94.32						
26.00	25.99	4269191.34	588047.76	1177.23	92.29	84.00	83.99	4269160.32	587999.45	1179.10	94.16						
27.00	26.99	4269190.62	588046.93	1177.25	92.31	85.00	85.00	4269159.67	587998.61	1179.22	94.28						
28.00	28.00	4269190.02	588046.09	1177.48	92.54	86.00	85.99	4269158.99	587997.78	1179.36	94.42						
29.00	29.00	4269189.44	588045.26	1177.75	92.81	87.00	86.99	4269158.56	587996.95	1179.26	94.32						
30.00	29.99	4269189.13	588044.43	1177.83	92.89	88.00	88.00	4269158.22	587996.11	1179.09	94.15						
31.00	30.99	4269188.54	588043.60	1177.79	92.85	89.00	88.97	4269157.66	587995.30	1179.18	94.24						
32.00	32.00	4269188.06	588042.76	1177.86	92.92	90.00	89.99	4269157.19	587994.45	1179.32	94.38						
33.00	32.97	4269187.19	588041.95	1177.93	92.99	91.00	90.95	4269156.29	587993.65	1179.39	94.45						
34.00	33.99	4269186.74	588041.10	1178.01	93.07	92.00	92.00	4269155.79	587992.78	1179.29	94.35						
35.00	34.97	4269186.90	588040.28	1178.00	93.06	93.00	92.99	4269155.48	587991.95	1179.33	94.39						
36.00	35.96	4269185.86	588039.46	1178.06	93.12	94.00	93.99	4269155.22	587991.12	1179.28	94.34						
37.00	36.99	4269185.20	588038.60	1178.28	93.34	95.00	94.99	4269154.41	587990.29	1179.33	94.39						
38.00	38.00	4269185.34	588037.76	1178.20	93.26	96.00	95.99	4269153.71	587989.45	1179.31	94.37						
39.00	39.00	4269184.74	588036.93	1178.32	93.38	97.00	96.99	4269153.48	587988.62	1179.31	94.37						
40.00	39.97	4269183.78	588036.12	1178.05	93.11	98.00	98.00	4269153.53	587987.78	1179.27	94.33						
41.00	40.99	4269183.33	588035.27	1178.11	93.17	99.00	99.00	4269152.52	587986.95	1179.08	94.14						
42.00	41.99	4269183.18	588034.44	1178.27	93.33	100.00	99.98	4269151.59	587986.13	1179.14	94.20						
43.00	42.99	4269182.29	588033.60	1178.52	93.58	101.00	100.98	4269151.38	587985.30	1179.16	94.22						
44.00	43.99	4269181.79	588032.77	1178.65	93.71	102.00	102.00	4269150.36	587984.45	1178.95	94.01						
45.00	45.00	4269181.18	588031.93	1178.55	93.61	103.00	102.99	4269150.06	587983.62	1179.09	94.15						
46.00	45.99	4269180.80	588031.10	1178.37	93.43	104.00	103.99	4269149.63	587982.79	1179.12	94.18						
47.00	46.99	4269179.74	588030.27	1178.31	93.37	105.00	105.00	4269149.30	587981.95	1178.95	94.01						
48.00	48.00	4269179.43	588029.43	1178.18	93.24	106.00	105.99	4269148.44	587981.12	1178.97	94.03						
49.00	48.97	4269179.03	588028.62	1178.03	93.09	107.00	106.99	4269147.84	587980.29	1178.93	93.99						
50.00	49.98	4269178.45	588027.78	1178.39	93.45	108.00	108.00	4269147.42	587979.45	1178.87	93.93						
51.00	50.99	4269177.78	588026.94	1178.37	93.43	109.00	109.00	4269146.94	587978.62	1178.88	93.94						
52.00	52.00	4269177.57	588026.10	1178.63	93.69	110.00	109.99	4269146.30	587977.79	1178.70	93.76						
53.00	52.99	4269177.11	588025.27	1178.66	93.72	111.00	110.98	4269146.29	587976.97	1178.69	93.75						
54.00	53.99	4269176.59	588024.44	1178.92	93.98	112.00	112.00	4269145.07	587976.12	1178.78	93.84						
55.00	55.00	4269175.99	588023.60	1179.20	94.26	113.00	112.98	4269144.53	587975.30	1178.78	93.84						
56.00	55.99	4269175.34	588022.77	1179.17	94.23	114.00	113.99	4269144.06	587974.46	1178.86	93.92						
57.00	56.98	4269174.65	588021.95	1179.29	94.35	115.00	114.99	4269143.74	587973.63	1178.90	93.96						
58.00	58.00	4269174.63	588021.10	1179.26	94.32	116.00	115.99	4269143.25	587972.79	1178.90	93.96						
59.00	59.00	4269173.65	588020.27	1179.34	94.40	117.00	116.99	4269142.77	587971.96	1178.82	93.88						
60.00	59.99	4269173.11	588019.44	1179.17	94.23	118.00	117.98	4269141.82	587971.14	1178.84	93.90						
61.00	60.99	4269172.45	588018.61	1178.90	93.96	119.00	119.00	4269141.59	587970.29	1178.77	93.83						
62.00	62.00	4269172.29	588017.77	1178.91	93.97	120.00	119.98	4269140.98	587969.47	1178.53	93.59						
63.00	62.99	4269171.87	588016.94	1178.97	94.03	121.00	120.98	4269140.74	587968.64	1178.58	93.64						
64.00	63.99	4269171.05	588016.11	1178.87	93.93	122.00	122.00	4269139.97	587967.79	1178.63	93.69						

XS 6

	Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
Left Pin	0.10	4269434.54	587730.41	99.70	1184.53
Right most point	0.00	4269333.69	587690.48		1182.62

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-13.93	4269447.59	587735.61	1186.11	101.28
-13.64	4269447.32	587735.81	1186.04	101.21
-11.17	4269445.02	587734.59	1185.75	100.93
-10.31	4269444.22	587734.09	1185.70	100.87
-8.27	4269442.32	587733.32	1185.47	100.65
-7.83	4269441.92	587733.95	1185.42	100.60
-5.25	4269439.52	587732.31	1185.31	100.48
-4.31	4269438.64	587732.11	1185.29	100.46
-2.51	4269436.96	587731.20	1184.94	100.11
0.00	4269434.63	587730.40	1184.64	99.81
1.32	4269433.39	587729.69	1184.24	99.42
3.07	4269431.77	587729.20	1183.61	98.78
3.93	4269430.97	587728.66	1183.18	98.36
5.38	4269429.62	587728.21	1181.93	97.10
102.53	4269339.21	587692.16	1181.89	97.07
103.09	4269338.69	587692.10	1182.46	97.63
103.68	4269338.14	587691.85	1182.67	97.84
104.62	4269337.27	587691.66	1183.15	98.33
105.67	4269336.29	587691.48	1183.69	98.87
106.41	4269335.60	587691.43	1183.70	98.87
107.46	4269334.63	587691.25	1183.28	98.45
108.46	4269333.69	587690.48	1182.62	97.80



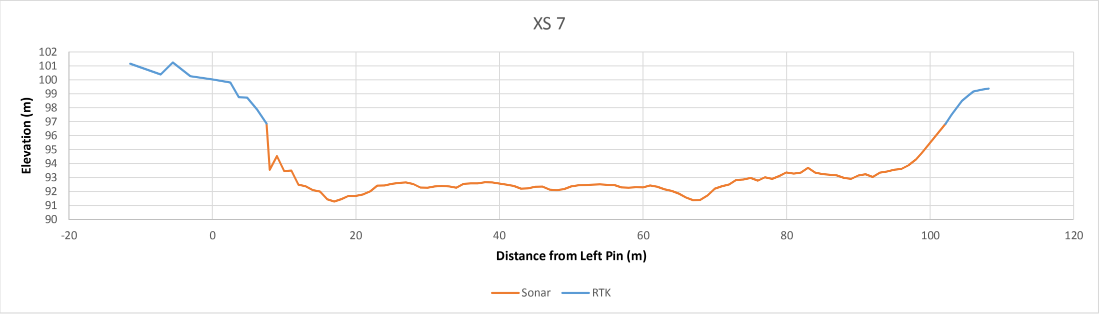
Sonar Data at 1m points

Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
5.38	5.38	4269429.62	587728.21	1181.93	97.10	56.00	55.99	4269425.02	587476.51	1177.53	92.71
7.01	7.01	4269428.10	587727.45	1180.19	95.37	57.00	56.99	4269424.02	587476.31	1177.36	92.54
8.00	7.99	4269472.92	587478.35	1178.62	93.80	58.00	58.00	4269423.01	587476.69	1177.33	92.51
9.00	9.00	4269471.92	587475.85	1179.60	94.78	59.00	58.99	4269422.02	587476.68	1177.37	92.55
10.00	10.00	4269470.92	587477.71	1178.53	93.71	60.00	59.99	4269421.02	587476.84	1177.36	92.54
11.00	10.99	4269469.93	587477.12	1178.56	93.74	61.00	60.99	4269420.02	587476.81	1177.50	92.68
12.00	11.99	4269468.93	587476.21	1177.55	92.73	62.00	62.00	4269419.02	587476.33	1177.40	92.58
13.00	12.99	4269467.93	587475.66	1177.44	92.62	63.00	62.99	4269418.03	587476.73	1177.22	92.40
14.00	14.00	4269466.93	587476.41	1177.16	92.34	64.00	63.99	4269417.03	587476.57	1177.10	92.28
15.00	14.99	4269465.94	587476.24	1177.06	92.24	65.00	64.99	4269416.03	587476.55	1176.91	92.09
16.00	16.00	4269464.93	587476.31	1176.51	91.69	66.00	65.98	4269415.04	587476.54	1176.63	91.81
17.00	16.99	4269463.94	587476.17	1176.35	91.53	67.00	67.00	4269414.03	587476.24	1176.44	91.62
18.00	17.99	4269462.94	587475.86	1176.52	91.70	68.00	67.98	4269413.05	587476.40	1176.46	91.64
19.00	18.98	4269461.96	587476.38	1176.75	91.93	69.00	68.99	4269412.04	587476.38	1176.78	91.96
20.00	20.00	4269460.94	587476.21	1176.75	91.93	70.00	69.99	4269411.04	587476.65	1177.27	92.45
21.00	21.00	4269459.94	587476.17	1176.85	92.03	71.00	70.98	4269410.05	587476.64	1177.44	92.62
22.00	21.99	4269458.95	587476.04	1177.07	92.25	72.00	71.99	4269409.05	587476.32	1177.56	92.74
23.00	22.99	4269457.95	587476.46	1177.48	92.66	73.00	72.98	4269408.06	587476.99	1177.88	93.06
24.00	23.99	4269456.95	587476.22	1177.49	92.67	74.00	73.98	4269407.06	587476.74	1177.92	93.10
25.00	25.00	4269455.95	587476.57	1177.61	92.79	75.00	74.99	4269406.05	587476.59	1178.03	93.21
26.00	26.00	4269454.95	587476.33	1177.68	92.86	76.00	75.99	4269405.05	587476.59	1177.84	93.02
27.00	26.96	4269453.99	587475.96	1177.71	92.89	77.00	76.98	4269404.06	587476.84	1178.08	93.26
28.00	27.99	4269452.96	587476.17	1177.60	92.78	78.00	78.00	4269403.05	587476.85	1177.97	93.15
29.00	28.98	4269451.97	587476.16	1177.35	92.53	79.00	79.00	4269402.05	587476.67	1178.17	93.35
30.00	29.99	4269450.97	587476.42	1177.33	92.51	80.00	79.94	4269401.11	587477.17	1178.43	93.61
31.00	30.98	4269449.98	587476.96	1177.42	92.60	81.00	80.99	4269400.06	587476.64	1178.35	93.53
32.00	31.98	4269448.98	587476.62	1177.46	92.64	82.00	81.97	4269399.08	587476.81	1178.41	93.59
33.00	32.99	4269447.97	587476.09	1177.42	92.60	83.00	82.98	4269398.08	587476.66	1178.76	93.94
34.00	33.98	4269446.98	587476.66	1177.33	92.51	84.00	84.00	4269397.06	587476.80	1178.41	93.59
35.00	34.99	4269445.98	587476.38	1177.61	92.79	85.00	84.99	4269396.07	587476.82	1178.31	93.49
36.00	36.00	4269444.97	587476.33	1177.64	92.82	86.00	85.96	4269395.10	587476.87	1178.26	93.44
37.00	36.97	4269444.00	587476.00	1177.64	92.82	87.00	86.98	4269394.08	587477.52	1178.22	93.40
38.00	37.97	4269443.00	587476.68	1177.72	92.90	88.00	88.00	4269393.07	587476.92	1178.03	93.21
39.00	38.99	4269441.98	587475.96	1177.71	92.89	89.00	89.00	4269392.07	587476.77	1177.97	93.15
40.00	40.00	4269440.98	587476.69	1177.63	92.81	90.00	90.00	4269391.07	587476.76	1178.21	93.39
41.00	41.00	4269439.98	587476.27	1177.55	92.73	91.00	90.99	4269390.08	587476.55	1178.30	93.48
42.00	42.00	4269438.98	587476.33	1177.46	92.64	92.00	91.99	4269389.08	587476.46	1178.10	93.28
43.00	42.99	4269437.99	587476.66	1177.26	92.44	93.00	93.00	4269388.08	587476.35	1178.41	93.59
44.00	43.98	4269437.00	587476.64	1177.29	92.47	94.00	94.00	4269387.08	587476.65	1178.49	93.67
45.00	44.98	4269436.00	587476.29	1177.40	92.58	95.00	95.00	4269386.08	587476.98	1178.62	93.80
46.00	45.98	4269435.01	587476.21	1177.41	92.59	96.00	95.99	4269385.09	587477.46	1178.68	93.86
47.00	46.98	4269434.01	587476.19	1177.20	92.38	97.00	96.99	4269384.09	587477.69	1178.94	94.12
48.00	47.99	4269433.00	587476.65	1177.16	92.34	98.00	97.99	4269383.09	587476.89	1179.35	94.53
49.00	48.98	4269432.01	587476.52	1177.23	92.41	99.00	98.83	4269382.26	587475.90	1179.82	95.00
50.00	49.98	4269431.01	587476.55	1177.43	92.61	102.53	102.53	4269339.21	587692.16	1181.89	97.07
51.00	51.00	4269430.00	587476.51	1177.51	92.69						
52.00	52.00	4269429.00	587476.42	1177.53	92.71						
53.00	52.98	4269428.02	587476.48	1177.55	92.73						
54.00	53.99	4269427.01	587476.56	1177.58	92.76						
55.00	54.96	4269426.04	587476.37	1177.54	92.72						

XS 7		Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
	Left Pin	0.02	4269480.88	587475.94	100.12	1185.18
	Right Pin	107.21	4269373.89	587476.50	99.52	1184.36

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
-11.44	4269492.32	587477.18	1186.22	101.16
-7.20	4269488.08	587475.80	1185.45	100.39
-5.52	4269486.41	587475.73	1186.31	101.25
-3.06	4269483.95	587475.93	1185.32	100.26
0.02	4269480.88	587475.92	1185.09	100.03
2.50	4269478.40	587476.50	1184.88	99.82
3.67	4269477.23	587476.41	1183.81	98.75
4.84	4269476.07	587476.31	1183.80	98.73
6.23	4269474.68	587476.35	1182.95	97.89
7.54	4269473.37	587476.31	1181.93	96.87
102.14	4269378.96	587476.45	1181.89	96.83
103.01	4269378.09	587476.72	1182.58	97.51
104.40	4269376.70	587476.80	1183.54	98.48
105.34	4269375.76	587476.66	1183.95	98.89
106.03	4269375.07	587476.55	1184.23	99.17
107.29	4269373.82	587476.61	1184.37	99.31
108.15	4269372.95	587476.67	1184.44	99.38



Sonar Data at 1m points

Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
7.54	7.54	4269473.37	587476.31	1181.93	96.87
8.00	7.99	4269472.92	587478.35	1178.62	93.56
9.00	9.00	4269471.92	587475.85	1179.60	94.54
10.00	10.00	4269470.92	587477.71	1178.53	93.47
11.00	10.99	4269469.93	587477.12	1178.56	93.50
12.00	11.99	4269468.93	587476.21	1177.55	92.49
13.00	12.99	4269467.93	587475.66	1177.44	92.38
14.00	14.00	4269466.93	587476.41	1177.16	92.10
15.00	14.99	4269465.94	587476.24	1177.06	92.00
16.00	16.00	4269464.93	587476.31	1176.51	91.45
17.00	16.99	4269463.94	587476.17	1176.35	91.29
18.00	17.99	4269462.94	587475.86	1176.52	91.46
19.00	18.98	4269461.96	587476.38	1176.75	91.69
20.00	20.00	4269460.94	587476.21	1176.75	91.69
21.00	21.00	4269459.94	587476.17	1176.85	91.79
22.00	21.99	4269458.95	587476.04	1177.07	92.01
23.00	22.99	4269457.95	587476.46	1177.48	92.42
24.00	23.99	4269456.95	587476.22	1177.49	92.43
25.00	25.00	4269455.95	587476.57	1177.61	92.55
26.00	26.00	4269454.95	587476.33	1177.68	92.62
27.00	26.96	4269453.99	587475.96	1177.71	92.65
28.00	27.99	4269452.96	587476.17	1177.60	92.54
29.00	28.98	4269451.97	587476.16	1177.35	92.29
30.00	29.99	4269450.97	587476.42	1177.33	92.27
31.00	30.98	4269449.98	587476.96	1177.42	92.36
32.00	31.98	4269448.98	587476.62	1177.46	92.40
33.00	32.99	4269447.97	587476.09	1177.42	92.36
34.00	33.98	4269446.98	587476.66	1177.33	92.27
35.00	34.99	4269445.98	587476.38	1177.61	92.55
36.00	36.00	4269444.97	587476.33	1177.64	92.58
37.00	36.97	4269444.00	587476.00	1177.64	92.58
38.00	37.97	4269443.00	587476.68	1177.72	92.66
39.00	38.99	4269441.98	587475.96	1177.71	92.65
40.00	40.00	4269440.98	587476.69	1177.63	92.57
41.00	41.00	4269439.98	587476.27	1177.55	92.49
42.00	42.00	4269438.98	587476.33	1177.46	92.40
43.00	42.99	4269437.99	587476.66	1177.26	92.20
44.00	43.98	4269437.00	587476.64	1177.29	92.23
45.00	44.98	4269436.00	587476.29	1177.40	92.34
46.00	45.98	4269435.01	587476.21	1177.41	92.35
47.00	46.98	4269434.01	587476.19	1177.20	92.14
48.00	47.99	4269433.00	587476.65	1177.16	92.10
49.00	48.98	4269432.01	587476.52	1177.23	92.17
50.00	49.98	4269431.01	587476.55	1177.43	92.37
51.00	51.00	4269430.00	587476.51	1177.51	92.45
52.00	52.00	4269429.00	587476.42	1177.53	92.47
53.00	52.98	4269428.02	587476.48	1177.55	92.49
54.00	53.99	4269427.01	587476.56	1177.58	92.52
55.00	54.96	4269426.04	587476.37	1177.54	92.48
56.00	55.99	4269425.02	587476.51	1177.53	92.47
57.00	56.99	4269424.02	587476.31	1177.36	92.30
58.00	58.00	4269423.01	587476.69	1177.33	92.27
59.00	58.99	4269422.02	587476.68	1177.37	92.31
60.00	59.99	4269421.02	587476.84	1177.36	92.30
61.00	60.99	4269420.02	587476.81	1177.50	92.44
70.00	69.99	4269411.04	587476.65	1177.27	92.21
71.00	70.98	4269410.05	587476.64	1177.44	92.38
72.00	71.99	4269409.05	587476.32	1177.56	92.50
73.00	72.98	4269408.06	587476.99	1177.88	92.82
74.00	73.98	4269407.06	587476.74	1177.92	92.86
75.00	74.99	4269406.05	587476.59	1178.03	92.97
76.00	75.99	4269405.05	587476.59	1177.84	92.78
77.00	76.98	4269404.06	587476.84	1178.08	93.02
78.00	78.00	4269403.05	587476.85	1177.97	92.91
79.00	79.00	4269402.05	587476.67	1178.17	93.11
80.00	79.94	4269401.11	587477.17	1178.43	93.37
81.00	80.99	4269400.06	587476.64	1178.35	93.29
82.00	81.97	4269399.08	587476.81	1178.41	93.35
83.00	82.98	4269398.08	587476.66	1178.76	93.70
84.00	84.00	4269397.06	587476.80	1178.41	93.35
85.00	84.99	4269396.07	587476.82	1178.31	93.25
86.00	85.96	4269395.10	587476.87	1178.26	93.20
87.00	86.98	4269394.08	587477.52	1178.22	93.16
88.00	88.00	4269393.07	587476.92	1178.03	92.97
89.00	89.00	4269392.07	587476.77	1177.97	92.91
90.00	90.00	4269391.07	587476.76	1178.21	93.15
91.00	90.99	4269390.08	587476.55	1178.30	93.24
92.00	91.99	4269389.08	587476.46	1178.10	93.04
93.00	93.00	4269388.08	587476.35	1178.41	93.35
94.00	94.00	4269387.08	587476.65	1178.49	93.43
95.00	95.00	4269386.08	587476.98	1178.62	93.56
96.00	95.99	4269385.09	587477.46	1178.68	93.62
97.00	96.99	4269384.09	587477.69	1178.94	93.88
98.00	97.99	4269383.09	587476.89	1179.35	94.29
99.00	98.83	4269382.26	587475.90	1179.82	94.76
	102.14	4269378.96	587476.45	1181.89	96.83

XS 8		Dist from Pin (m)	Northing	Easting	1996 Datum Z (m)	Z
	Left Pin	0.04	4269432.69	587230.89	99.58	1184.62
	Right most point	0.00	4269283.18	587293.90		1184.20

RTK Points

Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
0.08	4269432.65	587230.76	1184.58	99.54
0.10	4269432.63	587230.77	1184.59	99.54
1.80	4269431.06	587231.08	1184.25	99.21
4.25	4269428.81	587230.94	1184.22	99.18
5.59	4269427.57	587230.88	1184.42	99.38
7.08	4269426.20	587231.15	1184.16	99.11
9.11	4269424.33	587231.18	1183.78	98.73
9.97	4269423.54	587231.32	1183.11	98.06
10.57	4269422.98	587231.62	1183.01	97.96
10.83	4269422.74	587231.60	1182.78	97.74
11.31	4269422.30	587231.60	1182.71	97.66
12.42	4269421.28	587231.31	1182.11	97.06
149.87	4269294.59	587288.37	1181.98	96.94
150.50	4269294.01	587289.03	1182.63	97.58
152.45	4269292.21	587287.02	1182.41	97.36
152.88	4269291.81	587287.56	1182.59	97.55
153.71	4269291.05	587288.17	1182.70	97.66
154.43	4269290.38	587288.68	1184.57	99.52
156.54	4269288.43	587290.33	1184.29	99.24
157.41	4269287.64	587290.84	1184.19	99.14
162.24	4269283.18	587293.90	1184.20	99.16

Sonar Data at 1m points

Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z	Ideal Dist from L Pin (m)	Actual Dist from L Pin (m)	Northing	Easting	Z	Adj to 1996 Z
12.42	12.42	4269421.28	587231.31	1182.11	97.06	72.00	71.98	4269366.38	587255.33	1180.67	95.63	148.00	147.49	4269296.78	587281.62	1178.24	93.20
13.66	13.66	4269420.13	587236.01	1178.89	93.85	73.00	73.00	4269365.44	587255.79	1180.58	95.54	149.87	149.87	4269294.59	587288.37	1181.98	96.94
14.00	14.00	4269419.82	587236.02	1179.49	94.45	74.00	74.00	4269364.52	587256.13	1180.52	95.48						
15.00	14.99	4269418.91	587235.58	1178.78	93.74	75.00	74.99	4269363.60	587256.54	1180.36	95.32						
16.00	16.00	4269417.98	587236.39	1179.44	94.40	76.00	75.98	4269362.69	587256.79	1180.08	95.04						
17.00	16.99	4269417.06	587236.86	1179.20	94.16	77.00	76.98	4269361.77	587256.99	1180.05	95.01						
18.00	17.97	4269416.16	587237.38	1179.31	94.27	78.00	78.00	4269360.83	587257.25	1179.85	94.81						
18.00	18.97	4269415.24	587237.67	1179.36	94.32	79.00	78.98	4269359.93	587258.14	1179.53	94.49						
20.00	19.97	4269414.32	587237.78	1179.39	94.35	80.00	79.97	4269359.01	587258.50	1179.52	94.48						
21.00	21.00	4269413.37	587238.00	1179.51	94.47	81.00	80.97	4269358.09	587258.46	1179.31	94.27						
22.00	21.98	4269412.46	587238.34	1179.71	94.67	82.00	81.98	4269357.16	587258.99	1178.93	93.89						
23.00	22.98	4269411.54	587238.83	1179.74	94.70	83.00	82.97	4269356.25	587259.52	1179.03	93.99						
24.00	23.97	4269410.63	587239.43	1179.81	94.77	84.00	84.00	4269355.30	587259.98	1178.95	93.91						
25.00	24.97	4269409.71	587239.91	1179.68	94.64	85.00	84.99	4269354.39	587260.35	1178.85	93.81						
26.00	26.00	4269408.76	587240.13	1179.67	94.63	86.00	86.00	4269353.46	587260.63	1178.95	93.91						
27.00	26.99	4269407.85	587240.51	1179.73	94.69	87.00	86.96	4269352.57	587260.96	1178.95	93.91						
28.00	27.98	4269406.93	587240.88	1179.78	94.74	88.00	87.97	4269351.64	587260.96	1178.81	93.77						
29.00	28.99	4269406.00	587240.78	1179.54	94.50	89.00	88.99	4269350.70	587261.49	1178.85	93.81						
30.00	29.98	4269405.09	587241.11	1179.42	94.38	90.00	89.99	4269349.78	587262.13	1178.73	93.69						
31.00	30.99	4269404.16	587241.55	1179.77	94.73	91.00	90.95	4269348.89	587262.82	1178.62	93.58						
32.00	32.00	4269403.23	587242.20	1179.80	94.76	92.00	91.95	4269347.97	587263.05	1178.54	93.50						
33.00	32.99	4269402.32	587242.50	1179.52	94.48	93.00	92.98	4269347.02	587263.29	1178.30	93.26						
34.00	33.97	4269401.41	587242.89	1179.22	94.18	94.00	93.98	4269346.10	587263.61	1178.20	93.16						
35.00	34.97	4269400.49	587243.26	1179.06	94.02	95.00	94.97	4269345.19	587264.83	1178.56	93.52						
36.00	35.95	4269399.59	587243.48	1179.19	94.15	96.00	95.98	4269344.26	587264.28	1178.56	93.52						
37.00	36.98	4269398.64	587243.64	1179.49	94.45	97.00	97.00	4269343.32	587264.57	1178.45	93.41						
38.00	37.99	4269397.71	587243.87	1179.67	94.63	98.00	97.99	4269342.40	587265.37	1178.53	93.49						
39.00	38.99	4269396.79	587244.18	1179.88	94.84	99.00	98.95	4269341.52	587264.95	1178.54	93.50						
40.00	39.97	4269395.88	587244.84	1180.03	94.99	100.00	99.96	4269340.59	587265.67	1178.18	93.14						
41.00	40.98	4269394.95	587245.19	1180.06	95.02	101.00	100.98	4269339.65	587265.83	1178.09	93.05						
42.00	41.97	4269394.04	587245.33	1179.97	94.93	102.00	102.00	4269338.71	587265.98	1177.88	92.84						
43.00	43.00	4269393.09	587245.69	1179.91	94.87	103.00	102.97	4269337.81	587266.53	1178.05	93.01						
44.00	44.00	4269392.17	587246.24	1179.85	94.81	120.00	119.98	4269322.14	587272.22	1177.67	92.63						
45.00	44.98	4269391.26	587246.30	1179.89	94.85	121.00	120.97	4269321.22	587272.48	1177.63	92.59						
46.00	45.99	4269390.33	587246.68	1179.95	94.91	122.00	121.98	4269320.29	587272.78	1177.55	92.51						
47.00	46.98	4269389.42	587247.12	1179.80	94.76	123.00	122.99	4269319.36	587273.23	1177.48	92.44						
48.00	47.99	4269388.49	587247.69	1179.58	94.54	124.00	123.98	4269318.45	587273.73	1177.48	92.44						
49.00	48.98	4269387.58	587247.90	1179.69	94.65	125.00	125.00	4269317.51	587273.39	1177.30	92.26						
50.00	50.00	4269386.64	587248.66	1179.87	94.83	126.00	126.00	4269316.59	587274.33	1177.04	92.00						
51.00	50.98	4269385.73	587248.85	1179.83	94.79	127.00	126.97	4269315.69	587274.41	1177.07	92.03						
52.00	51.97	4269384.82	587248.92	1179.67	94.63	128.00	127.99	4269314.75	587274.65	1177.32	92.28						
53.00	52.96	4269383.91	587249.18	1179.90	94.86	129.00	128.99	4269313.83	587274.97	1177.22	92.18						
54.00	53.98	4269382.97	587249.36	1180.03	94.99	130.00	129.97	4269312.93	587275.45	1177.14	92.10						
55.00	55.00	4269382.03	587249.75	1179.96	94.92	131.00	131.00	4269311.98	587275.58	1177.06	92.02						
56.00	55.98	4269381.13	587250.20	1180.11	95.07	132.00	131.97	4269311.08	587276.03	1177.01	91.97						
57.00	56.97	4269380.21	587250.72	1179.94	94.90	133.00	132.97	4269310.16	587276.43	1176.89	91.85						
58.00	57.98	4269379.28	587251.15	1180.25	95.21	134.00	133.98	4269309.23	587276.26	1176.79	91.75						
59.00	58.96	4269378.38	587251.51	1180.24	95.20	135.00	134.95	4269308.34	587276.94	1176.89	91.85						
60.00	59.96	4269377.46	587251.79	1180.46	95.42	136.00	135.99	4269307.38	587277.24	1177.13	92.09						
61.00	60.98	4269376.52	587251.97	1180.32	95.28	137.00	137.00	4269306.45	587277.67	1177.22	92.18						
62.00	61.99	4269375.59	587252.49	1180.42	95.38	138.00	137.97	4269305.55	587278.34	1177.32	92.28						
63.00	62.97	4269374.68	587252.21	1180.49	95.45	139.00	138.98	4269304.62	587278.81	1177.31	92.27						
64.00	63.99	4269373.74	587252.43	1180.60	95.56	140.00	139.97	4269303.71	587279.14	1177.32	92.28						
65.00	64.99	4269372.82	587253.50	1180.52	95.48	141.00	140.99	4269302.77	587278.70	1177.48	92.44						
66.00	65.99	4269371.90	587253.72	1180.53	95.49	142.00	141.99	4269301.85	587279.77	1178.23	93.19						
67.00	66.97	4269371.00	587253.47	1180.52	95.48	143.00	143.00	4269300.92	587279.33	1178.58	93.54						
68.00	68.00	4269370.05	587254.18	1180.62	95.58	144.00	144.00	4269300.00	587279.66	1178.48	93.44						
69.00	68.98	4269369.14	587254.33	1180.62	95.58	145.00	144.99	4269299.08	587279.84	1178.32	93.28						
70.00	69.97	4269368.23	587254.69	1180.59	95.55	146.00	145.98	4269298.17	587280.75	1178.12	93.08						
71.00	70.98	4269367.30	587255.24	1180.65	95.61	147.00	146.98	4269297.25	587281.13	1177.99	92.95						

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