

Luckiamute State Natural Area Floodplain Reconnection



Prepared for
Mr. Jean-Paul Zagarola
Luckiamute Watershed Council



Prepared by



September 6, 2017

www.riverdesigngroup.com

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EXECUTIVE SUMMARY

The Luckiamute Watershed Council (LWC) retained River Design Group, Inc. (RDG) to prepare concepts for floodplain reconnection at the Luckiamute State Natural Area (LSNA). The goal of the project is to improve hydraulic connectivity at two previously identified Site Investigation Areas (SIA) to enhance rearing habitat for anadromous fish species, including ESA-listed threatened Upper Willamette River (UWR) Chinook salmon and the ESA-listed threatened UWR distinct population segment (DPS) winter steelhead. At the SIA7 and SIA8 project sites, streambank elevations and altered hydrology due to Willamette River regulation restricts flow from accessing existing floodplain swales and depressions. Reconnection of these floodplain features will increase the frequency and duration of inundation of the available habitat for fish and wildlife.

Project tasks included a topographic survey of the two project sites, a hydrological analysis to inform alternative concepts for floodplain reconnection, concept level design drawings, a preliminary cost analysis of the concepts, and a preliminary investigation of other potential floodplain habitat enhancement projects at the LSNA.

RDG completed a detailed topographic survey of SIA7 and SIA8 during the Winter of 2017 and merged the data with an existing LiDAR dataset to construct a seamless digital elevation model (DEM) of the project areas. RDG also installed a pressure transducer (PT) on the Luckiamute River between the two sites to record river stage in the project vicinity. The suitability of nearby gages (Luckiamute River near Suver, OR, Willamette River at Albany, OR, and Willamette River at Salem, OR) was evaluated to develop rating curves in conjunction with the pressure transducer observations. The hydrological analysis indicates that floodplain inundation at LSNA is primarily influenced by stage on the Willamette River, rather than from discharge on the Luckiamute River. Rating curve and flow duration analyses were completed for both Willamette gages to estimate inundation at the project sites.

RDG prepared alternative concepts for SIA7 and SIA8. The concepts include modifying existing floodplain features to increase the frequency and duration of inundation at the two sites. Project alternatives were then evaluated based on the predicted increases in the annual duration and area of inundation relative to anticipated construction costs.

Table of Contents

1	Introduction.....	1
2	Field Data Collection and Hydrologic Analysis	2
2.1	Data Collection	2
2.2	Hydrologic Analysis	3
	Luckiamute River near Suver, OR Gage.....	5
	Willamette River at Salem and Albany.....	8
	Hydrologic Conditions at the Project Sites.....	15
3	Concept Development and Alternatives Analysis	17
3.1	SIA7.....	20
3.2	SIA8.....	22
3.3	Cost-Benefit Analysis.....	26
4	Summary.....	27
5	References.....	28

Appendices

Appendix A – Project Conceptual Design Drawings

1 Introduction

River Design Group, Inc. (RDG) was retained by the Luckiamute Watershed Council (LWC) to provide technical assistance for hydrologic analysis, conceptual designs, and cost analysis for two floodplain enhancement projects at the Luckiamute State Natural Area (LSNA). Alternative design concepts were developed for two Site Investigation Area (SIA) sites (SIA7 and SIA8) at LSNA (Figure 1-1), and the hydrologic analysis was used to determine the existing conditions and evaluate potential benefits of the recommended projects. The hydrologic analysis, which expands upon previous analyses completed by RDG (2013) for LWC, was used to identify additional locations that could be investigated more rigorously for possible floodplain restoration or enhancement projects.

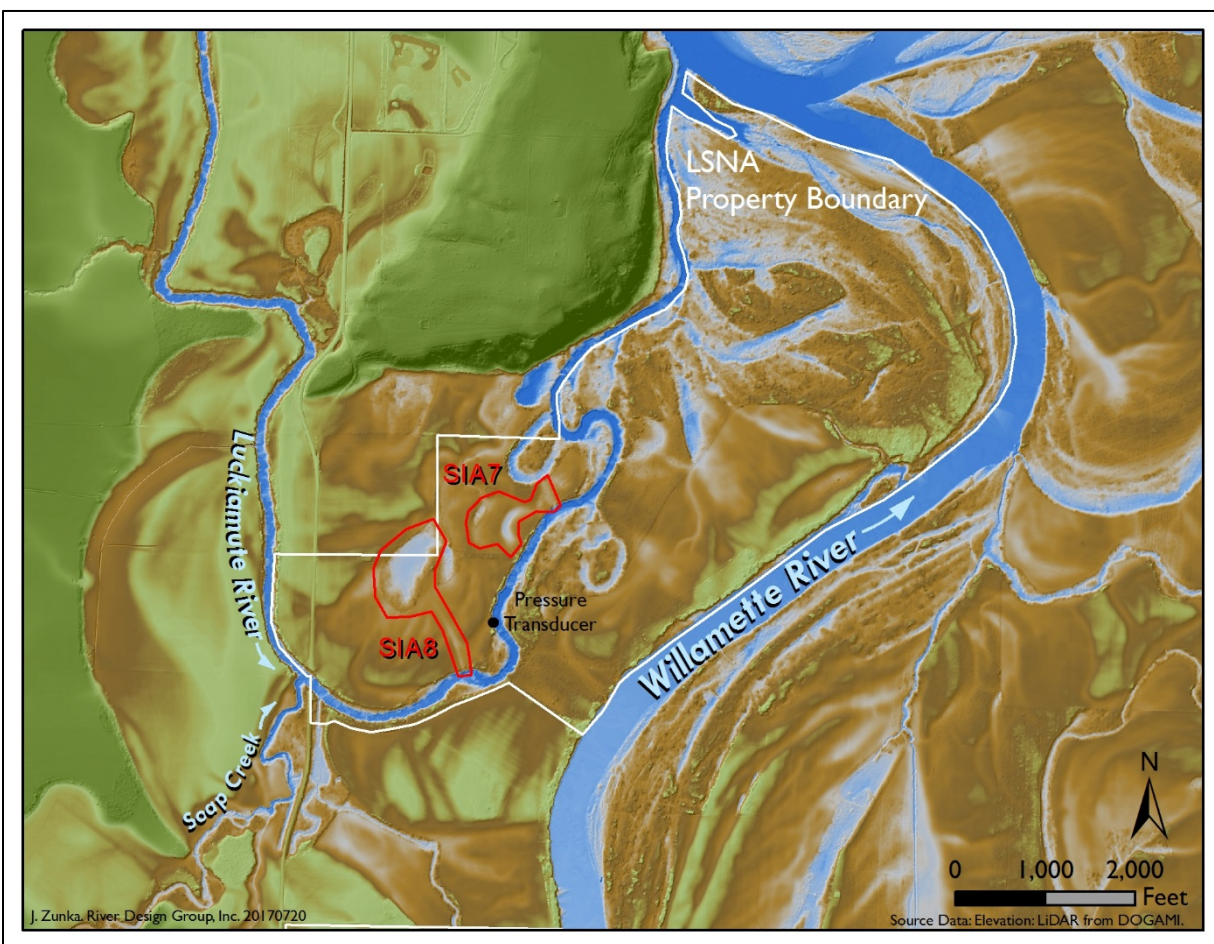


Figure 1-1. The LSNA property, including the SIA7 and SIA8 project locations.

LSNA, which is owned and managed by the Oregon Parks and Recreation Department (OPRD), is divided into two tracts, the North Tract and South Tract, totaling approximately 926 acres. LSNA contains important floodplain habitats at the confluence of the Luckiamute and Willamette rivers and is considered part of the Luckiamute-Santiam anchor habitat on the Willamette River. Anchor habitats are areas in the 100-year floodplain considered of high ecological value and high

restoration potential (OWEB, 2015). LSNA is home to a variety of at-risk native species that include western pond turtles and red-legged frogs, as well as ESA-listed threatened Upper Willamette River (UWR) spring Chinook salmon and UWR winter steelhead.

This technical memorandum provides a summary of 1) field data collection and the corresponding hydrologic analysis, and 2) alternative design concepts and evaluation of project costs and potential benefits.

2 Field Data Collection and Hydrologic Analysis

LSNA contains a large dynamic floodplain near the confluence of the Luckiamute, Santiam, and Willamette rivers. Despite significant reductions to the frequency and magnitude of large flood events on the Willamette and Santiam rivers due to flood control operations, LSNA still experiences annual flooding throughout much of the property. The following sections review existing hydrologic conditions and the effects of flood control operations on the Willamette River, field data collection activities and results, and hydrologic analysis for LSNA. In a previous effort for LWC, RDG (2013) completed a hydrologic analysis at LSNA using the U.S. Geological Survey (USGS) Willamette River at Albany, OR gage record. Here, we extend that analysis to include an investigation of the utility of the USGS Luckiamute River at Suver, OR and Willamette River at Salem, OR gages for a more rigorous inundation analysis at LSNA project sites.

2.1 Data Collection

RDG completed a topographic survey of the two project sites using GNSS enabled RTK GPS on February 22, 2017. Survey data were processed and merged with an existing LiDAR dataset to create an existing ground surface model for the project sites. All elevation data are referenced to the NAVD88 datum. The survey occurred during high flow, so water surface elevations and edge of water were also surveyed. In addition, an unmanned aerial vehicle (UAV) was used to capture high-resolution aerial photos of the project site showing the current extent of inundation (Figure 2-1). A pressure transducer (PT) was installed in the Luckiamute River between the two project sites (Figure 2-1), and logged river stage data at 15-minute intervals between its deployment on January 16, 2017 and its most recent download on April 11, 2017 (the PT Period).

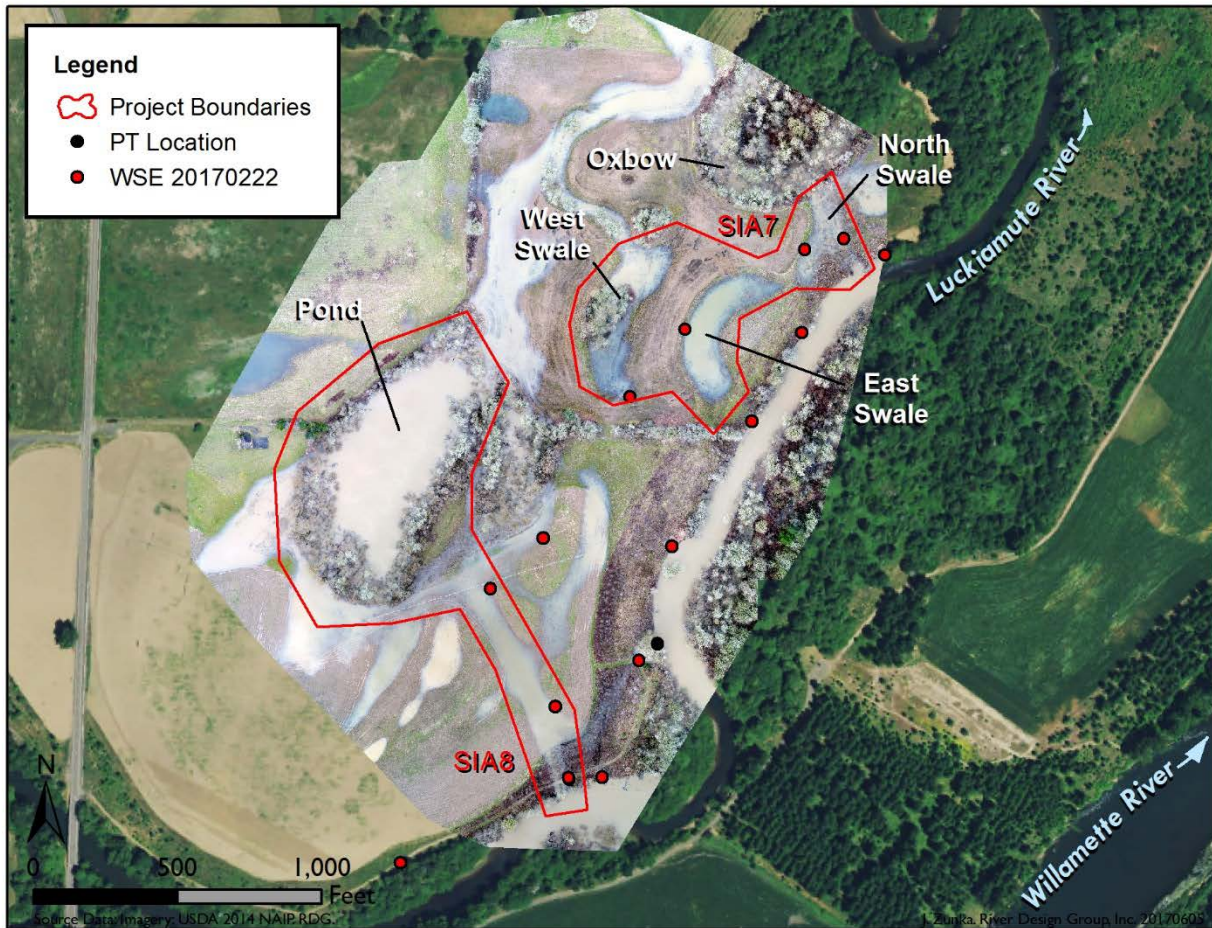


Figure 2-1. UAV acquired aerial imagery taken February 22, 2017 overlaid on the 2014 NAIP imagery. The discharge at the Suver gage was 4,900 cfs, 45,000 cfs at the Willamette River Albany gage, and 80,000 cfs at the Willamette River Salem gage. Locations of the pressure transducer, water surface elevation survey data, and pre-existing floodplain features are shown.

2.2 Hydrologic Analysis

The primary goals of the hydrologic analysis were to develop a stage-discharge relationship (i.e., rating curve) between the water surface elevation at the LSNA project sites and a nearby gage, and to use the rating curve in conjunction with a flow-duration analysis for the gages to estimate the frequency and duration of inundation at the two project sites under existing conditions and for the design concepts. Rating curves were built using 15-minute instantaneous stage and discharge data from the pressure transducer and the USGS gages, respectively. The flow duration analysis used daily average flow records to calculate the percentage of time a discharge of a given magnitude is exceeded on an annual basis. There are three USGS gages of note in the project vicinity: #14190500 Luckiamute River near Suver, OR (Suver gage), which is located approximately 12 miles upstream of the project site; #14174000 Willamette River at Albany, OR (Albany gage), which is located approximately 9 miles upstream of the Luckiamute River mouth; and #14191000 Willamette River at Salem, OR (Salem gage), which is located approximately 24

miles downstream of the Luckiamute River mouth. RDG previously completed a similar hydrologic analysis using staff plates at the LSNA site and the Albany gage, and we updated the Albany analysis using the recently acquired pressure transducer data.

A primary focus of the hydrologic analysis was the development of a functional rating curve. Figure 2-2 illustrates a typical stage-discharge relationship. Under steady flow conditions, a rating curve is a straightforward relationship where each stage is associated with a single discharge such that a single function can be used to define the curve (dashed line in Figure 2-2). However, due to unsteady flow conditions associated with the propagation of a flood wave, rating curves usually show hysteresis effects at higher stages and discharges. The stage-discharge relationship will then vary between the rising or falling limbs of the hydrograph. For a given discharge, stage should be higher on the falling limb of the hydrograph than the rising limb, or, alternatively, for a given stage, the discharge will be lower on the rising limb than the falling limb (e.g., Figure 2-2). In general, stage will rise with the approach of the flood wave, and then continue to rise for some time after the peak of the flood wave as passed before falling. The range of discharge and stage values due to hysteresis effects can be significant.

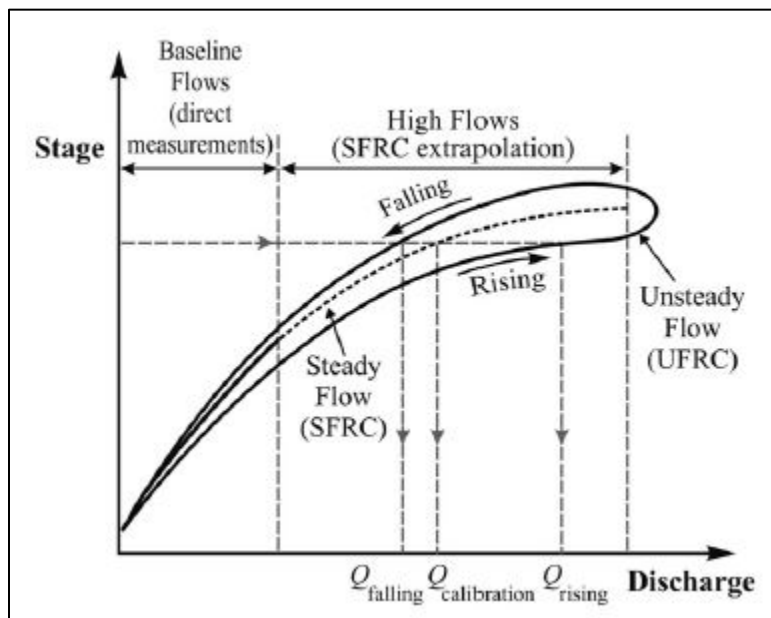


Figure 2-2. Illustration of rating curve hysteresis for a system controlled by the propagation of flood waves. From Muste et al. (2011).

The lower Luckiamute River may exhibit this type of hysteresis associated with floods from upstream as measured at the Suver gage. However, hydraulic conditions at LSNA are heavily influenced by the Willamette River, so the rating curves and hysteresis patterns are more complicated. The direction of the hysteresis curves between the Willamette and the LSNA pressure transducer are reversed for several of the flow events observed during the PT Period. Hysteresis effects increase the scatter of a given rating curve and thereby increase the

uncertainty associated with inundation analyses. The range of corresponding values possible for a given stage or discharge can vary on the order of 10 to 100 percent. The following sections describe these issues in more detail.

Luckiamute River near Suver, OR Gage

RDG evaluated the Luckiamute River Suver gage for its effectiveness in constructing a suitable rating curve for the LSNA site. The Suver gage is located approximately 9 miles upstream of the project sites. Soap Creek, which is the second largest tributary to the Luckiamute River, enters from river-right approximately 2,000 ft upstream of SIA8 and is the only notable tributary between the gage and the project site. The gage record consists of peak and daily mean discharge data, which extends from 1905 to the present, and 15 min instantaneous stage and discharge data from 1986 to the present. A flood frequency analysis (FFA) was completed for the entire peak flow record (1905 to 2016) following the USGS 17B protocol (Table 2-1). The water surface elevations and inundation extents visible in the high resolution aerial photo on February 22, 2017 correspond to a discharge of 4,900 cfs at the Suver gage, which represents an approximately 1.05 year recurrence interval (RI) flow (Table 2-1).

Table 2-1. Flood frequency analysis for USGS gage 14190500 Luckiamute River near Suver, OR calculated from USGS 17B protocol. The 95% confidence limits on the discharge are shown.

Recurrence Interval (yrs)	Chance Exceedance (%)	Peak Discharge (cfs)	Discharge 95% min (cfs)	Discharge 95% max (cfs)
1.001	99.9	2,775	2,220	3,311
1.01	99.0	3,785	3,155	4,381
1.05	95.0	5,058	4,368	5,706
1.25	80.0	7,233	6,480	7,963
2	50.0	10,724	9,819	11,708
5	20.0	16,217	14,737	18,089
10	10.0	20,292	18,184	23,129
50	2.0	30,482	26,393	36,458
100	1.0	35,336	30,168	43,079

A flow duration analysis was completed for the Luckiamute River using the daily average flow record from the Suver gage. The analysis was completed for three periods of the record: 1905 - 2017, 1942 – 2017, and 1999 – 2017, and results are shown for 1999 – 2017, which appear to be most representative of current conditions (Table 2-2).

Table 2-2. Flow duration analysis for USGS gage 14190500 Luckiamute River near Suver, OR for the daily mean discharge record from 1999 to 2017.

Days Inundated Per Year	Time Exceeded (%)	Discharge (cfs)	Days Inundated Per Year	Time Exceeded (%)	Discharge (cfs)
0	0.1	10,267	26	7	2,500
4	1	6,007	29	8	2,276
7	2	4,763	33	9	2,100
11	3	4,057	37	10	1,970
15	4	3,510	73	20	1,170
18	5	3,080	183	50	340
22	6	2,760	274	75	74

To provide context for the flow period for which the pressure transducer was collecting stage data (January to April, 2017), Figure 2-3 shows the magnitude of select duration flows relative to the hydrographs from the past five years at the Suver gage. These data show that, at the time of this report, the 2017 WY (period between October 1, 2016 and September 30, 2017) has been wetter and has more intermediate-sized flows than previous years but has a lower annual peak flood magnitude than 2013, 2015, and 2016. These differences are characteristic of most of the hydrographs with which the 2017 WY was compared (dating back to the 2000 WY).

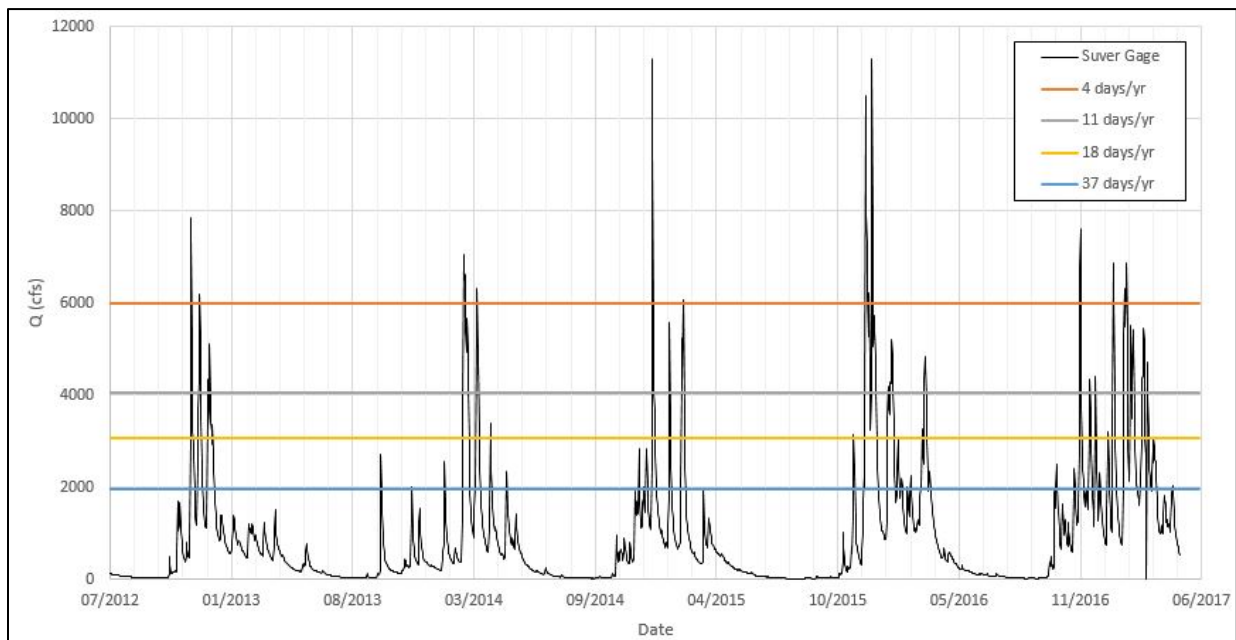


Figure 2-3. Hydrographs for the past five years at the Suver gage with select flows from the flow duration analysis marked for reference.

To construct an effective rating curve, there needs to be a consistent relationship through time between stage at the pressure transducer and discharge at the gage. We compared the water surface elevation recorded by the transducer at the project site to the discharge measured at the Suver gage (Figure 2-4). The timing of the flood peaks and receding limbs of the hydrographs at the Suver gage correspond well to the timing at the pressure transducer with a mean travel time of approximately 5 hours between peaks at the Suver gage and peaks in stage at the transducer location. Figure 2-4 shows that the relative magnitude of peak water surface elevations measured at the pressure transducer increases throughout the year with respect to the Suver gage discharge. The vertical distance between corresponding pressure transducer and Suver gage peaks on their corresponding axes increases with time, suggesting other factors influence the water surface elevation at LSNA during peak flows later in the season. For example, the two peak values for the February 10, 2017 event plot in a similar location, but for a similar stage event on March 10, 2017, the Suver gage discharge was approximately 1,500 cfs lower. In effect, the rating curve between the pressure transducer and the Suver gage changes throughout the season based on an array of hydrological conditions. We attribute most of the decoupling between the pressure transducer and the Suver gage to the controlling influence of Willamette River stage on the lower Luckiamute River at higher Willamette River flows. Hysteresis patterns on the Suver rating curve follow typical flood wave patterns, where stage is higher on the falling limbs of the hydrograph.

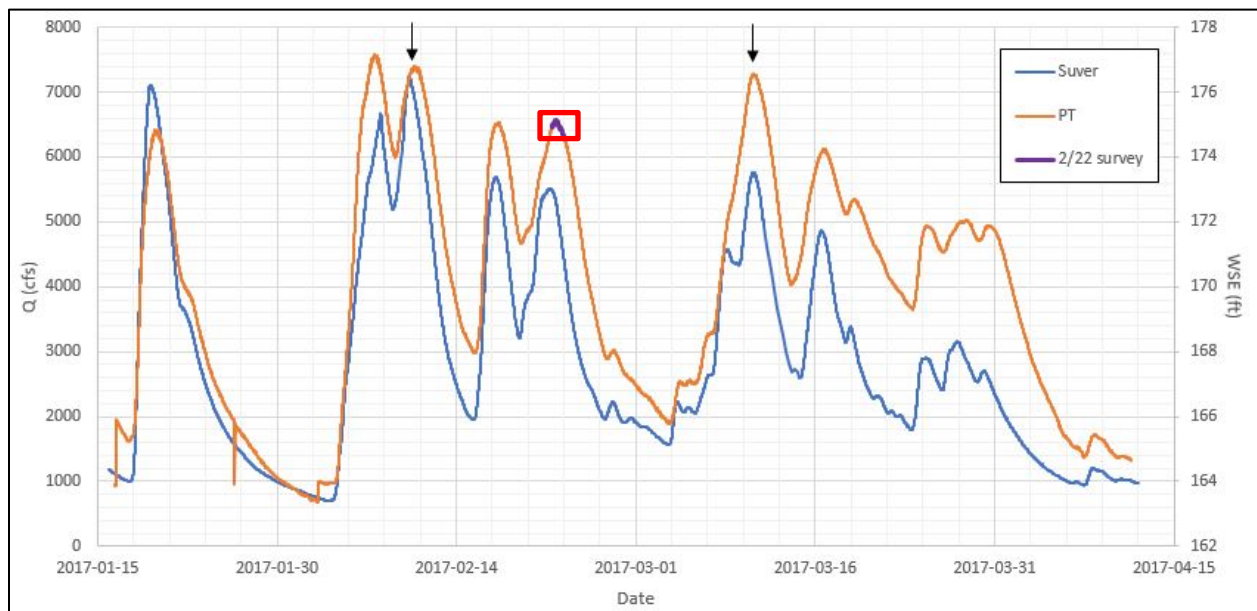


Figure 2-4. The Suver gage hydrograph compared to corresponding water surface elevation (WSE) recorded by the LSNA pressure transducer. Surveyed water surface elevation from the February 22, 2017 field survey are shown in the red box, example events illustrating the breakdown of the stage-discharge relationship are marked with black arrows.

This analysis supports the previous argument (RDG, 2013) that water surface elevations at LSNA are driven primarily by the Willamette River at moderate to high flows on the Willamette River,

but that localized meteorological and runoff events in the Luckiamute River basin, as measured at the Suver gage, can exert control on site inundation when Willamette River flows are low. Based on this analysis, the Suver gage cannot solely be used to predict water surface elevations at LSNA. While Suver gage data are informative for predicting the stage of the Luckiamute River at LSNA when the Willamette River stage is low, the Willamette River gages are more instructive for predicting water surface elevation at LSNA when the Willamette River experiences moderate to high flows that influence the lower Luckiamute River. Given that higher flows are those that factor more significantly into inundation at the project sites, the rating curves that more effectively predict these events are preferable. Further discussion of the rating curves used for this analysis is included in the following sections.

Willamette River at Salem and Albany

The Willamette River is highly regulated by 13 dams including 11 flood control dams and 2 reregulating dams (although Foster Dam serves partially as a re-regulating dam for the larger upstream Green Peter Dam) that affect the natural flow of water in the Willamette River Basin. In reviewing the history of flood control operations in the Willamette River Basin, three river management periods were delineated:

- Pre-1942: Historical or Pre-regulation period
- 1943 to 1968: Dam Construction period
- 1969 to Present: Regulated period

Flood control operations have had a profound effect on the Willamette River hydrograph. Runoff retention and later release from flood control reservoirs effectively reduces flood peak magnitudes while increasing summer base flows relative to the historical condition for irrigation, industrial water availability, dilution of municipal and industrial discharges, and recreation.

Hydrographic modifications have influenced the magnitude of return interval events, such as the 2-year discharge and in turn influenced geomorphic and ecological function in the Willamette River corridor. Compared to historical flows, regulated flows are less likely to interact with the Willamette River floodplain due to the lower discharge magnitude. Table 2-3 includes a list of the dams upstream from the Salem gage and their date of completion.

Dam Name	Location	Year Completed	Height (ft)	Storage (acre-ft)	Upstream Dams
Big Cliff	North Santiam	1953	191	NA	Detroit
Blue River Dam	Blue River	1969	270	89,500	
Cottage Grove Dam	CF Willamette River	1942	95	32,900	
Cougar Dam	SF McKenzie River	1963	452	219,000	
Detroit Dam	North Santiam	1953	463	455,100	

Table 2-3. Flood control dams located in the Willamette Basin upstream from the USGS Salem gage.

Dam Name	Location	Year Completed	Height (ft)	Storage (acre-ft)	Upstream Dams
Big Cliff	North Santiam	1953	191	NA	Detroit
Dexter Dam	MF Willamette River	1954	93	NA	Lookout Point, Hills Creek
Dorena Dam	Row River	1949	145	77,600	
Fall Creek Dam	Fall Creek	1966	180	125,000	
Fern Ridge Dam	Long Tom River	1941	44	116,800	
Foster Dam	South Santiam	1968	126	60,700	Green Peter
Green Peter Dam	South Santiam	1968	327	28,100	
Hills Creek Dam	MF Willamette River	1961	304	355,500	
Lookout Point Dam	MF Willamette River	1954	276	455,800	Hills Creek

A flood frequency analysis was completed for the Regulated period (1969 to 2017) for the Albany and Salem gages (Table 2-4 and Table 2-5, respectively).

Table 2-4. Flood frequency analysis for USGS gage 14174000 Willamette River at Albany, OR calculated from USGS 17B protocol. The 95% confidence limits on the discharge are shown.

Recurrence Interval (yrs)	Chance Exceedance (%)	Peak Discharge (cfs)	Discharge 95% min (cfs)	Discharge 95% max (cfs)
1.001	99.9	24,433	19,733	28,557
1.01	99.0	31,427	26,600	35,574
1.05	95.0	39,126	34,403	43,191
1.25	80.0	50,327	45,903	54,362
2	50.0	65,027	60,500	69,915
5	20.0	83,390	77,185	91,459
10	10.0	94,683	86,795	105,648
50	2.0	117,749	105,542	136,117
100	1.0	126,981	112,818	148,752

Table 2-5. Flood frequency analysis for USGS gage 14191000 Willamette River at Salem, OR calculated from USGS 17B protocol. The 95% confidence limits on the discharge are shown.

Recurrence Interval (yrs)	Chance Exceedance (%)	Peak Discharge (cfs)	Discharge 95% min (cfs)	Discharge 95% max (cfs)
1.001	99.9	47,919	39,876	54,883
1.01	99.0	56,786	48,725	63,715
1.05	95.0	67,027	59,141	73,856
1.25	80.0	82,977	75,487	89,807
2	50.0	106,054	98,450	114,134
5	20.0	138,704	128,229	152,293
10	10.0	161,103	147,239	180,521
50	2.0	212,900	188,863	249,875
100	1.0	236,083	206,814	282,313

A flow duration analysis was completed for the Salem and Albany gages using daily mean flows for the regulated time period of the gage record from the 1969 WY to May 2017 (Table 2-6).

Table 2-6. Selections from the flow-duration analysis for the Willamette River at the Albany and Salem gages over the regulated period of record (1969 to 2017).

Percent of Time Exceeded	Equivalent Number of Days Per Year	Albany Gage Discharge (cfs)	Salem Gage Discharge (cfs)
0.10%	0	82,264	156,000
1%	4	61,000	108,000
2%	7	54,200	96,770
3%	11	49,800	90,705
4%	15	46,400	85,500
5%	18	43,200	81,375
6%	22	40,300	77,100
7%	26	37,800	73,400
8%	29	35,400	69,580
9%	33	33,500	66,515
10%	37	31,500	63,750
20%	73	19,000	42,700
50%	183	9,180	21,200
75%	274	6,060	14,225
85%	310	5,300	12,300
90%	329	4,940	11,500
95%	347	4,460	10,700
98%	358	4,070	10,300
99%	361	3,890	10,100
100%	365	3,100	10,000

RDG completed additional hydrologic analyses for the Salem and Albany gages on the Willamette River to relate discharge data to the project site. The LSNA project sites are located 1.5 miles upstream from the confluence of the Luckiamute and Willamette rivers. The Luckiamute River confluence with the Willamette River is coincident with the Santiam River confluence, so the Salem gage includes the Santiam River's contributions. The Santiam River provides a significant amount of flow to the Willamette River, but this flow is impacted by the large flood control dams on the North and South Santiam rivers. As such, the hydrologic regime is complicated not only by natural stochasticity in the large watershed, but also by flow regulation.

A travel time analysis was completed between the Willamette River gages and the pressure transducer, but yielded inconclusive results. There was no consistent correlation between the timing of peak flow values between the two Willamette River gages, nor each gage and the pressure transducer. This result is unsurprising given the complexity of Willamette Basin hydrology that results from flow regulation, the location, size, and shape of tributary basins, and the spatial and temporal variability in precipitation, among other factors. Furthermore, the peaks

of flood events can be broad, i.e., lasting for hours to days, and have several local maxima, which further complicates time of travel analysis even if the hydrograph is statistically smoothed. Based on these conclusions, a time correction was not applied to the Willamette River gage discharges for our rating curves.

An examination of two decades of hydrographs for the Suver gage, the Albany gage, and the Salem gage reveals that instances where the relative magnitudes and their respective flow events are decoupled are rare, occurring typically fewer than one time per year. The January 19, 2017 event is one such instance (Figure 2-5 and Figure 2-6), and potentially leads to the perception that the pressure transducer (PT) stage data may be more or as strongly correlated with the Suver gage than the Willamette River gages. Given the lack of a strong correlation between the PT and the Suver gage during later flows in the record and the rarity of decoupled peak flow events between the Willamette River and Luckiamute River, we excluded this event from our Willamette River rating curves. Additionally, we exclude the time period that includes an unexplained increase in the water surface elevation at the pressure transducer on February 2, 2017. Irregularities and discontinuities in PT records such as this can occur when the instrument is dry or close to dry. Therefore, stage-discharge rating curves for the transducer and the Willamette River gages were developed for the time period from February 7, 2017 to April 11, 2017.

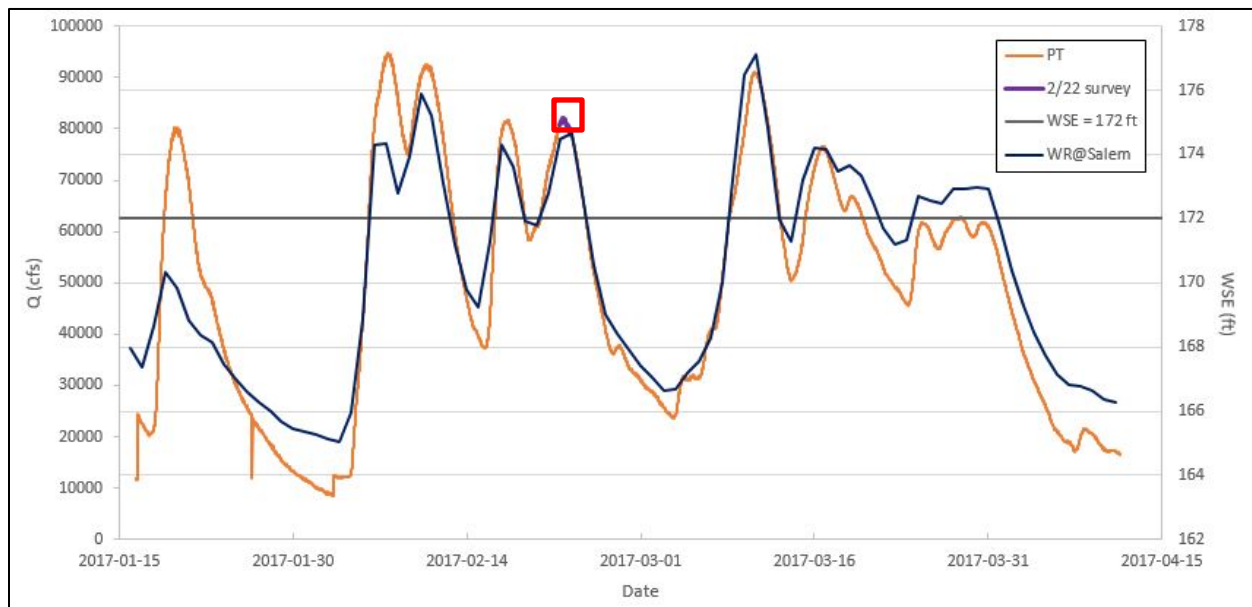


Figure 2-5. The Willamette River at Salem gage hydrograph compared to water surface elevation (WSE) recorded at the LSNA pressure transducer. Surveyed water surface elevations from the February 22, 2017 field survey are shown in the red box. A reference water surface elevation of 172 ft at the pressure transducer is included.

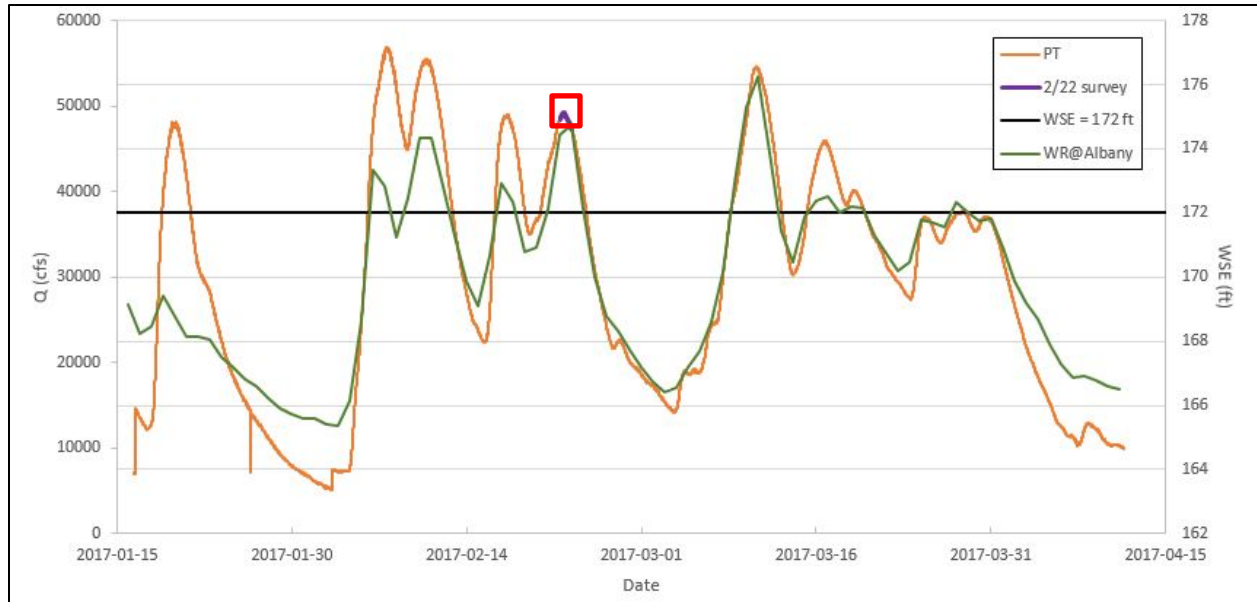


Figure 2-6. The Willamette River at Albany gage hydrograph compared to water surface elevations recorded at the LSNA pressure transducer. Surveyed WSEs from the February 22, 2017 field survey are shown in the red box. A reference water surface elevation of 172 ft at the pressure transducer is included.

RDG constructed rating curves for both the Salem and Albany gages from the 15-minute instantaneous data for the period between February 7, 2017 to April 11, 2017. Stage values are related to water surface elevation using a datum of 164 ft. The raw data and power function trendline are shown for the Salem gage (Figure 2-7) and the Albany gage (Figure 2-8). Both fits have relatively high R^2 -values, and the scaling exponents are similar. Hysteresis loops are visible in both datasets and reflect the differing hydraulics of rising and falling limbs of the hydrograph. As a result of this hysteresis and flow contributions from the Luckiamute River, there is scatter about the fit on the order of several feet of stage for a given discharge and 10,000 to 20,000 cfs for a given stage.

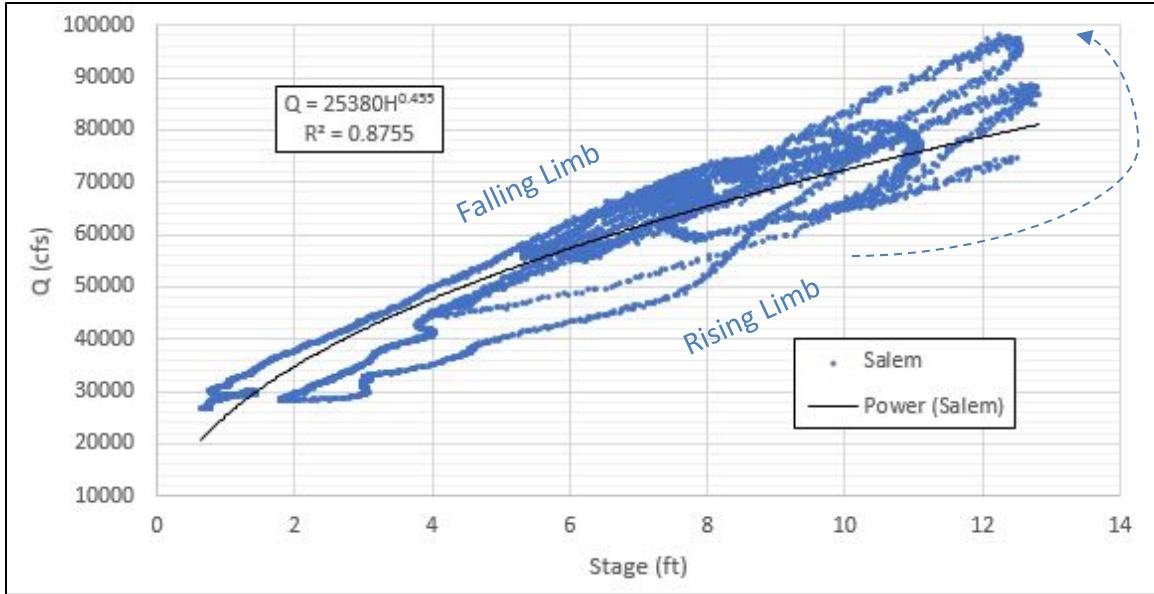


Figure 2-7. Raw data of stage (height in ft) at the pressure transducer versus corresponding discharge (Q in cfs) at the Salem gage for the period from February 7, 2017 to April 11, 2017. The rating curve is a power law fit to the data. The primary direction of hysteresis with respect to rising and falling limbs of the gage hydrograph is noted.

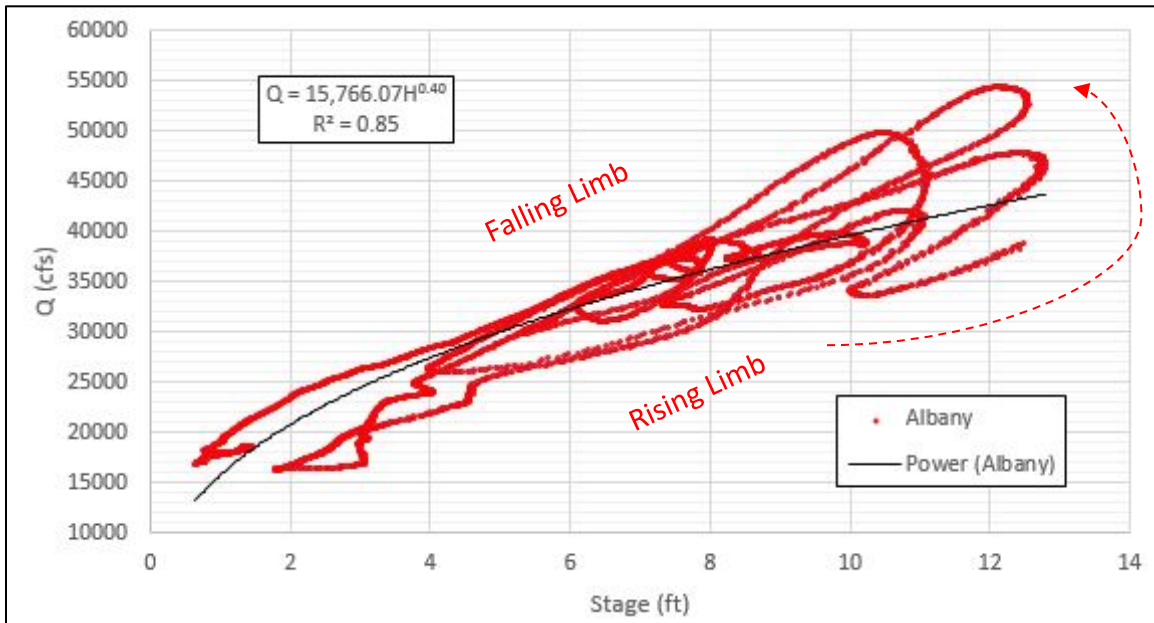


Figure 2-8. Raw data of stage (height in ft) at the pressure transducer versus corresponding discharge (Q in cfs) at the Albany gage for the period from February 7, 2017 to April 11, 2017. The rating curve is a power law fit to the data. The primary direction of hysteresis with respect to rising and falling limbs of the gage hydrograph is noted.

After a closer examination of the rating curve hysteresis loops, most follow the reverse pattern of what would be expected based on flood wave propagation. As a result, the rising limbs of the hydrographs plot at lower discharges for a given stage, and the falling limbs plot at higher discharges. Stages tend to be higher for the rising rather than falling stages. When linked to the flow duration analyses (Table 2-6), the rising limbs rating curves would predict more frequent and longer duration inundation for a given water surface elevation than the falling limbs. Given the tendency for falling limbs to be longer duration than their corresponding rising limbs and therefore have a more long-lived effect on stages at the site, rating curves were developed for three falling limbs in the PT Period for both Salem (Figure 2-9) and Albany (Figure 2-10). The three time periods are February 10 to February 15, February 22 to March 3, and March 11 to March 14, and they include the field survey event. The slope of the power law trendlines increase and the R²-values increase considerably compared with the longer record. The predicted durations of inundation from these rating curves and the flow duration analysis are consistent with field observations by RDG staff at LSNA. We therefore use the falling limb rating curves to evaluate hydrologic conditions at the two project sites.

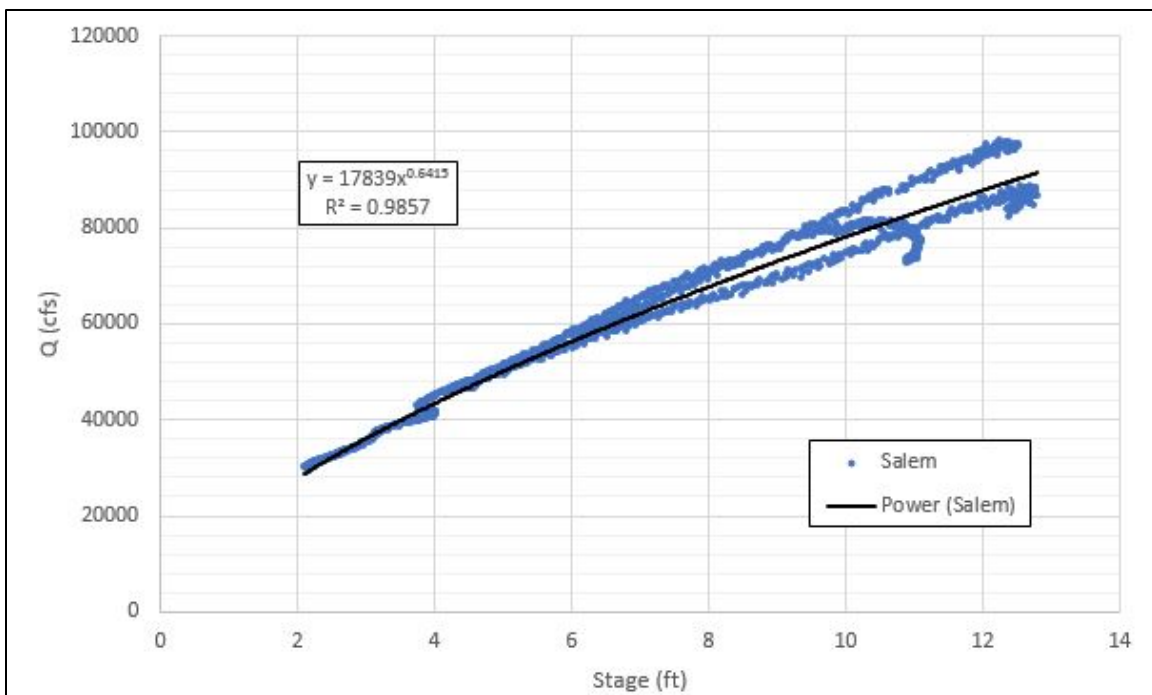


Figure 2-9. Raw data of stage (height in ft) at the pressure transducer versus corresponding discharge (Q in cfs) at the Salem gage for three falling limbs in the pressure transducer period. The rating curve is a power law fit to the data.

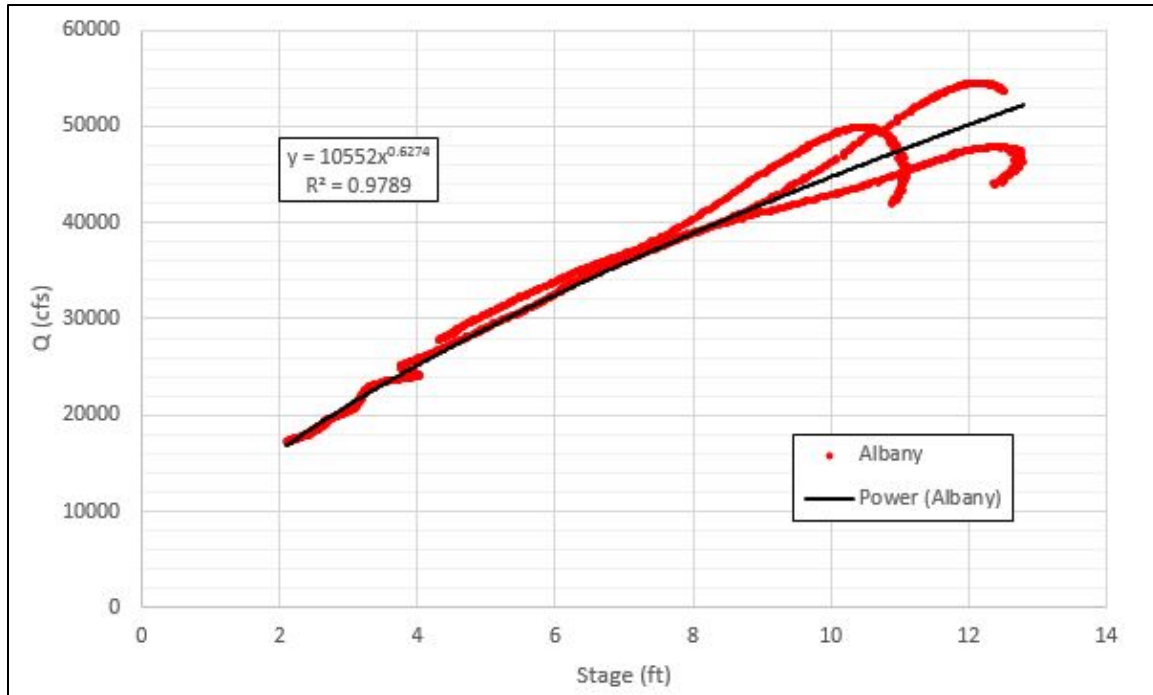


Figure 2-10. Raw data of stage (height in ft) at the pressure transducer versus corresponding discharge (Q in cfs) at the Albany gage for three falling limbs in the pressure transducer period. The rating curve is a power law fit to the data.

Hydrologic Conditions at the Project Sites

The water surface elevations and edge of water locations were surveyed with RTK GPS on February 22, 2017 (Figure 2-1). Discharge at the time of survey was 4,900 cfs at the Suver gage (approximately a 1.05 year RI flow), 46,600 cfs at the Albany gage, and 78,000 cfs at the Salem gage. A linear trendline was fit to the surveyed WSEs along the mainstem Luckiamute River and the pressure transducer water surface elevation at the time of survey to calculate a water surface slope in the project reach of 0.04%. Water surface slope is more longitudinally variable at low flows and generally approaches a single, constant value with increasing stage for a given longitudinal location. Given the relatively large magnitude of the event during which water surface elevations were surveyed (large enough to overtop the banks onto the floodplain) and the short reach length (relative to the length of the entire channel), we assume the calculated water surface slope value is appropriate for even larger flows and use it to calculate water surface elevations at the two project sites for any stage recorded at the transducer or calculated from the rating curve. The water surface elevation is 0.5 ft lower at SIA7 and 0.4 ft higher at SIA8 relative to the pressure transducer, and inundation elevations from the pressure transducer are corrected accordingly (to the nearest 0.5 ft) to reflect the local stage at the project sites.

The limiting invert elevation (the highest elevation of a floodplain channel thalweg above which surface water will flow into the floodplain depression or swale) at each project site is determined from the existing ground surface and is used in conjunction with the flow duration results to

estimate the number of days per year each feature is connected by surface water under current hydrologic conditions. As flood waters recede below the limiting invert elevation, there is the chance of stranding of fish in the swales. Note that many of the project swales may have standing water without surface water connection, but this subsurface-driven inundation does not provide access to the swales for fish and is not examined further. Discharges are predicted by the rating curve for each pressure transducer elevation, and those discharges are then related to the corresponding inundation durations from the flow duration analysis. The pressure transducer elevations, which are paired with a given discharge and inundation duration, are then corrected based on distance and slope from the pressure transducer location to reflect the hydrologic conditions at each project site. Conceptual design alternatives are then evaluated in AutoCAD by grading the existing ground topography to the lowest elevation found in each floodplain feature to maximize the potential inundation duration. This target grading elevation is then used to estimate the duration of inundation for the concept alternative design under the proposed condition.

Since we are interested in evaluating potential floodplain inundation, the Albany and Salem gages were used to characterize river flows and stage for the LSNA project areas since the Willamette River most strongly influences the LSNA stage at moderate to high Willamette River flows. Discharge for the falling limbs of the Willamette hydrographs have the strongest relationship to pressure transducer stage observations at the project site, so those rating curves were used for the analysis. Although Luckiamute River flows can play a significant role in hydrologic function at the site (as observed during the January 19th, 2017 event), pressure transducer stage, and therefore floodplain inundation at LSNA, is more strongly correlated to flow conditions on the Willamette River.

It is possible that the inundation at the project site included in this report is underestimated due to the omission of flow contributions from the Luckiamute River and the omission of the rising limbs of the Willamette hydrographs. However, the omission of the Luckiamute likely only affects rare early season events where flow on the Willamette River is low, and these events will factor less significantly than the Willamette River into the overall inundation over the course of a year at the project sites. Furthermore, given that the inundation analysis is intended to be instructive and for comparative purposes between project alternatives, rather than predictive in an applied sense, the additional analytical complexity and associated costs required by trying to incorporate the role of the Luckiamute was not warranted.

The days of inundation predicted by the Albany and Salem gages do not match perfectly, and the disparity between the two predictions is greater for smaller, more frequent flows. A mismatch between the two predictions is not unexpected given the hydrologic complexity of the Willamette basin system, the distance between the gages, and the Luckiamute-Santiam-Willamette confluence. As an additional complication, we used the full regulated mean daily flow record to build a more robust flow-duration curves, whereas we used only the falling limbs to build rating curves with tighter relationships. Although the two gage records do not make

identical predictions for the number of days of inundation for a given stage, they do make similar prediction for the change in number of days of inundation in response to a given change in WSE. In any case, these inundation duration values are based on averages and trends in the flow data and intended to be used as a guide. Interannual variability in inundation is expected due to natural processes and will cause deviations from the estimated values regardless of the hydrologic complexity of a site. This variability does not alter the first-order impact of the proposed designs, however, as excavation of floodplain swales will increase inundation.

We evaluated the potential inundation risks for the infrastructure at LSNA. The primary features of concern are the “ranger house,” which is located 100 yards west of the pond, and the pivot field, which is located in the floodplain south of the pond and overlaps the SIA8 site. There is not expected to be any additional risk of inundation to the ranger house, or the houses on the northern portion of the floodplain, that is attributable to the project designs. The ranger house is located away from the project footprints and is situated at an elevation 180.5 ft, which is higher than any of the design alternative features. Furthermore, the projects are expected to lower water surface elevations in their immediate vicinities because there is a proposed net removal of floodplain material. The pivot field is in active use, and the SIA8 project designs involve excavation of material in the field with the intent to increase inundation in the interior of the floodplain. Pivot field operations could be affected by design alternatives (as will be discussed in Section 3.2), but the impacts will be primarily limited to the preexisting swale where excavation will occur.

3 Concept Development and Alternatives Analysis

The primary design goal is to increase the frequency and duration of inundation of floodplain features at LSNA, specifically at higher flows important for winter rearing habitat. The project alternatives do not target low flow, summer aquatic habitat at LSNA. RDG developed three alternative project concepts for SIA7 and four concepts for SIA8 (Appendix A). For each project alternative concept, the proposed connection surface is graded to the lowest elevation in each depression or swale to prevent stranding of aquatic species following high flow events. Each design channel has a 0 percent gradient with a flat bottom in cross-section and 6:1 slopes on the banks, unless otherwise noted in the text. Native vegetation will be planted, and large wood will be placed in each design swale (Figure 3-2). Each project inlet would include the installation of large wood to stabilize the entrance to the swales (e.g., Figure 3-3). The placement of large wood would increase velocities and promote local scour during inundation, thereby increasing the longevity and performance of the design swales and decreasing maintenance costs. A conceptual design planset is included in Appendix A.



Figure 3-1. Example of floodplain swale restoration from Harkens Lake on the Willamette River. The project swale is labeled, and black and white arrows mark same location on road for reference. Top: Recently completed construction floodplain swale construction. Large wood elements are visible in the swale. Bottom: View of same swale the following winter showing inundated conditions. Red box marks location of low water gravel crossing pictured in Figure 3-4.

To estimate construction costs for each alternative, an estimate of \$15 per cubic yard (CY) was applied for excavation and hauling of floodplain material away from the project site. This value was estimated from similar past projects and does not include costs of other services, e.g., engineering design, drafting, and construction oversight. In general, and with considerable variability depending on the type of project and project elements involved, the costs of other project components scale with the total cost of the project, e.g., larger projects will have higher costs. An estimate of 15% of the total cost will be design and 15% will be construction oversight.

Replanting costs will be a function of the project footprint, and mobilization costs would be the similar. Project construction is typically two-thirds of the project budget.

Cost estimates do not include project maintenance, such as management costs to address potential aggradation. Floodplain aggradation is a natural response to floodplain inundation by sediment-laden water. With increased inundation at the project sites, some aggradation is expected. That said, scour or deposition in the swales and project features is a stage-dependent phenomenon, and predictions regarding the relative amounts of scour versus deposition are not possible for the sites without more detailed analysis, e.g., morphodynamic modeling. Larger events would tend to scour the constructed channels, whereas smaller events would be more likely to deposit. Design elements, i.e., large wood at the inlets to the design swales, will stabilize the channel during larger events and maintain velocities that prevent aggradation at the entrance to the sites. This will ensure more long-lived conveyance into the project sites and reduce potential maintenance costs.



Figure 3-2. Example vegetation in a completed floodplain swale project at Harkens Lake. Large wood elements and the diverse native species that were planted are visible in the photo.



Figure 3-3. Example of the use of large wood stabilization measures at a side channel inlet from Green Island on the Willamette River. View is towards mainstem Willamette from the side channel.

Flow duration tables for the Albany and Salem gages for given project site elevations are presented in Table 3-2 and Table 3-4. Summary tables of project components and costs for SIA7 and SIA8 are provided in Table 3-1 and Table 3-3, respectively. The quantities for the cost of inundation area and duration analysis are in Table 3-5.

3.1 SIA7

SIA7 is the downstream project site, located on river-left of the Luckiamute River. There are several existing swales that are primarily inundated without a surface water connection during higher stages (e.g., Figure 2-1). Surface flow is inhibited by elevated sediment deposits, that if removed, would provide floodwater access to the floodplain swales. Inundated floodplain habitats provide Willamette River fish with refuge from higher velocity mainstem river flows. A summary of project alternative details is provided in Table 3-1, and project elevations and inundation durations are presented in Table 3-2.

Table 3-1. Summary table of current and design invert elevations for each SIA7 alternative with associated material excavation volumes and costs. Inundation values from the Albany flow-duration analysis are used.

Project Alternative	Current Invert Elevation (ft)	Design Invert Elevation (ft)	Current Inundation (days/yr)	Design Inundation (days/yr)	Net Material Removed (CY)	Estimated Excavation Cost (\$)
SIA7a	173.5	167	15-18	55-58	15,000	226,000
SIA7b	175	169	11-15	37-40	8,200	124,000
SIA7c	175	171	11-15	29-33	5,400	81,000

The first project alternative, SIA7a, targets an enhanced connection of the east swale. The current limiting invert elevation is 173.5 ft, which corresponds to averages of 15 to 18 and 18 to 22 days of inundation per year based on the Salem and Albany gages, respectively. This swale has the potential to strand fish once flows recede below the limiting invert elevation. The design concept follows existing low topography to grade into the lowest part of the swale at an elevation of 167 ft, which corresponds to an average of 57 days of inundation based on the Albany gage flow duration analysis, and 80 days of inundation per year based on the Salem gage flow duration analysis. This design requires approximately 750 linear feet of excavation and a net removal of 15,000 CY of material. The estimated cost of excavation and removal is approximately \$225,000. This alternative results in an estimated increase in inundation of 35 to 65 days per year using the combined Albany and Salem inundation record. The excavation footprint is 2.7 acres and the swale to be connected is 1.6 acres for a total increase in inundated area of 4.3 acres.

The second project alternative, SIA7b, is an enhanced connection between the east swale and the west swale, with or without the 7a project. The current limiting invert elevation separating the 7a and 7b swales is 175.0 ft, which corresponds 11 to 15 and 15 to 18 days of inundation per year based on the Salem and Albany gages, respectively. The design follows existing low topography and grades into the lowest part of the 7b swale at 169.0 ft, which corresponds to approximately 37 days and 52 days of inundation per year on the Albany and Salem gages, respectively. This design requires approximately 500 linear feet of excavation and a removal of 8,200 CY of material. The estimated cost of excavation and removal for 7b is approximately \$125,000. This alternative results in an estimated increase in inundation of 19 to 41 days per year using the combined Albany and Salem inundation record. The swale reconnected in 7b is 1.9 acres for a total 7b project footprint and increase in inundated area of 3.4 acres.

The third project alternative, SIA7c, connects the east, west, and north swales with the Luckiamute River and the oxbow lake. This alternative has the same limiting invert elevations as the other alternatives, but is graded to a higher elevation of 171.0 ft, which corresponds to 26 to 29 and 29 to 33 days of inundation per year on the Albany and Salem gages, respectively. This design excavates 8,000 CY of material, and 2,500 CY of the excavated material will be placed in the deeper portions of the 7a and 7b swales to bring their bottom elevations to 171.0 ft and prevent stranding. The net removal is 5,400 CY of material at an estimated cost of approximately \$81,000. This alternative results in an estimated increase in inundation of 11 to 22 days per year using the combined Albany and Salem inundation record. The project footprint and expected increase in inundated area for 7c is 5.4 acres.

Table 3-2. SIA7 inundation analysis, in number of days inundated per year, for given limiting invert elevations and discharges predicted by the falling limb rating curves at Albany and Salem. The current and design invert elevations are provided.

PT Measured Stage (ft)	Limiting Invert Elevation (ft)	Predicted Discharge at Albany (cfs)	Number of days per year	Predicted Discharge at Salem (cfs)	Number of days per year	Note
11.5	175	49000	11-15	85000	15-18	7b,7c current invert
11	174.5	48000	11-15	83000	15-18	
10.5	174	46000	15-18	81000	18-22	
10	173.5	45000	15-18	78000	18-22	7a current invert
9.5	173	43000	18-22	76000	22-26	
9	172.5	42000	18-22	73000	26-29	
8.5	172	40000	22-26	70000	26-29	
8	171.5	39000	22-26	68000	29-33	
7.5	171	37000	26-29	65000	29-33	7c design invert
7	170.5	36000	26-29	62000	37-40	
6.5	170	34000	29-33	59000	40-44	
6	169.5	32000	33-37	56000	47-51	
5.5	169	31000	37-40	53000	51-55	7b design invert
5	168.5	29000	40-44	50000	55-58	
4.5	168	27000	44-47	47000	62-66	
4	167.5	25000	47-51	43000	69-73	
3.5	167	23000	55-58	40000	77-80	7a design invert

3.2 SIA8

SIA8 is the upstream project site, located on river-left of the Luckiamute River. The design alternatives consist of enhancing the surface water connection to an existing floodplain swale, including a large man-made pond that has a berm built around the perimeter. Surface flow to the existing swale is inhibited by two plugs, one along the bank of the Luckiamute River and the other approximately 200 ft landward, and the design projects target these plugs. A summary of project alternative details is provided in Table 3-3, and project elevations and inundation durations are presented in Table 3-4.

Table 3-3. Summary table of current and design invert elevations for each SIA8 alternative with associated material excavation volumes and costs. Inundation values from the Albany flow-duration analysis are used.

Project Alternative	Current Invert Elevation (ft)	Design Invert Elevation (ft)	Current Inundation (days/yr)	Design Inundation (days/yr)	Net Material Removed (CY)	Estimated Excavation Cost (\$)
SIA8a	173	171.5	22-26	26-29	1,265	19,000
SIA8b	173	172	22-26	26-29	1,670	25,000
SIA8c	173	170.5	22-26	33-37	4,200	64,000
SIA8d	175	166.5	15-18	91	37,000	556,000

The first project alternative, SIA8a, removes the bank plug, which has a limiting invert elevation of 173.2 ft, which corresponds to an average of 22 to 29 of inundation per year from the Albany and Salem gages. SIA8a includes limited grading to remove the natural levee at the bank margin. The swale at the natural levee would be graded to an elevation of 171.5 ft, corresponding with inundation of 28 days and 39 days of inundation at the Albany and Salem gages, respectively. The grading requires approximately 120 ft of grading and a removal of 1,265 CY of material at a cost of approximately \$20,000. The design results in an estimated increase in inundation of 2 to 6 days per year using the combined Albany and Salem inundation record. The impact area of this project is approximately 0.5 acres.

The second project alternative, SIA8b, removes the bank plug and the next topographic high point landward in the swale. The project has the same limiting invert elevation as SIA8a of 173.2 ft and requires one vertical foot of excavation along 250 linear feet. The project results in a removal of 1,670 CY of material at a cost of approximately \$25,000. The design invert elevation of 172 ft results in 26 to 29 and 29 to 33 days of inundation per year for the Albany and Salem gages, respectively. This represent an increase in inundation of up to 11 days per year using the combined Albany and Salem inundation record. The impact area for this project is approximately 0.9 acres.

SIA8c includes more extensive grading to connect with the interior swale. The conceptual design grades into existing low topography with a design invert elevation of 170.5 ft, which corresponds to 33 to 37 days and 47 to 51 days of inundation at the Albany and Salem gages, respectively. The grading requires approximately 450 linear feet of excavation and a removal of 4,200 CY of material at a cost of approximately \$64,000. This design results in an estimated increase in inundation of 6 to 25 days per year using the combined Albany and Salem inundation record. The impacted area and increase in inundated area of this project is limited to approximately the excavation footprint of 1.2 acres.

The fourth project alternative, SIA8d, extends the channel associated with 8c along existing low topography to the man-made pond. There is a berm constructed around the pond that functions

as the limiting invert elevation of 175 ft. The design channel would remove a portion of the berm to allow the entry of surface flow. The current invert elevation corresponds to inundation of 15 to 18 and 18 to 22 days per year at the Albany and Salem gages, respectively. Grading to the deepest part of the pond at 166.5 ft increases the inundation to 91 days and 130 days per year on the Albany and Salem gages, respectively. To connect the pond, more than 1,000 ft of excavation are needed, resulting in 37,500 CY of material at a cost of approximately \$556,000. The excavation footprint is large at 4.9 acres, but leverages the 5.6 acres of the pond that will be reconnected, for a total of 10.5 acres of connected inundated area. The berm bordering the pond is a local high point in the floodplain, and the pond is the deepest feature. Reconnection of the pond, therefore, represents a larger increase in inundated area than just the pond footprint as the swales bordering the design channel and pond would also experience inundation. The excavation quantity, which is based on grading to the lowest elevation in the pond in attempt to prevent stranding, is accordingly large. Costs can be reduced by grading to a higher elevation, but the risks of stranding increases.



Figure 3-4. Example lower water gravel road crossing from the Harkens Lake pictured in Figure 3-1 showing dry (top) and inundated (bottom) conditions. Typical design large wood elements are visible in both photos.

The SIA8 project alternatives are designed to increase inundation into the floodplain, which would increase inundation of the field currently undergoing pivot irrigation. Alternatives SIA8c and SIA8d directly remove material from the pivot field. Therefore, the projects have the potential to interfere with current operations. However, the conversion of portions of the field to a natural area would increase the habitat benefits of the proposed designs by enabling the planting of native vegetation in and along the project swales and minimizing agricultural ground disturbance that increases fine sedimentation. Continued use of the pivot field would necessarily have to work with increased inundation, the degree to which dependent on the project alternative and the sizes of flows. Inundation of the pivot field is most common in the swales during the winter months when agricultural options are inactive. However, a lower water gravel crossing (e.g., Figure 3-4) could be constructed across the excavated swale in SIA8c or SIA8d to enable access to the eastern portion of the pivot field.

Table 3-4. SIA8 inundation analysis, in number of days inundated per year, for given invert elevations and discharges predicted by the falling limb rating curves at Albany and Salem. The current and design invert elevations are provided.

PT Measured Stage (ft)	Limiting Invert Elevation (ft)	Predicted Discharge at Albany (cfs)	Number of days per year	Predicted Discharge at Salem (cfs)	Number of days per year	
10.5	175	46000	15-18	81000	18-22	8d current invert
10	174.5	45000	15-18	78000	18-22	
9.5	174	43000	18-22	76000	22-26	
9	173.5	42000	18-22	73000	26-29	
8.5	173	40000	22-26	70000	26-29	8a,8b,8c current invert
8	172.5	39000	22-26	68000	29-33	
7.5	172	37000	26-29	65000	29-33	8b design invert
7	171.5	36000	26-29	62000	37-40	8a design invert
6.5	171	34000	29-33	59000	40-44	
6	170.5	32000	33-37	56000	47-51	8c design invert
5.5	170	31000	37-40	53000	51-55	
5	169.5	29000	40-44	50000	55-58	
4.5	169	27000	44-47	47000	62-66	
4	168.5	25000	47-51	43000	69-73	
3.5	168	23000	55-58	40000	77-80	
3	167.5	21000	62-66	36000	91-95	
2.5	167	19000	73	32000	106-110	
2	166.5	16000	91	28000	128-131	8d design invert

3.3 Cost-Benefit Analysis

A metric was developed to quantify the potential project benefits (increase in inundation and the approximate area impacted by this increase) relative to the cost of the material to be excavated. The project footprint, or acreage below the current limiting invert elevation, is multiplied by the estimated increase in inundated days per year and divided by the expected excavation cost. The resulting metric (cost of inundation area and duration) has units of acreage-days per year per dollar. Note that the project swales are currently inundated via subsurface flow and without surface water connection. The inundation values used in this analysis are in reference to inundation from surface water at the design and current limiting invert elevations to reflect hydraulic conditions that are usable by fish. A single value, rather than a range, for the increase in inundation is used to simplify comparisons of cost of inundation area and duration. The values for increase in inundation are derived from differencing the approximate days of inundation from within the range of days for the current and design alternative inundation values for the Albany gage.

The cost of inundation area and duration analysis quantities are presented in Table 3-5, and the higher values reflect the greatest benefit per cost. Any criteria below may be used to evaluate the relative value of each alternative. Based on the current analysis, project SIA8d, which is the most expensive, is also the most valuable given the large increases in inundation days and acreage that result from the great depth and footprint of the pond. Project SIA8a has the least value but is also the least expensive and easiest project. The SIA7c project is the most valuable alternative for SIA7, given that it has the largest footprint and uses nearly a third of the excavated material as fill, which reduces the cost.

The project alternatives are relatively similar in regard to several other potential metrics, although there are several differences between SIA7 and SIA8. The projects are all low risk. They do not increase the potential for damage to infrastructure, such as the ranger's house. Given that all the projects involve the relatively simple excavation of swales, the constructability will be similar, although the larger volume projects have more material to deal with, logistically. The site disturbance should be limited to each project footprint and routes used for access. SIA8 projects can utilize an existing road at the site, thereby limiting the site disturbance and increasing the constructability. SIA7 alternatives require some construction of an access road that would require some planning.

Table 3-5. Summary of cost-benefit analysis quantities for the calculation of cost of inundation area and duration analysis. Increase in inundation values estimated from median inundation values for current and design alternatives using the Albany gage inundation analysis.

Project Alternative	Increase in Inundated Area (acres)	Increase in Inundation (days/yr)	Cost of Excavation (\$)	Cost of Inundation Area and Duration (ac-days/yr/\$)
SIA7a	4.3	40	226,000	0.00075
SIA7b	3.4	24	124,000	0.00065
SIA7c	5.4	20	81,000	0.00094
SIA8a	0.5	5	19,000	0.00012
SIA8b	0.9	4	25,000	0.00014
SIA8c	1.2	11	64,000	0.00021
SIA8d	10.5	75	556,000	0.00142

4 Summary

RDG was retained by LWC to complete a hydrologic analysis and develop project design alternatives for two floodplain features at the Luckiamute State Natural Area with the goal of enhancing floodplain-river connectivity to improve aquatic habitat for native fish and wildlife.

The hydrologic analysis reveals the complexity of the hydrology at the LSNA site due to its geographic location at the confluence of the Luckiamute, Santiam, and Willamette rivers. Water surface elevations and resulting floodplain inundation at the project sites are a function of both the Willamette and Luckiamute rivers, but controlled more strongly by the Willamette River at moderate and high flows. Rating curves were developed from river stage observations recorded at a pressure transducer at LSNA and the falling limbs of hydrographs from the Willamette River at the USGS Albany and Salem gages. The rating curves, in conjunction with a flow duration analysis for each Willamette River gage, are used to estimate inundation durations at the project sites relative to existing and proposed design elevations at the project site.

RDG developed three alternative design concepts for SIA7 and four concepts for SIA8. The designs opportunistically utilize existing floodplain depressions and swales by excavating high topographic plugs that preclude surface flow from entering the features. The design swales are graded to the lowest existing elevation in each feature. For each alternative, a comparison of the increase in inundation relative to existing conditions and the area affected by that increase to the excavated volumes of material and cost of its removal is included. This cost-benefit analysis allows for comparison between the different project alternatives.

5 References

Muste, M., Ho, H.C. and Kim, D. 2011. Considerations on direct stream flow measurements using video imagery: Outlook and research needs. *Journal of Hydro-environment Research*, 5(4), pp.289-300.

River Design Group, Inc. 2013. Hydrologic Analysis and Recommendations for the Luckiamute State Natural Area. Completed for the Luckiamute Watershed Council. 30 p.

APPENDIX A

Project Conceptual Design Drawings

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LUCKIAMUTE STATE NATURAL AREA FLOODPLAIN RECONNECTION

BUENA VISTA, OR

PROJECT PARTNERS



PROJECT DESCRIPTION

THIS PROJECT INTENDS TO RESTORE FLOODPLAIN PROCESSES TO A PORTION OF THE LUCKIAMUTE RIVER FLOODPLAIN AND TO ENHANCE WATER QUALITY AND HYDRAULIC CONNECTIVITY OF OFF-CHANNEL HABITATS. THE PROJECT AREA IS LOCATED ON THE RIVER LEFT BANK OF THE LUCKIAMUTE RIVER APPROXIMATELY 1.5 MILES UPSTREAM OF THE CONFLUENCE WITH THE WILLAMETTE RIVER AND INCLUDES MODIFYING TWO EXISTING SECONDARY CHANNELS.

AN EXISTING NATURAL LEVEE THAT PREVENTS WATER FROM ACCESSING THE FLOODPLAIN WILL BE LOWERED, AND PORTIONS OF THE FLOODPLAIN WILL BE GRADED TO ALLOW FLOODWATERS TO INUNDATE THE FLOODPLAIN WITH GREATER FREQUENCY AND DURATION. CONNECTION FREQUENCY WILL INCREASE FROM THE CURRENT CONDITION OF 2-3 WEEKS ANNUALLY.

SPATIAL REFERENCE

SURVEY CONTROL USED FOR THE PROJECT IS PROVIDED ON DRAWING 2.0 AND COORDINATES CORRESPOND TO THE TOP CENTER OF CONTROL MARKERS.

LIDAR, GPS RTK, AND TOTAL STATION:

HORIZONTAL PROJECTION: STATE PLANE NORTH
HORIZ DATUM: NAD 83 UNITS: US FT
VERT DATUM: NAVD 88 UNITS: US FT

SURVEY DATE: 04/11/17
LIDAR COLLECTED: 2008

STANDARD OF PRACTICE

RDG WORKS EXCLUSIVELY IN THE RIVER ENVIRONMENT AND EMPLOYS THE MOST CURRENT AND ACCEPTED PRACTICES AVAILABLE FOR PLANNING AND DESIGN OF THIS SIDE CHANNEL ENHANCEMENT PROJECT. ALL WORK WAS PERFORMED OR DIRECTED BY A REGISTERED PROFESSIONAL CIVIL ENGINEER WITH PAST EXPERIENCE IN THE DESIGN OF HABITAT ENHANCEMENT PROJECTS.

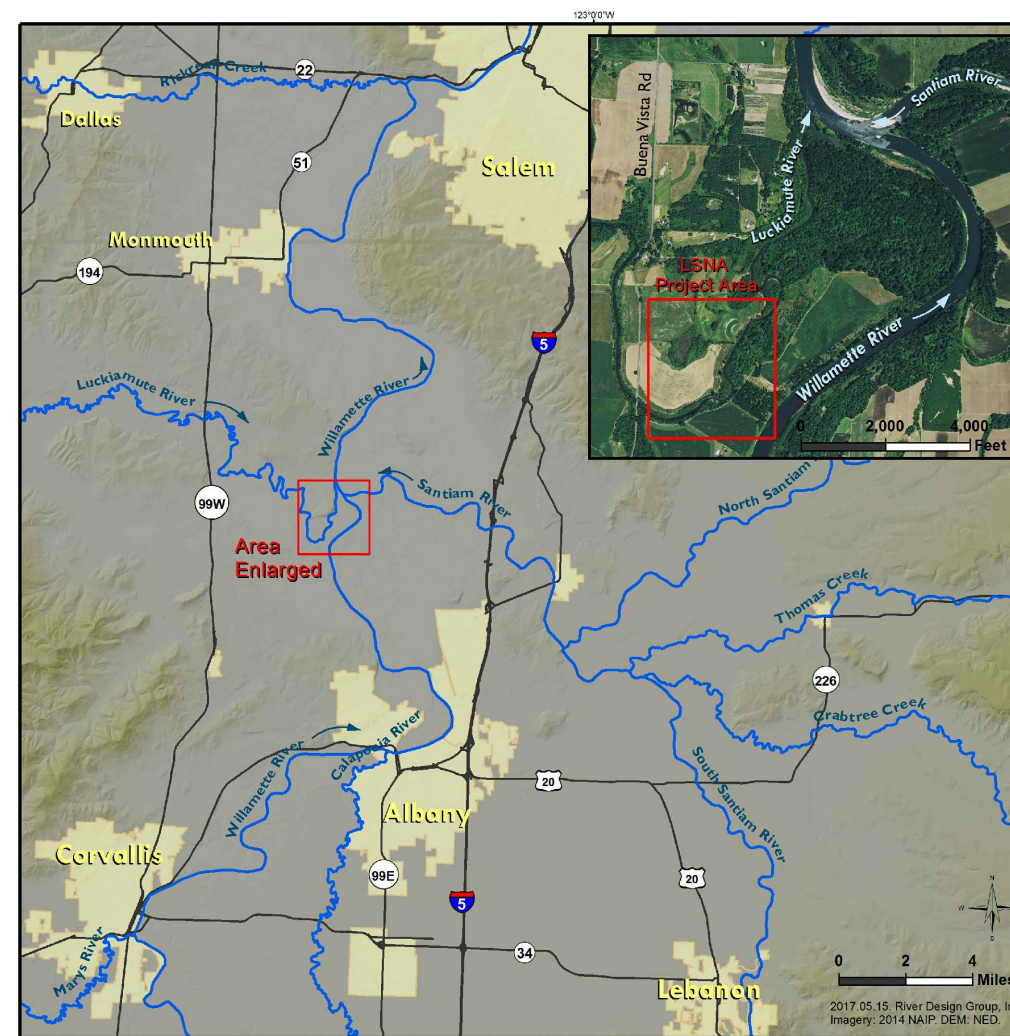
REUSE OF DRAWINGS

THESE DRAWINGS, THE IDEAS AND DESIGNS INCORPORATED HEREIN, AS AN INSTRUMENT OF PROFESSIONAL SERVICE, ARE THE PROPERTY OF RIVER DESIGN GROUP, INC. (RDG) AND ARE NOT TO BE USED, IN WHOLE OR IN PART, FOR ANY OTHER PROJECT WITHOUT THE WRITTEN AUTHORIZATION OF RDG. LIKEWISE, THESE DRAWINGS MAY NOT BE ALTERED OR MODIFIED WITHOUT AUTHORIZATION OF RDG. DRAWING DUPLICATION IS ALLOWED IF THE ORIGINAL CONTENT IS NOT MODIFIED.

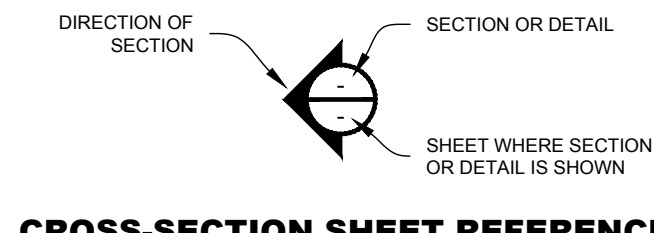
DRAWING INDEX

1.0	COVER SHEET AND NOTES	2.10	SITE 7 - ALTERNATIVE C NORTH SWALE DESIGN SECTIONS	3.3	SITE 8 - ALTERNATIVE B DESIGN SECTIONS
1.1	PROJECT OVERVIEW	2.11	SITE 7 - ALTERNATIVE D PLAN AND PROFILE	3.4	SITE 8 - ALTERNATIVE C PLAN AND PROFILE
2.0	SITE 7 - ALTERNATIVE A PLAN AND PROFILE	2.12	SITE 7 - ALTERNATIVE D WEST SWALE DESIGN SECTIONS	3.5	SITE 8 - ALTERNATIVE C DESIGN SECTIONS
2.1	SITE 7 - ALTERNATIVE A EAST SWALE DESIGN SECTIONS	2.13	SITE 7 - ALTERNATIVE E PLAN	3.6	SITE 8 - ALTERNATIVE D PLAN AND PROFILE
2.2	SITE 7 - ALTERNATIVE A EAST SWALE DESIGN SECTIONS	2.14	SITE 7 - ALTERNATIVE E PROFILES	3.7	SITE 8 - ALTERNATIVE D DESIGN SECTIONS
2.3	SITE 7 - ALTERNATIVE B PLAN AND PROFILE	2.15	SITE 7 - ALTERNATIVE E EAST SWALE DESIGN SECTIONS	3.8	SITE 8 - ALTERNATIVE D DESIGN SECTIONS
2.4	SITE 7 - ALTERNATIVE B WEST SWALE DESIGN SECTIONS	2.16	SITE 7 - ALTERNATIVE E EAST SWALE DESIGN SECTIONS	3.9	SITE 8 - ALTERNATIVE D DESIGN SECTIONS
2.5	SITE 7 - ALTERNATIVE C PLAN	2.17	SITE 7 - ALTERNATIVE E WEST SWALE DESIGN SECTIONS	4.0	SITE 8 - ALTERNATIVE D DESIGN SECTIONS
2.6	SITE 7 - ALTERNATIVE C PROFILES	2.18	SITE 7 - ALTERNATIVE E NORTH SWALE DESIGN SECTIONS	4.1	SWALE TYPICAL SECTION DETAIL
2.7	SITE 7 - ALTERNATIVE C EAST SWALE DESIGN SECTIONS	3.0	SITE 8 - ALTERNATIVE A PLAN AND PROFILE		SWALE ROUGHNESS DETAIL
2.8	SITE 7 - ALTERNATIVE C EAST SWALE DESIGN SECTIONS	3.1	SITE 8 - ALTERNATIVE A DESIGN SECTIONS		
2.9	SITE 7 - ALTERNATIVE C WEST SWALE DESIGN SECTIONS	3.2	SITE 8 - ALTERNATIVE B PLAN AND PROFILE		

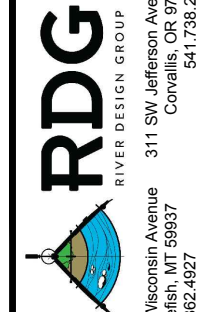
PROJECT VICINITY MAP



NW 1/4 OF SECTION 2 & NE 1/4 SECTION 3, T.10S., R.04W.,
WILLAMETTE MERIDIAN
POLK COUNTY, OREGON
USGS QUADRANGLE: LEWISBURG, OR



CROSS-SECTION SHEET REFERENCE



236 Wisconsin Avenue
Whitefish, MT 59937
406.862.4927

311 SW Jefferson Avenue
Corvallis, OR 97333
541.738.2920

COVER SHEET AND NOTES

LSNA FLOODPLAIN RECONNECTION

BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		

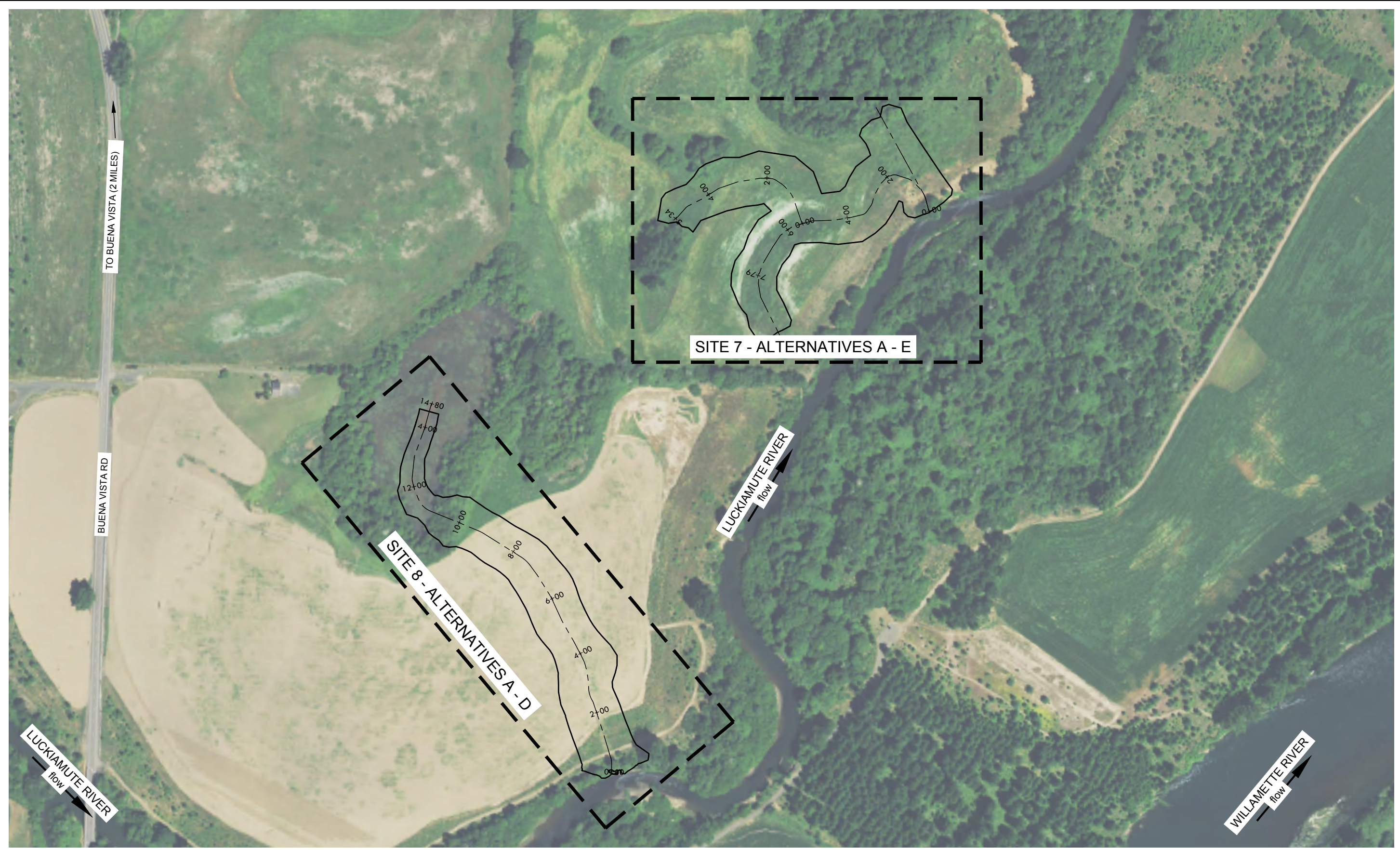
PROJECT NUMBER
RDG-17-009

DRAWING NUMBER

1.0

Drawing 1 of 33

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1 PROJECT OVERVIEW

1" = 300'



NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

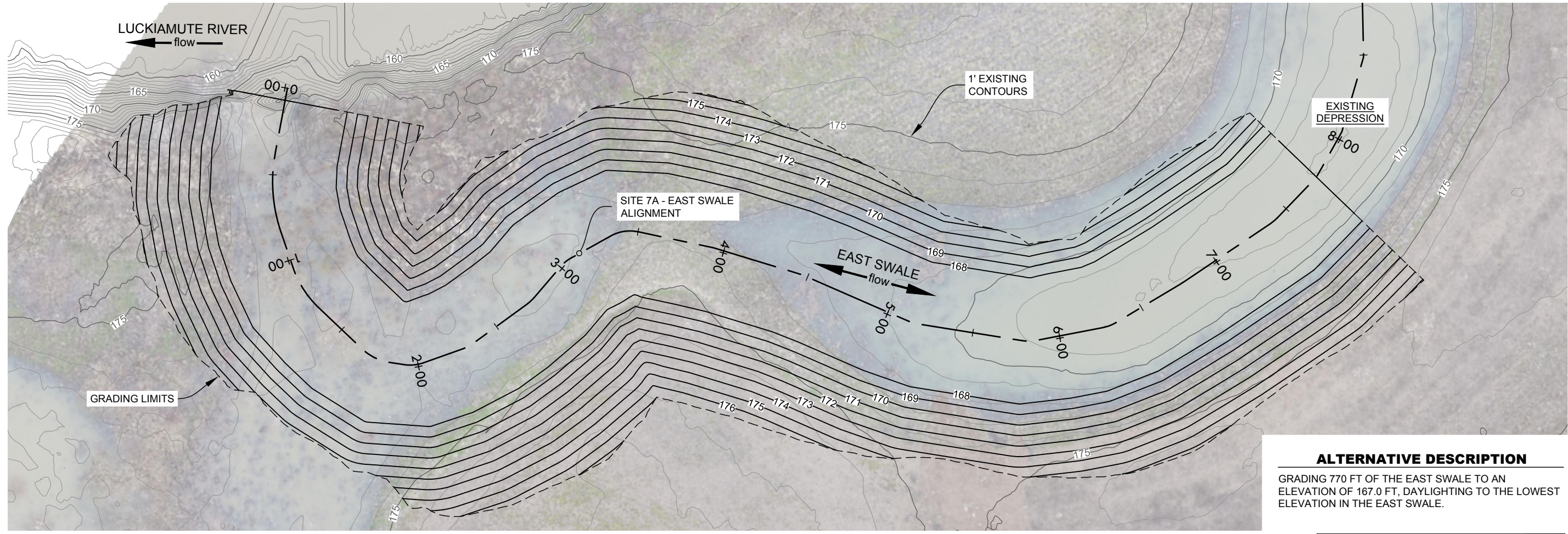
PROJECT NUMBER
RDG-17-009

DRAWING NUMBER
1.1

Drawing 2 of 33

PROJECT OVERVIEW
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

RDG
RIVER DESIGN GROUP
236 Wisconsin Avenue
Whitefish, MT 59937
406.862.4927
311 SW Jefferson Avenue
Corvallis, OR 97333
541.738.2920

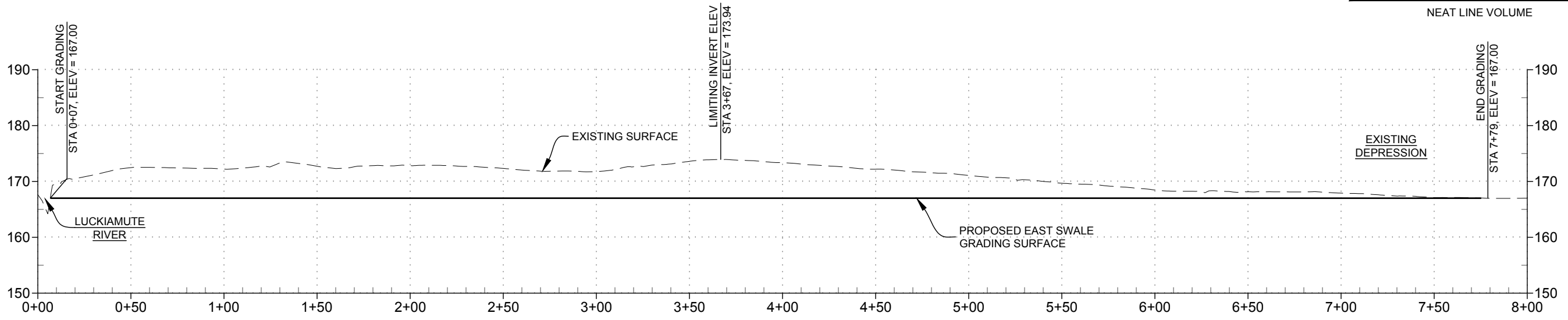


ALTERNATIVE DESCRIPTION
 GRADING 770 FT OF THE EAST SWALE TO AN ELEVATION OF 167.0 FT, DAYLIGHTING TO THE LOWEST ELEVATION IN THE EAST SWALE.

SITE 7 - ALTERNATIVE A ESTIMATED QUANTITIES	
CUT VOLUME	15,000 CY
LENGTH OF REMOVAL	772 FT
AREA OF REMOVAL	117,800 SQ. FT.

NET LINE VOLUME

1 **SITE 7 - ALTERNATIVE A PROPOSED LAYOUT**
 1" = 40'



2 **SITE 7 - ALTERNATIVE A EAST SWALE PROFILE**
 HORIZ 1" = 40'
 VERT 1" = 20'

SITE 7 - ALTERNATIVE A
PLAN AND PROFILE
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

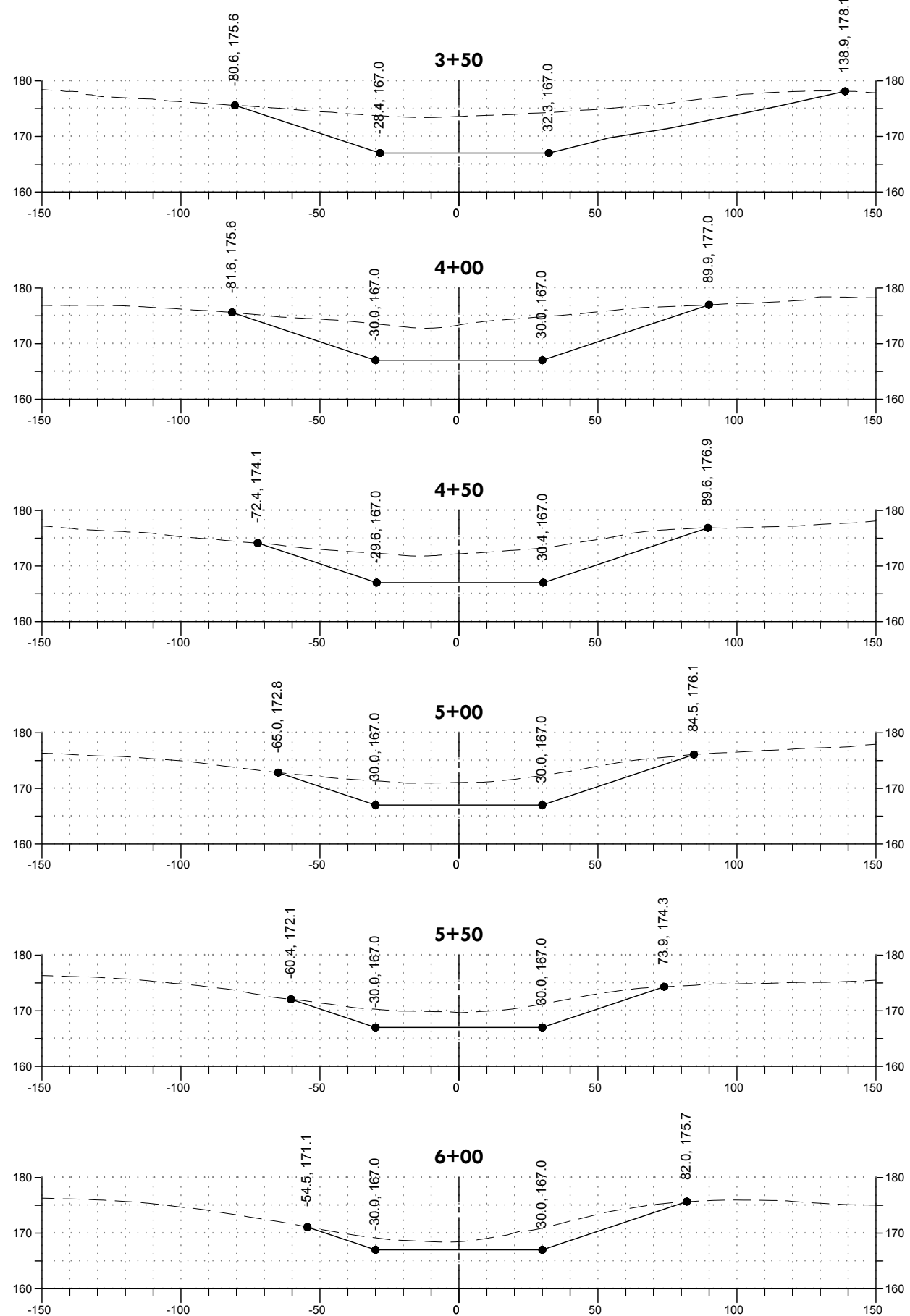
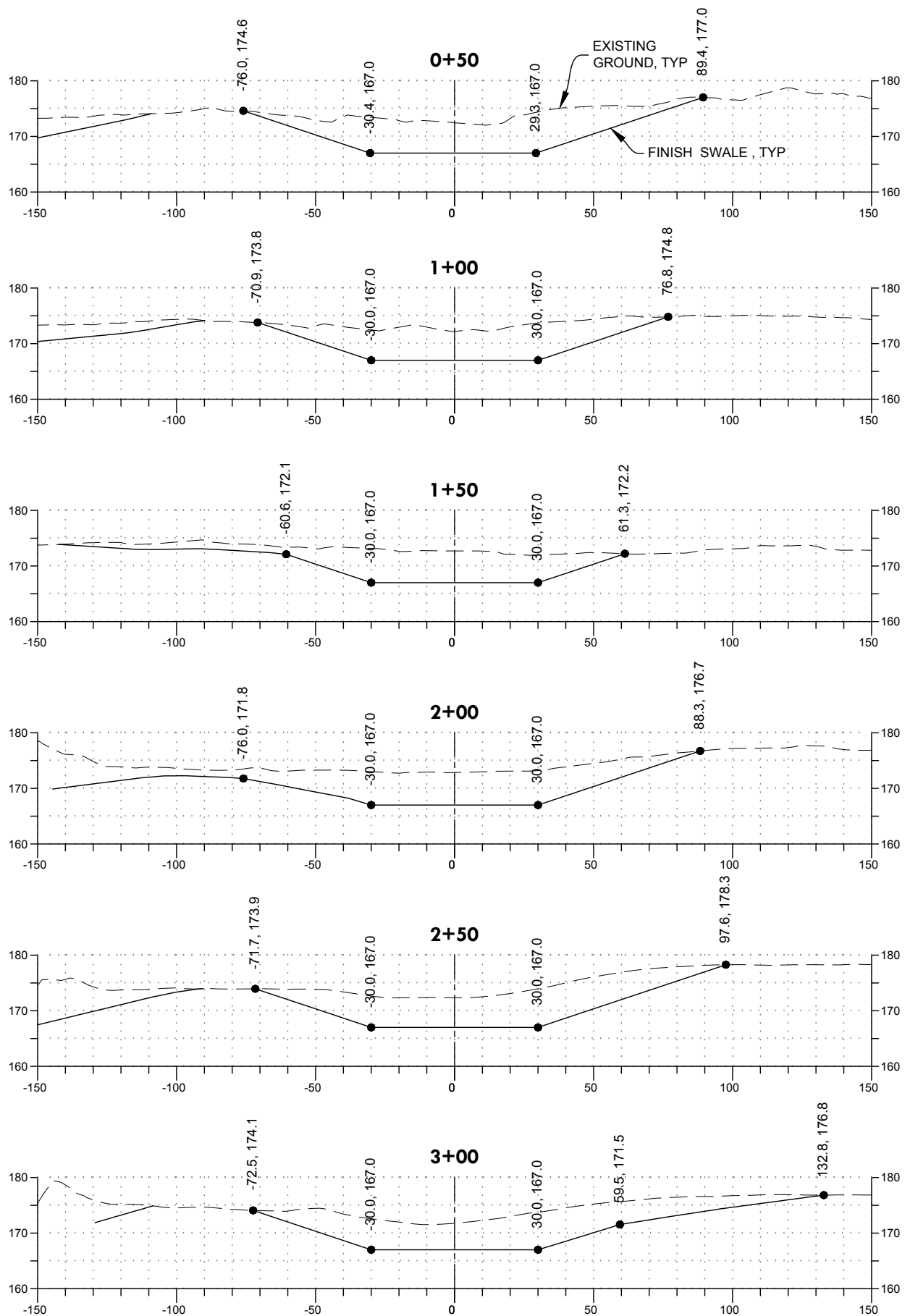
NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

PROJECT NUMBER
RDG-17-009

DRAWING NUMBER
2.0

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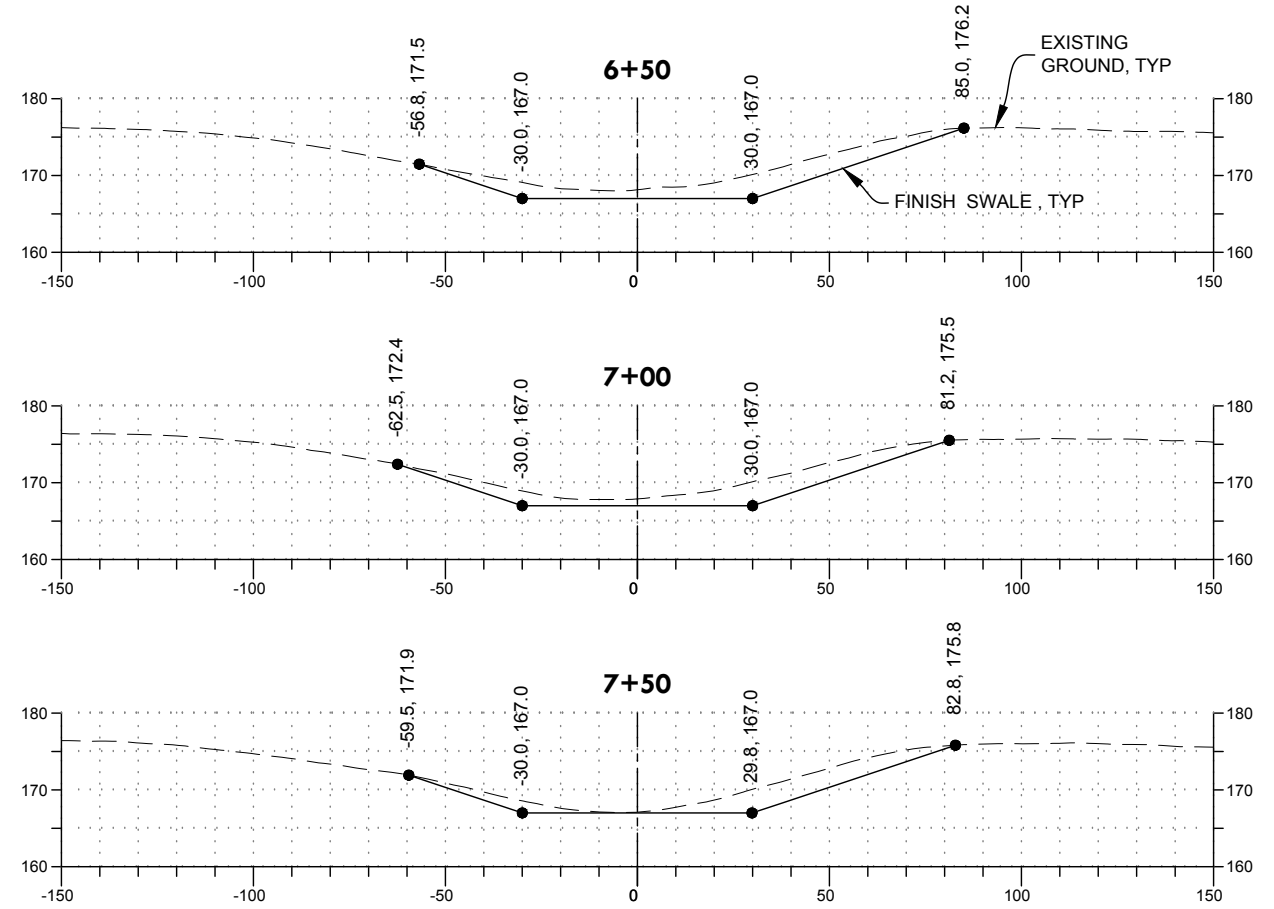


1 **SITE 7 - ALTERNATIVE A EAST SWALE DESIGN SECTIONS**
 HORIZ 1" = 50'
 VERT 1" = 25'

SITE 7 - ALTERNATIVE A EAST SWALE DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		

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1 **SITE 7 - ALTERNATIVE A**
EAST SWALE DESIGN SECTIONS
 HORIZ 1" = 50'
 VERT 1" = 25'

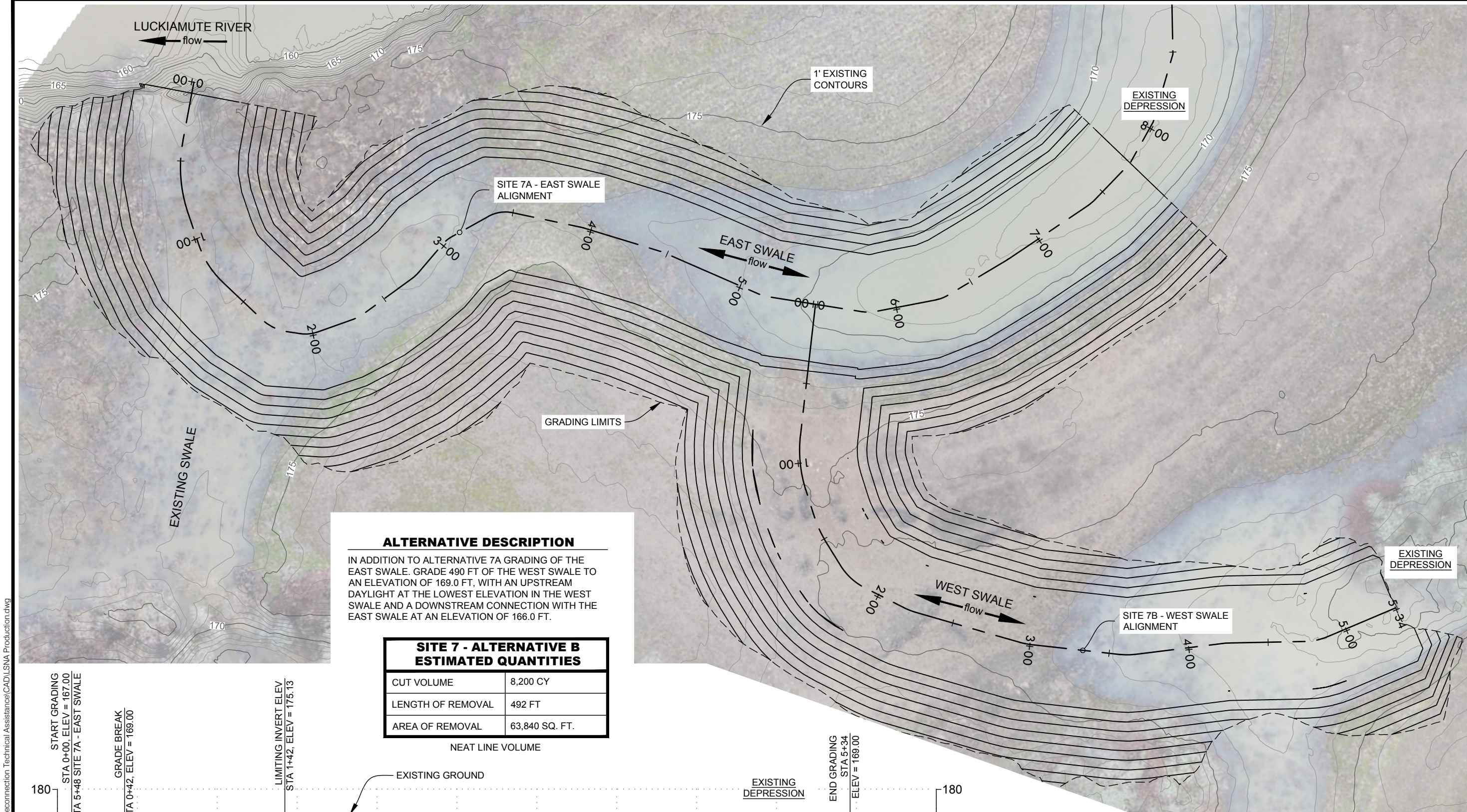
SITE 7 - ALTERNATIVE A EAST
SWALE DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

PROJECT NUMBER
 RDG-17-009

DRAWING NUMBER
2.2

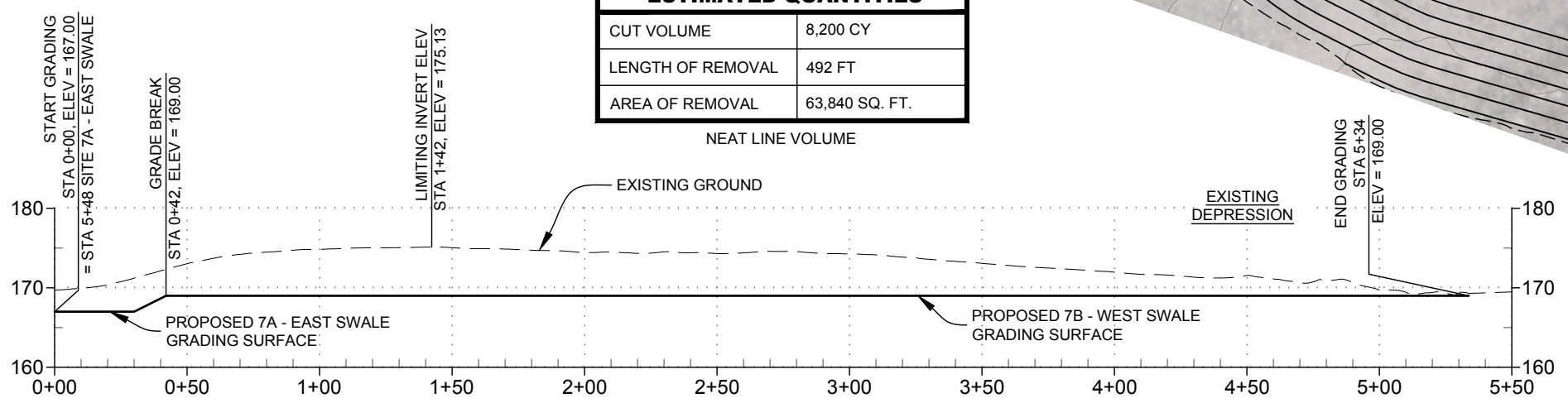
Drawing 5 of 33



ALTERNATIVE DESCRIPTION
 IN ADDITION TO ALTERNATIVE 7A GRADING OF THE EAST SWALE, GRADE 490 FT OF THE WEST SWALE TO AN ELEVATION OF 169.0 FT, WITH AN UPSTREAM DAYLIGHT AT THE LOWEST ELEVATION IN THE WEST SWALE AND A DOWNSTREAM CONNECTION WITH THE EAST SWALE AT AN ELEVATION OF 166.0 FT.

SITE 7 - ALTERNATIVE B ESTIMATED QUANTITIES	
CUT VOLUME	8,200 CY
LENGTH OF REMOVAL	492 FT
AREA OF REMOVAL	63,840 SQ. FT.

NEAT LINE VOLUME



SITE 7 - ALTERNATIVE B WEST SWALE PROFILE

HORIZ 1" = 60'
 VERT 1" = 20'

SITE 7 - ALTERNATIVE B PROPOSED LAYOUT

1" = 60'

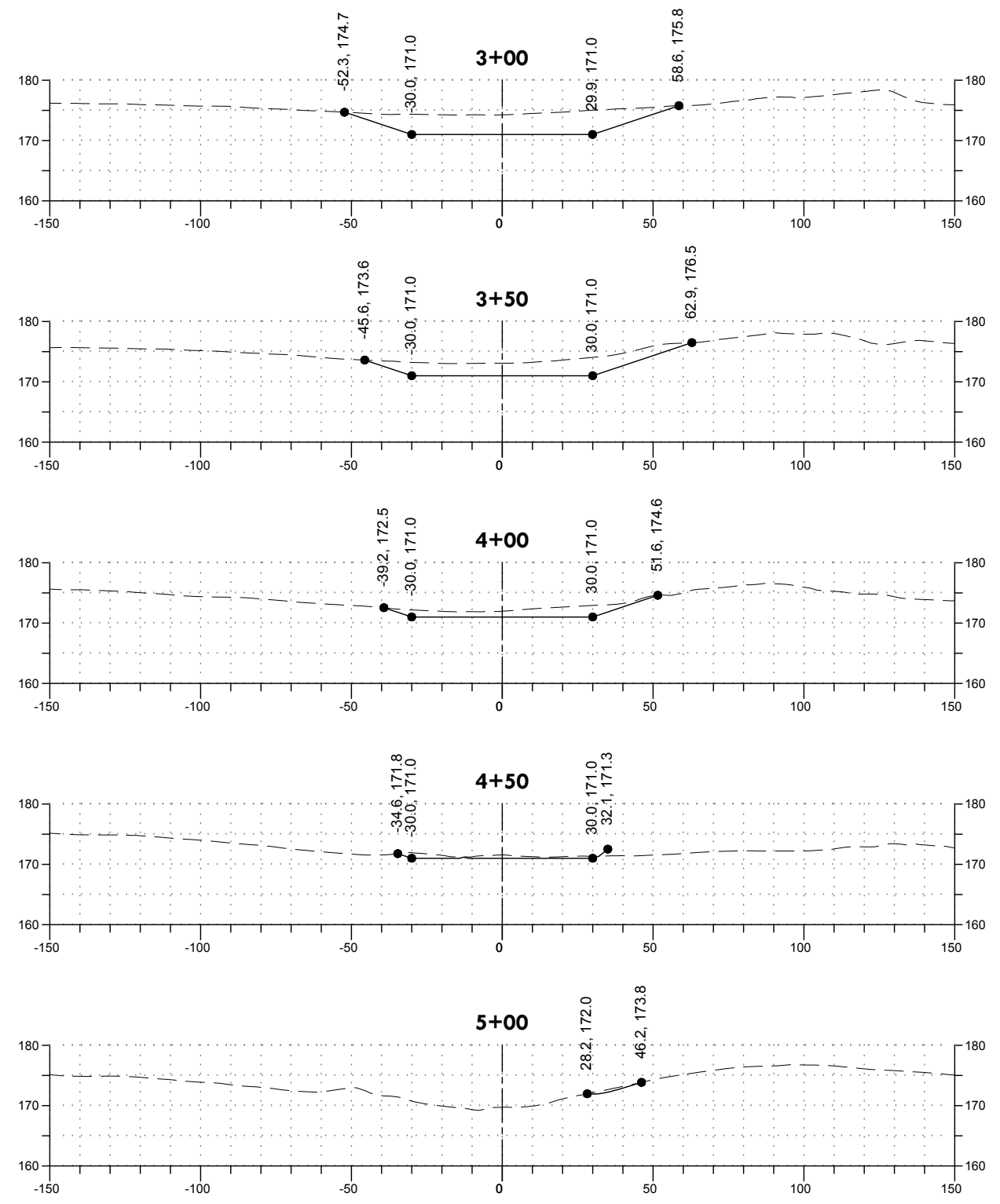
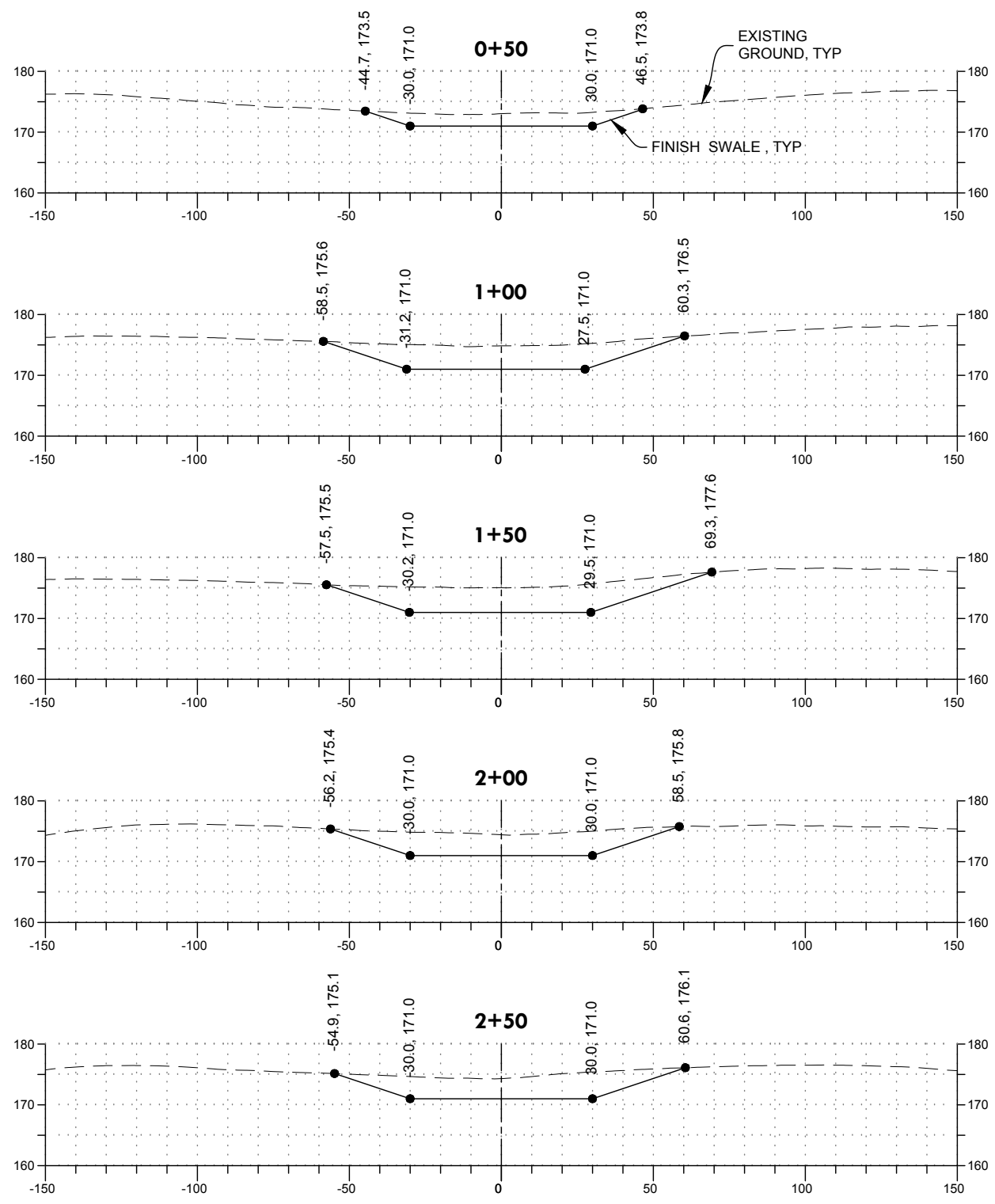


**SITE 7 - ALTERNATIVE B
 PLAN AND PROFILE**
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

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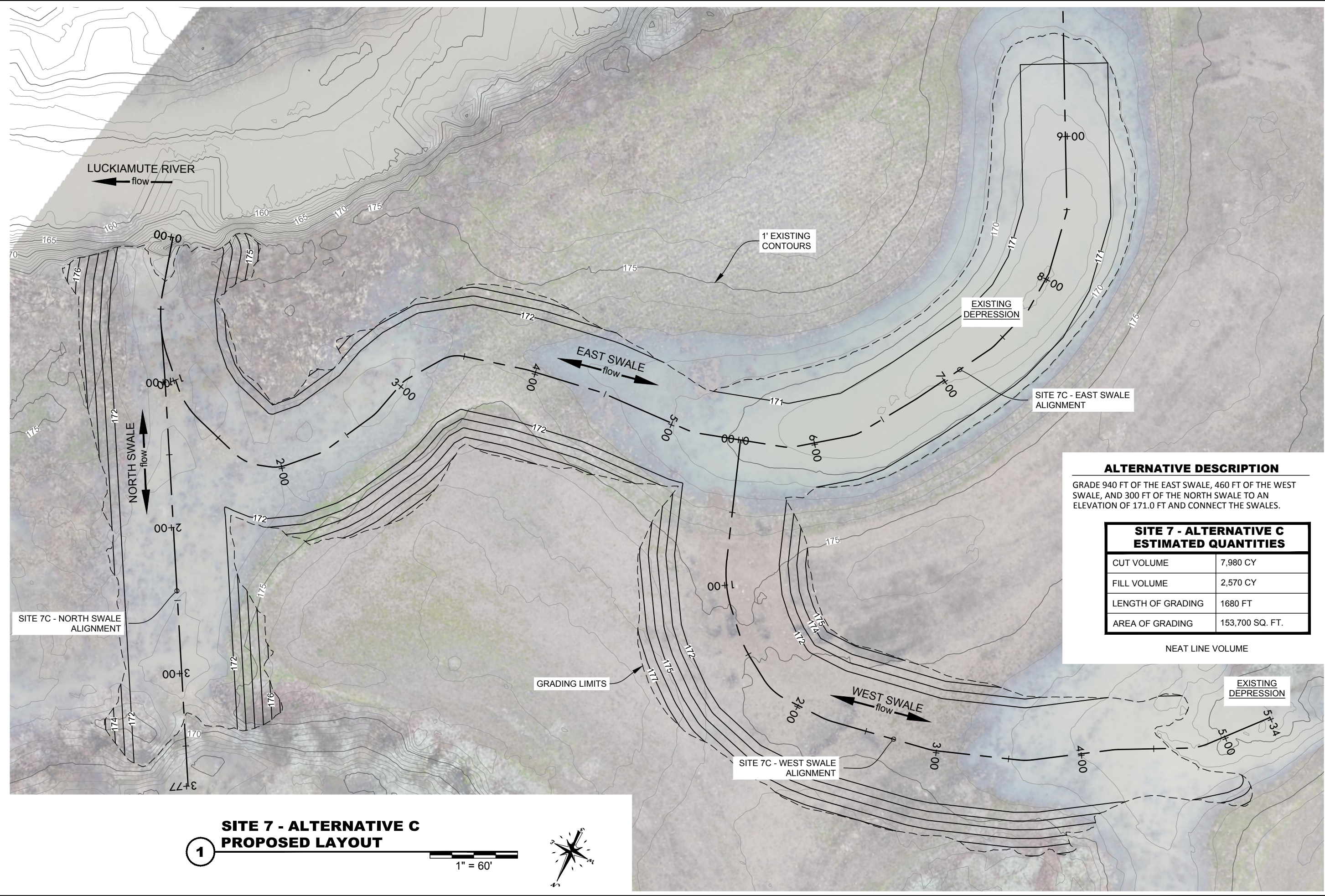


1 **SITE 7 - ALTERNATIVE B**
WEST SWALE DESIGN SECTIONS
 HORIZ 1" = 50'
 VERT 1" = 25'

SITE 7 - ALTERNATIVE B WEST
SWALE DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		

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1 SITE 7 - ALTERNATIVE C PROPOSED LAYOUT
 1" = 60'



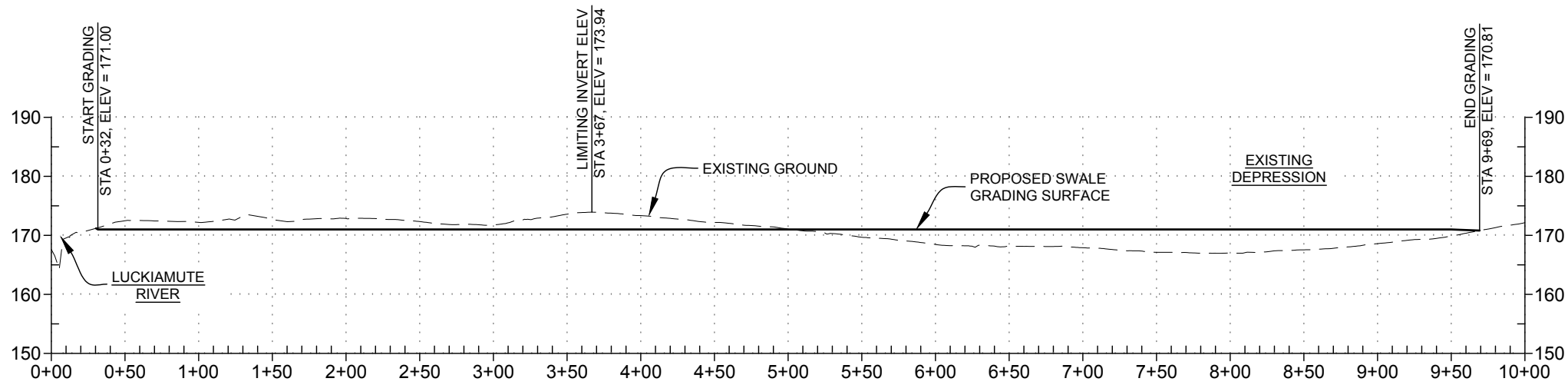
ALTERNATIVE DESCRIPTION
 GRADE 940 FT OF THE EAST SWALE, 460 FT OF THE WEST SWALE, AND 300 FT OF THE NORTH SWALE TO AN ELEVATION OF 171.0 FT AND CONNECT THE SWALES.

SITE 7 - ALTERNATIVE C ESTIMATED QUANTITIES	
CUT VOLUME	7,980 CY
FILL VOLUME	2,570 CY
LENGTH OF GRADING	1680 FT
AREA OF GRADING	153,700 SQ. FT.

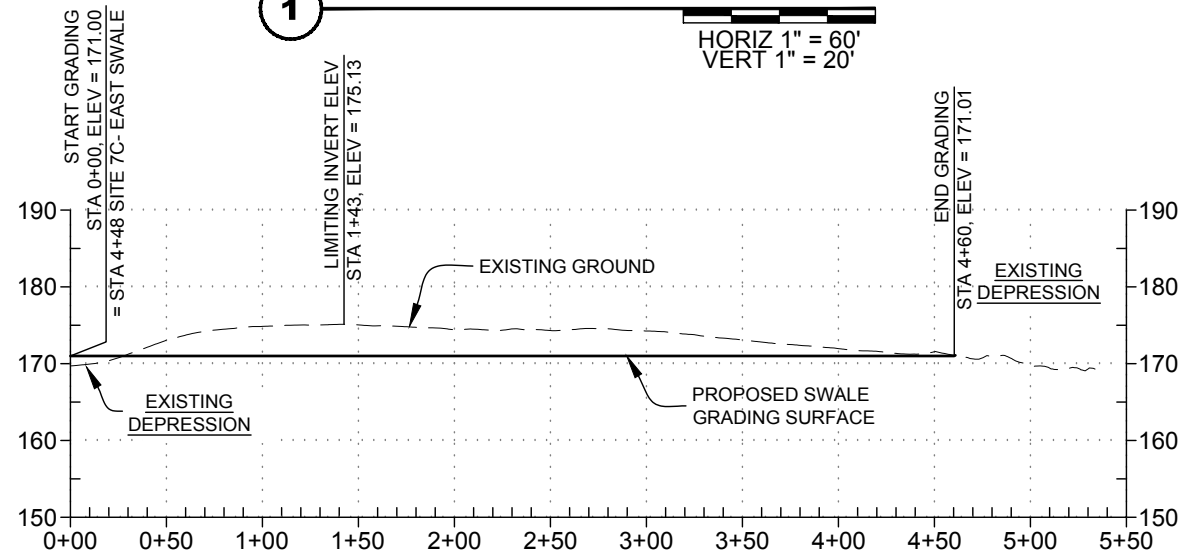
NEAT LINE VOLUME

SITE 7 - ALTERNATIVE C PLAN
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

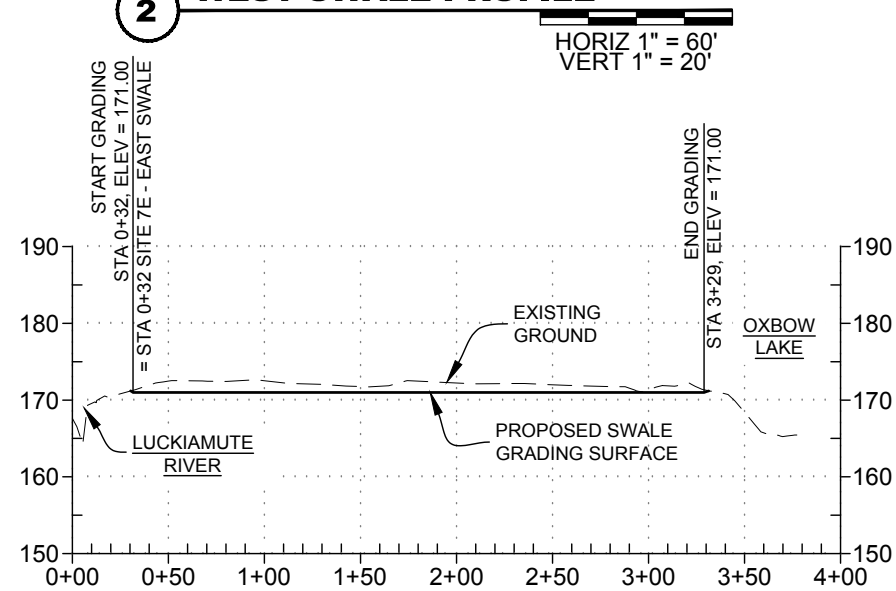
NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		



**SITE 7 - ALTERNATIVE C
EAST SWALE PROFILE**



**SITE 7 - ALTERNATIVE C
WEST SWALE PROFILE**



**SITE 7 - ALTERNATIVE C
NORTH SWALE PROFILE**

**SITE 7 - ALTERNATIVE C
PROFILES**
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

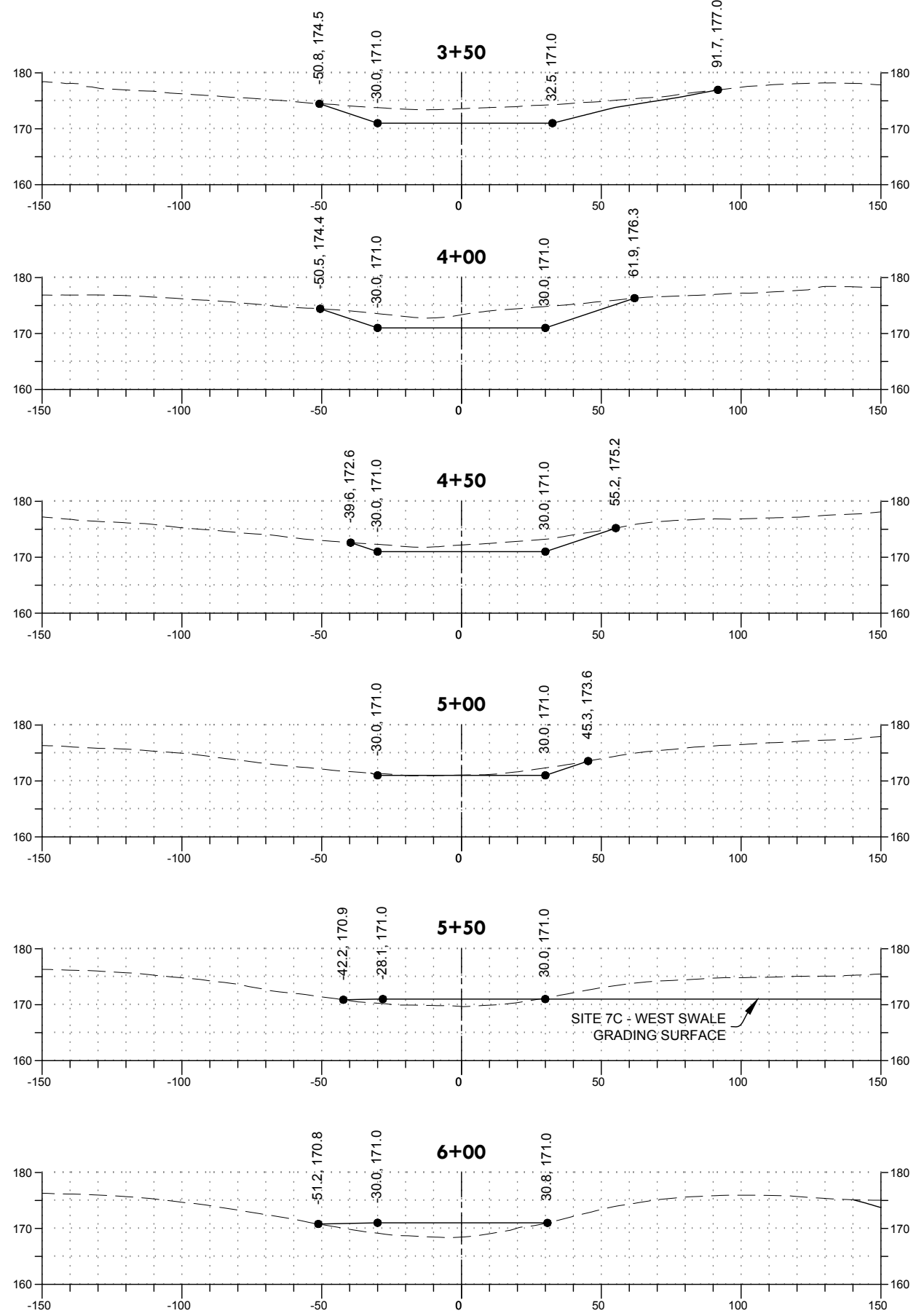
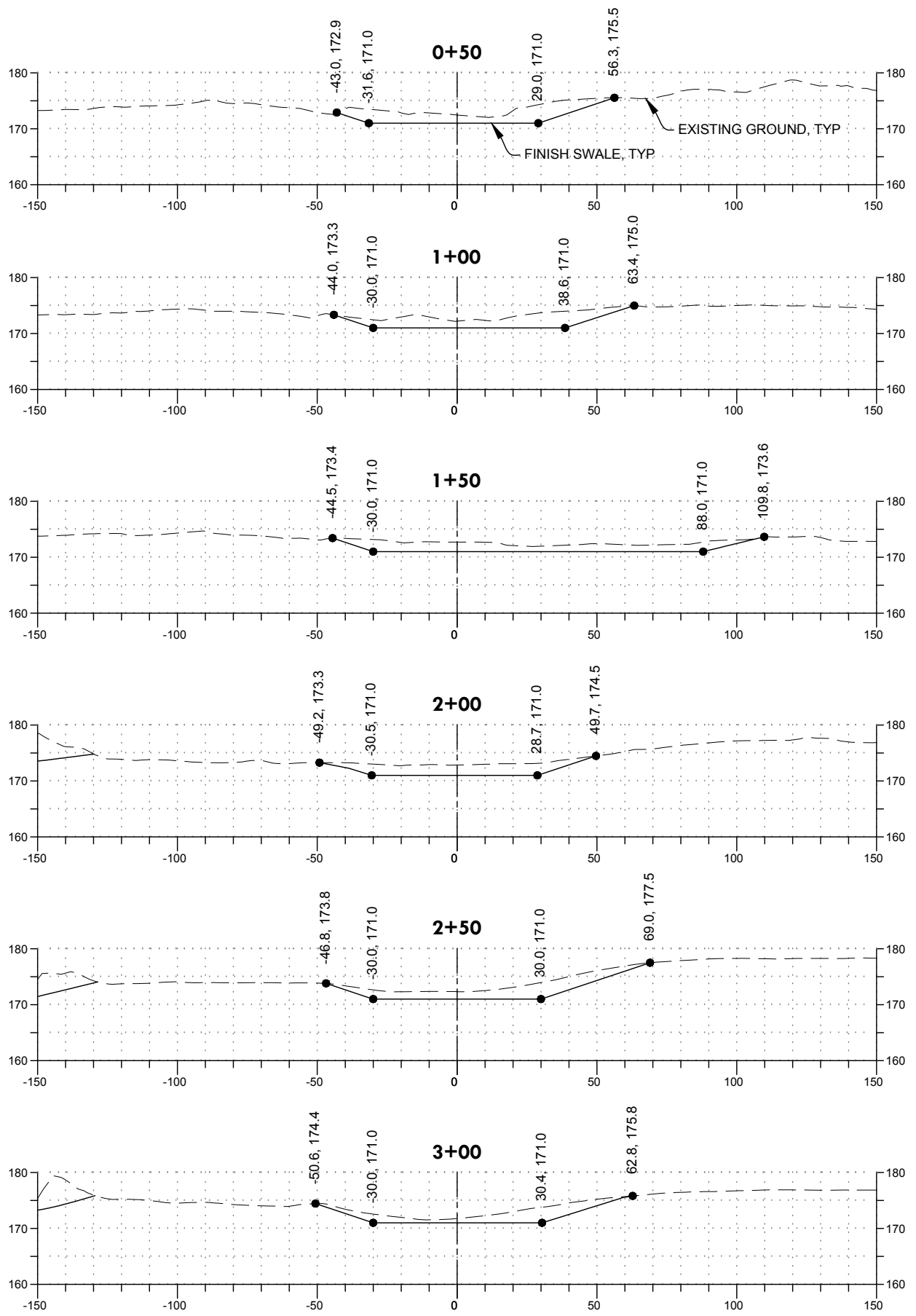
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*	09/27/17	TF	CONCEPTS		

PROJECT NUMBER
RDG-17-009

DRAWING NUMBER
2.6

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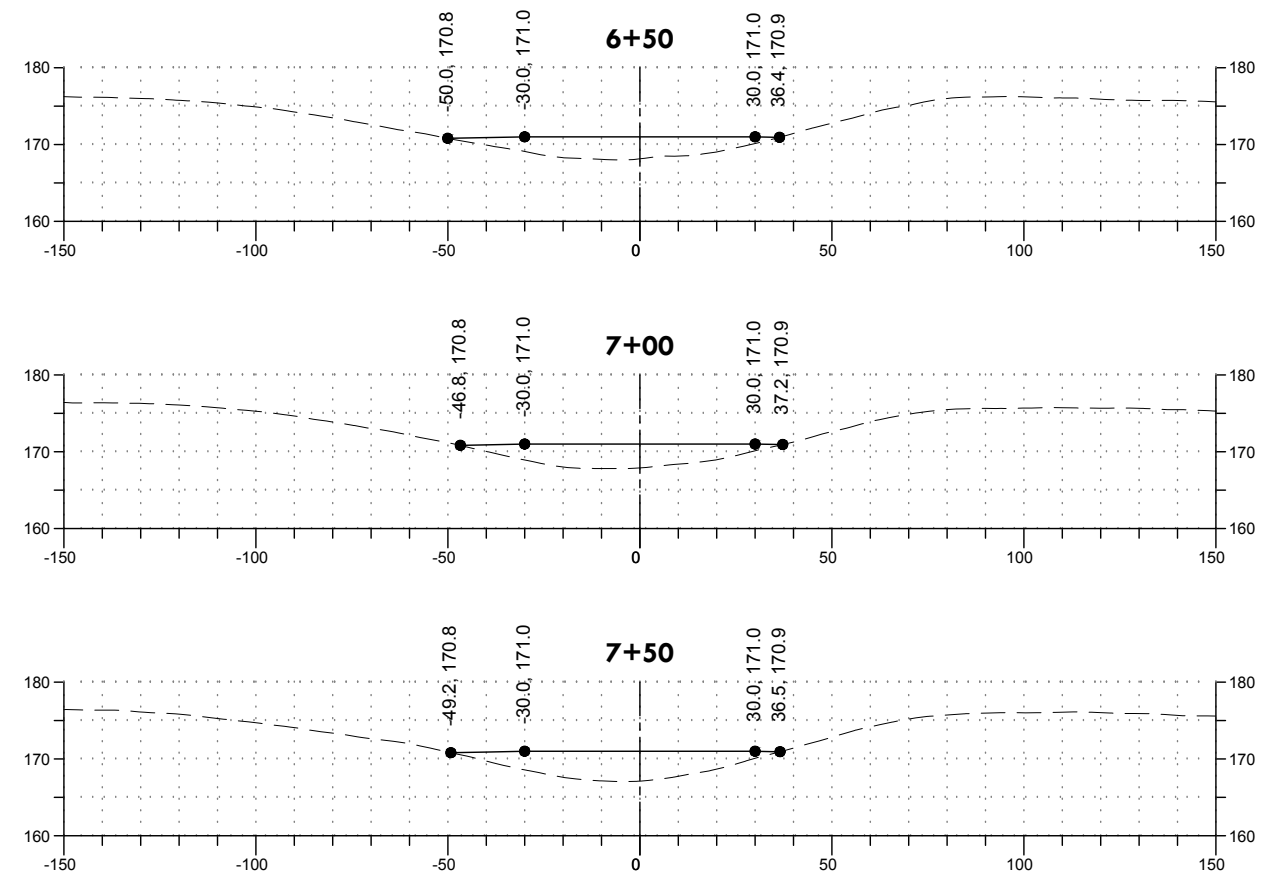


1 **SITE 7 - ALTERNATIVE C**
EAST SWALE DESIGN SECTIONS
 HORIZ 1" = 50'
 VERT 1" = 25'

SITE 7 - ALTERNATIVE C EAST
SWALE DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		

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1 **SITE 7 - ALTERNATIVE C**
EAST SWALE DESIGN SECTIONS
 HORIZ 1" = 50'
 VERT 1" = 25'

SITE 7 - ALTERNATIVE C EAST
SWALE DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

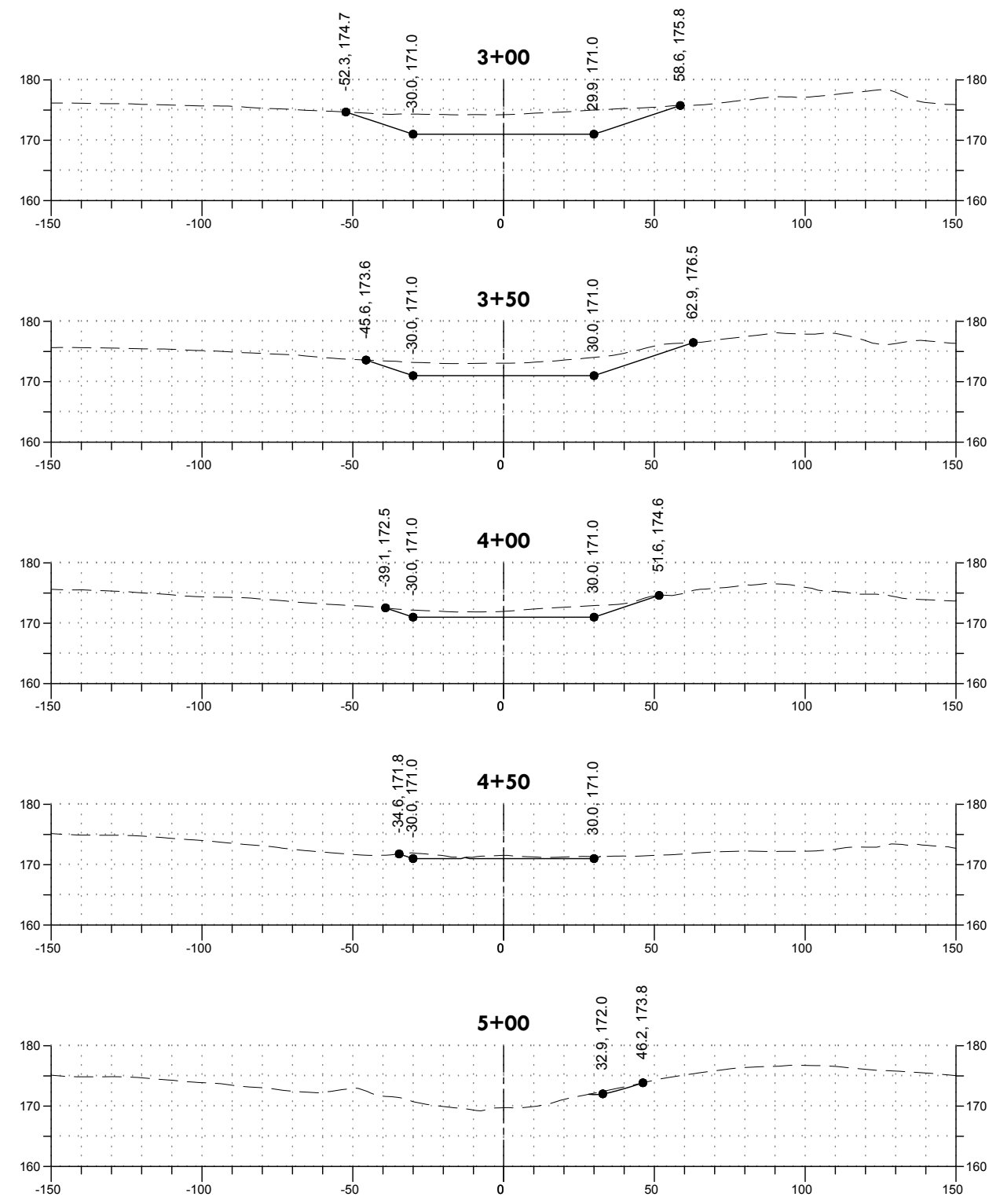
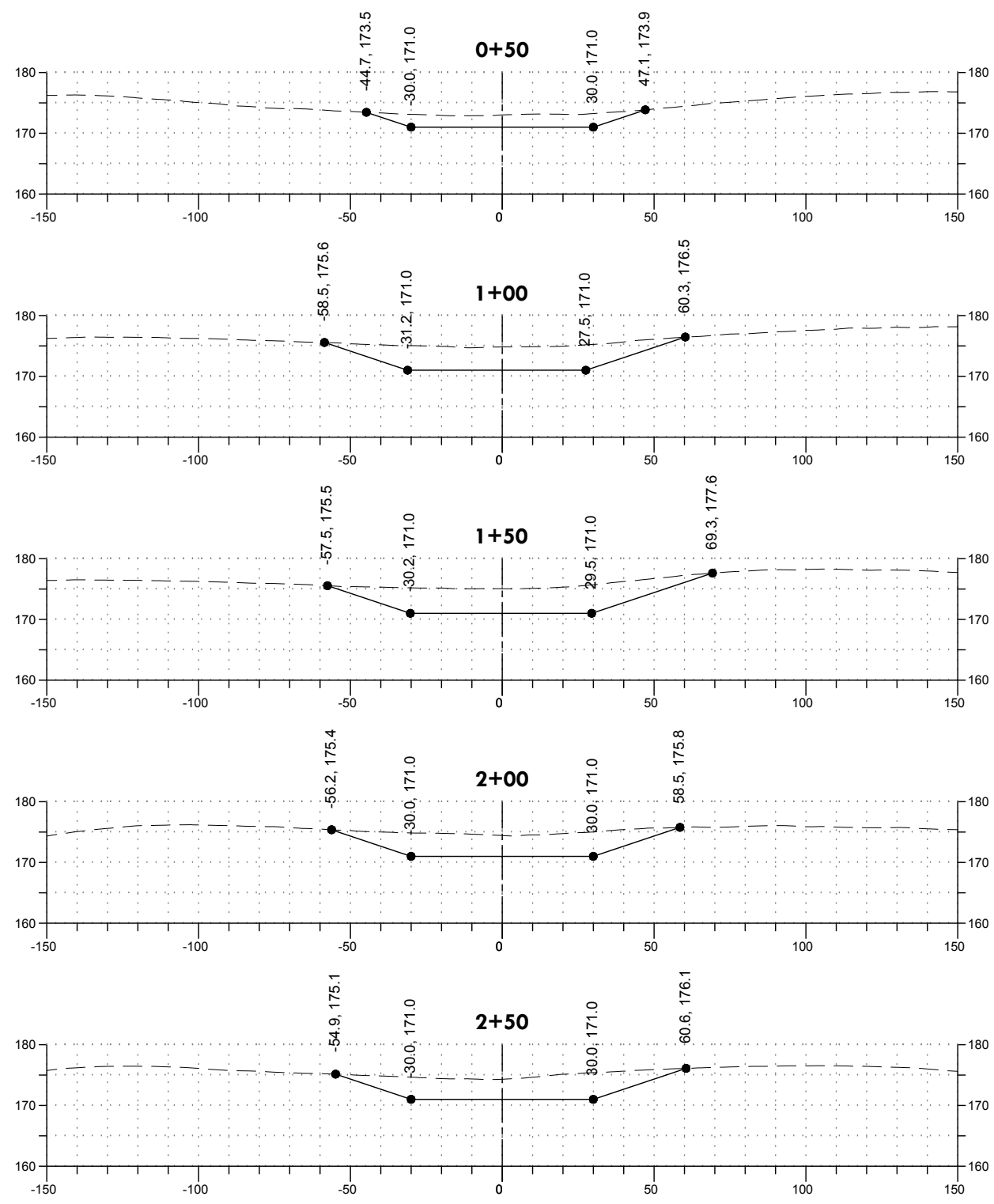
NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

PROJECT NUMBER
 RDG-17-009

DRAWING NUMBER
2.8

Drawing 11 of 33

M:\Projects\2017\RDG-17-009 LSNA Floodplain Reconnection Technical Assistance\CAD\LSNA Production.dwg



1 SITE 7 - ALTERNATIVE C
WEST SWALE DESIGN SECTIONS
HORIZ 1" = 50'
VERT 1" = 25'

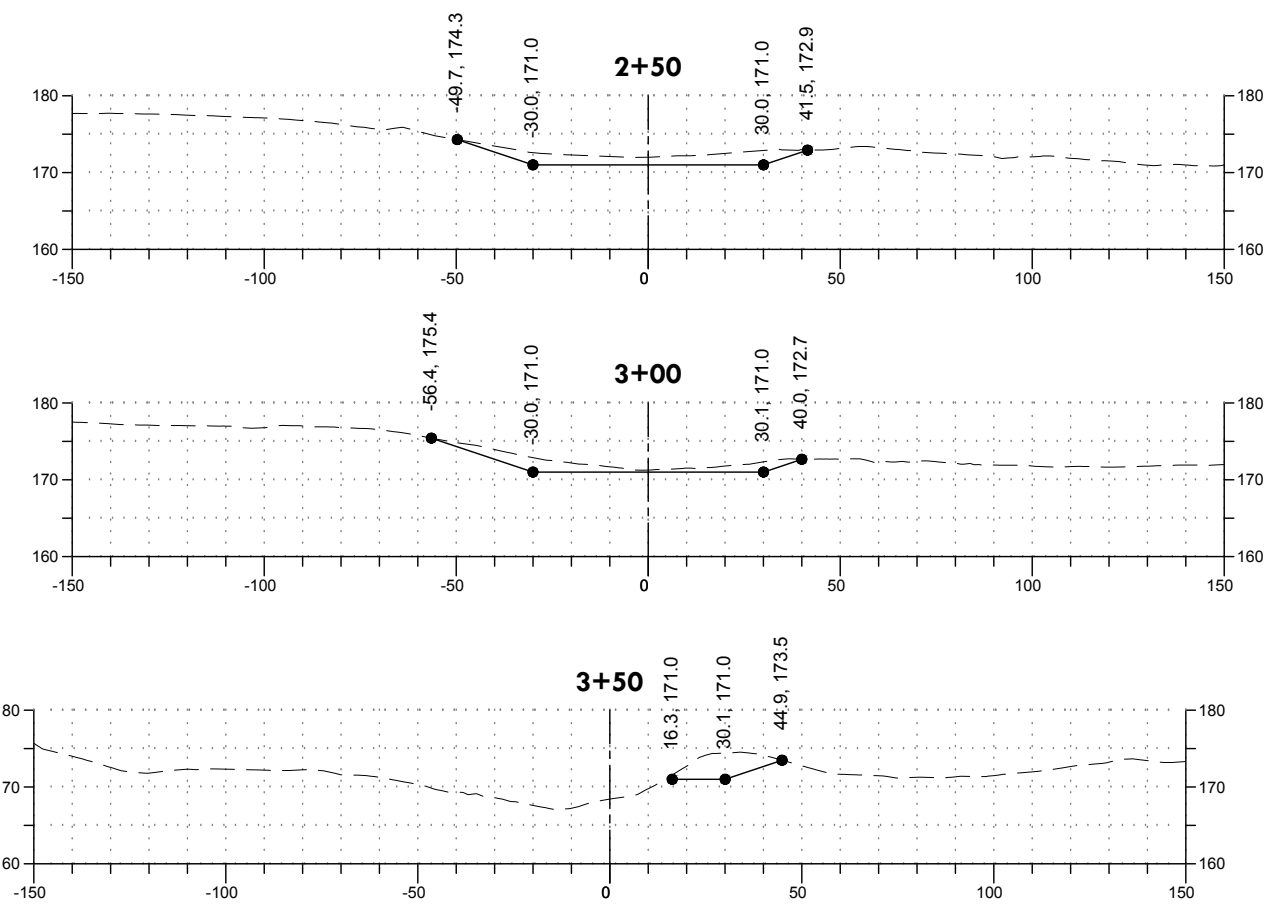
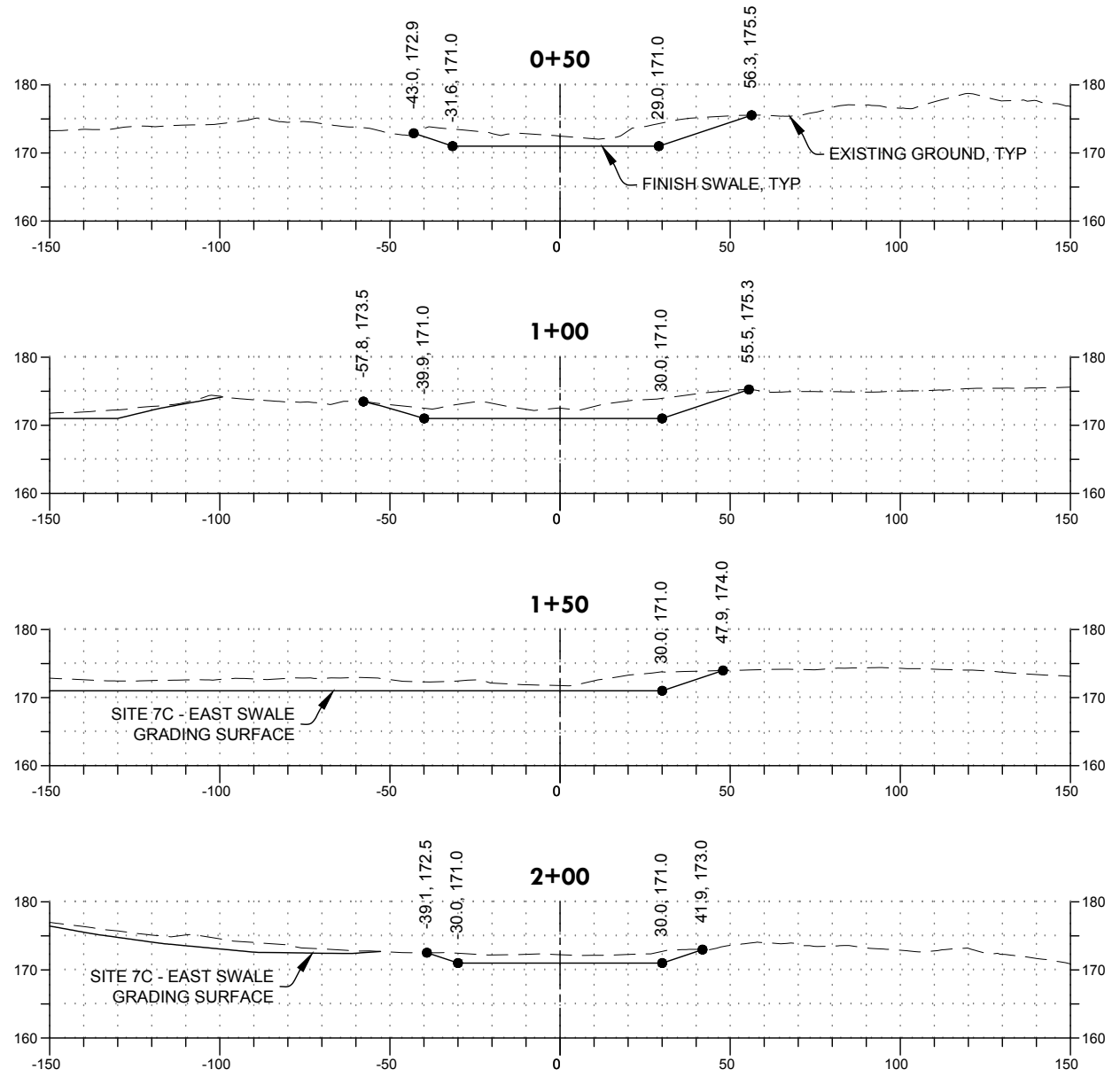
**SITE 7 - ALTERNATIVE C WEST
SWALE DESIGN SECTIONS**
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
				SW
*	09/27/17	TF	CONCEPTS	

PROJECT NUMBER
RDG-17-009

DRAWING NUMBER
2.9
Drawing 12 of 33

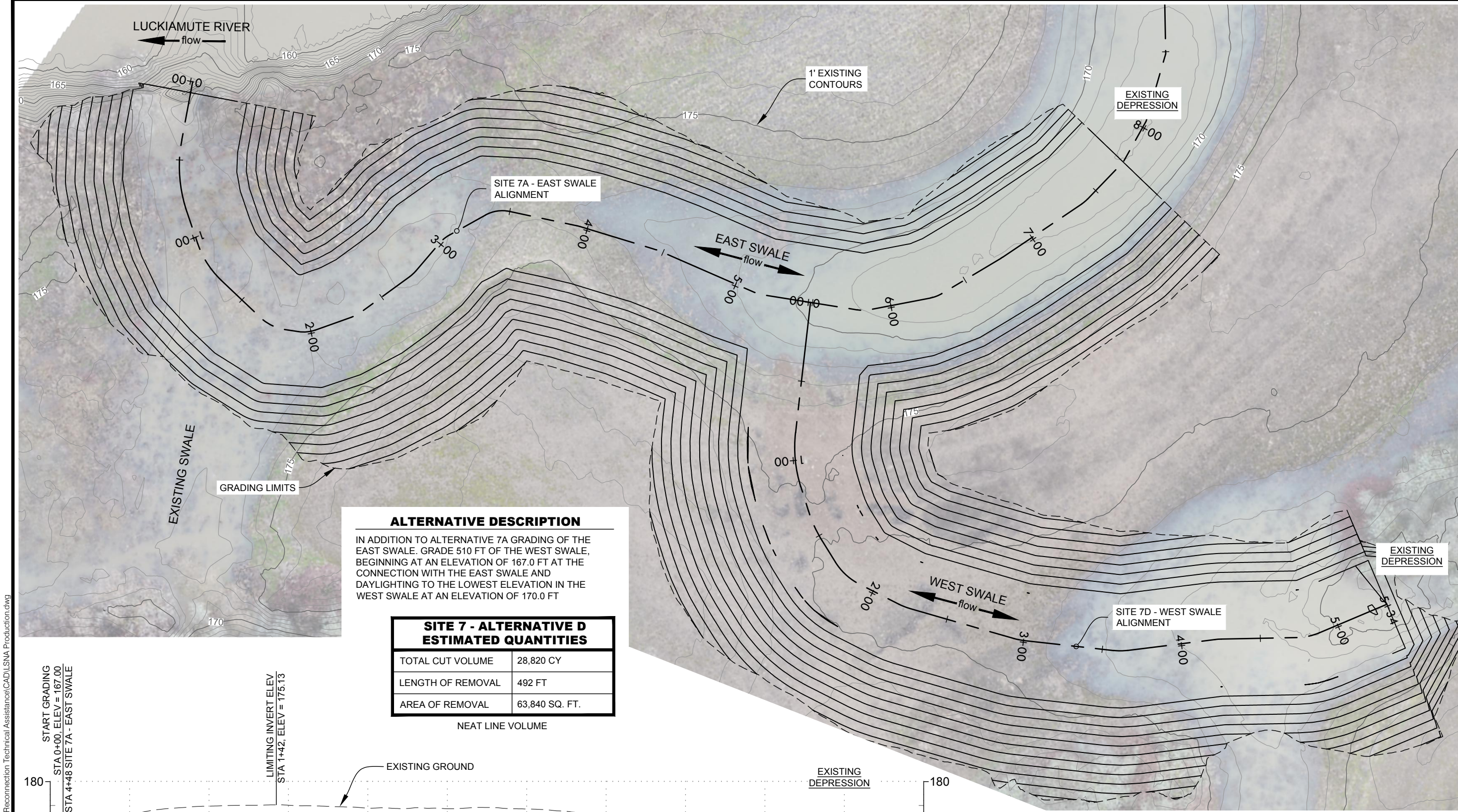
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1 **SITE 7 - ALTERNATIVE C**
NORTH SWALE DESIGN SECTIONS
 HORIZ 1" = 50'
 VERT 1" = 25'

SITE 7 - ALTERNATIVE C NORTH
SWALE DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

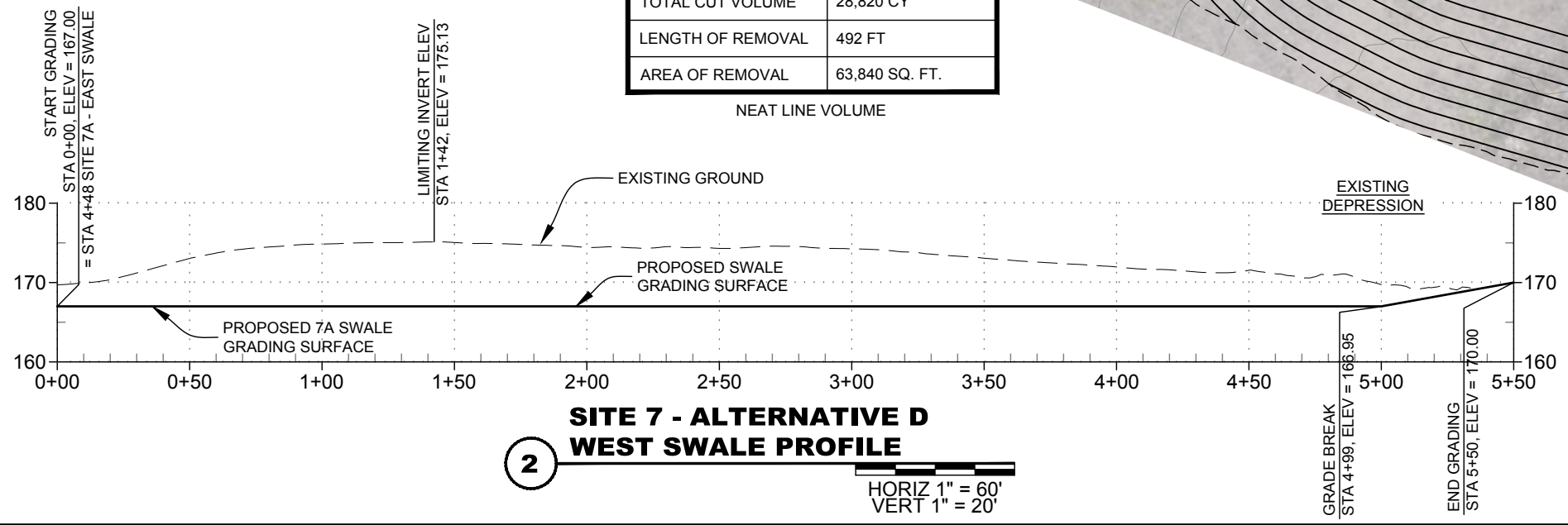
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				SW
*	09/27/17	TF	CONCEPTS	
PROJECT NUMBER				
RDG-17-009				
DRAWING NUMBER				
2.10				
Drawing 13 of 33				



ALTERNATIVE DESCRIPTION
 IN ADDITION TO ALTERNATIVE 7A GRADING OF THE EAST SWALE. GRADE 510 FT OF THE WEST SWALE, BEGINNING AT AN ELEVATION OF 167.0 FT AT THE CONNECTION WITH THE EAST SWALE AND DAYLIGHTING TO THE LOWEST ELEVATION IN THE WEST SWALE AT AN ELEVATION OF 170.0 FT

SITE 7 - ALTERNATIVE D ESTIMATED QUANTITIES	
TOTAL CUT VOLUME	28,820 CY
LENGTH OF REMOVAL	492 FT
AREA OF REMOVAL	63,840 SQ. FT.

NET LINE VOLUME



2 SITE 7 - ALTERNATIVE D WEST SWALE PROFILE



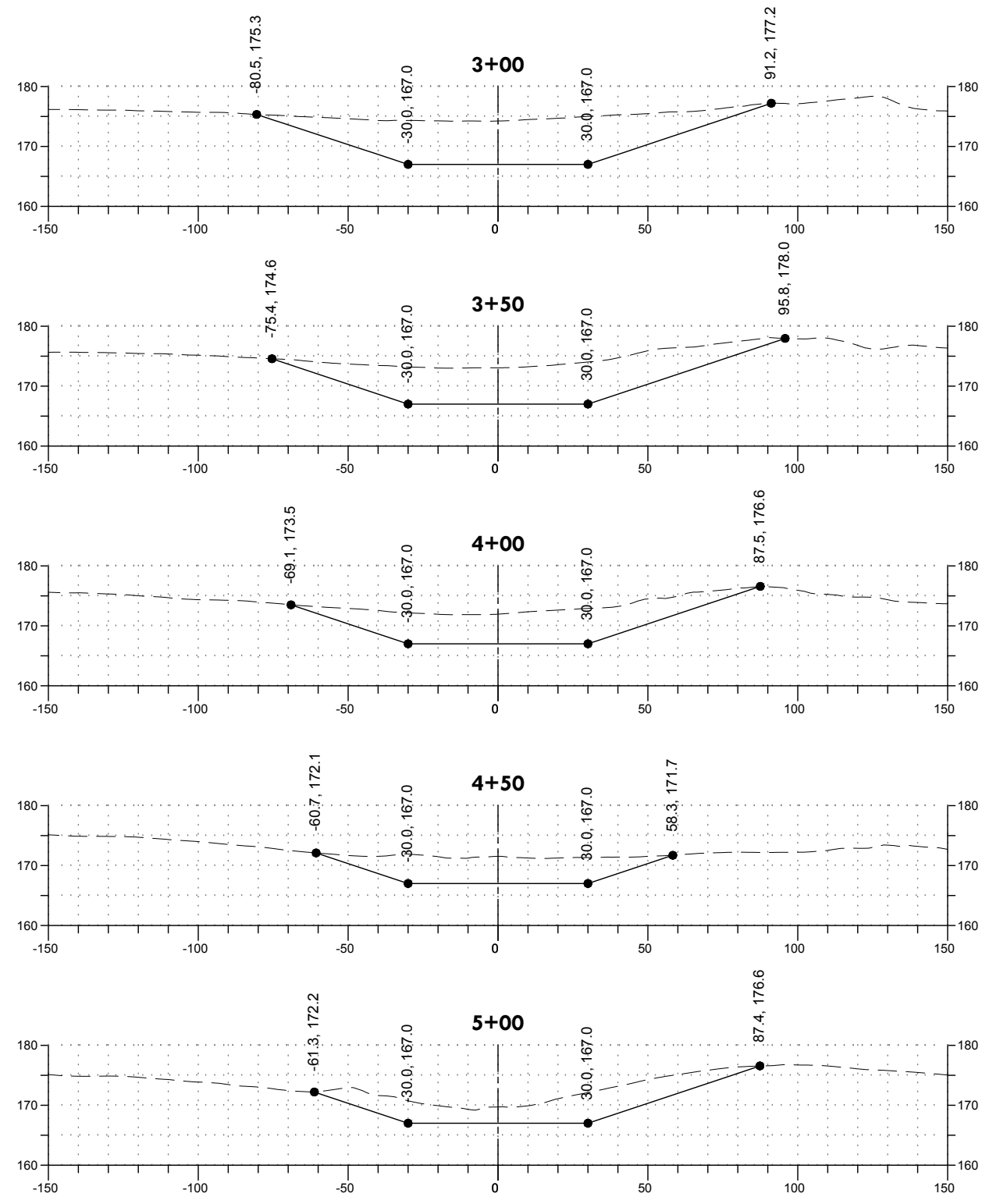
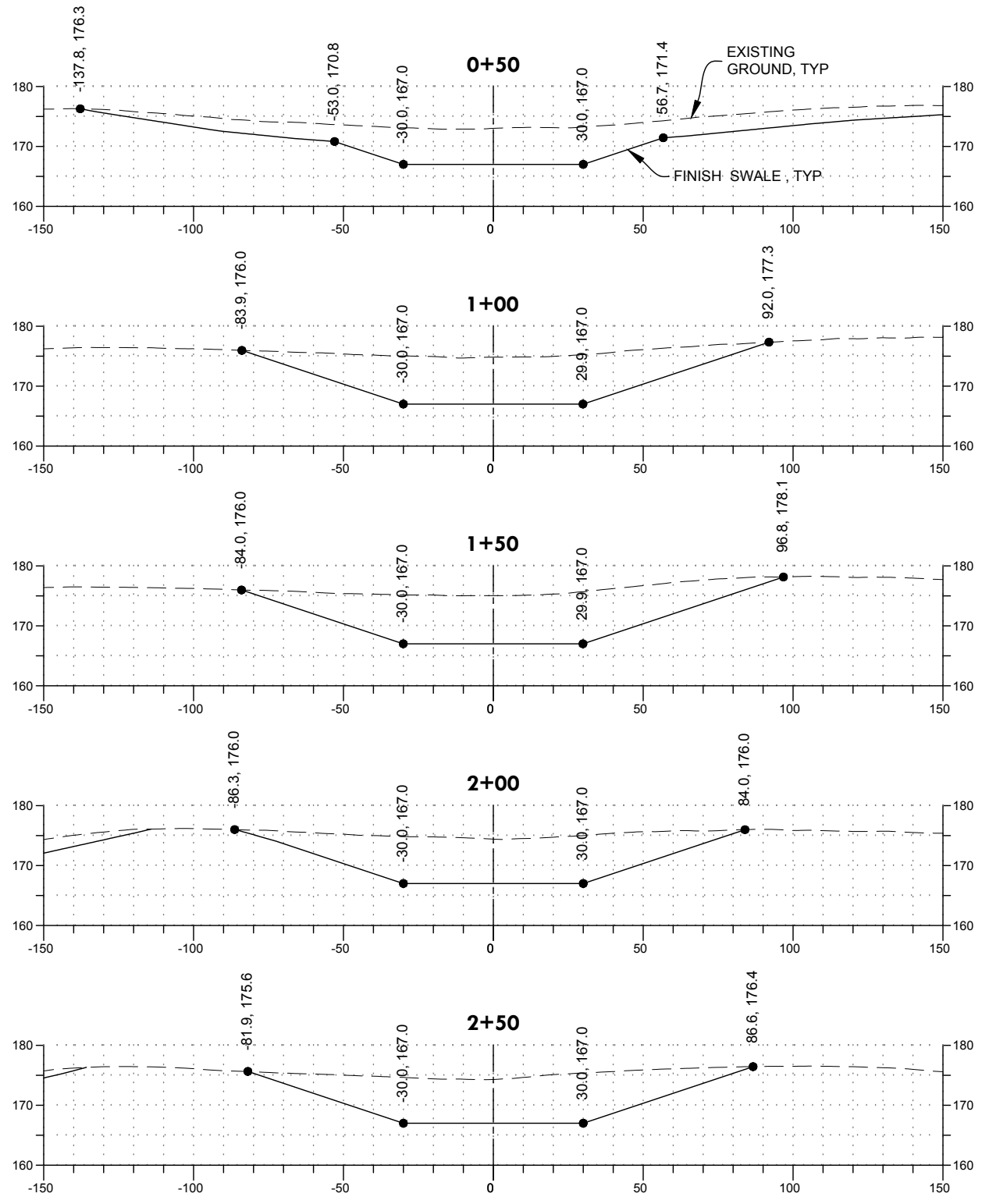
1 SITE 7 - ALTERNATIVE D PROPOSED LAYOUT

**SITE 7 - ALTERNATIVE D
 PLAN AND PROFILE**
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

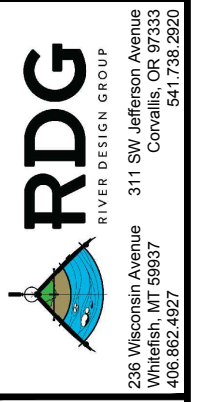
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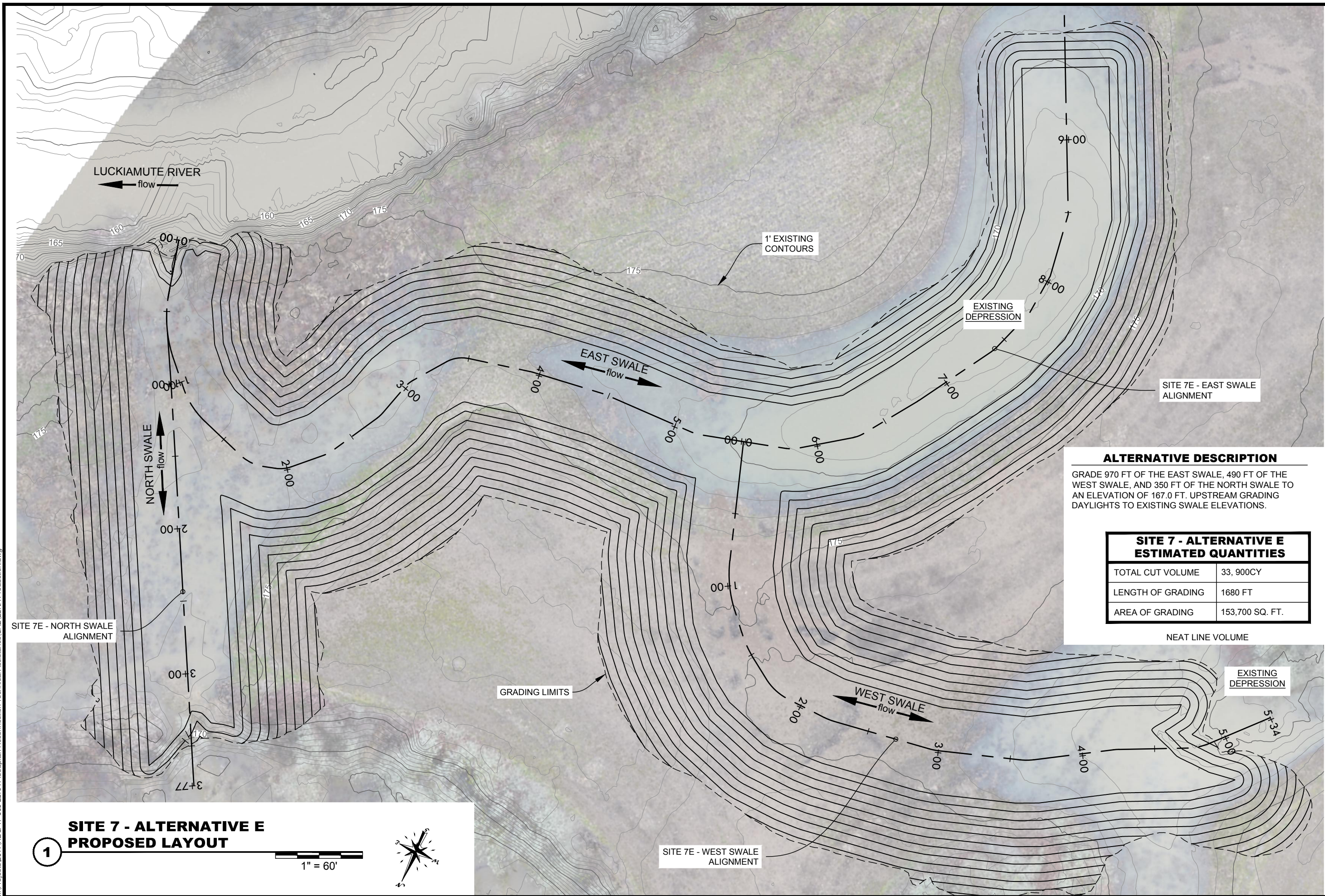
1 SITE 7 - ALTERNATIVE D
WEST SWALE DESIGN SECTIONS

HORIZ 1" = 50'
VERT 1" = 25'



SITE 7 - ALTERNATIVE D WEST SWALE DESIGN SECTIONS
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		
PROJECT NUMBER				RDG-17-009	
DRAWING NUMBER				2.12	
Drawing 15 of 33					



ALTERNATIVE DESCRIPTION
 GRADE 970 FT OF THE EAST SWALE, 490 FT OF THE WEST SWALE, AND 350 FT OF THE NORTH SWALE TO AN ELEVATION OF 167.0 FT. UPSTREAM GRADING DAYLIGHTS TO EXISTING SWALE ELEVATIONS.

SITE 7 - ALTERNATIVE E ESTIMATED QUANTITIES	
TOTAL CUT VOLUME	33,900CY
LENGTH OF GRADING	1680 FT
AREA OF GRADING	153,700 SQ. FT.

NEAT LINE VOLUME

1 SITE 7 - ALTERNATIVE E PROPOSED LAYOUT

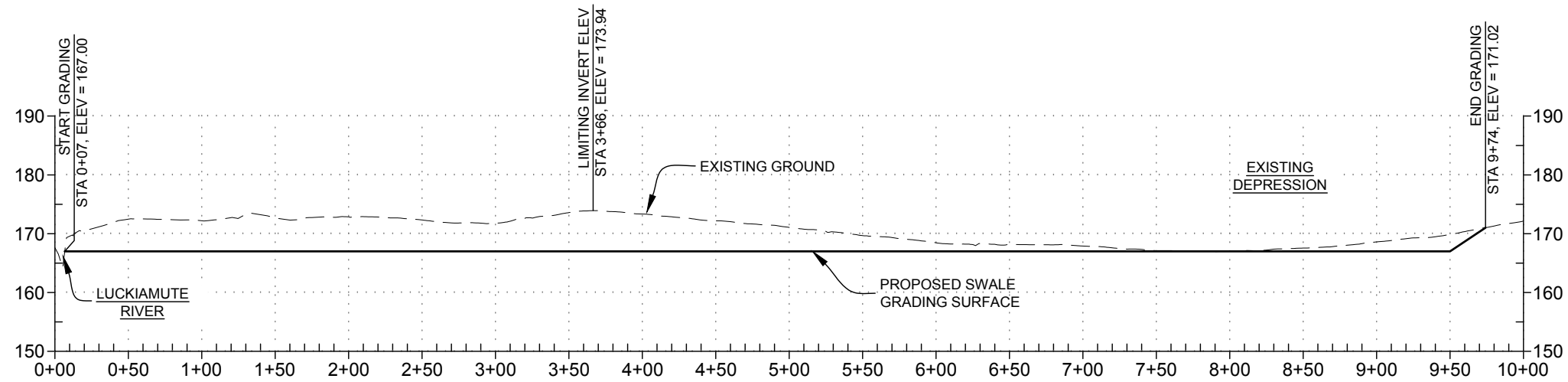
1" = 60'



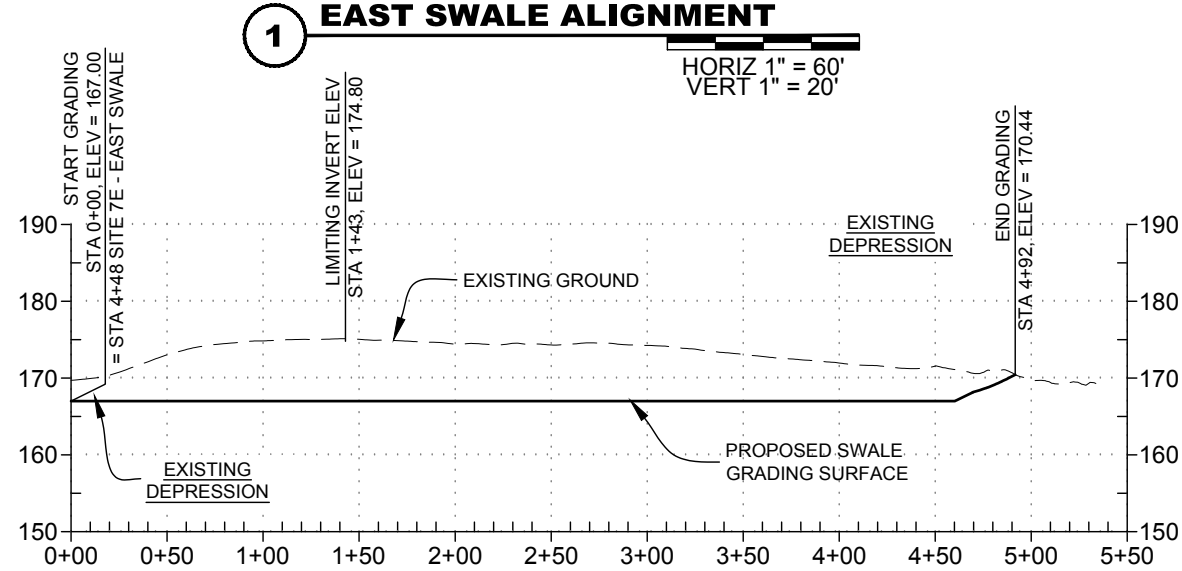
SITE 7 - ALTERNATIVE E PLAN
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

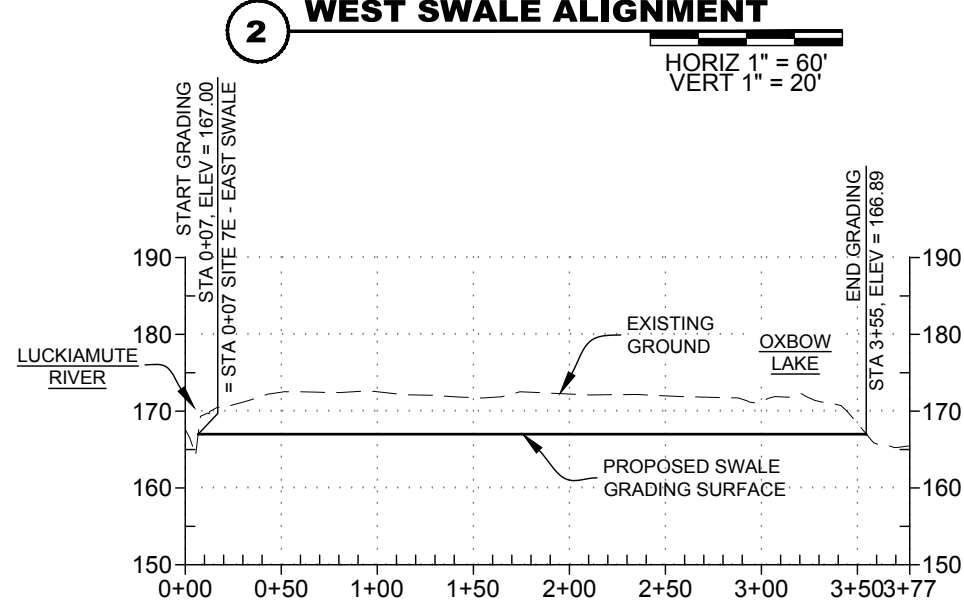
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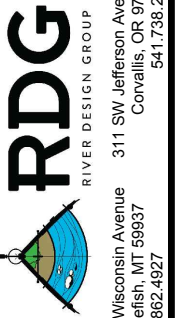
**SITE 7 - ALTERNATIVE E
EAST SWALE ALIGNMENT**



**SITE 7 - ALTERNATIVE E
WEST SWALE ALIGNMENT**



**SITE 7 - ALTERNATIVE E
NORTH SWALE ALIGNMENT**



236 Wisconsin Avenue
Whitefish, MT 59937
406.862.4927

311 SW Jefferson Avenue
Corvallis, OR 97333
541.738.2920

**SITE 7 - ALTERNATIVE E
PROFILES**
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		

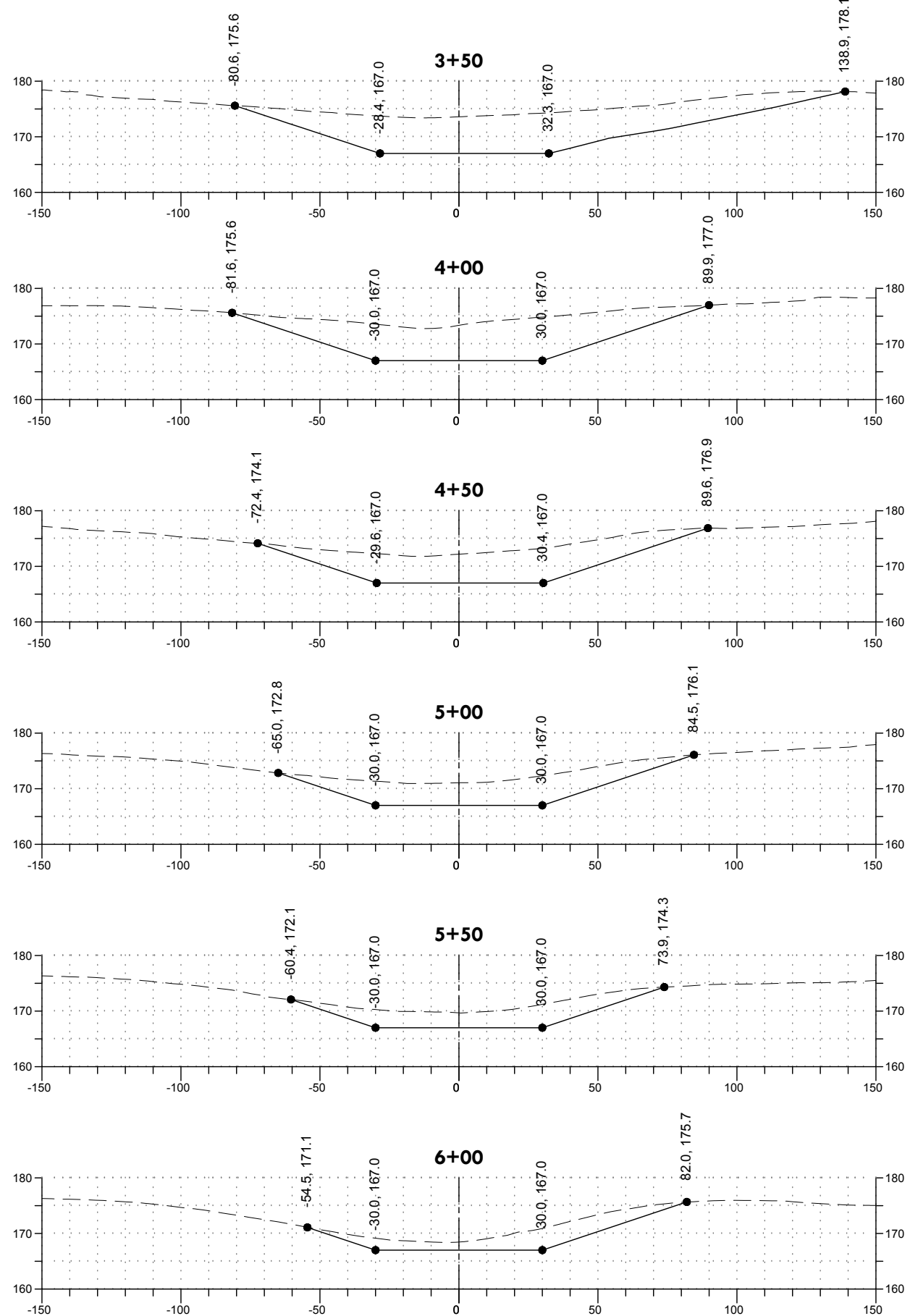
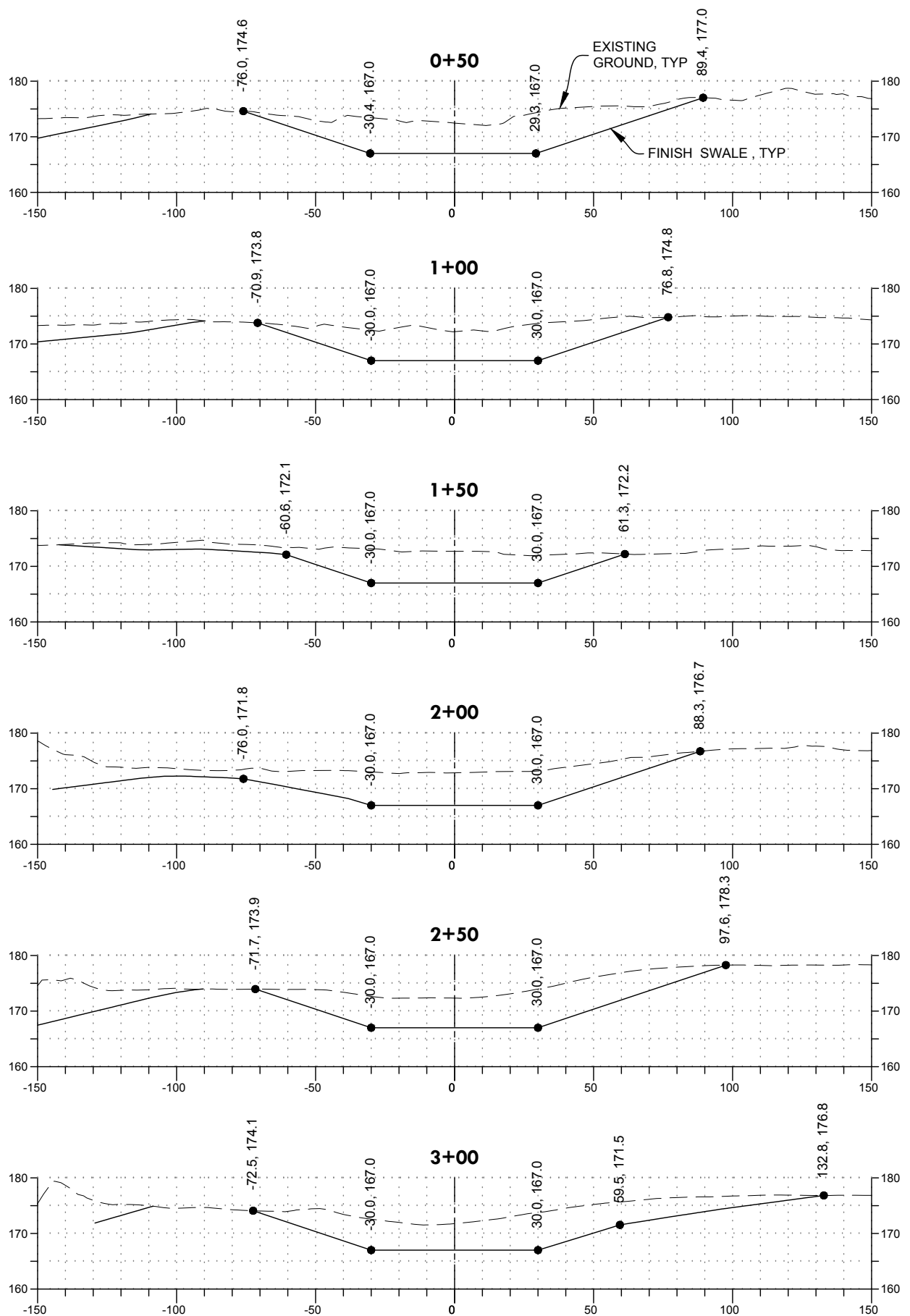
PROJECT NUMBER
RDG-17-009

DRAWING NUMBER

2.14

Drawing 17 of 33

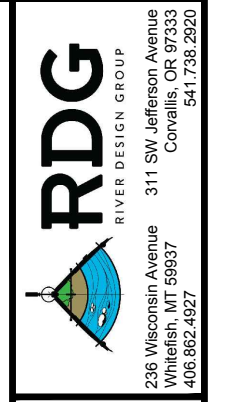
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1

**SITE 7 - ALTERNATIVE E
 EAST SWALE DESIGN SECTIONS**

HORIZ 1" = 50'
 VERT 1" = 25'



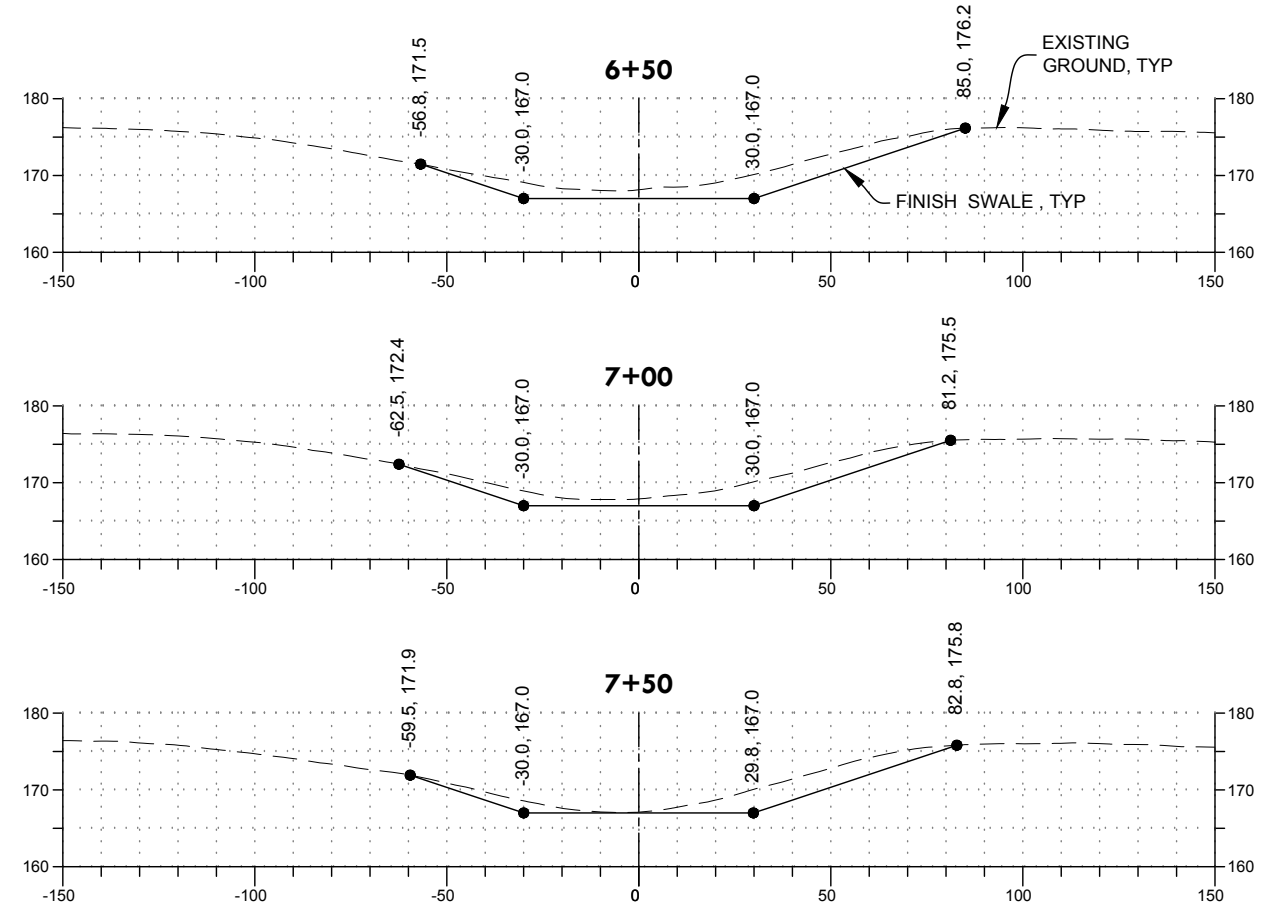
**SITE 7 - ALTERNATIVE E EAST
 SWALE DESIGN SECTIONS**
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		

PROJECT NUMBER
 RDG-17-009

DRAWING NUMBER
2.15

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1 **SITE 7 - ALTERNATIVE E**
EAST SWALE DESIGN SECTIONS
 HORIZ 1" = 50'
 VERT 1" = 25'

SITE 7 - ALTERNATIVE E EAST
SWALE DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

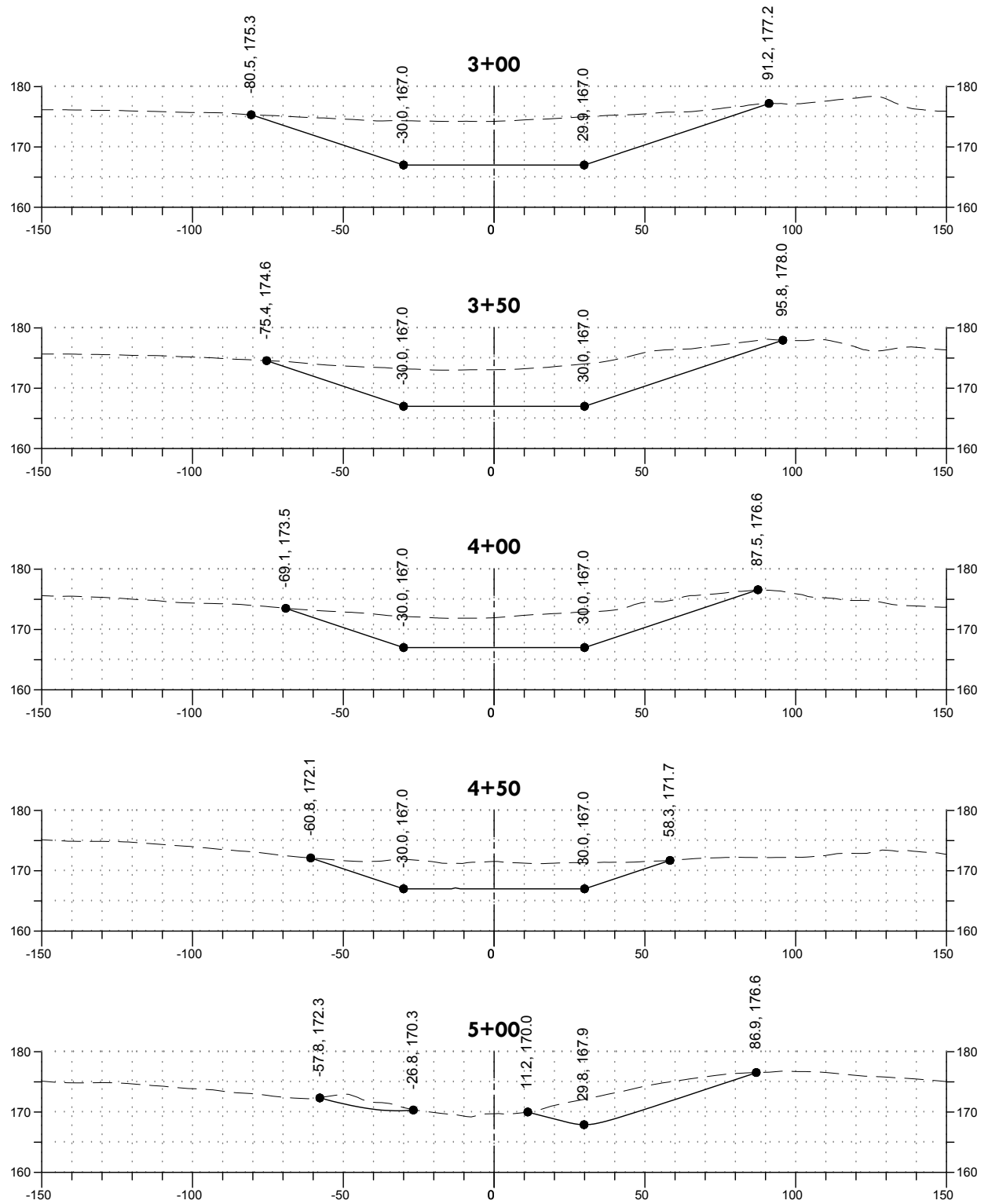
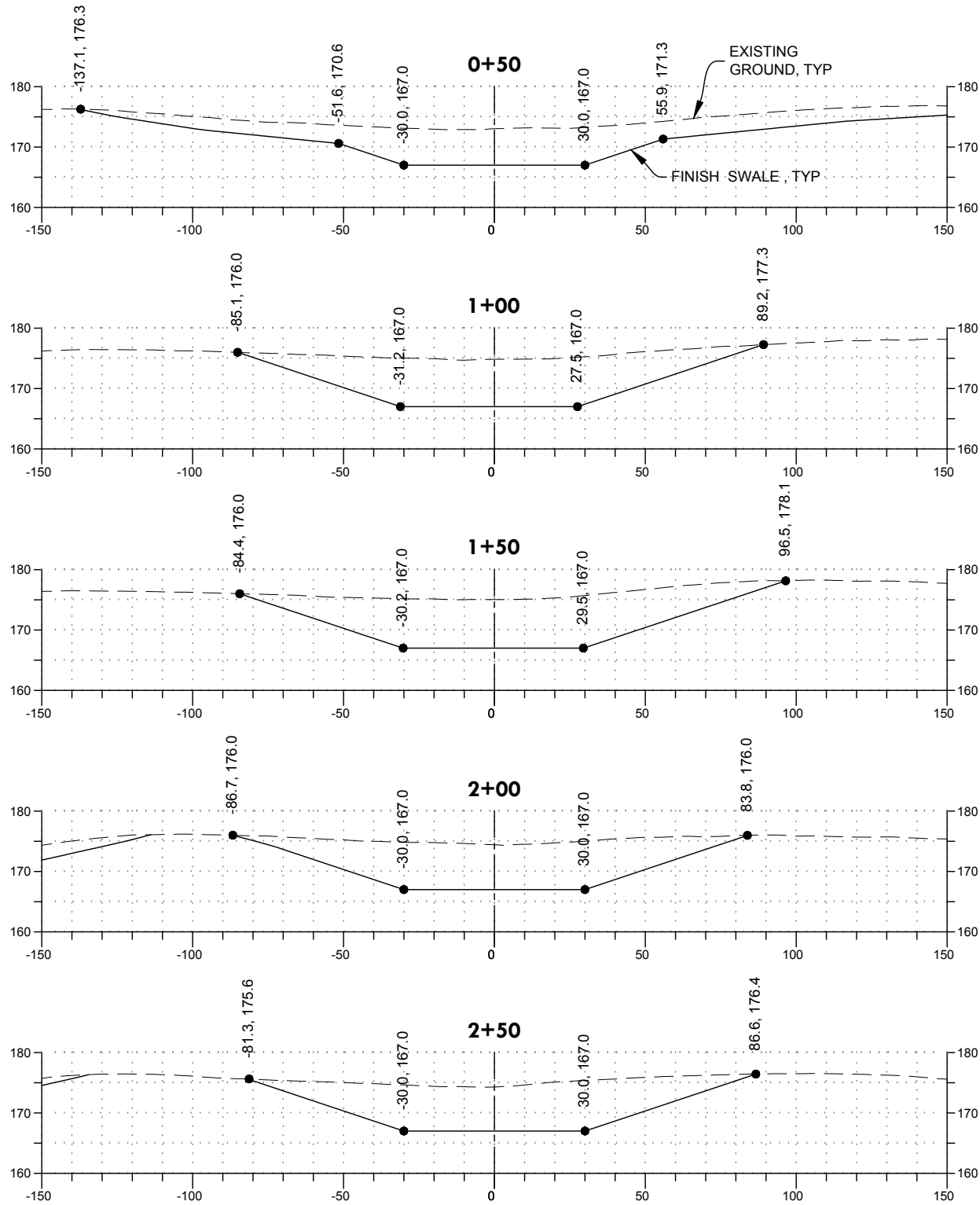
NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

PROJECT NUMBER
RDG-17-009

DRAWING NUMBER
2.16

Drawing 19 of 33

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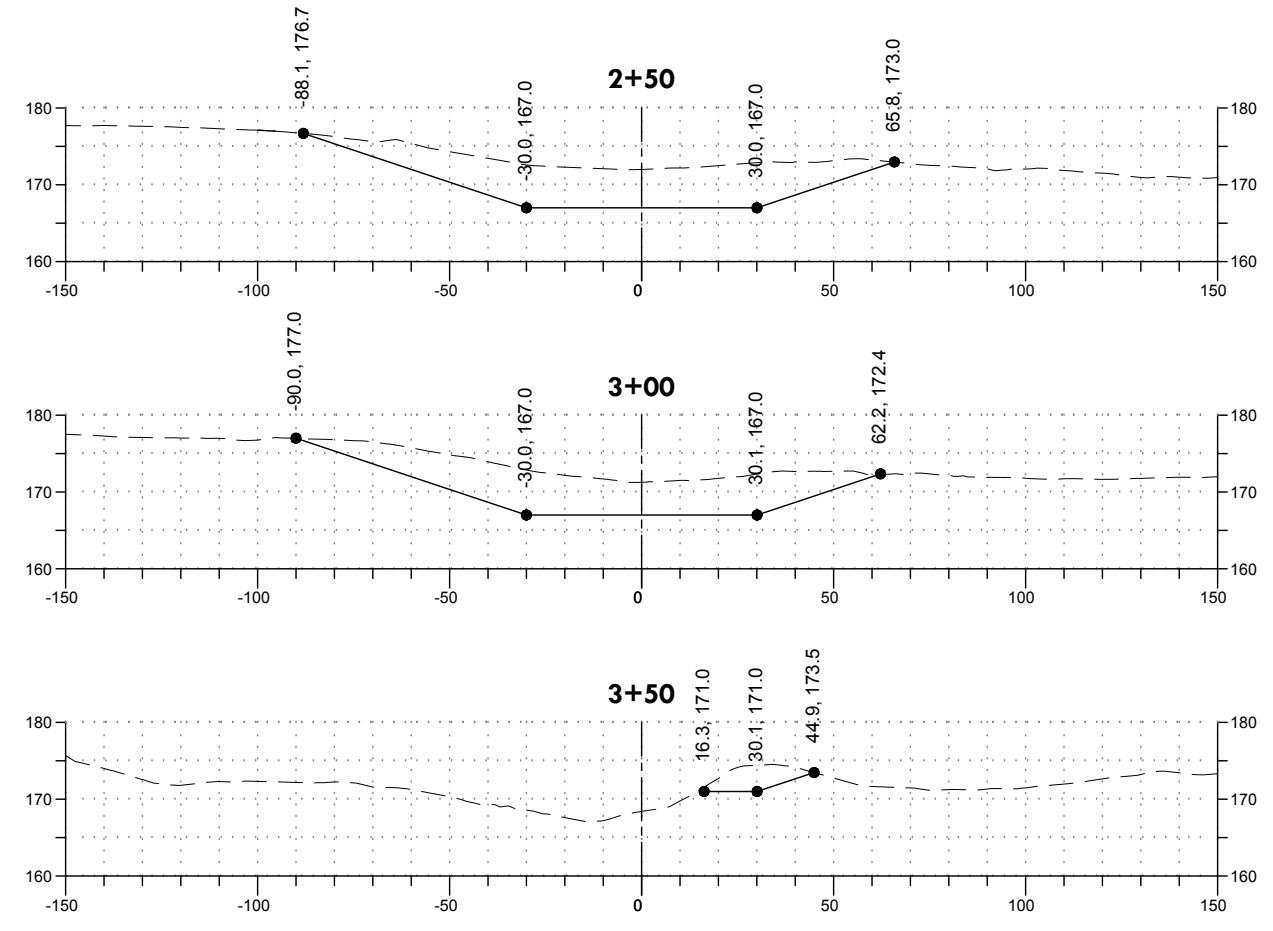
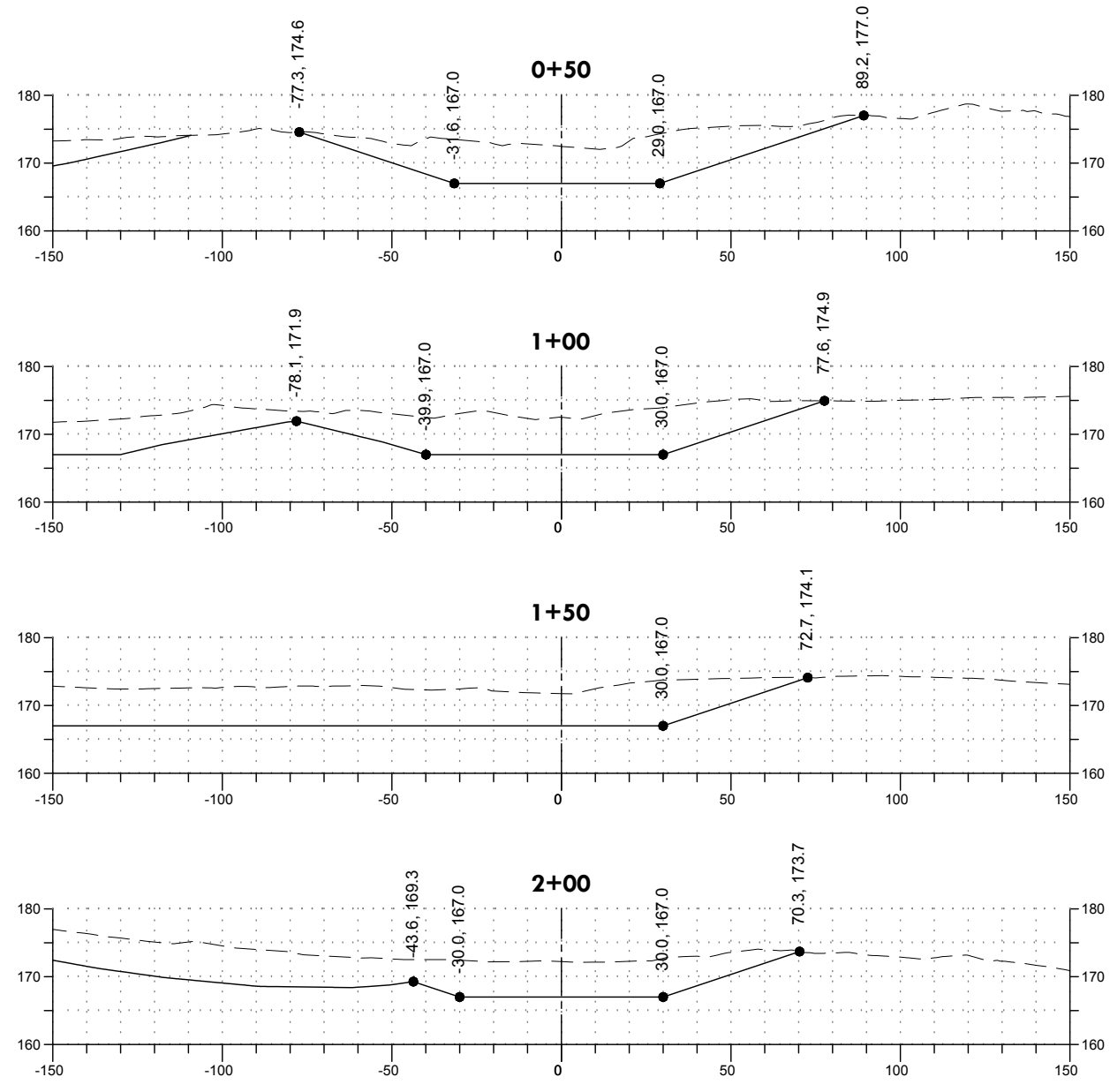
1 SITE 7 - ALTERNATIVE E
WEST SWALE DESIGN SECTIONS

HORIZ 1" = 50'
VERT 1" = 25'

**SITE 7 - ALTERNATIVE E WEST
SWALE DESIGN SECTIONS**
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

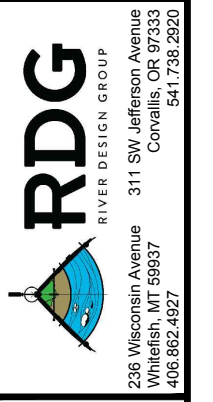
NO.	DATE	BY	DESCRIPTION	CHK
				SW
*	09/27/17	TF	CONCEPTS	

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1 **SITE 7 - ALTERNATIVE E**
NORTH SWALE DESIGN SECTIONS

HORIZ 1" = 50'
VERT 1" = 25'



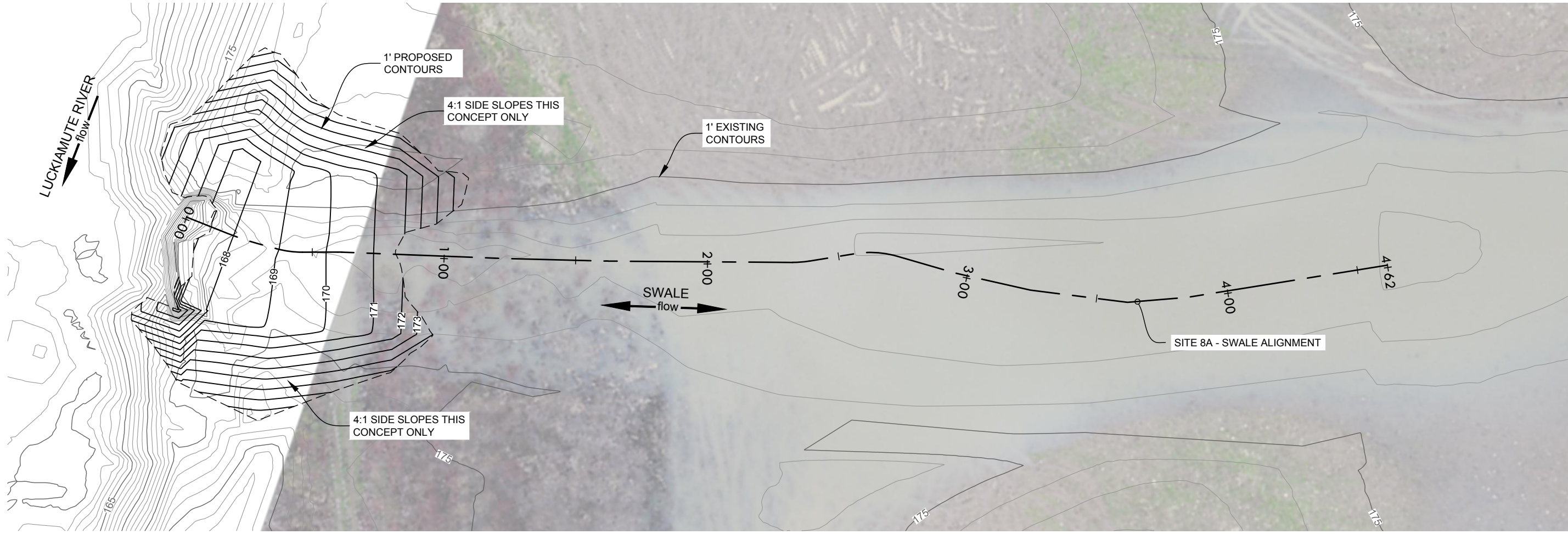
SITE 7 - ALTERNATIVE E NORTH
SWALE DESIGN SECTIONS
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW
PROJECT NUMBER RDG-17-009				
DRAWING NUMBER 2.18				
Drawing 21 of 33				

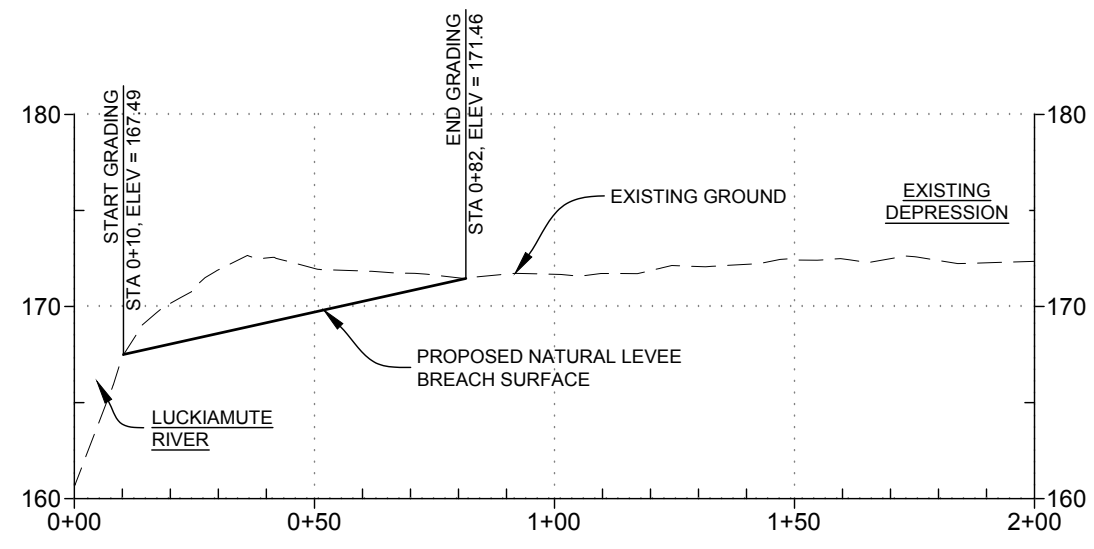


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SITE 8 - ALTERNATIVE A
PLAN AND PROFILE
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR



1 **SITE 8 - ALTERNATIVE A PROPOSED LAYOUT**
1" = 40'



2 **SITE 8 - ALTERNATIVE A SWALE PROFILE**
HORIZ 1" = 40'
VERT 1" = 10'

ALTERNATIVE DESCRIPTION

GRADE 70 FT OF THE NATURAL LEVEE AT THE SWALE CONFLUENCE WITH THE LUCKIAMUTE RIVER. THE DOWNSTREAM GRADING WILL BE TO AN ELEVATION OF 167.5 FT. GRADING WILL DAYLIGHT INTO THE EXISTING SWALE AT AN ELEVATION OF 171.5 FT.

SITE 8 - ALTERNATIVE A ESTIMATED QUANTITIES	
CUT VOLUME	1,265 CY
LENGTH OF REMOVAL	72 FT
AREA OF REMOVAL	10,557 SQ. FT.

NEAT LINE VOLUME

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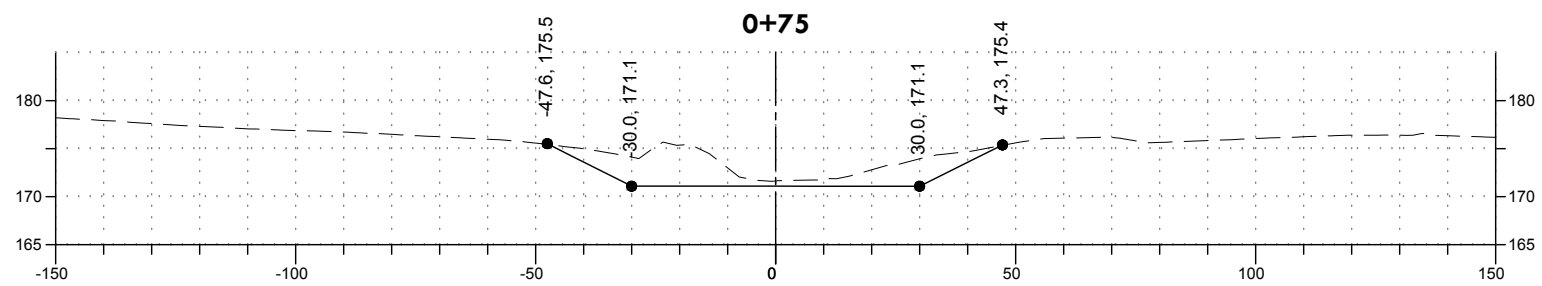
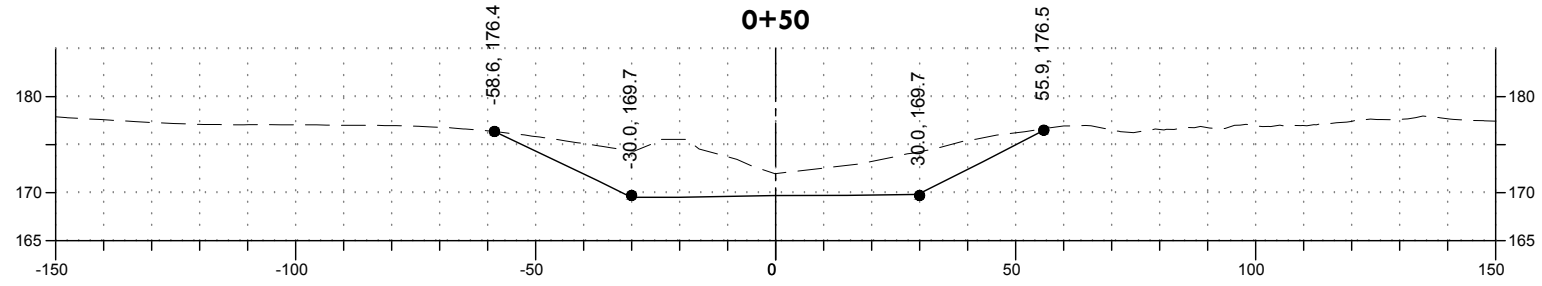
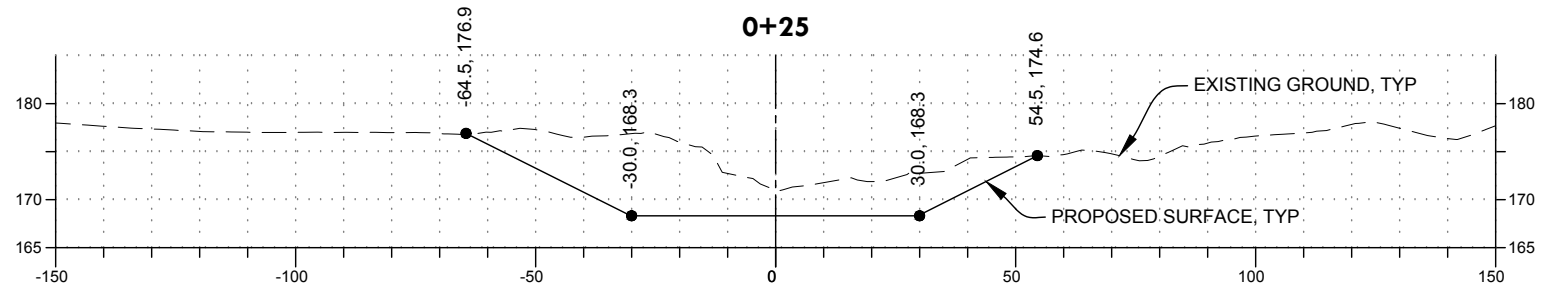
PROJECT NUMBER
RDG-17-009

DRAWING NUMBER

3.0

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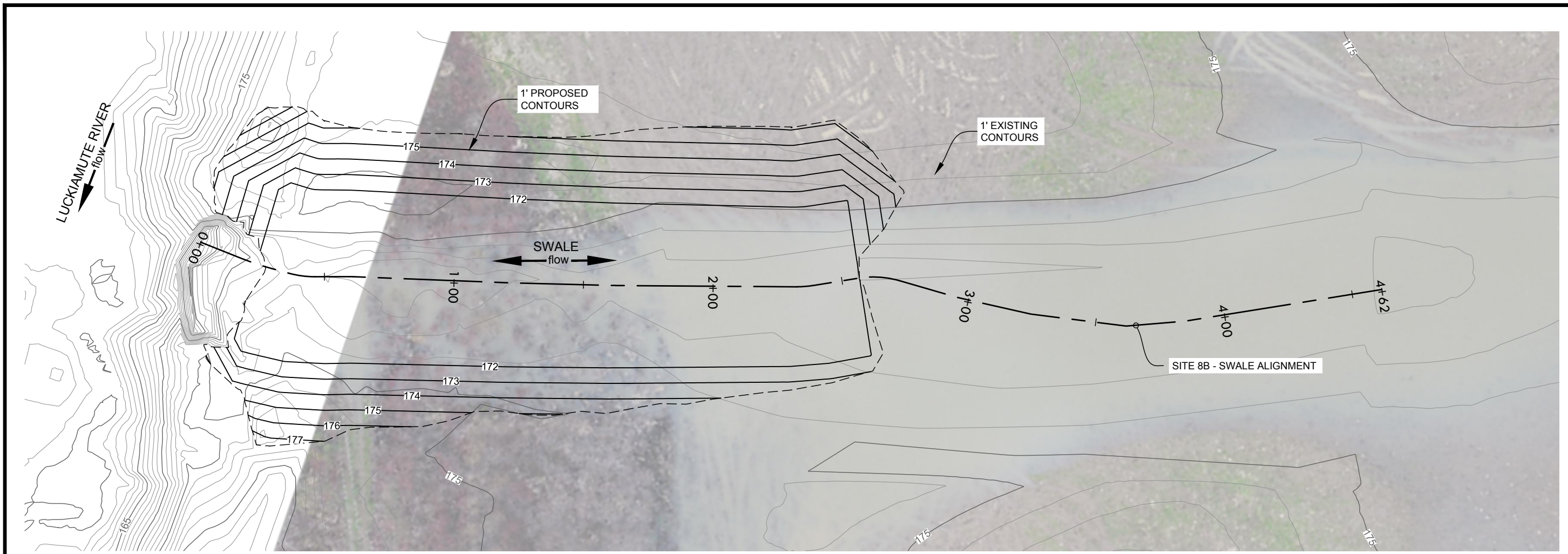


1 **SITE 8 - ALTERNATIVE A**
SWALE DESIGN SECTIONS

HORIZ 1" = 40'
 VERT 1" = 20'

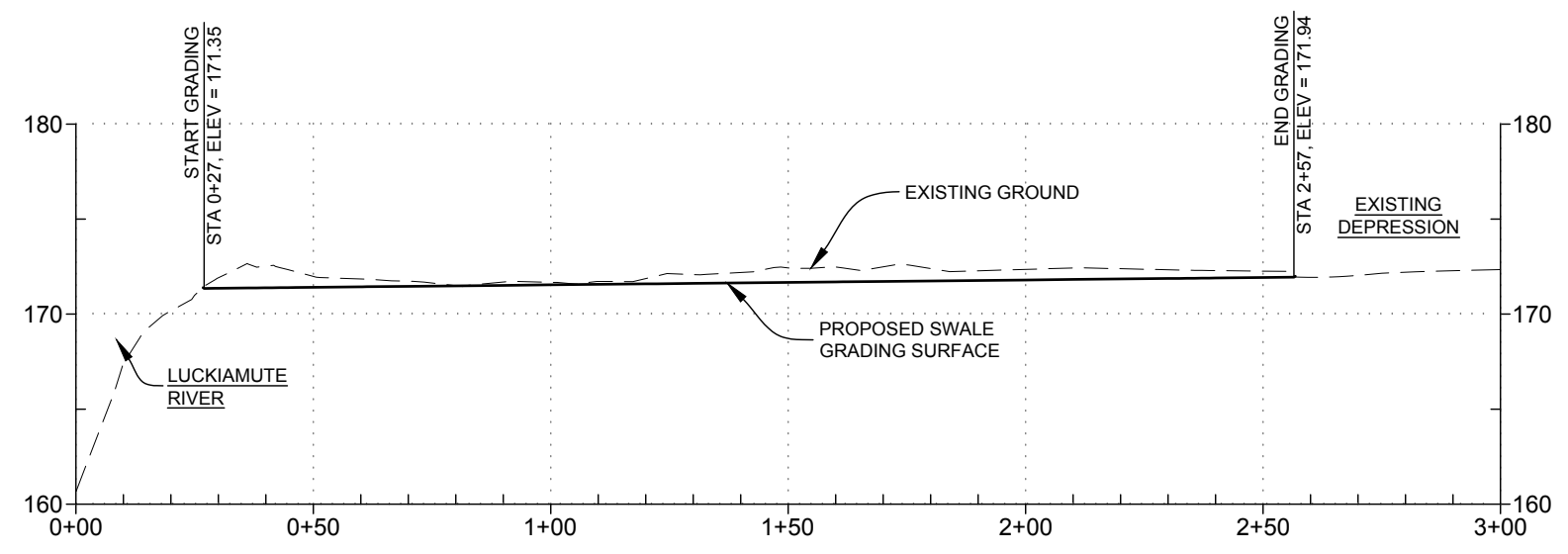
SITE 8 - ALTERNATIVE A
DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW



1 **SITE 8 - ALTERNATIVE B PROPOSED LAYOUT**

1" = 40'



2 **SITE 8 - ALTERNATIVE B SWALE PROFILE**

HORIZ 1" = 40'
VERT 1" = 10'

ALTERNATIVE DESCRIPTION

GRADE 230 FT OF THE SWALE BEGINNING AT AN ELEVATION OF 171.4 FT AT THE SWALE CONFLUENCE WITH THE LUCKIAMUTE RIVER, DAYLIGHTING AT AN ELEVATION OF 172.0 FT.

SITE 8 - ALTERNATIVE B ESTIMATED QUANTITIES	
CUT VOLUME	1,671 CY
LENGTH OF REMOVAL	230 FT
AREA OF REMOVAL	27,054 SQ. FT.

NET LINE VOLUME

**SITE 8 - ALTERNATIVE B
PLAN AND PROFILE**
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

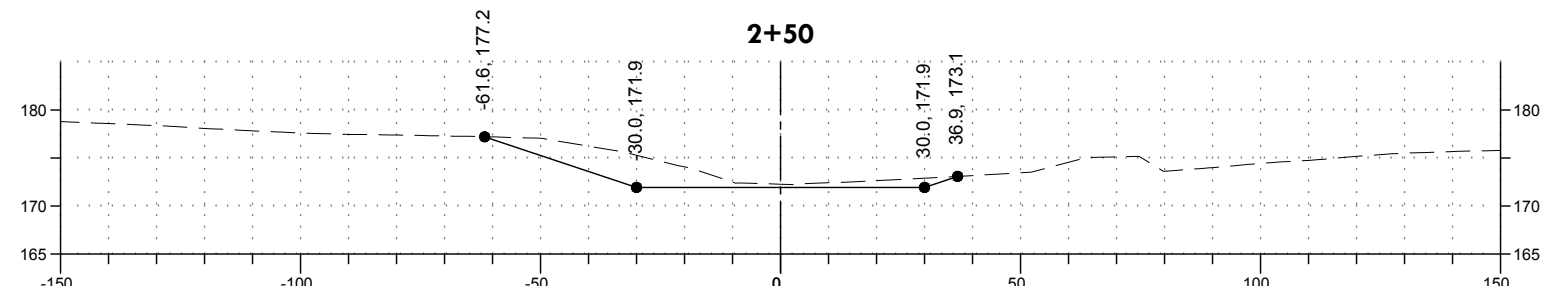
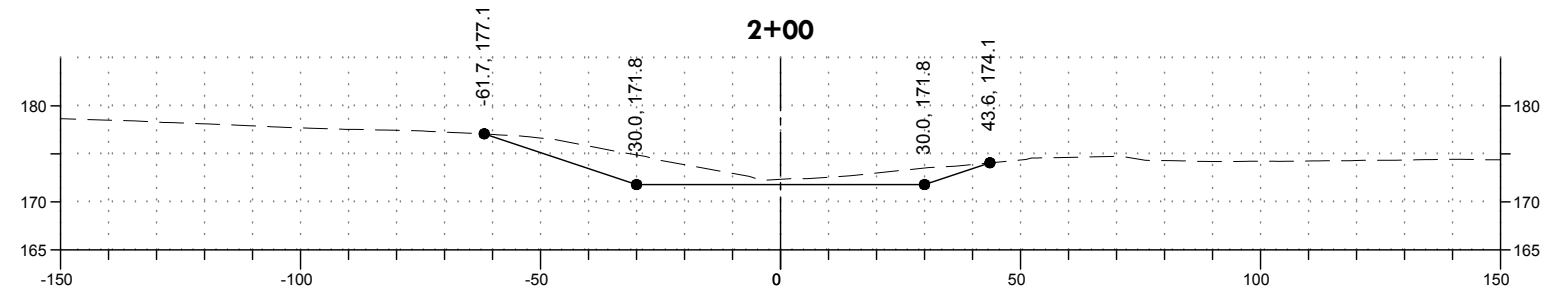
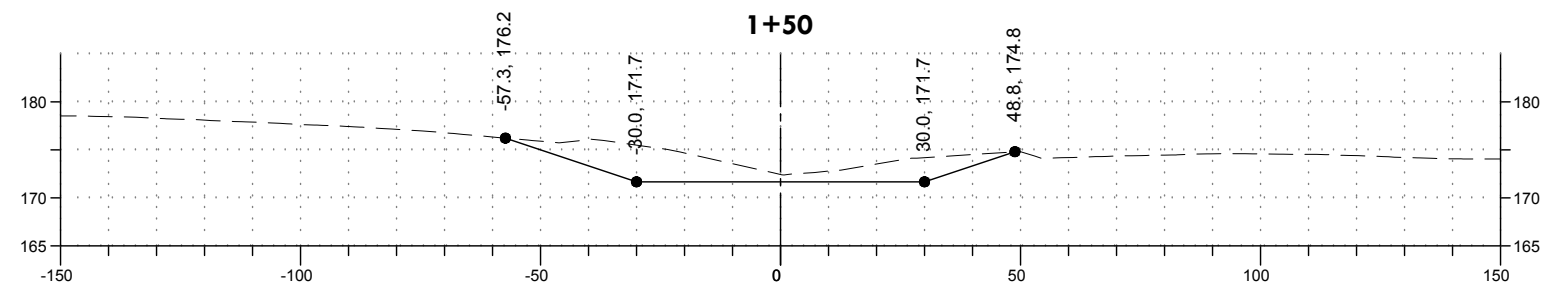
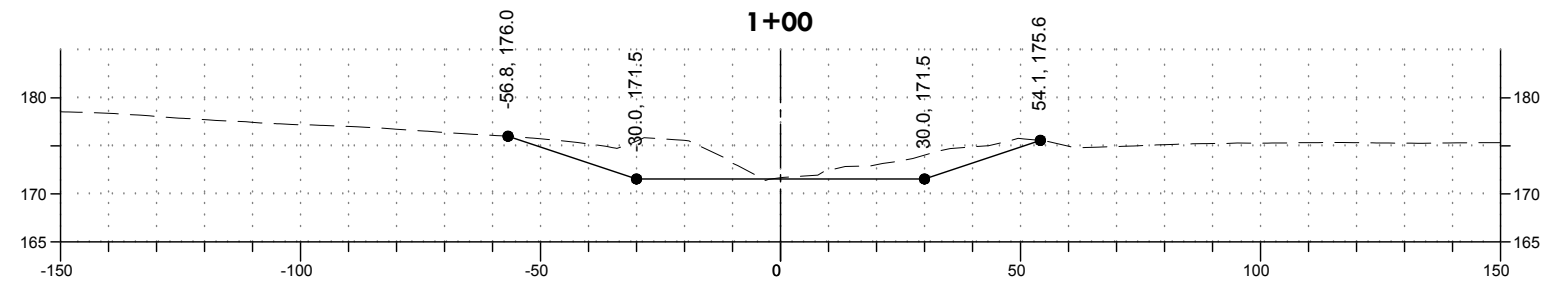
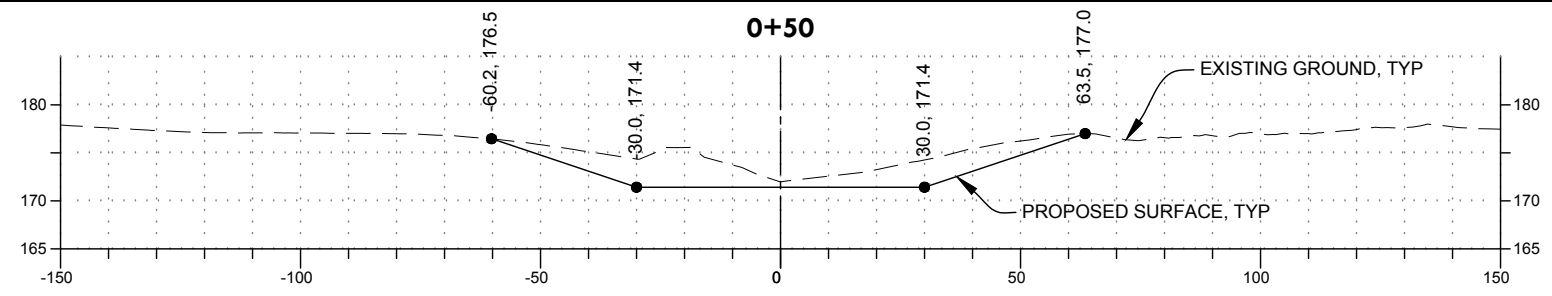
PROJECT NUMBER
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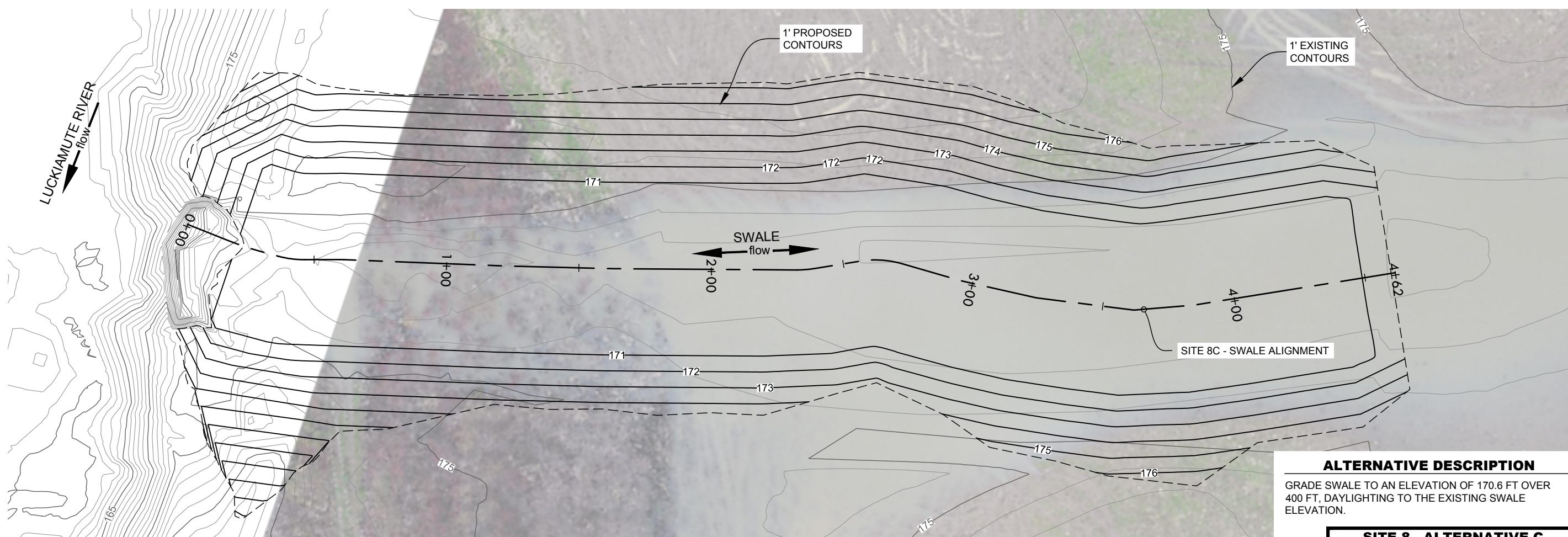
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1 **SITE 8 - ALTERNATIVE B**
SWALE DESIGN SECTIONS
 HORIZ 1" = 40'
 VERT 1" = 20'

SITE 8 - ALTERNATIVE B
DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

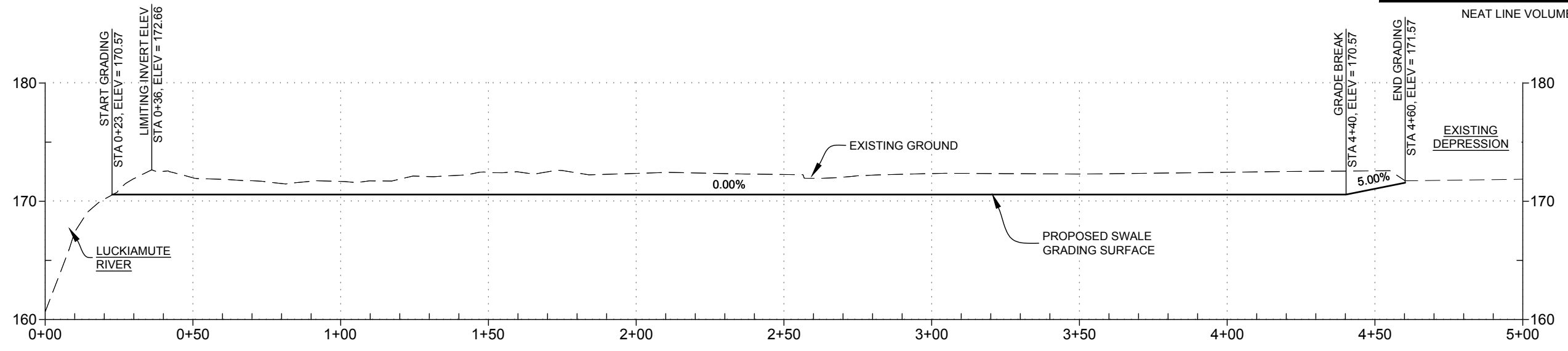
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*	09/27/17	TF	CONCEPTS	SW



ALTERNATIVE DESCRIPTION
 GRADE SWALE TO AN ELEVATION OF 170.6 FT OVER 400 FT, DAYLIGHTING TO THE EXISTING SWALE ELEVATION.

SITE 8 - ALTERNATIVE C ESTIMATED QUANTITIES	
CUT VOLUME	4,200 CY
LENGTH OF REMOVAL	437 FT
AREA OF REMOVAL	53,990 SQ. FT.

1 SITE 8 - ALTERNATIVE C PROPOSED LAYOUT
 1" = 40'



2 SITE 8 - ALTERNATIVE C SWALE PROFILE
 HORIZ 1" = 40'
 VERT 1" = 10'

**SITE 8 - ALTERNATIVE C
 PLAN AND PROFILE**
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

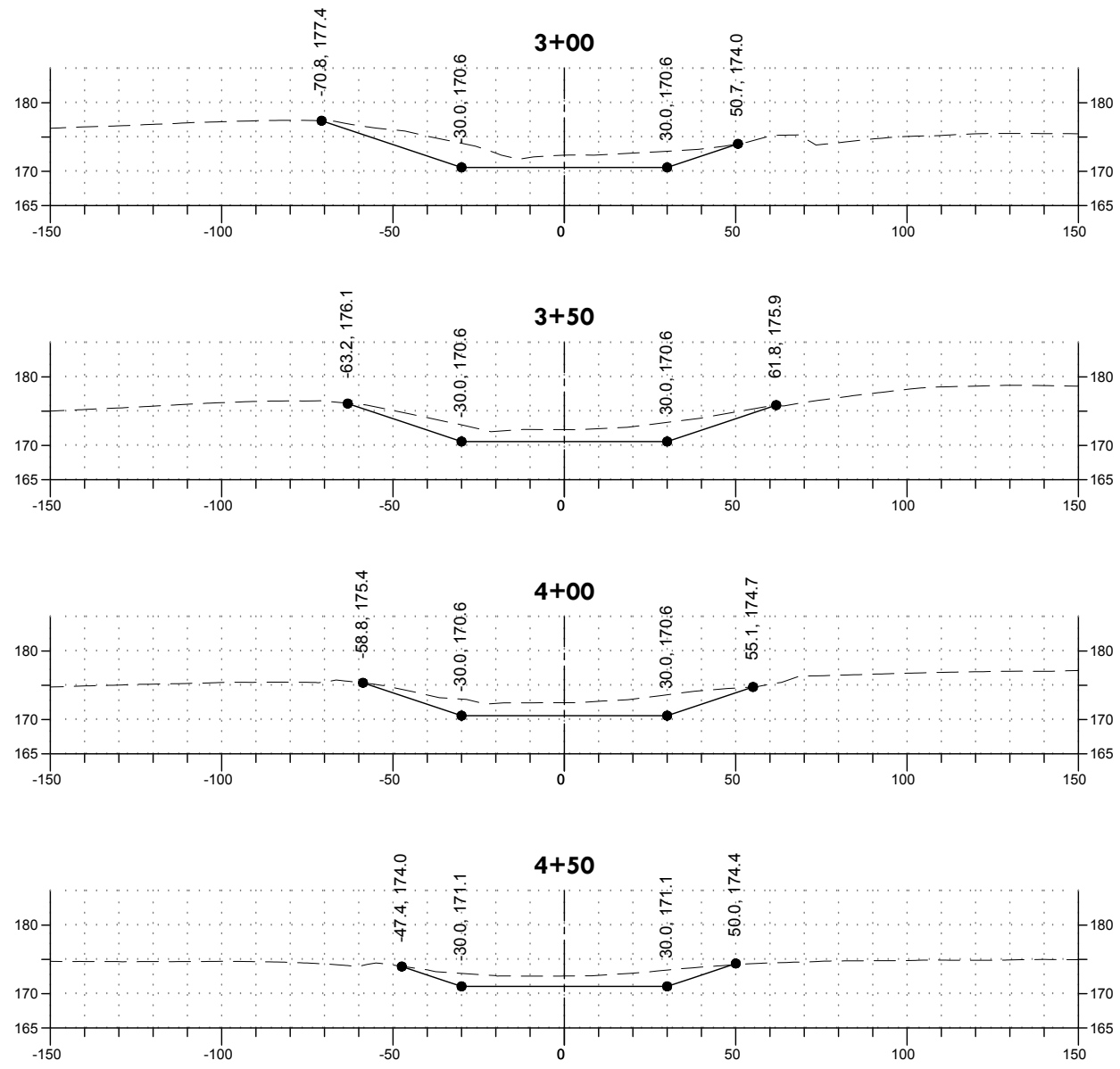
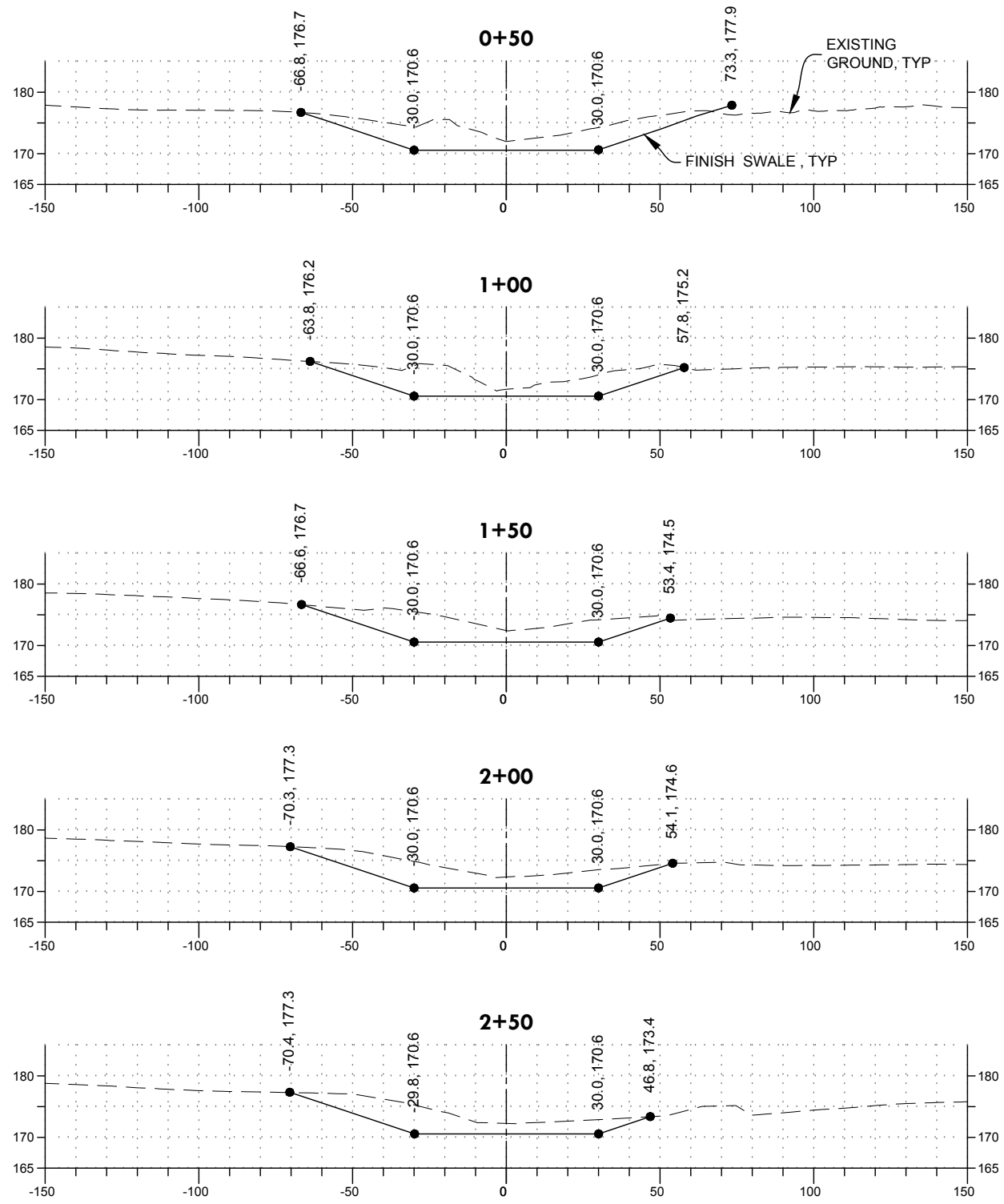
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*	09/27/17	TF	CONCEPTS	SW

PROJECT NUMBER
RDG-17-009

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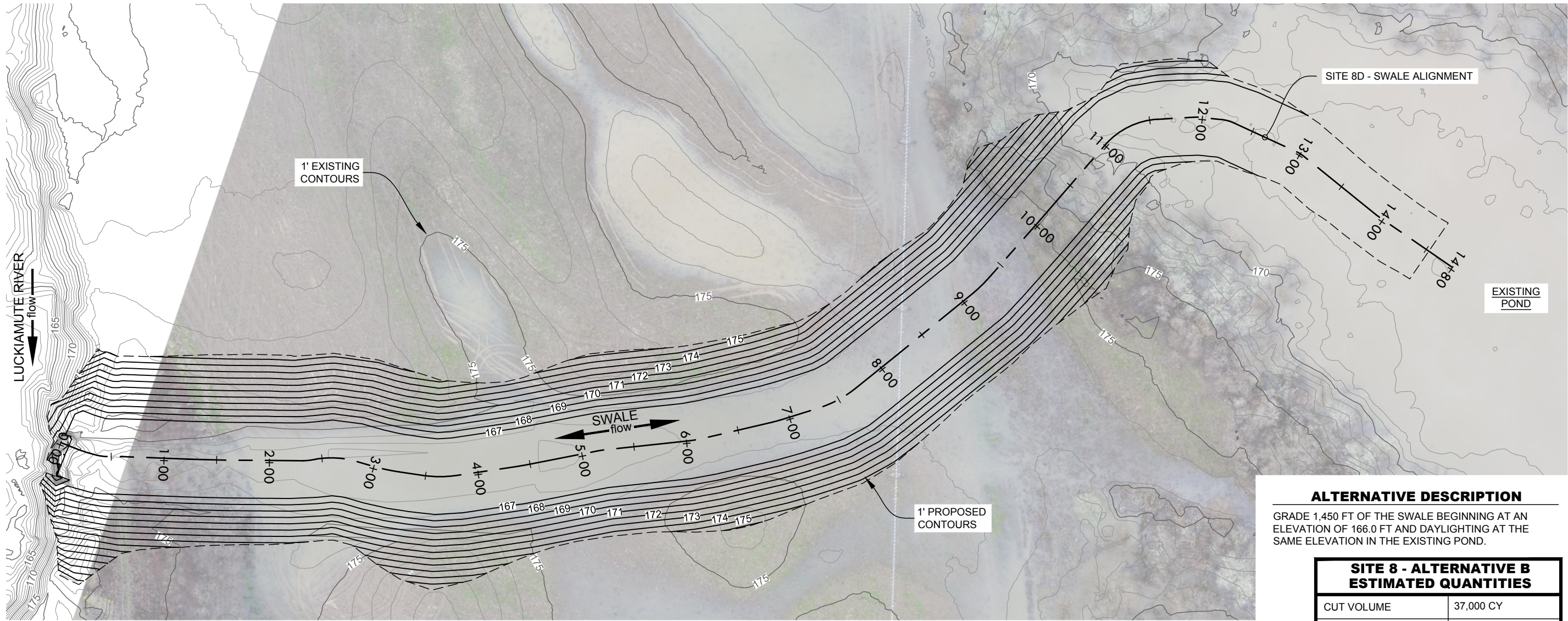


1 SITE 8 - ALTERNATIVE C
SWALE DESIGN SECTIONS

HORIZ 1" = 50'
VERT 1" = 25'

SITE 8 - ALTERNATIVE C
DESIGN SECTIONS
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		



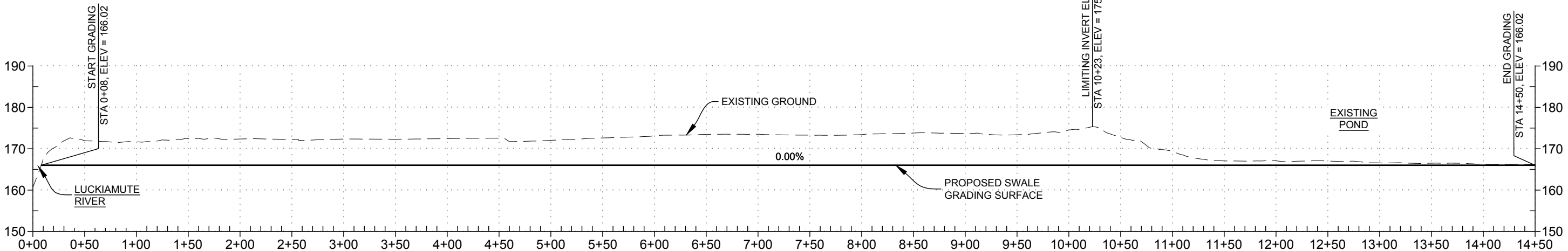
ALTERNATIVE DESCRIPTION
 GRADE 1,450 FT OF THE SWALE BEGINNING AT AN ELEVATION OF 166.0 FT AND DAYLIGHTING AT THE SAME ELEVATION IN THE EXISTING POND.

SITE 8 - ALTERNATIVE B ESTIMATED QUANTITIES	
CUT VOLUME	37,000 CY
LENGTH OF REMOVAL	1,442 FT
AREA OF REMOVAL	213,960 SQ. FT.

NEAT LINE VOLUME

**1 SITE 8 - ALTERNATIVE D
PROPOSED LAYOUT**

1" = 100'



**2 SITE 8 - ALTERNATIVE D
SWALE PROFILE**

HORIZ 1" = 100'
VERT 1" = 25'

**SITE 8 - ALTERNATIVE D
PLAN AND PROFILE**
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

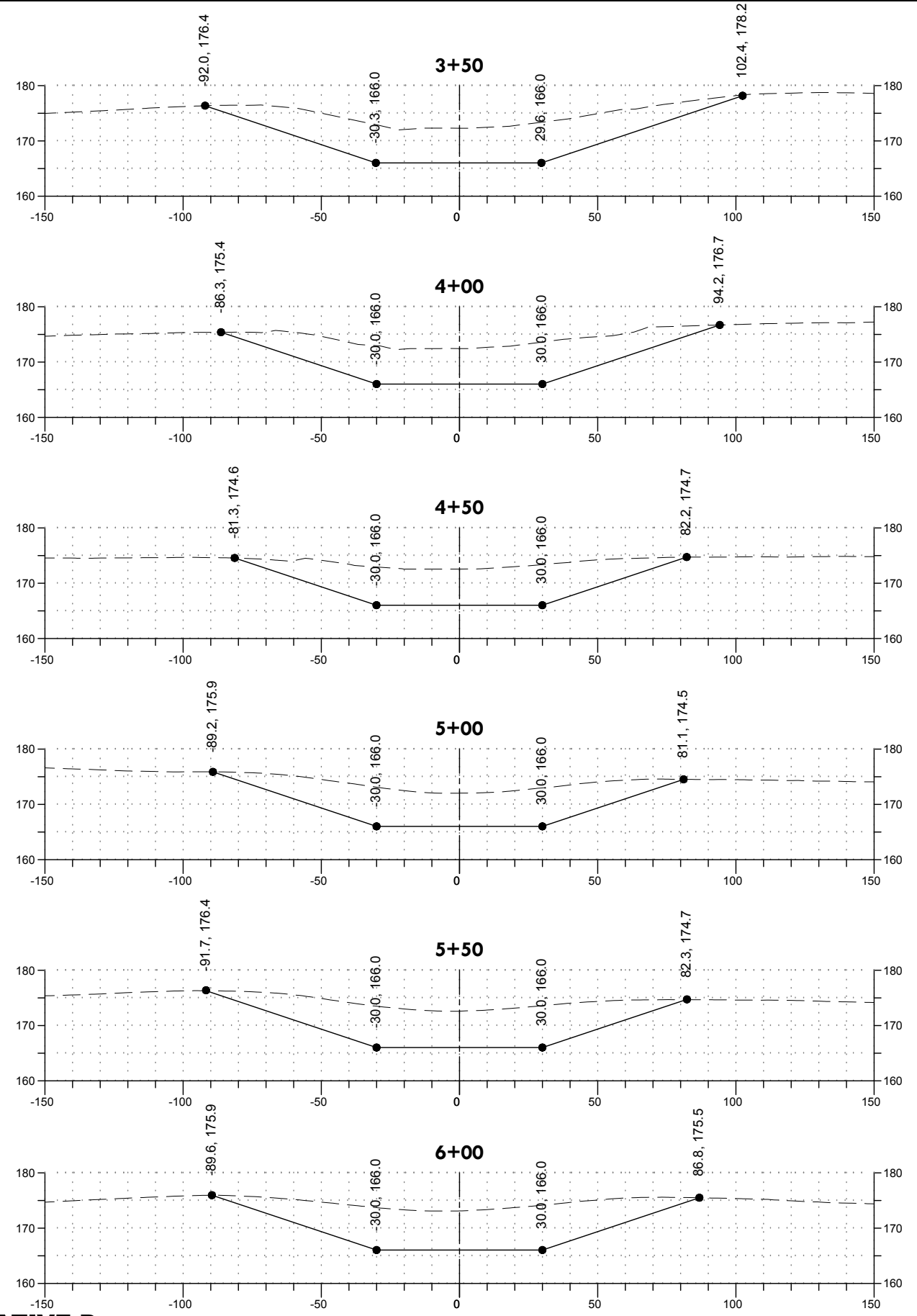
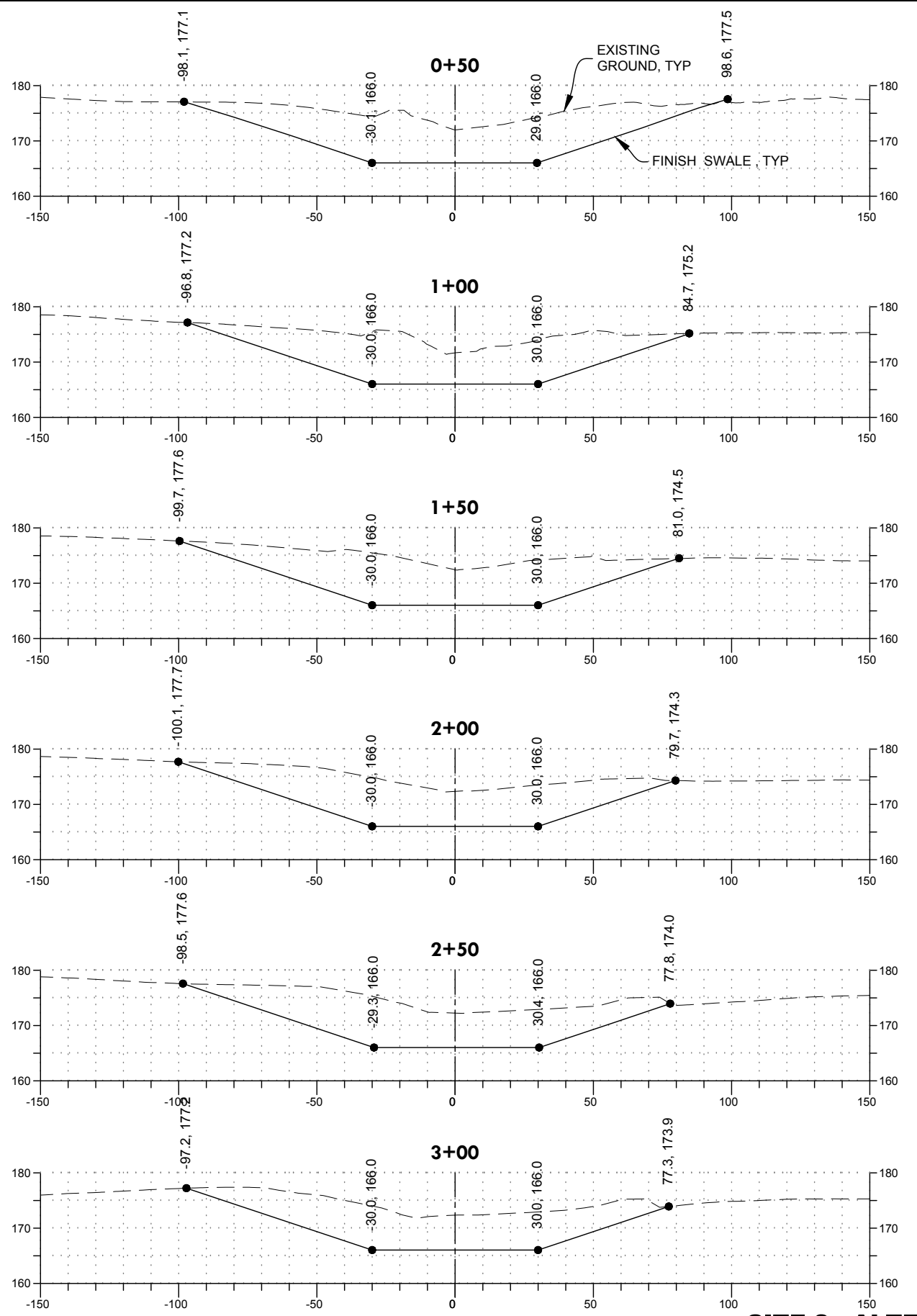
PROJECT NUMBER
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**SITE 8 - ALTERNATIVE D
SWALE DESIGN SECTIONS**

1

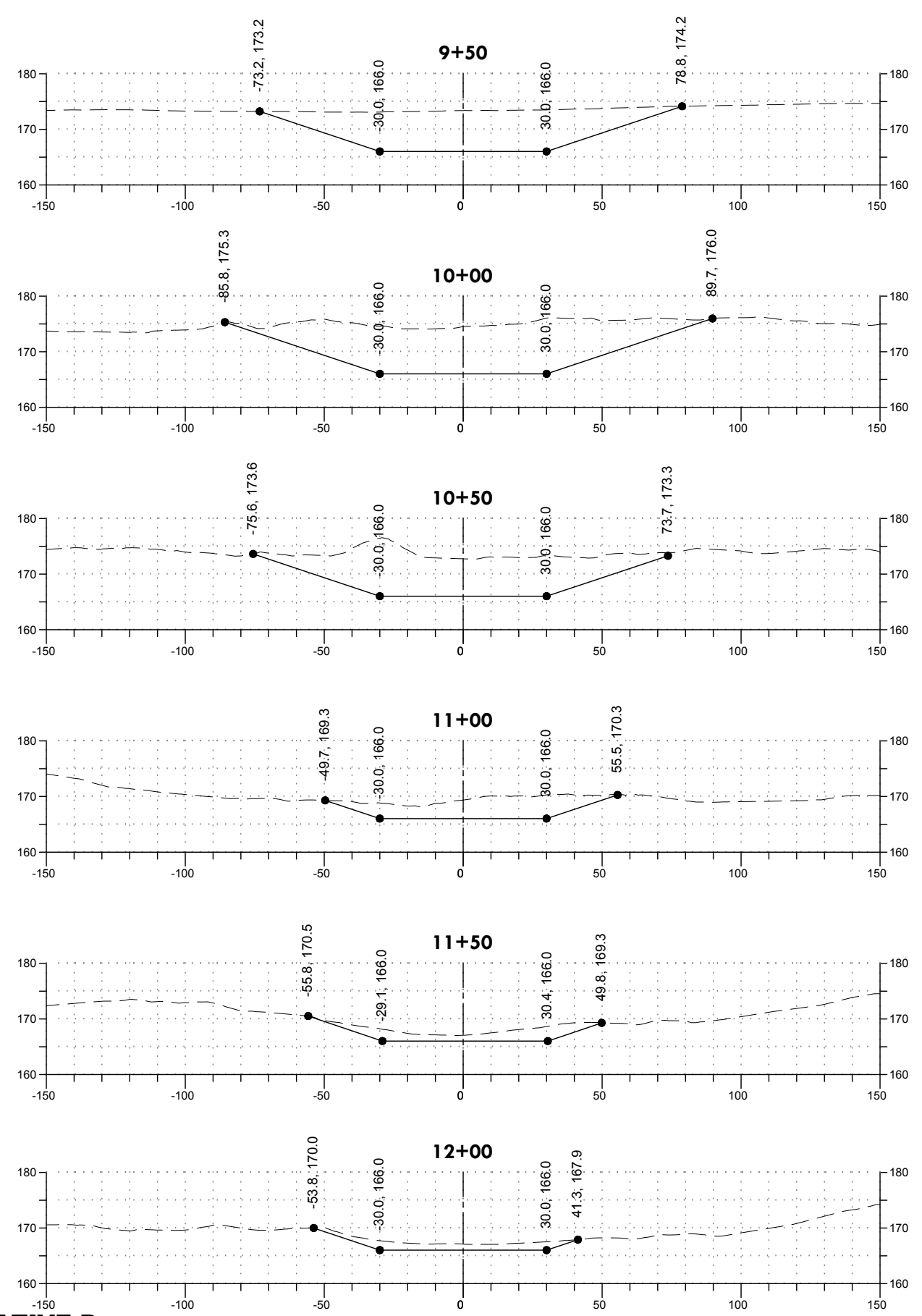
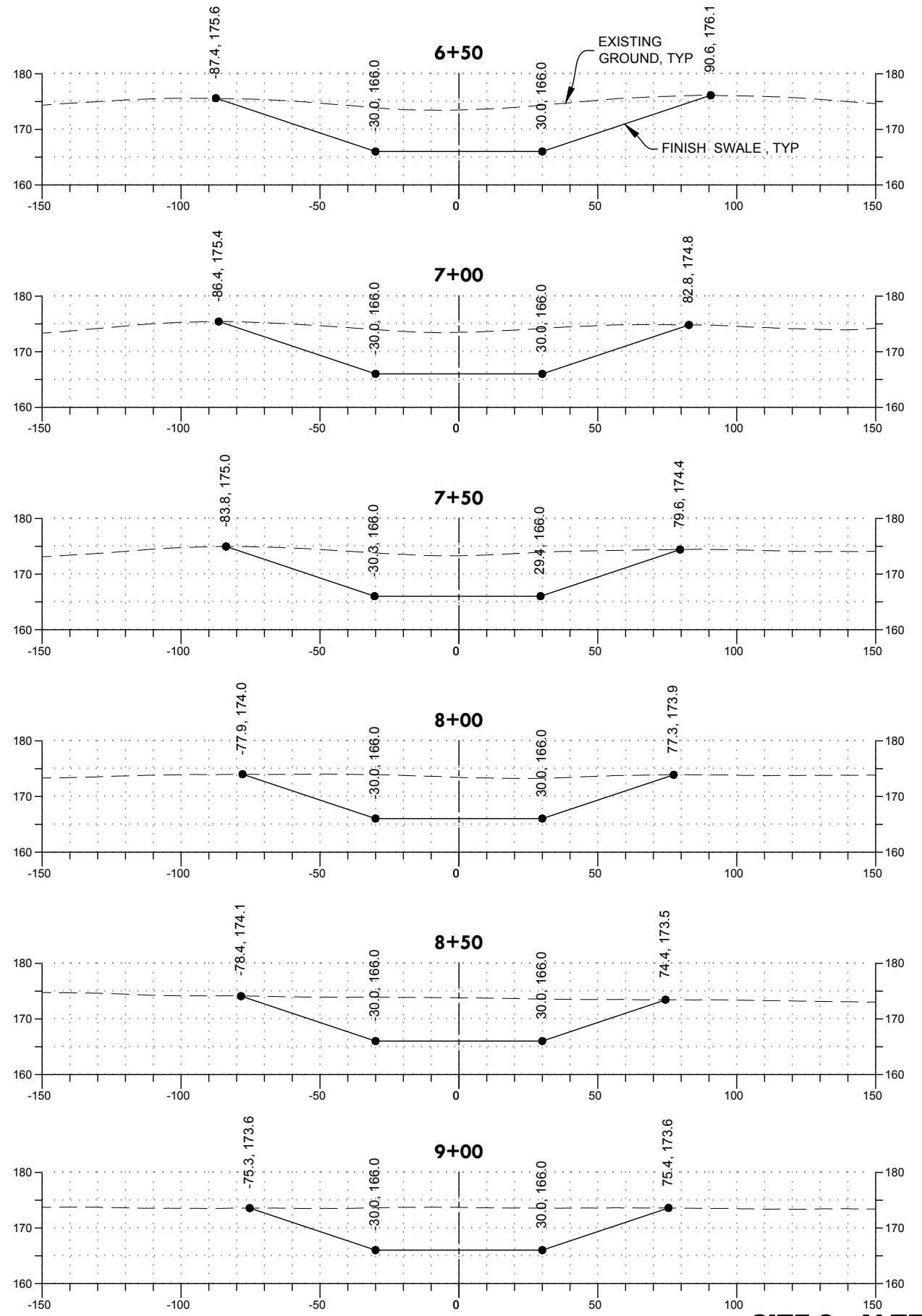
HORIZ 1" = 50'
VERT 1" = 25'

**SITE 8 - ALTERNATIVE D
DESIGN SECTIONS**
LSNA FLOODPLAIN RECONNECTION
BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
*	09/27/17	TF	CONCEPTS		

PROJECT NUMBER
RDG-17-009
DRAWING NUMBER
3.7
Drawing 29 of 33

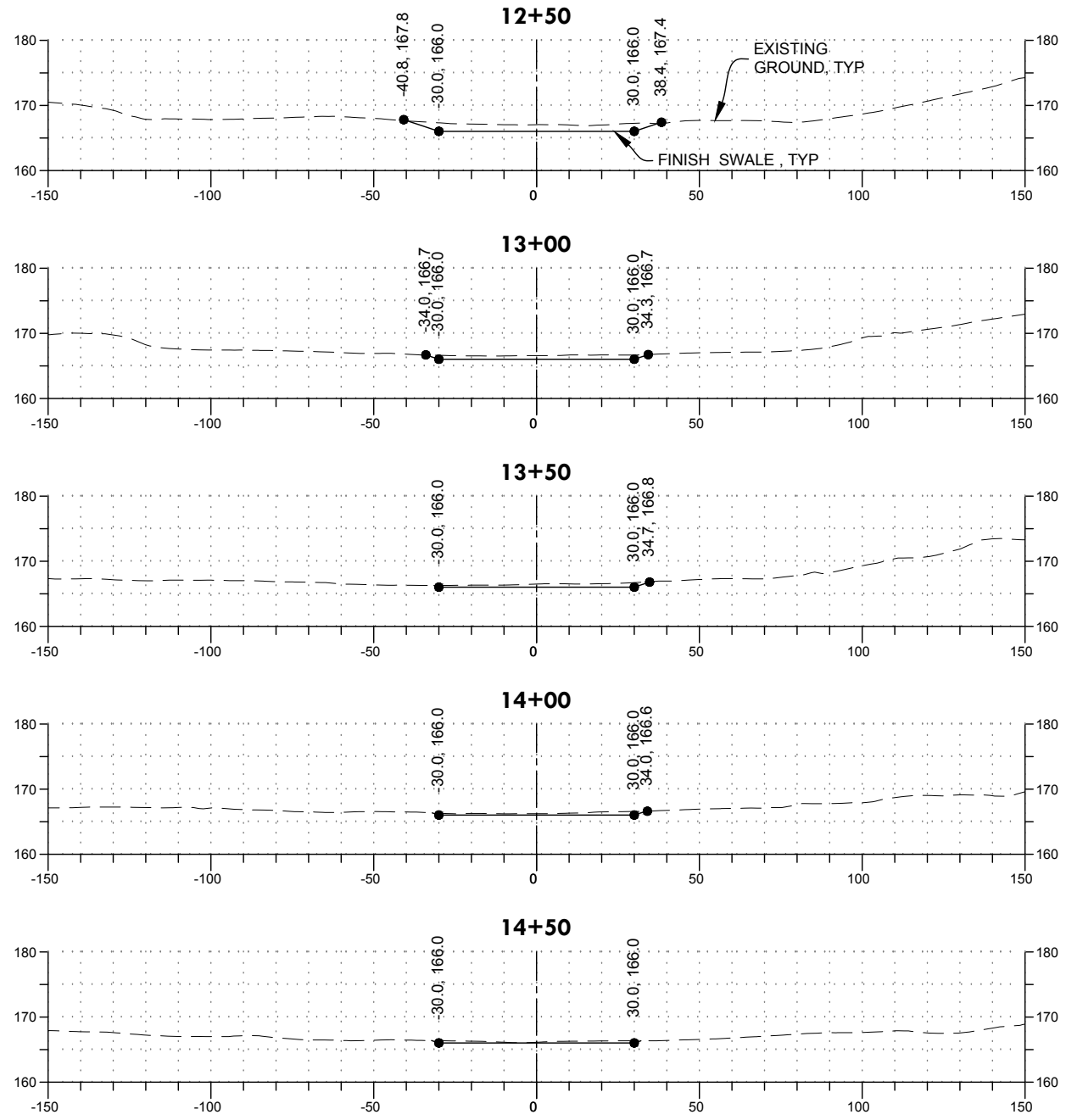
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1 **SITE 8 - ALTERNATIVE D SWALE DESIGN SECTIONS**
 HORIZ 1" = 50'
 VERT 1" = 25'

**SITE 8 - ALTERNATIVE D
 DESIGN SECTIONS**
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK	
				SW	
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1 **SITE 8 - ALTERNATIVE D**
SWALE DESIGN SECTIONS
 HORIZ 1" = 50'
 VERT 1" = 25'



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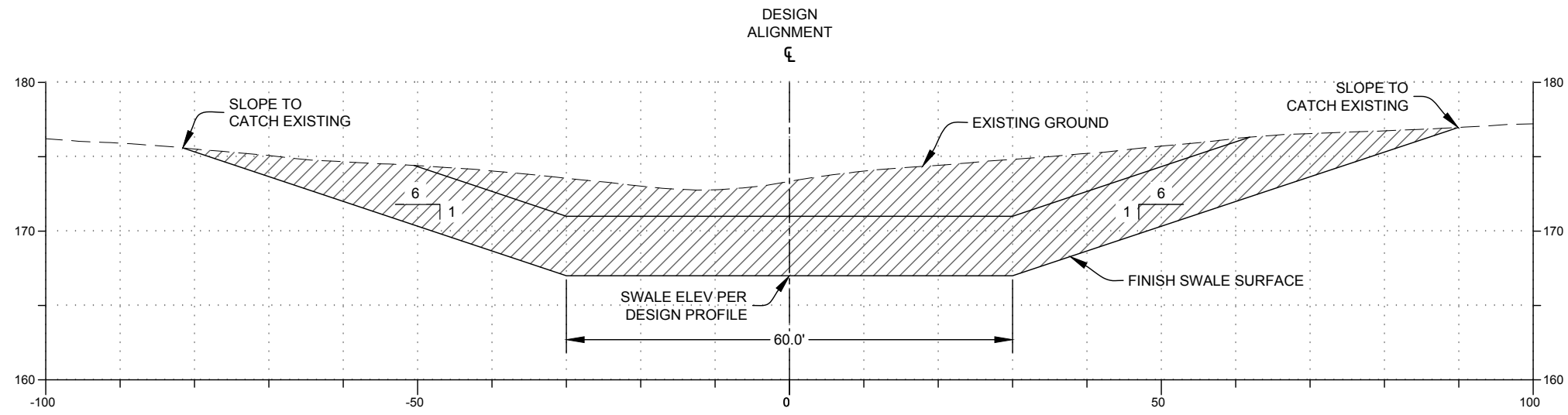
311 SW Jefferson Avenue
 Corvallis, OR 97333
 541.738.2920

SITE 8 - ALTERNATIVE D
DESIGN SECTIONS
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
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PROJECT NUMBER
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DRAWING NUMBER
3.9



1 SWALE TYPICAL SECTION
 HORIZ 1" = 20'
 VERT 1" = 10'

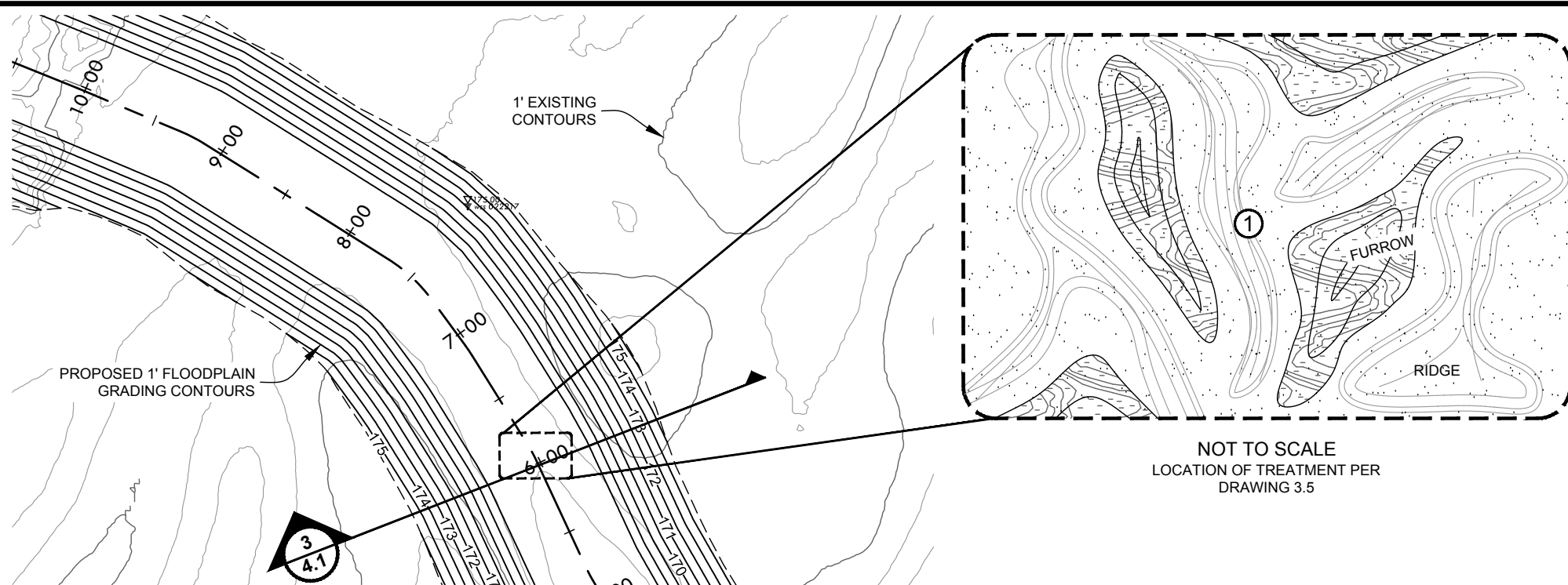
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**SWALE TYPICAL SECTION
 DETAIL**
 LSNA FLOODPLAIN RECONNECTION
 BUENA VISTA, OR

NO.	DATE	BY	DESCRIPTION	CHK
*	09/27/17	TF	CONCEPTS	SW

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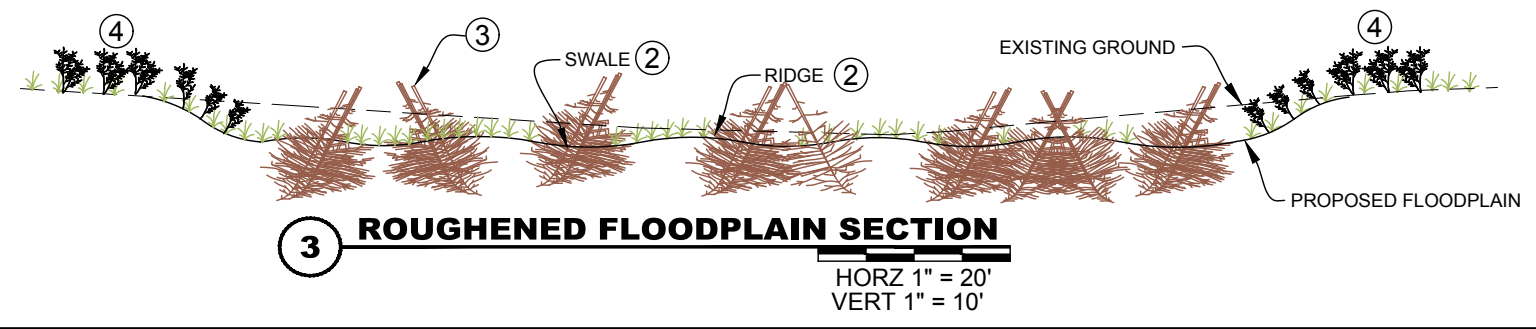
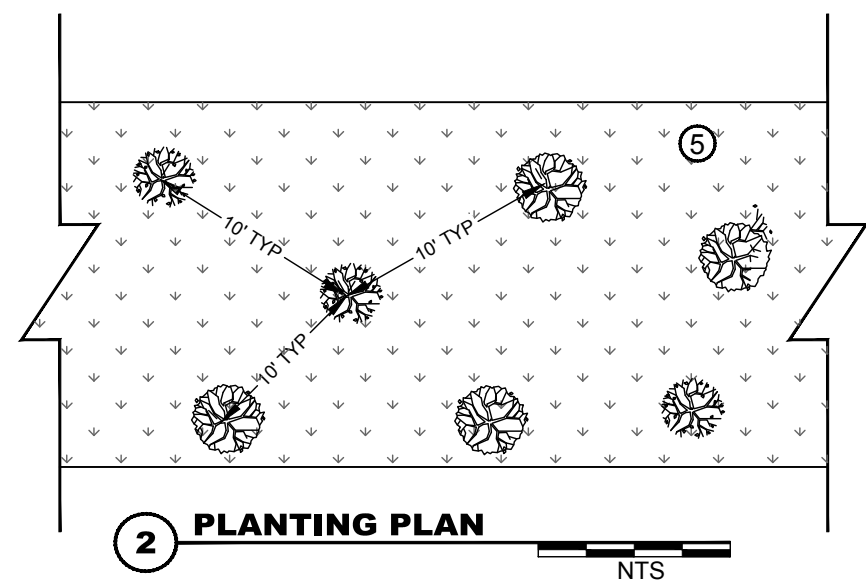
GENERAL NOTES
 SPECIAL ATTENTION SHALL BE TAKEN TO OPERATE EQUIPMENT IN A SAFE AND EFFICIENT MANNER WITH MINIMAL DISTURBANCE OUTSIDE OF GRADING LIMITS UNLESS OTHERWISE SPECIFIED. ROUGHEN FLOODPLAIN BY EXCAVATING RIDGES AND SWALES UPON FLOODPLAIN SURFACES AND BURYING WOOD DEBRIS INTO THE CONSTRUCTED FEATURES.

- CONSTRUCTION NOTES**
- CONTRACTOR SHALL CONSTRUCT SWALES AND RIDGES IN THE FLOODPLAIN AS SHOWN ON THE DRAWINGS. ROUGHENED FLOODPLAIN SHALL EXTEND OVER THE ENTIRE FLOODPLAIN SURFACE IN EACH TREATMENT AREA. APPROXIMATELY 20 PERCENT OF THE TOTAL SURFACE AREA OF EACH TREATMENT AREA SHALL CONSIST OF SWALES AND APPROXIMATELY 20 PERCENT SHALL CONSIST OF RIDGES.
 - SWALES DEPTHS SHALL BE ±0.5 FT BELOW THE FLOODPLAIN SURFACE GRADE ±0.5 FIVE (5) FT LONG BY THREE (3) FT WIDE. RIDGES SHOULD BE ±0.5 FT ABOVE SURFACE GRADE BE THREE (3) FT WIDE AND FIVE (5) FT LONG. COMPLETED SURFACE SHALL BE COMPLEX AND IRREGULAR.
 - CONTRACTOR SHALL THEN PLACE SMALL LOGS (6-12 INCH DIAMETER 10-15 FEET LONG) AND BRUSH DEBRIS (3-6 INCH DIAMETER 5-8 FEET LONG WITH LIMBS) WITHIN THE ROUGHENED FLOODPLAIN TREATMENT AREA AS SHOWN ON THE DRAWINGS. SMALL LOGS AND BRUSH DEBRIS SHALL BE BURIED MINIMUM 50% OF STEM LENGTH WITHIN THE FLOODPLAIN SURFACE. PLACEMENT DENSITY SHALL BE AT A DISTANCE OF 30 FEET FOR SMALL LWD AND 20 FEET FOR BRUSH DEBRIS OR AS DIRECTED BY THE CONSTRUCTION MANAGER.
 - COMPLETED ROUGHENED FLOODPLAIN SURFACE SHALL BE RE-VEGETATED WITH SALVAGED OR TRANSPLANTED VEGETATION AT LOCATIONS IDENTIFIED BY THE CONSTRUCTION MANAGER.
 - SEEDING SHALL BE PERFORMED ON CONSTRUCTION SURFACES ACCORDING TO EROSION CONTROL PLANS.



FLOODPLAIN ROUGHNESS TREATMENT QUANTITIES (ACRES TBD)

ITEM	QUANTITY (EACH)	DIAMETER (IN)	LENGTH (FT)	ROOTWADS	LIMBS
BRUSH	TBD	3 - 6	5 - 8	OPTIONAL	YES
SMALL LOGS	TBD	6 - 12	10 - 15	OPTIONAL	YES



EXAMPLE OF CONSTRUCTED FLOODPLAIN SWALES

NO.	DATE	BY	DESCRIPTION	CHK	
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