Final Report
Phase 2 Milwaukee Estuary Area of Concern (AOC)
Fish Spawning Reef Project 2014
Will Wawrzyn, WDNR

1. SUMMARY

The Wisconsin Department of Natural Resources (WDNR) constructed Phase 2 of the Milwaukee Estuary Area of Concern (AOC) fish spawning habitat project during October 2014. The project involved the modification and expansion of the existing Phase 1, 0.45-acre rock reef constructed in 2006 (Wawrzyn, 2007). Both phases of the reef project were planned to meet over lapping spawning life-requisites of walleye, lake sturgeon and other game and non-game simple lithophilic spawning fishes, and contribute to de-listing the Milwaukee Estuary AOC Beneficial Use Impairments (BUIs) impacting fish populations and their habitat.

Modifications to the existing reef involved lowering a portion of the existing rock reef to reduce the frequency that areas of the reef are desiccated by long-term (monthly-annual) decreasing Lake Michigan water levels, and more frequent short-term (hourly) fluctuations in water levels caused by lake seiche amplified through the Milwaukee River's long and confined connecting channel. The existing reef elevations ranged from 576.0-ft to 577.4-ft. Based on Lake Michigan's 95-year record low elevation of 576.02-ft and seiche of $\pm$0.8-ft observed during construction of the Phase 1 reef, the planned maximum elevation for modifying or expanding the reef was proposed to be 575.0-ft[1].

The plan to expand the existing reef by 0.4-acres and 200-linear feet was not feasible. Lake levels increased by 1.7-ft between the planning and construction phase of the project. Higher lake levels required a reduction in the reef length as greater volumes of rock were needed to construct a wider and higher causeway to provide a visible, stable and safe foundation for the contractor equipment and operator.

The existing 0.45 reef was expanded by 0.30-acres and along two planes. It was expanded laterally by 0.10-acres by re-using 80-cubic yards of re-graded alluvial rock plus the addition of 412-cubic yards (900-tons) of 6 to 12-inch limestone rip rap. The existing reef was lowered between 0.5-ft and 1.0-ft to elevations 576.5-ft and 576.0-ft. Lowering the entire existing reef to the desired 575.0-ft elevation was not feasible as it would have exposed areas of the original sandy shoal that the reef was constructed on. The lateral expansion began at the left edge of the re-graded reef at elevation 576.0-ft, extending to the mid-channel at an average slope of 9% and elevation 573.0-ft. The existing reef was expanded downstream by 0.20-acre. The downstream expansion began at the downstream edge of the existing reef for a distance of 150-ft. It had a narrow crest at elevation 575.0-ft extending to the mid-channel at an average slope of 8% and elevation 573.0-ft. The Phase 2 reef project cost was $63,331 or a unit cost of $211,000 per acre.

[1] All report vertical elevations are referenced to the International Great Lakes Datum 1985 (IGLD 1985). For ease of reporting elevation values are rounded to the nearest 0.1-ft. Conversion factors between various vertical datum are provided in Appendix 1.

A comprehensive inventory and management plan for fish and aquatic life habitat is lacking for the Milwaukee Estuary. Should such a plan be developed, it should include an evaluation of the benefits for target species, costs and institutional feasibility of enhancing physical habitat features and restoring native aquatic plants in the Milwaukee Estuary.

The project was made possible by a generous grant from the Fund for Lake Michigan, the WDNR Office of Great Lakes, and assistance from the River Revitalization Foundation (RRF).

2. BACKGROUND

The existing Phase 1 0.45-acre spawning reef was constructed during 2006 specifying 6-inch to 12-inch alluvial rock. The rock was placed onto an existing elliptical-shaped and relatively flat and featureless sandy shoal downstream of the former North Avenue Dam. The elevations of the finished reef ranged from 576.0-ft to 577.4-ft and averaged 576.7-ft and generally followed the surface elevations of the original sandy shoal. The mean lake elevation during the planning and construction of the Phase 1 reef was 577.5-ft or 0.8-ft above the reef's average finished elevation, and approximately equal to the maximum reef elevation of 577.4-ft.

Following construction of the reef in 2006 and continuing through 2013, the general trend was for decreasing mean annual Lake Michigan elevations resulting in the reefs higher elevations being exposed over long periods of time (Figure 1). Compounding the potential impact of decreasing lake levels, random measures from a staff gage located at the site during construction showed a maximum hourly seiche driven oscillation of ±0.8-ft resulting in portions of the reef being exposed for brief (minutes) and frequent (hourly) periods of time. The amplitude of seiche driven oscillations can be greater through the confined Milwaukee River channel compared to those observed in the open lake (Figure 2).

Figure 1. Comparison of the 2006 constructed Phase 1 reef mean and maximum elevations (ft) to the Lake Michigan 2006 to 2014 monthly mean elevations (red), the 2006 to 2014 monthly mean levels based on low water seiche of -0.8-ft observed during reef construction (blue), and Lake Michigan 95-year mean elevation.

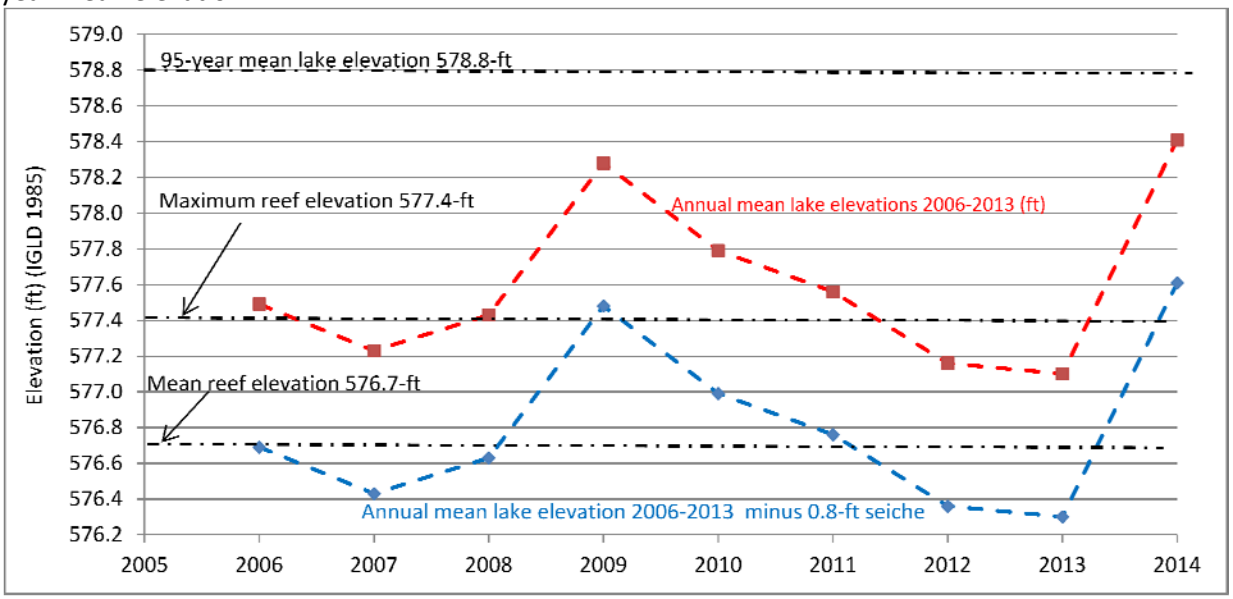
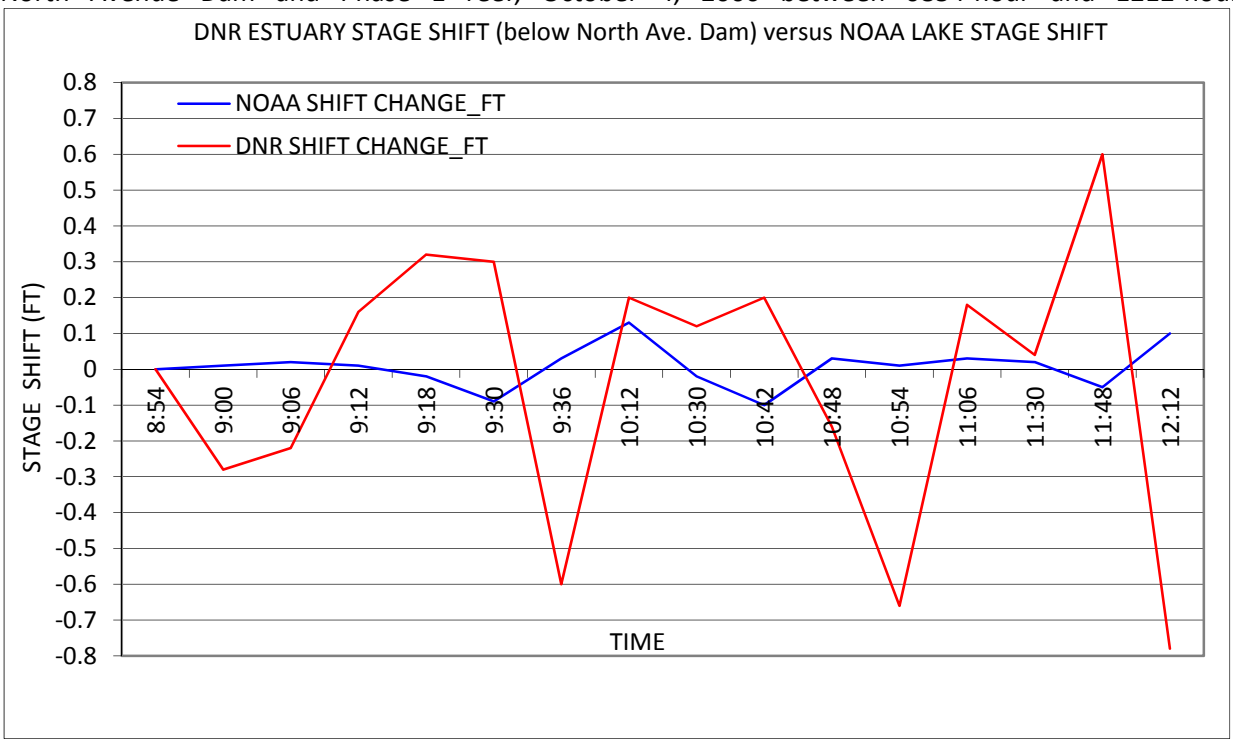


Figure 2. Observed short-term seiche stage shifts and differences between Lake Michigan's Milwaukee Outer Harbor NOAA gage and the DNR's Milwaukee River Inner Harbor staff gage downstream of former North Avenue Dam and Phase 1 reef, October 4, 2006 between 0854-hour and 1212-hour.



The combination of lake seiche and lake elevations at or below the mean reef elevation of 576.7-ft between November 2007 and March 2008, and between October 2012 and April 2013 exposed large areas of the reef. The Lake Michigan 95-year low level monthly mean of 576.02-ft was observed during January 2013. As of April 2015, the elevation reached 579.2-ft or 0.4-ft above the lakes 95-year mean elevation of 578.8-ft.

Project Goals

1. Enhance and expand the existing reef's function and value for lithophilic spawning fishes.
2. Abate the potential impacts caused by low lake levels and seiche oscillations.
3. Contribute to the de-listing of the Milwaukee Estuary AOC BUIs impacting fish populations and their habitat.

Design Objectives

1. Complete a survey and observations of the existing reef and bathymetric survey of the Milwaukee River estuary from the former North Avenue Dam to Pleasant Street. This 1-mile reach has experienced extensive shoaling and provides the best opportunity for future physical and biological based enhancements.
2. Complete surveys referencing the IGLD1985 vertical datum adopted as the standard for the Great Lakes (ACOE, 1992) and NAD1927 Wisconsin State Plan South 4803 vertical datum.
3. Re-grade the existing reef to the lowest practicable elevation (575.0-ft) without disturbing the original sandy shoal.

4. Based on the lake's record low monthly mean elevation of 576.0-ft and the observed seiche of ±0.8-ft, expanded areas of the reef should be ≤575.0-ft.
5. Re-use rock from the graded reef and additional purchased rock for expanding the reef riverward and downstream.
6. The lateral extent of the reef should be located on riverbed extending from land and river bed titled to the River Revitalization Foundation to the channel centerline.
7. Prepare various reef configurations and provide bathymetry and cross-sections to the Southeastern Wisconsin Regional Planning Commission (SEWRPC) to complete hydrologic and hydraulic analysis to insure no increase in the regulatory 100-year floodplain elevation, and provide estimates of other river hydraulic conditions (e.g., shear stress and velocities).
8. Consistent with the spawning life-requisites for walleye and Lake sturgeon (McMahon et al., 1984; Aadland and Kuitunen, 2006).
9. Design must be buildable, acceptable to landowners, and permitable by regulatory agencies.

3. RESULTS

Planning

A bathymetric survey was completed by wading and boats using a sub-centimeter grade GPS survey unit during November 2013 for the river reach between the abandoned North Avenue Dam and the Pleasant St. Bridge. Data files were created in text (.csv) and AutoCad formats for creating bathymetric and shoreline drawings. The mean lake elevation at the time of the survey was 577.5-ft.

The channel morphology and upper banks are distinctly different between the 700-ft reach located between the abandoned North Avenue Dam and the Humboldt Avenue Bridge versus the 3,400-ft reach located between the Humboldt Avenue and Pleasant Street Bridges.

The Humboldt Avenue to Pleasant Street Bridges reach is characterized as having an asymmetric cross-section. The right-1/3 of the channel includes the thalweg with a mean water depth[2] of 12.5-ft. Cover is limited at <1%. The entire shoreline is vertical with a steel or concrete bulkhead. The middle-1/3 and left-1/3 of the channel have a mean water depth of 10-ft and 7-ft, respectively. The left-1/3 of the channel exhibits more extensive shoaling than the middle and right side of the channel with gradual sloping and wadable water depths. The substrate along the entire reach is dominated by fines (clay-silt-sand) and is armored by a veneer of coarse sand and small gravel. The left shoreline includes small amounts of larger substrate as rip rap and broken concrete. Compared to the right-half of the channel bank, the left bank has less steel or concrete bulkhead. Some areas of the left shoreline include failed wooden bulkheads at the water line and undeveloped and sloping earthen upper banks that allows trees (willow and box elder) and shrubs to take root. Cover is still limiting at <5%, and when present, consists of woody and man-made debris (broken concrete), overhanging tree limbs and shrubs, and some small isolated patches of Sago pondweed, *Potamogeton pectinatus* L.

The reach between the abandoned North Avenue Dam and Humboldt Avenue Bridge has a more diverse channel morphology and upper bank (Attachment 1). The right-half of the channel includes the 0.45-acre Phase 1 reef. The reef generally follows the relatively flat contours of the former sandy shoal. At the time of the survey, the alluvial stone used to construct the reef was observed to be 25% to 50% embedded by coarse sand and small gravels. The upper 20-ft of the reef was covered by a veneer of silt

[2] Reported water depths are based on the difference between the observed channel elevation and Lake Michigan 95-year average of 578.8-ft (rounded 579-ft) IGLD 1985.

and sand. Downstream of the reef, the channel is relatively flat with water depths averaging 7-ft (elevation 572-ft). An isolated 10-ft hole (elevation 569-ft) is located at the downstream limits of the reef and near the shoreline and the substrate is predominately coarse sand and fine gravel over thick cohesive silt-clay. The former developed shoreline that included a commercial building and impervious parking lot has been removed and enhanced with natural landscape and stormwater treatment features by the River Revitalization Foundation. The shoreline includes soil filled fabric lifts with woody shrubs, emergent forbs, woody debris and large cobble-sized alluvial rock placed riverward from the bank. During high flow periods, a strong back eddying current sweeps across the original reef and follows the shoreline upstream and along the former right-half of the spillway before encountering the main channel flow. The channel along the former dam's right abutment is aggrading with fine sediment.

The left-half of the channel includes a large 22-ft deep (elevation 557-ft) scour hole located immediately downstream of the former dam spillway. Substrate and cover types are unknown. Proceeding downstream, the channel invert elevation increases gradually for approximately 350-ft with an average water depth of 7-ft (elevation 572-ft) similar to those observed downstream of the reef. Upper bank and shore line features include 300-ft of steel sheet pile extending downstream from the former left dam abutment. A concrete walk and railing constructed along the top of the sheet pile failed in 2014 and now lies partially submerged in the river. The remainder of the shoreline is approximately 50-ft or more high and steep at 1:1.5, and is generally stable with hardwood trees and woody shrubs. Fish cover is present as woody debris, rip rap and man-made concrete. The channel substrate type is not known. A strong back eddy current flows upstream to the former left dam abutment and along the left-half of the former spillway before encountering the main channel flow.

Sixteen cross-sections (vertical $\pm$0.1-ft, horizontal 1-ft) were developed through the project area, extending from the river left and right banks and floodplain. Nine were located through the original Phase 1 reef and seven through the proposed Phase 2 reef expansion. Following multiple hydrologic and hydraulic analyses by SEWRPC and design changes, a final design was proposed that could expand the existing 0.45-acre reef by 0.40-acres without increasing the local floodplain elevations using an estimated 412-cubic yards (900-tons) of 6 to 12-inch rip rap and re-graded rock from the existing reef. Exhibits for the existing and expanded reef locations, cross-sections, and elevations are presented in Attachment 2.

The project was originally proposed to be constructed with WDNR Fisheries Operations personnel and heavy equipment providing significant construction cost savings. However, a late and wet spring resulted in delayed construction projects statewide. As a result, the earliest start time for the reef project by WDNR personnel and equipment was estimated at late-November or early-December. Constructability would not have been feasible if ice conditions were encountered. A decision was made to construct the project with a private contractor. All the necessary federal, state and local reviews and approvals were obtained along with a temporary construction easement with the RRF.

Construction

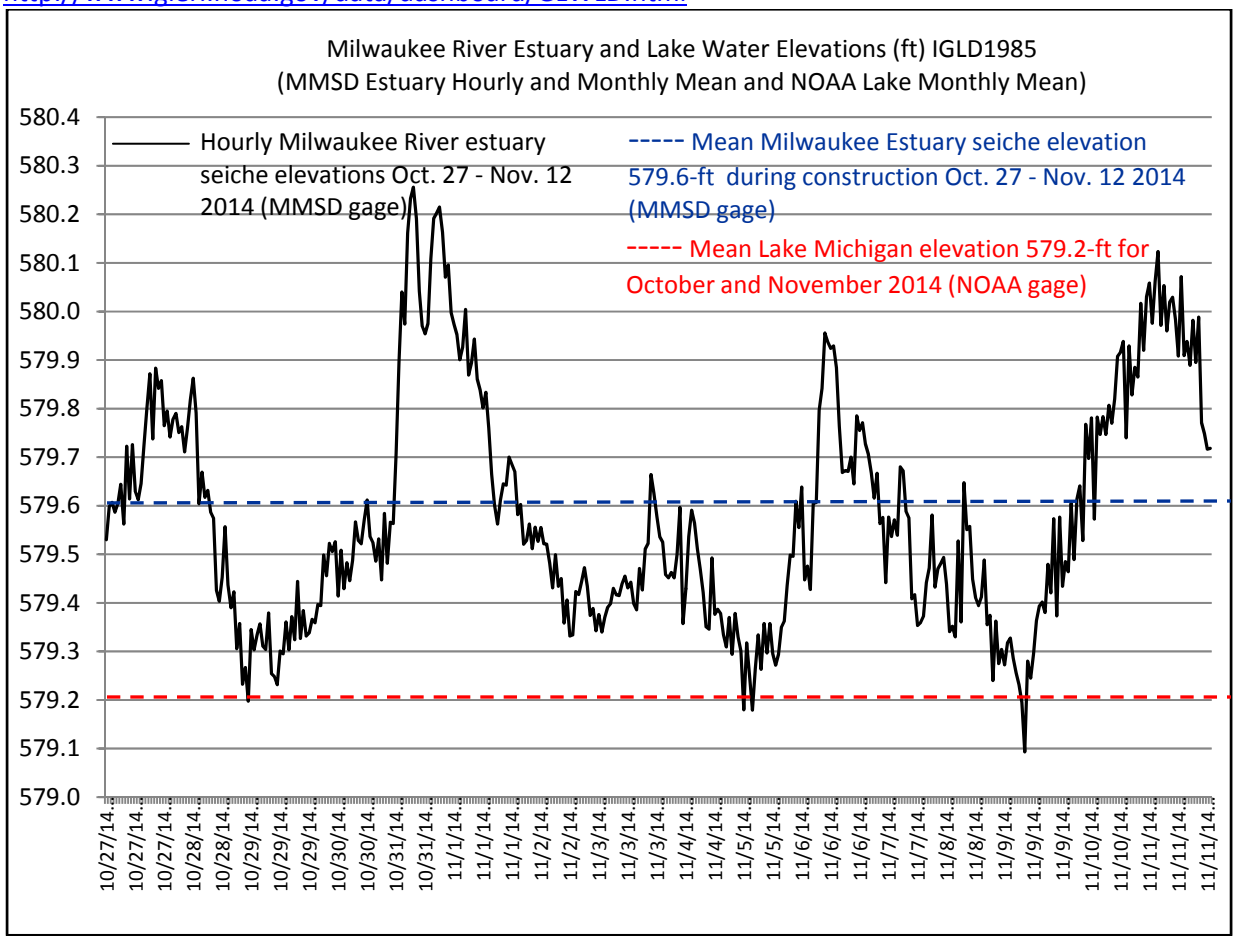
Mobilization and in-water construction began on October 27, 2014 and was completed on November 12, 2014. The mean lake elevation for the period was 579.2-ft or 1.7-ft higher than when the bathymetric survey was completed during November 2013. Milwaukee River discharge ranged from 300 to 392 ft^3/s.

The Milwaukee Metropolitan Sewerage District (MMSD) operates a continuous recording (at 15 and 60-minute intervals) water elevation gage located just downstream of the former North Ave. Dam (MMSD

Station NS07RL). The average hourly estuary seiche water elevation during in-water construction was 579.6-ft or 0.4-ft higher than the mean October-November 2014 lake elevation, and 1.7-ft higher than the October-November 2013 planning period lake elevation (Figure 3). The greater lake and seiche effect required larger volumes of rock to construct the causeway wider and higher in order to provide a visible, stable and safe foundation for the contractor equipment and operator. As a result, the reef was not expanded between XS-4 and XS-5 or less by 0.06-acres. Also a field decision was made not to expand the existing reef by the planned 0.04-acre between XS8 and XS9 due to the accumulation of silt and fine sand observed at the time of construction over concerns that fine sediment would continue to settle onto the expanded rock reef.

The combination of a sustained seiche elevation of 580.2-ft, or 1.0-ft greater than the mean lake elevation of 579.2-ft, combined with very turbid water (transparency <1-ft) ebbing from the inner harbor caused cancellation of the October 31, 2014 in-water construction date over safety concerns due to equipment limitations and operator safety concerns (Figure 3).

Figure 3. Milwaukee River estuary hourly and mean seiche water elevations during the Phase 2 reef construction October 27 through November 11, 2014 and NOAA monthly mean lake water elevations for October through November 2014. MMSD station NS07RL downstream of the former North Avenue Dam and NOAA Milwaukee gage station 9087058 at Outer Harbor US Coast Guard Station. http://www.glerl.noaa.gov/data/dashboard/GLWLD.html



The existing 0.45-acre reef was expanded by 0.30-acres, or 0.10-acres less than the planned 0.40-acre expansion. The existing reef was expanded along two planes, lateral to and downstream of the existing reef. The reef was expanded laterally by 0.10-acres by re-using 80-cubic yards of re-graded alluvial rock from the existing reef. Lateral expansion began at the left edge of the re-graded reef at elevation 576.0-ft, extending to the mid-channel at an average slope of 9% and elevation 573.0-ft. The lateral expansion of the existing reef offset the area of the existing reef that could not be expanded upstream due to sedimentation concerns and because re-grading some areas below 576.0-ft would have exposed the original sandy shoal.

The downstream expansion totaled 0.20 acres over 150 linear feet using approximately 350-cubic yards of the total 412-cubic yards of the 6 to 12-inch limestone rip rap purchased for this project. The temporary causeway was constructed through cross-section XS-4 with a flat top width of 16-ft, 2:1 side slopes and elevations ranging from 576.5 to 577.0. Once completed, the reef was expanded by excavating the causeway and placing the rock toward the shoreline (right bank) and up to the mid-channel (left) to an average slope of 8% and elevation of 573.0-ft with a narrow crest set to elevation of 575.0-ft (Attachment 2).

A portion of the remaining 60-cubic yards of rip rap were used to create two 10-ft long by 3-ft wide spurs located at cross-section XS-2 and XS-3. The spurs were orientated downstream at an approximate 30-degree to direct flow over the expanded reef and increase scouring of fines. The remainder of the rock was used to enhance the laterally expanded reef and the existing reef to create localized scour, current breaks and larger voids for protecting deposited eggs. Enhancements to the laterally expanded reef included random clusters and top dressing with rip rap. Enhancements to the existing reef included three approximate 12 to 15-ft long by 3-ft wide barbs at XS4, XS5 and XS6 laid perpendicular to the eddy flow observed during higher Milwaukee River discharges.

The total cost of the year-2014 Phase 2 reef project was $63,300 or a unit cost of $211,000 per acre. The total cost of the year-2006 Phase 1 reef project was $82,400 or $183,000 per acre. Cost comparisons between the two phases of the reef construction are not necessarily comparable.

4. DISCUSSION and RECOMMENDATIONS

Potential fish, other aquatic life and wildlife habitat enhancement practices for the Milwaukee Estuary generally include physical (e.g., rock and coarse woody debris) and biological (e.g., emergent and submergents aquatic plants, riparian vegetation) features. Opportunities for enhancing fish and aquatic life and wildlife habitats in the Milwaukee Estuary are limited by land and water-based uses and potential institutional conflicts (e.g., river bed and bank ownership, bulkheads, established floodplain, navigation, piers and moorings, outfalls and other infrastructure), sediment characteristics (e.g., quality, geotechnical, and sedimentation rates), access and constructability.

<u>Physical Habitat Enhancement Features</u>

Extensive areas of the Milwaukee River Estuary Inner Harbor and the open water Outer Harbor areas south of the Milwaukee River may not be conducive to rock spawning reef or shoal construction, or use of coarse woody debris and other structures for cover. These features could be subject to burial by sediment transported by the three rivers. Existing sediments are thick and may not bear the weight of rock without specially engineered base caps such as those included in draft designs for the Burnham Canal wetland project. Large tracts will continue to be dredged to maintain commercial navigation depths including the Harbor's Kinnickinnic River channel, the Menomonee River to 25th St., the

Milwaukee R. to Buffalo St. extended, and Outer Harbor south of its confluence with the Milwaukee R. Placement of physical structures could conflict with navigational uses.

Top dressing the large armor stone that lines the harbor side of the 2.8 mile long breakwater and the 2.0 mile long shoreline north of the City of Milwaukee Municipal Pier, the McKinley Marina, the Lake Shore State Park and the Summerfest grounds could provide substrate for warm, cool and coldwater simple lithophilic spawning species, cover for juveniles, adults, and their forage. Using GLRI funds, the ACOE recently completed such a project along a 1,000-ft long reach of breakwater just south of the north gap. Dr. John Janssen of the UW Milwaukee SFS is currently monitoring the project.

Within the Inner Harbor, the Milwaukee R. between the former North Avenue Dam and Humboldt Avenue Bridge and constructed rock spawning reef provide the best opportunities for similar rock habitat improvement projects. Preferred locations are from the river channel centerline east and along the left bank where higher flows and velocities are concentrated and load bearing substrate are present. Remaining areas along the right bank and west of the channel centerline are depositional. Deeper rock spawning areas should mimic the morphology of sloping arched riffles described by Aadland (2010) for river restoration practices, and Petersen et el., (2002) and Manny and Kennedy (2002) for Lake sturgeon spawning habitat restoration in the Detroit River's Fighting Island. Sloping shoreline with adequate current and access to deeper water could be enhanced with rock substrate similar to areas located downstream of the Shawano Dam and elsewhere along the Wolf River, Wisconsin. Multiple landowners requiring easements, floodplain regulations, and lack of land access and suitable water depths for barge access are significant challenges to constructing additional rock spawning habitat in this reach of the Milwaukee River estuary.

Biological Habitat Enhancement Features

Emergent and submergent aquatic plants provide spawning habitat for phytophilic spawning fishes (e.g., northern pike and lake perch), and cover and forage for juvenile and adults. Despite improvements in water quality, in particular light transparency, rooted aquatic vegetation is nearly absent from the Inner Harbor. In addition, extensive beds of macrophytes once present in the Outer Harbor areas of the South Shore and north Outer Harbor tracts that include the Lakeshore State Park "lagoon", the area north of the City of Milwaukee Municipal Pier and especially the McKinley Marina are, based on recent but limited observations, declining or nearly absent. Dominant species included American waterweed (*Elodea canadensis*) and Eurasian watermilfoil (*Myriophyllum spicatum*), and lesser amounts of Sago pondweed (*Potamogeton pectinatus*) and Floating pondweed (*Potamogeton natans*). If continuing declines are observed the causes should be identified. Possible reasons may include grazing (e.g., Rusty crayfish, *Orconectes rusticus*, bioturbation (e.g., rooting by Common carp, *Cyprinus carpio*), and sediment quality especially in the Inner Harbor.

There are opportunities to enhance spawning habitat, in particular along publicly owned reaches of the Milwaukee and Menomonee Rivers, and their floodplains located upstream of the estuary. As such efforts to provide fish access to historic lotic spawning habitat connected to the Milwaukee Estuary is a priority consistent with the goals and objectives of the Milwaukee Estuary AOC Remedial Action Plan (WDNR, 2014).

A comprehensive inventory and management plan for fish and aquatic life habitat is lacking for the Milwaukee Estuary. Should such a plan be developed, it should include an evaluation of the benefits, costs and the feasibility of enhancing physical habitat features and restoring native aquatic plants in the Milwaukee Estuary.

5. REFERENCES

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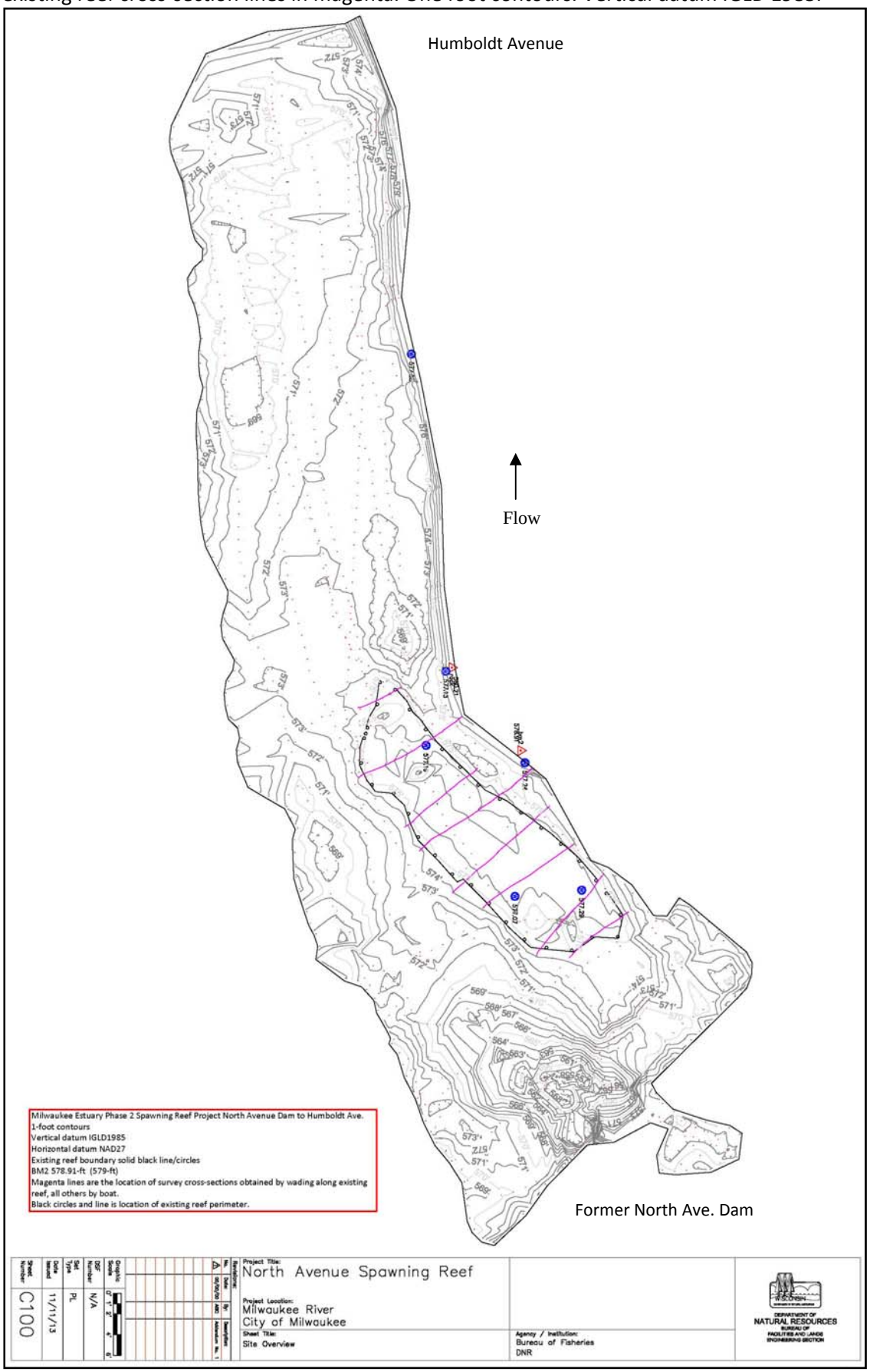
Vertical Datum Conversion Factors:

From Datum:	To Datum:	Conversion
City of Milwaukee	NGVD 1929	Add 580.603’
NGVD 1929	IGLD 1985	Subtract 0.86’
City of Milwaukee	LWD	Add 3.103’
NGVD 1929	LWD	Subtract 578.36’
NGVD 1929	IGLD 1985	Add 579.743’

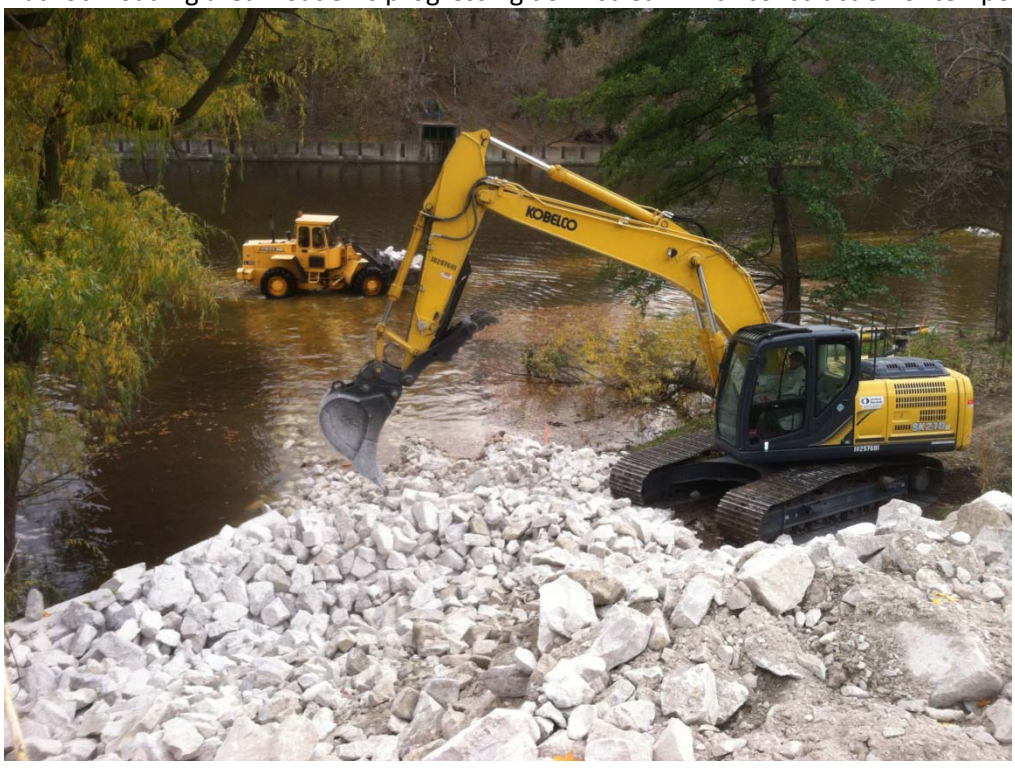
NGVD 1929 = National Geodetic Vertical Datum of 1929
IGLD 1985 = International Great Lakes Datum of 1985
LWD = Low Water Datum. The dynamic elevation accepted as a base elevation for each of the Great Lakes to which is referred the depths shown on the navigation charts and the authorized depths for navigation improvement projects. Elevations for these planes are referred to the International Great Lakes Datum of 1985 and is 577.5-ft for Lakes Michigan and Huron.
Source: US Army Corps of Engineers (ACOE), 1985.

Attachment 1. Bathymetry of Milwaukee River estuary in the vicinity of the former North Avenue Dam and Humboldt Avenue Bridge and constructed Phase 1 reef. Existing reef outline in bold and eight existing reef cross-section lines in magenta. One foot contours. Vertical datum IGLD 1985.

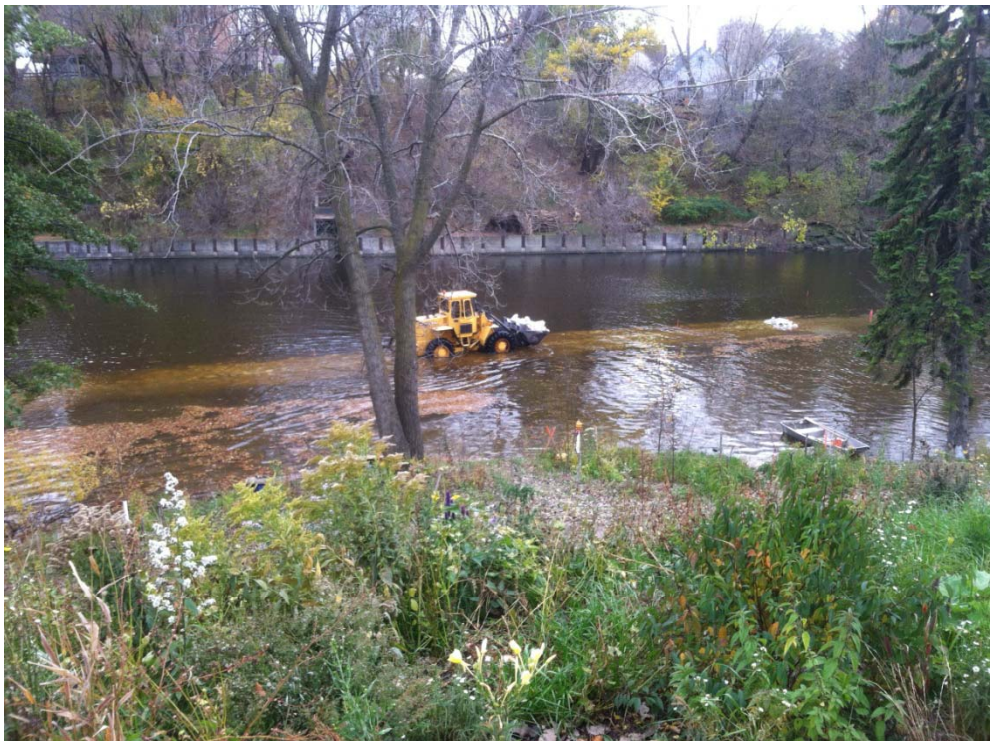


Milwaukee River Estuary exposed Phase 1 reef section. April 2013

Milwaukee River Estuary. Phase 2 reef construction. Looking east along cross-section 4 from RRF property at rock loading area. Loader is progressing downstream with construction of temporary causeway.

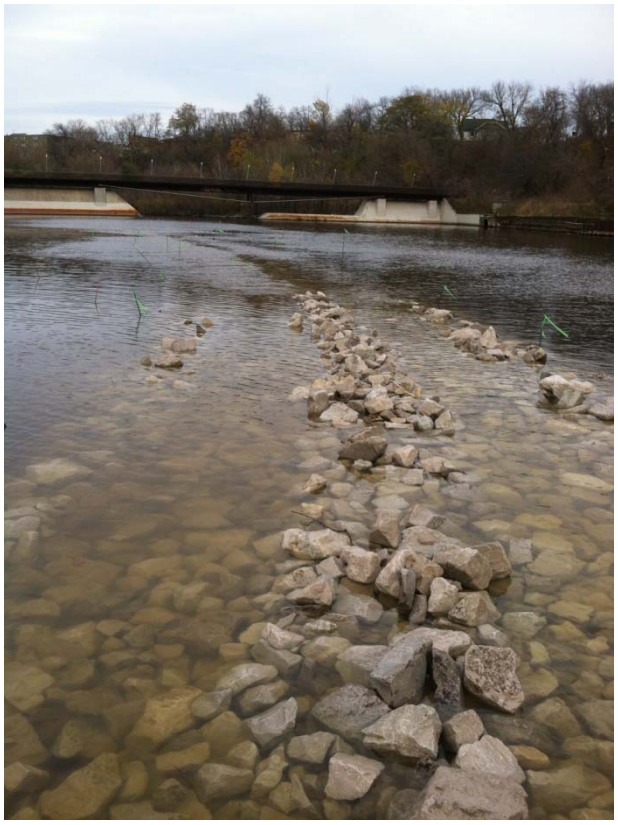


Milwaukee River Estuary Phase 2 reef construction. Looking east along cross-section 2 from RRF property as loader tracks transports stone along causeway. Existing submerged stone is the linear light brown track.



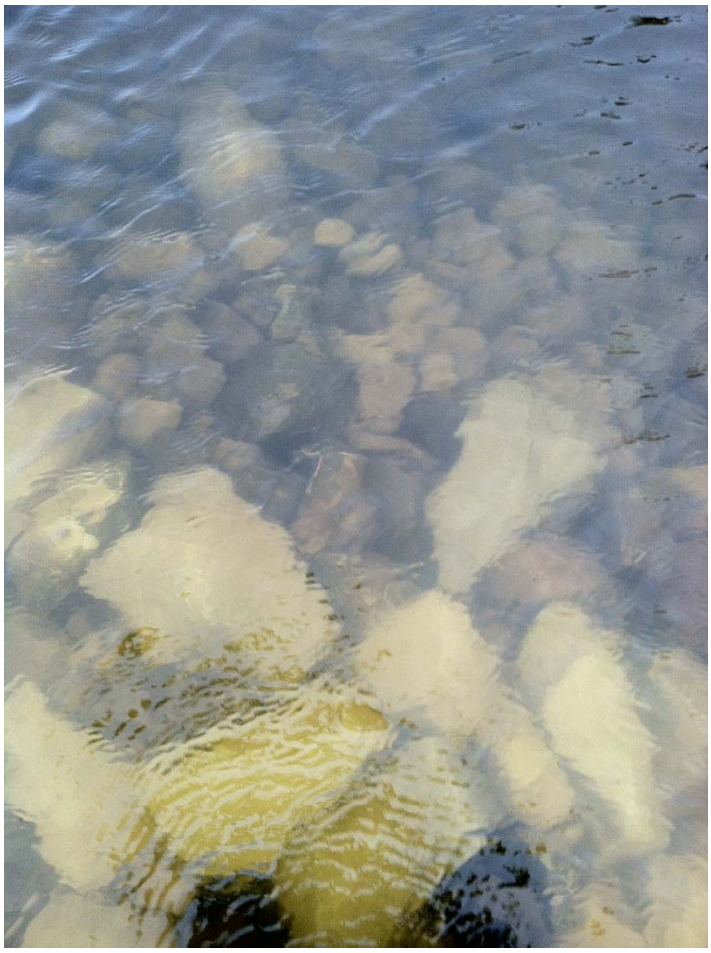
Milwaukee River Estuary Phase 2 reef construction. Looking northwest toward RRF property and right abutment of former North Ave. Dam. Loader is tracking along a section of completed temporary causeway. Rebar stakes locate center line, left and right limits of causeway alignment.

Milwaukee River Estuary. Phase 2 reef construction. Looking north toward former North Ave. Dam.



Milwaukee River Estuary. Phase 2 reef construction. Typical rip rap used for causeway and reef.

Milwaukee River Estuary. Phase 2 reef construction. Placed 6-12 inch rip rap used to top dress re-used alluvial stone from existing Phase 1 reef.



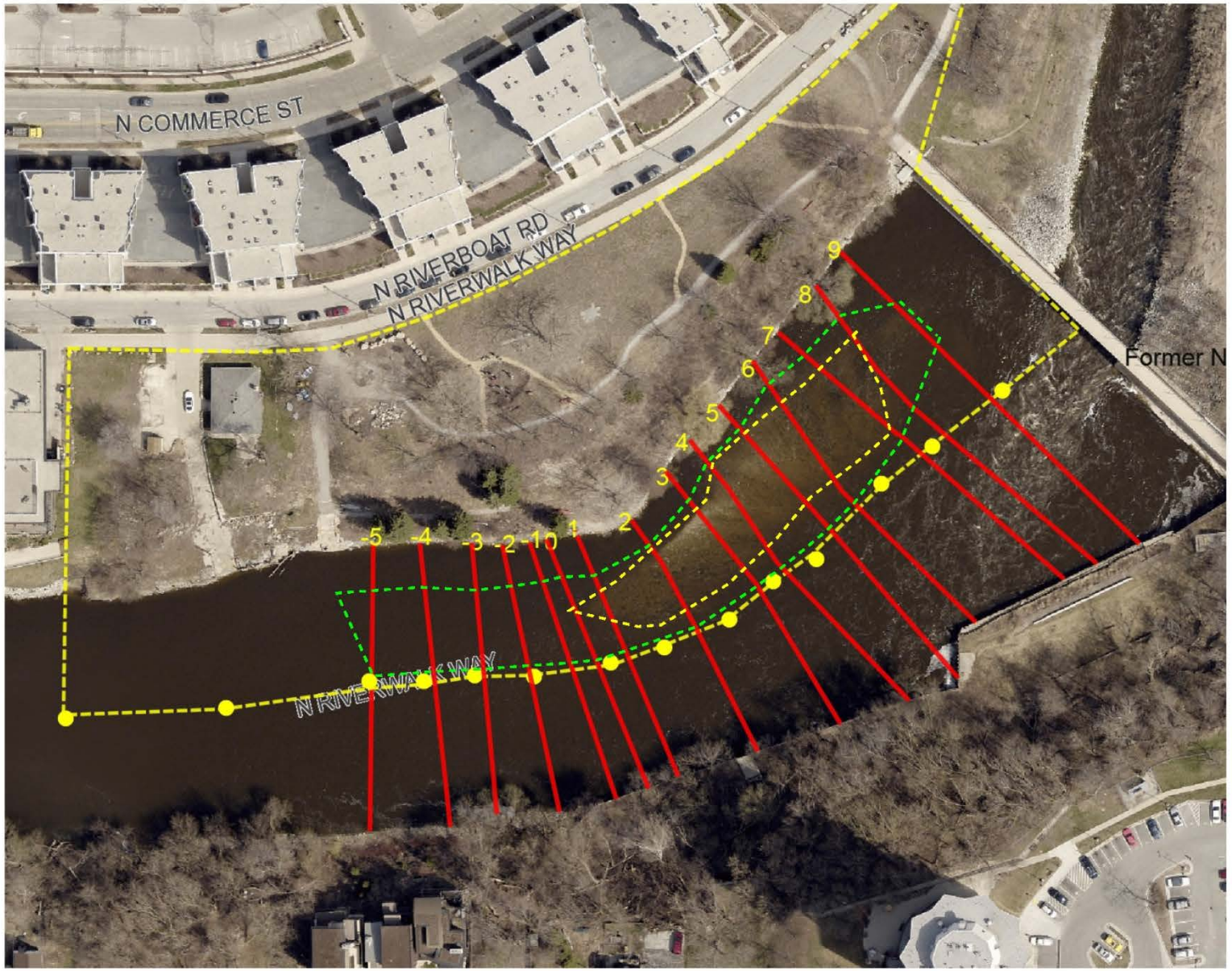
Attachment 2. Exhibits for the existing and expanded reef planview of cross-sections, cross-sections and elevations.
Cross-Section Legends:
All cross-sections looking downstream.

Existing channel elevation (IGLD 1988) 

Proposed new stone "fill" for exapnded reef 

Proposed existing reef stone to be "cut" and re-used to expand reef 

Plan view of existing and proposed reef, cross-sections (9 through -5), and River Revitalization Foundation property boundary.



Legend

Existing Reef Boundary

Proposed Reef

Cross-Sections

RRF Property Boundary

River Center Line

1:1,315

219 0 110 219 Feet

NAD_1927_StatePlane_Wisconsin_South_FIPS_4803

THIS MAP IS NOT TO BE USED FOR NAVIGATION

Notes

Yellow line is the RRF property limits

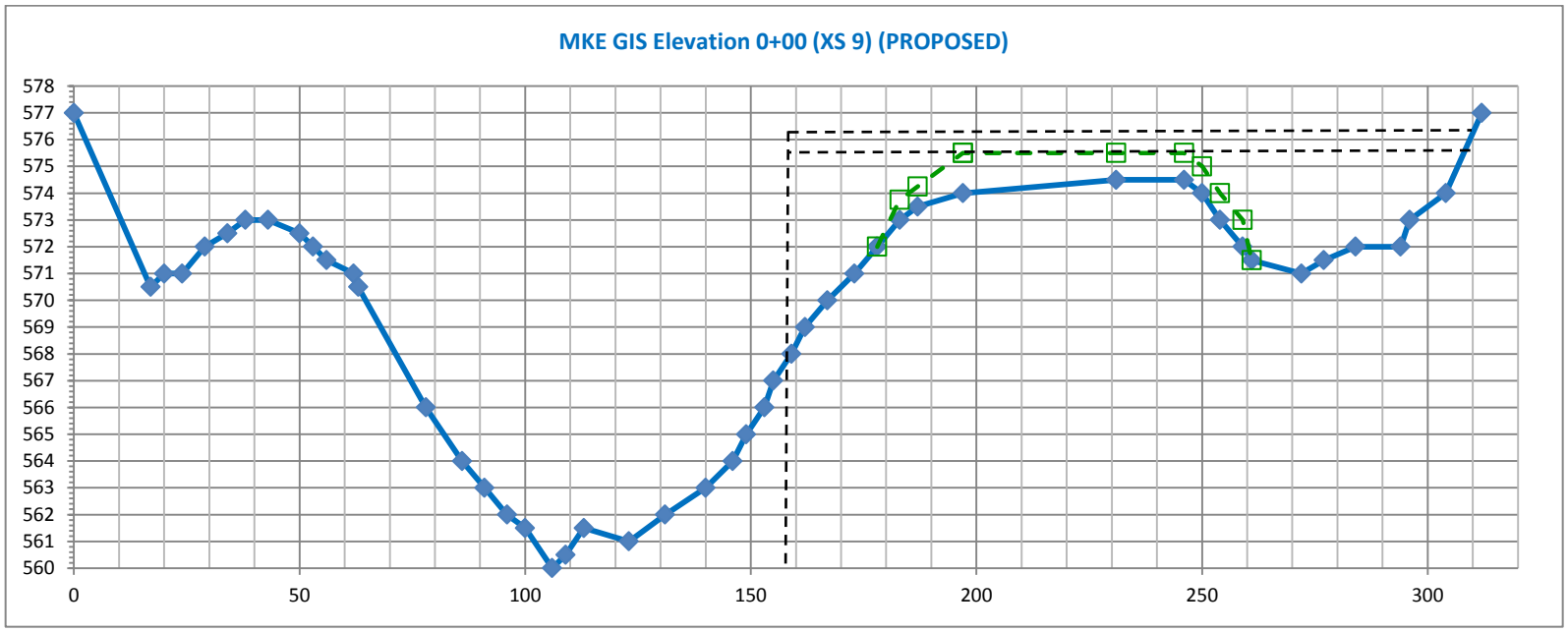
Cross-Section Legends:

All cross-sections looking downstream.

Existing channel elevation (IGLD 1988) 

Proposed new stone "fill" for exapnded reef 

Proposed existing reef stone to be "cut" and re-used to expand reef 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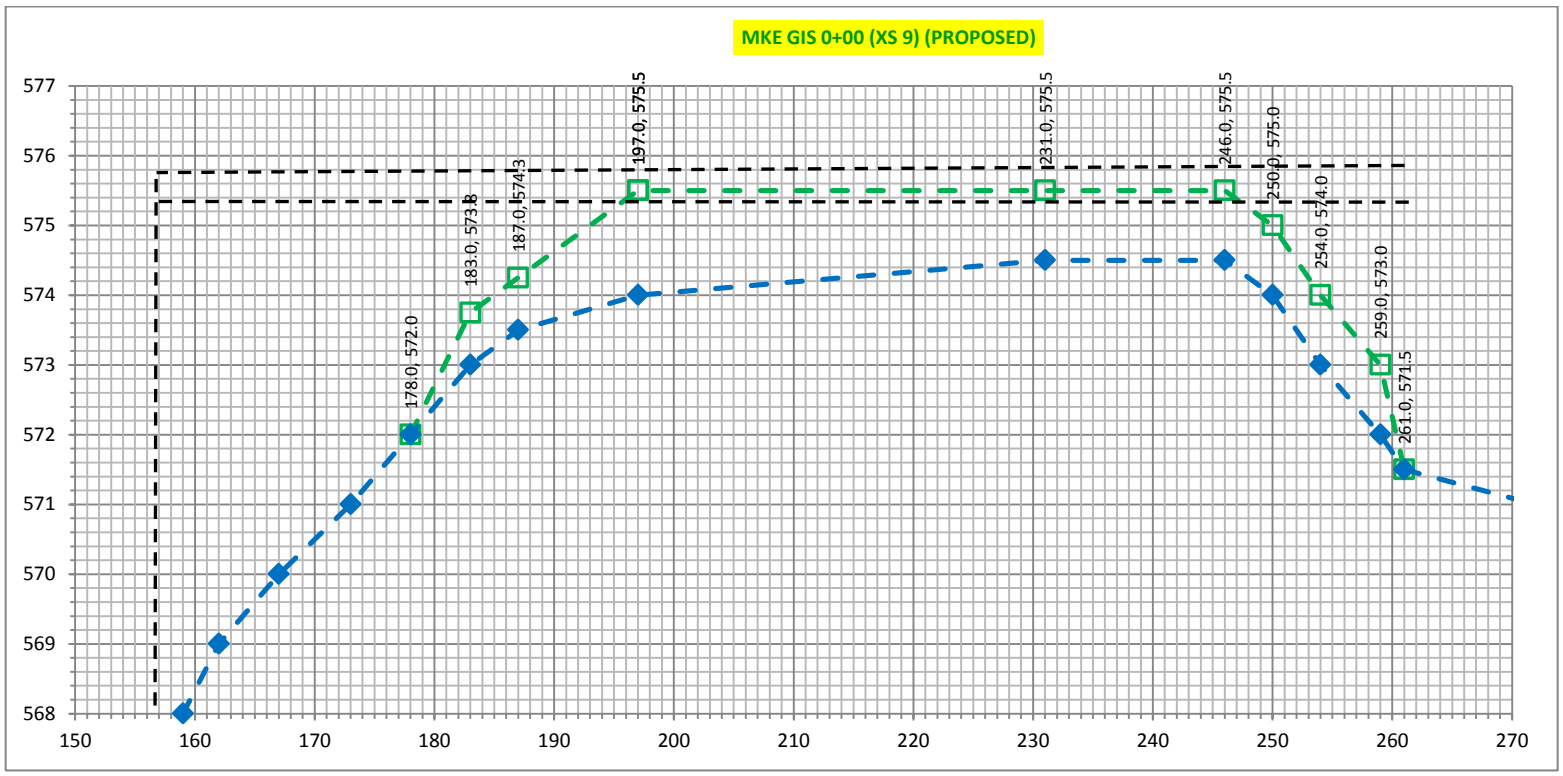
MKE GIS 0+00 (XS 9) (PROPOSED)
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178.0, 572.0
183.0, 573.8
187.0, 574.3
197.0, 575.5
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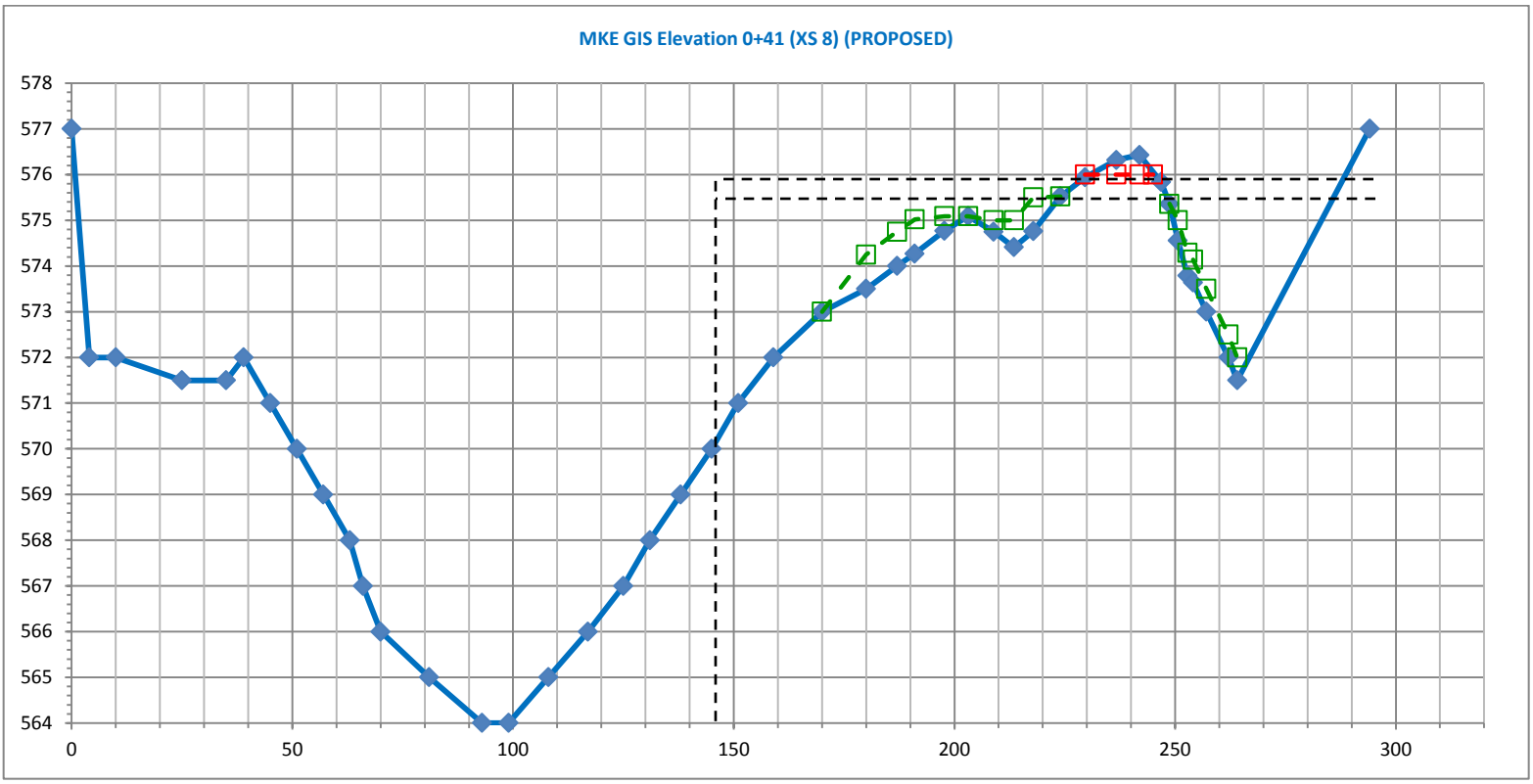
MKE GIS Elevation 0+41 (XS 8) (PROPOSED)
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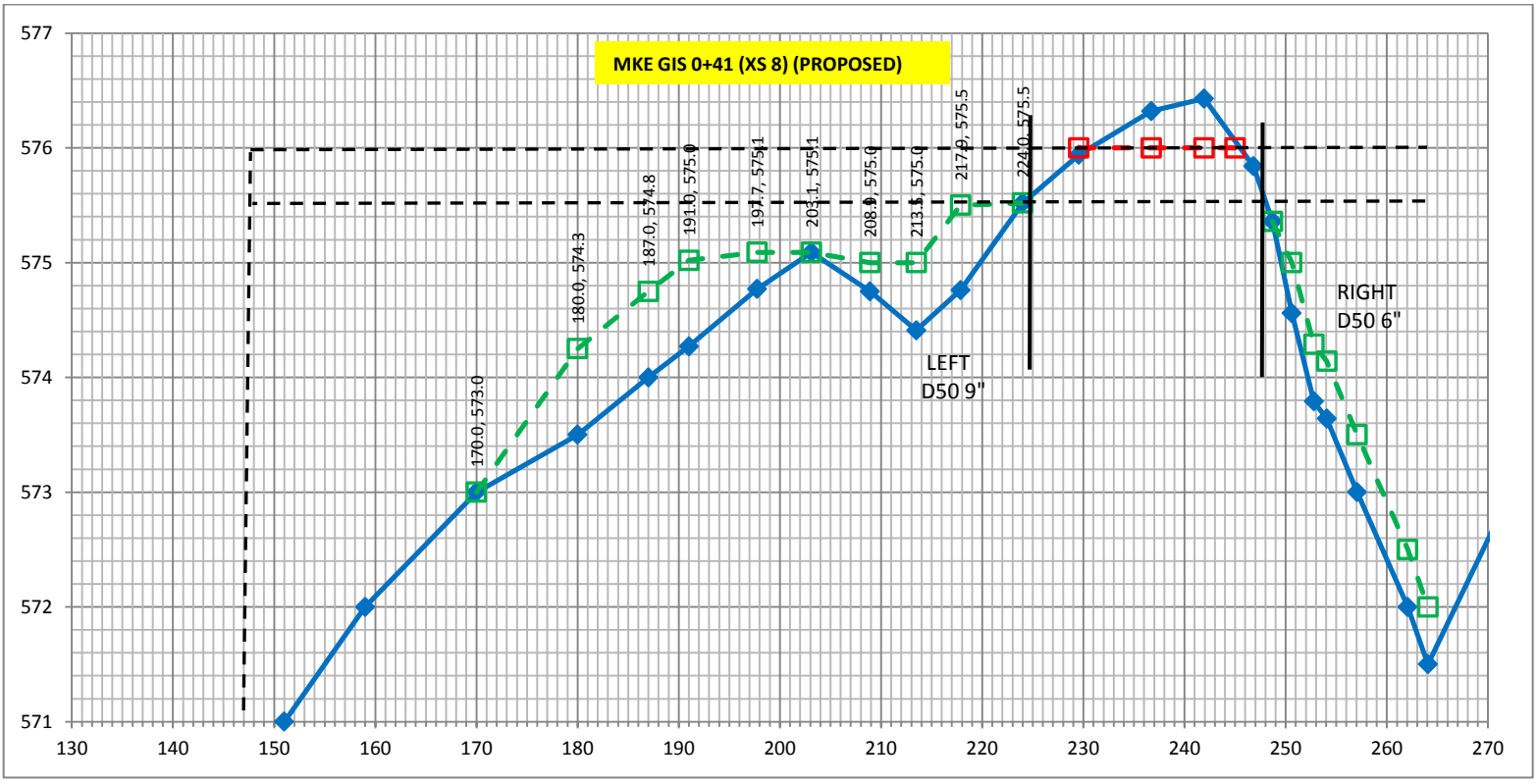
MKE GIS 0+41 (XS 8) (PROPOSED)
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187.0, 574.8
191.0, 575.0
197.7, 575.1
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213.5, 575.0
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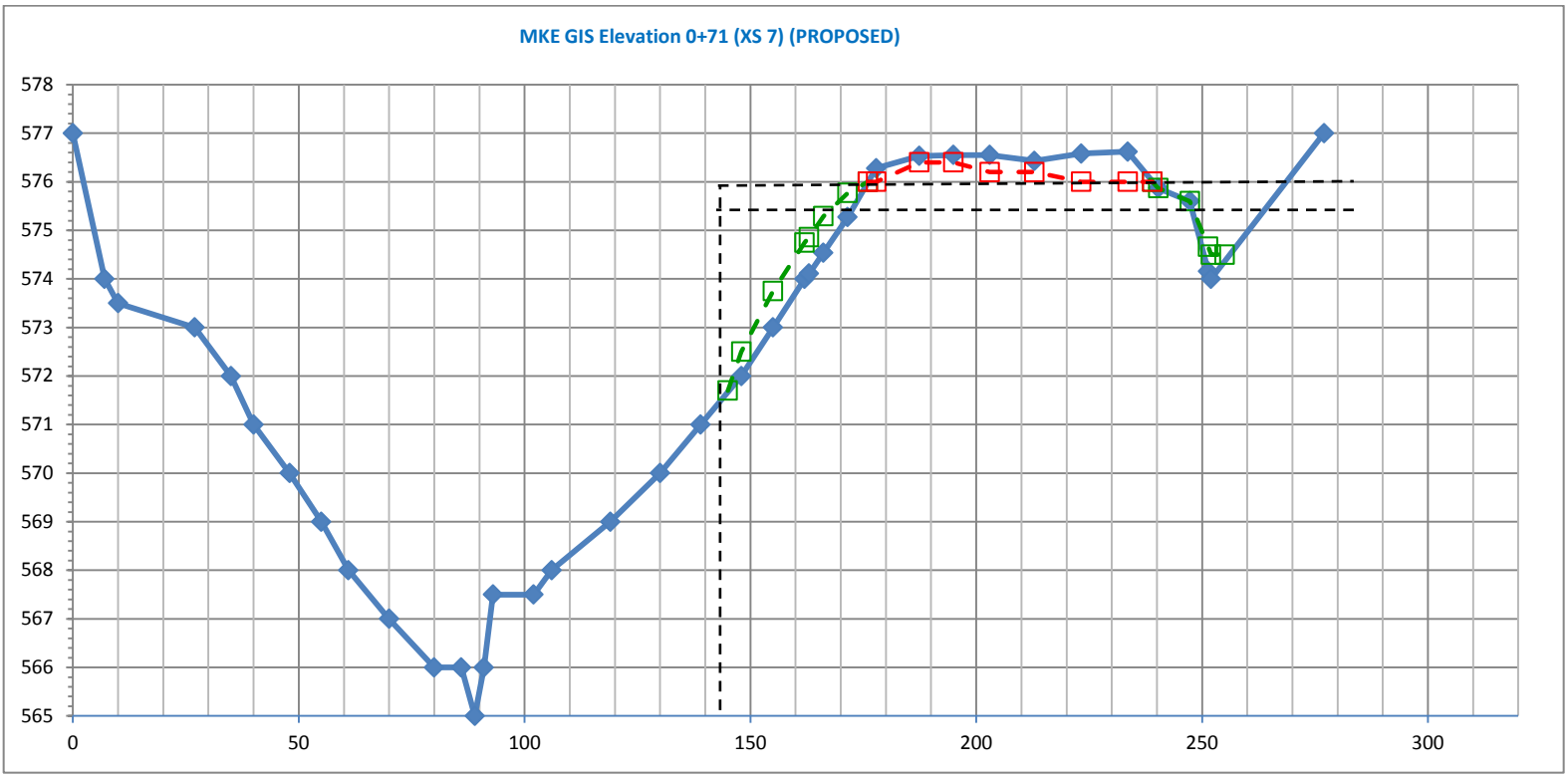
224.0, 575.5
LEFT
D50 9"
RIGHT
D50 6"


MKE GIS Elevation 0+71 (XS 7) (PROPOSED)
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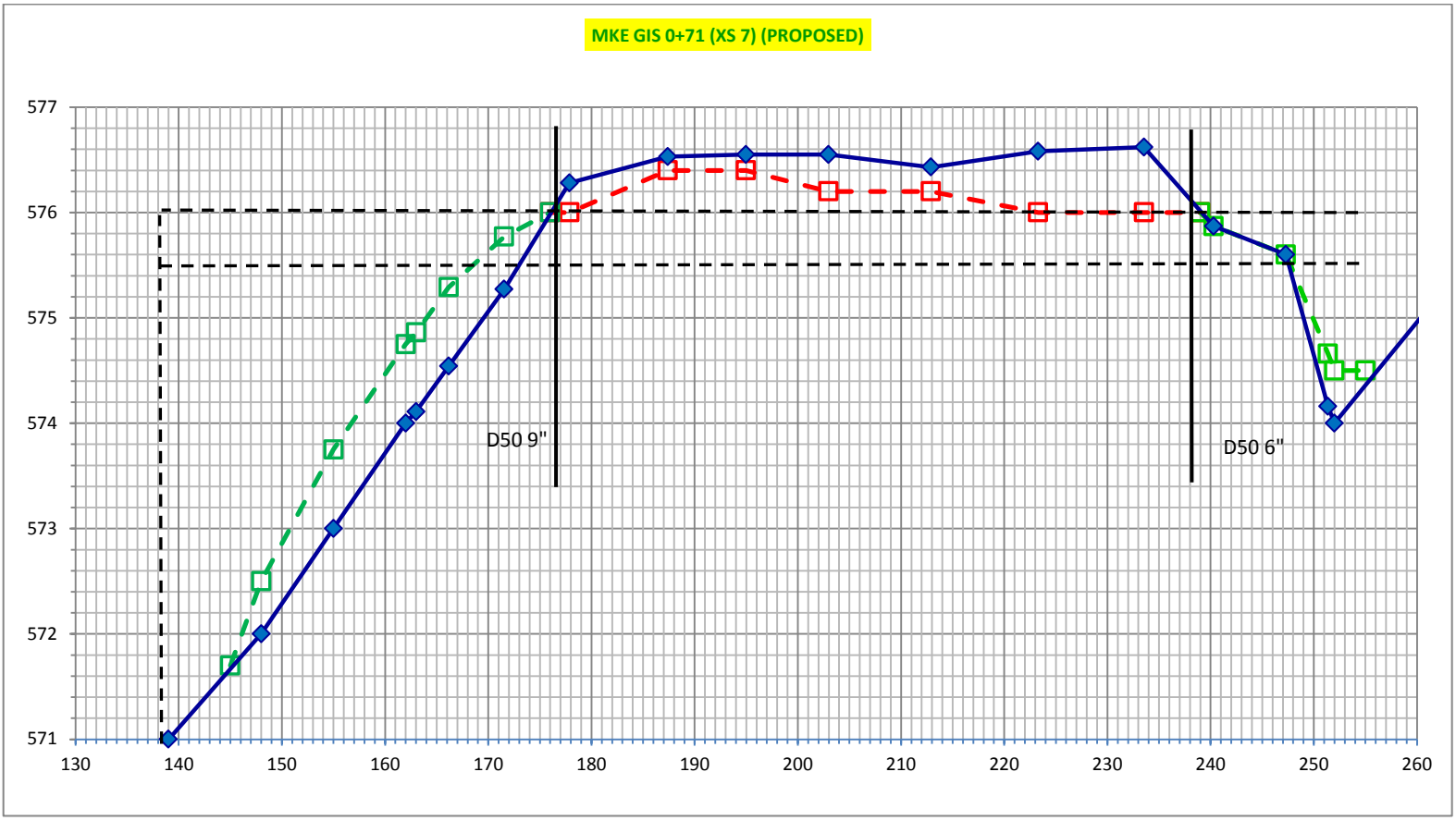
MKE GIS 0+71 (XS 7) (PROPOSED)
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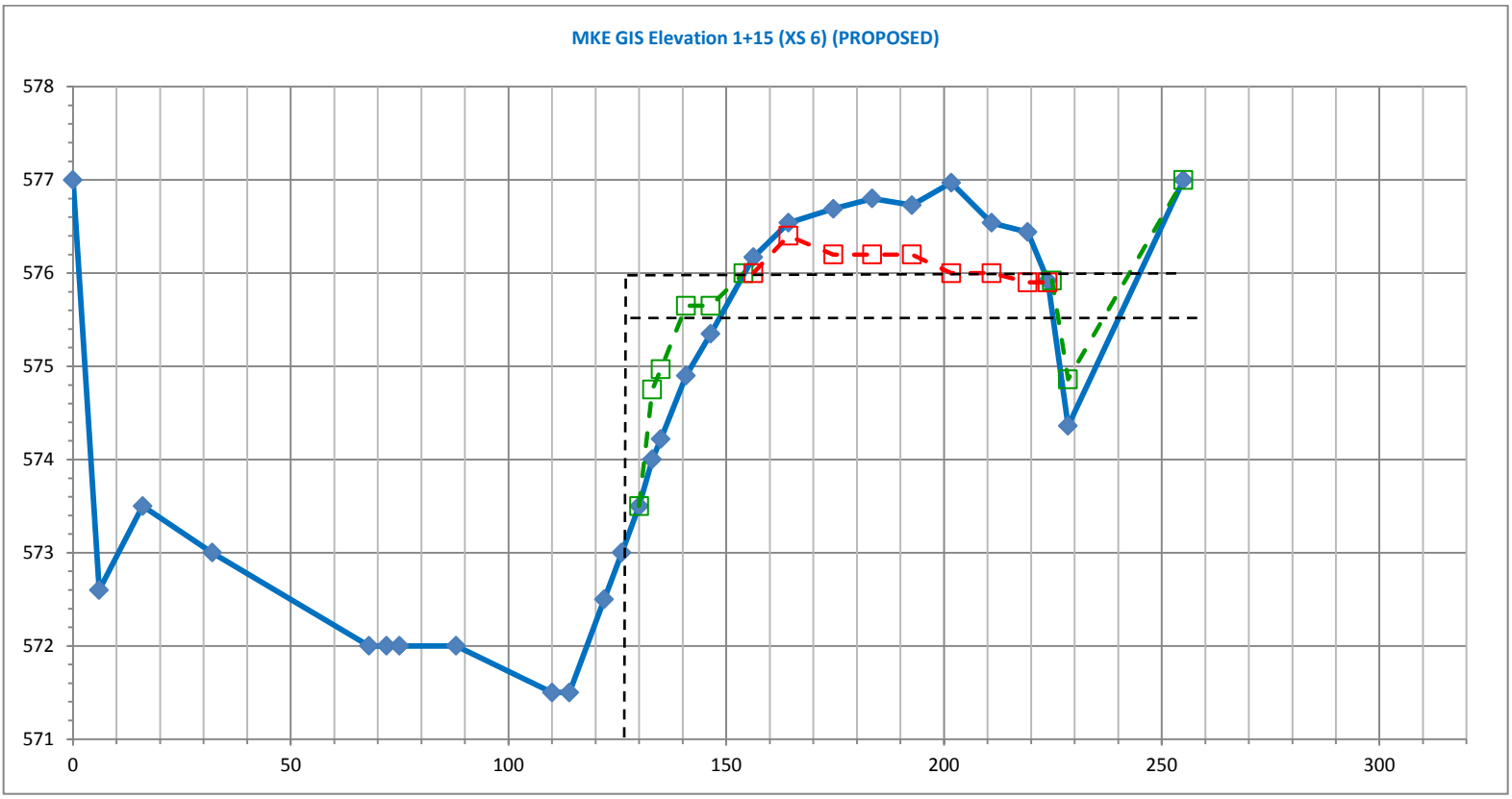
MKE GIS Elevation 1+15 (XS 6) (PROPOSED)
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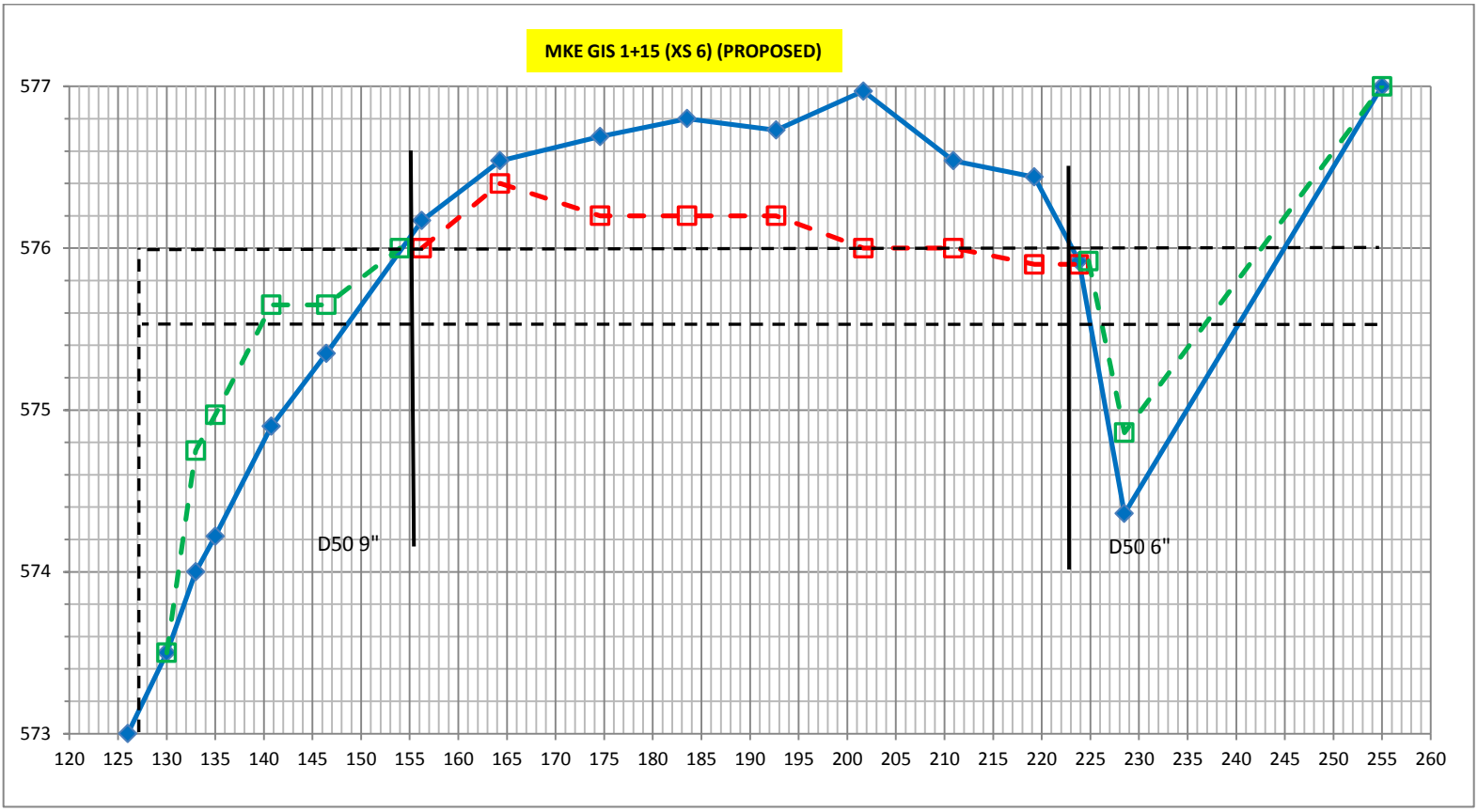
MKE GIS 1+15 (XS 6) (PROPOSED)
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D50 9"
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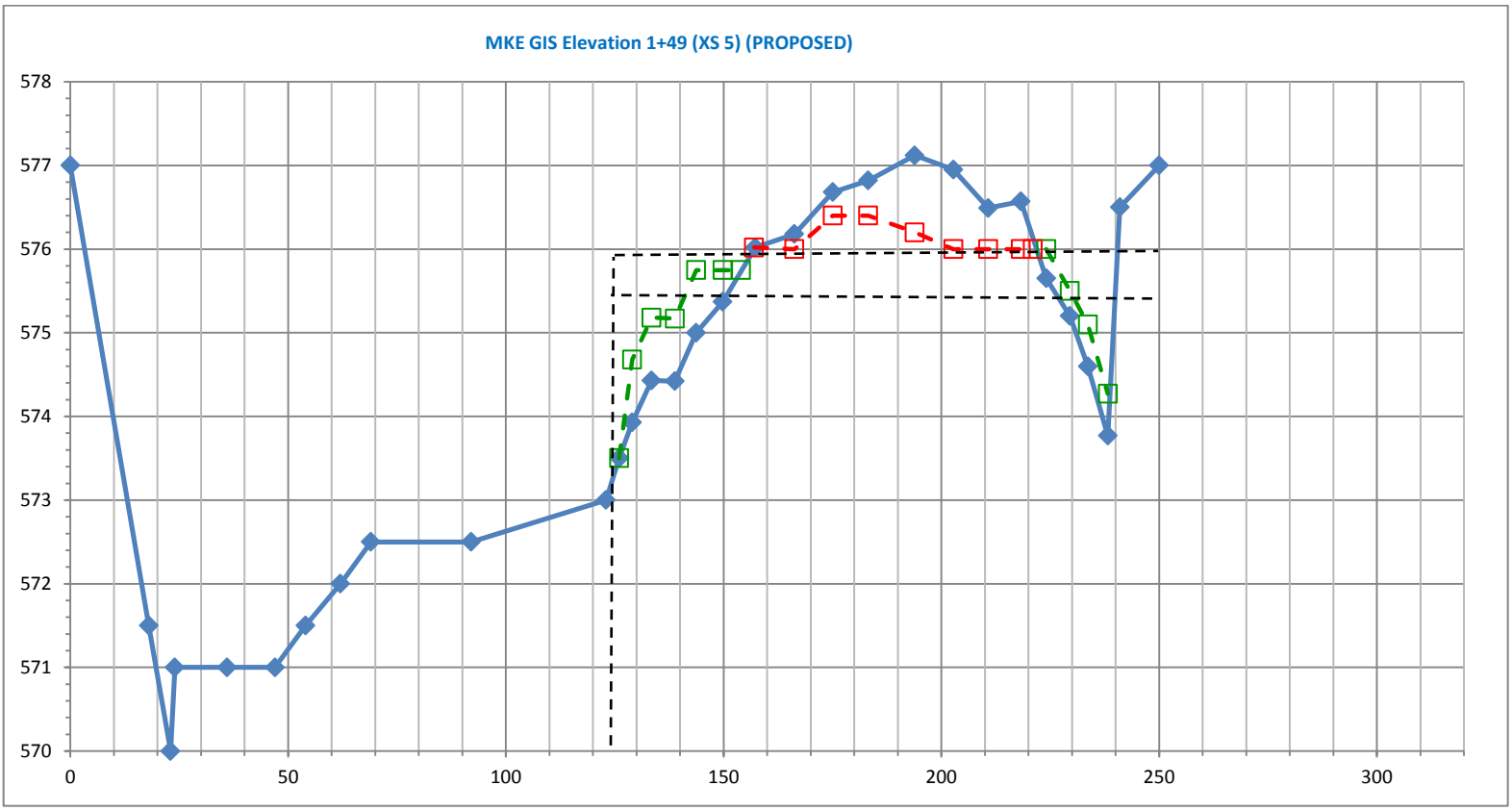
MKE GIS Elevation 1+49 (XS 5) (PROPOSED)
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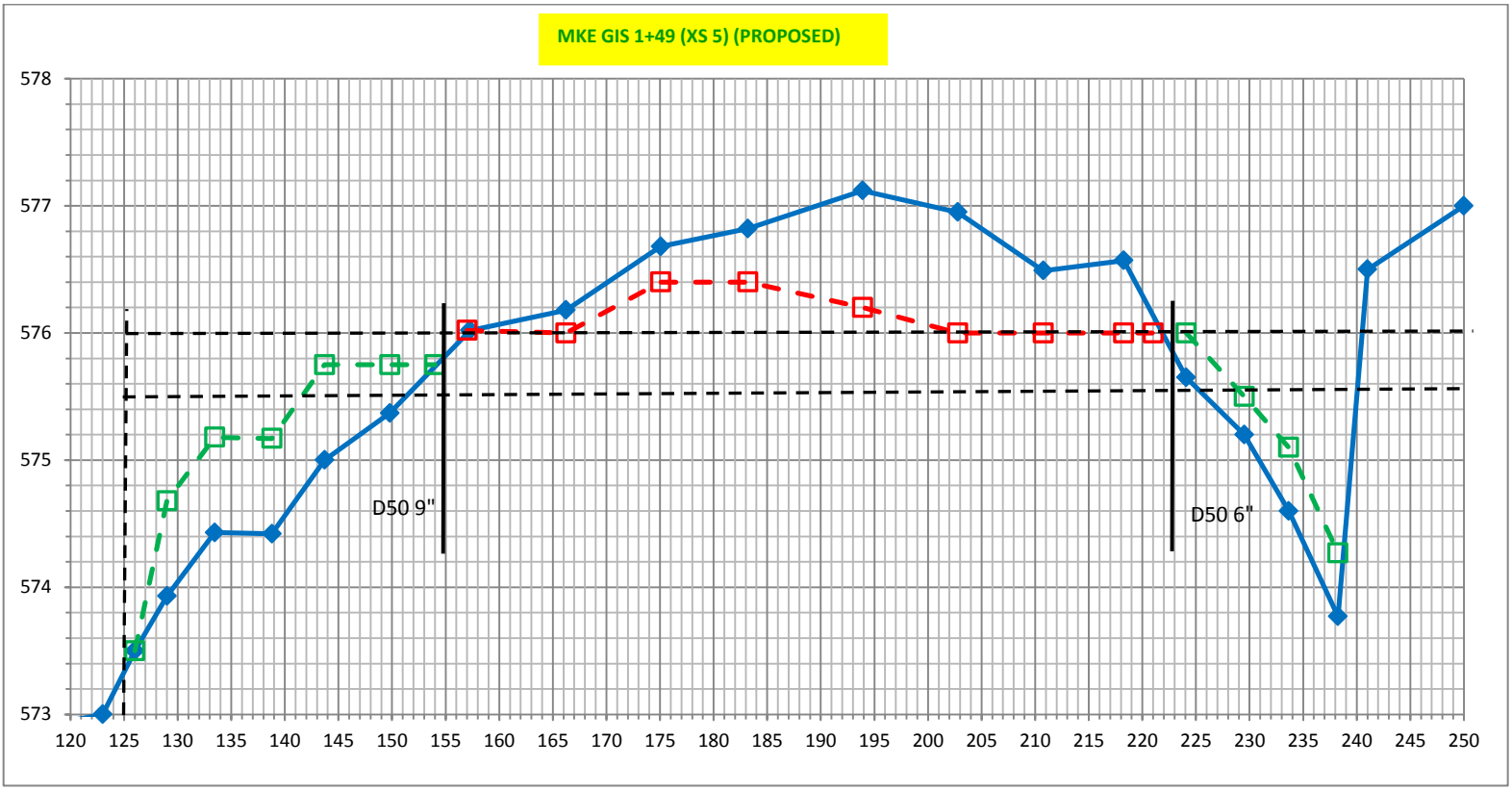
MKE GIS 1+49 (XS 5) (PROPOSED)
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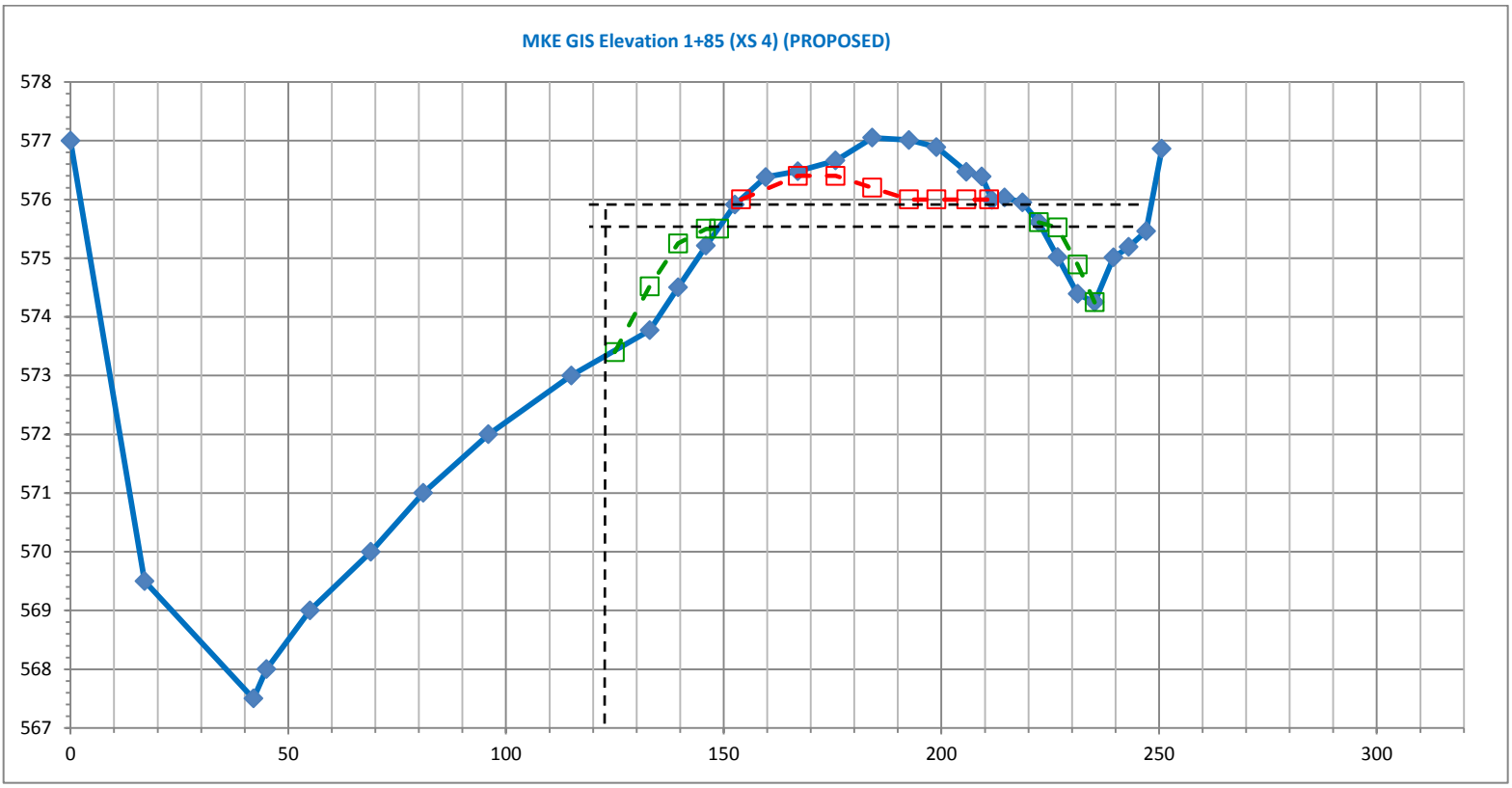
D50 6"


MKE GIS Elevation 1+85 (XS 4) (PROPOSED)
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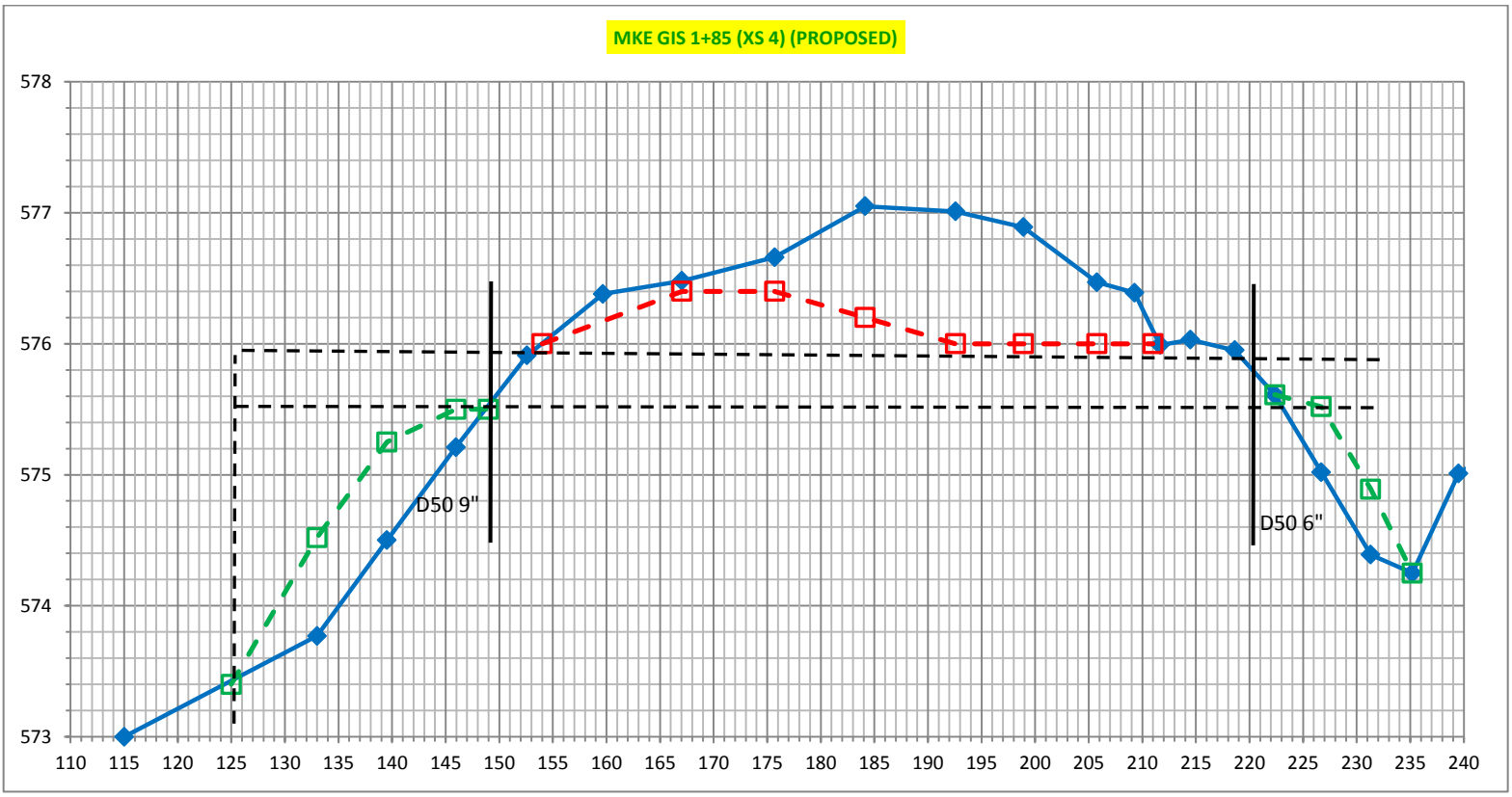
MKE GIS 1+85 (XS 4) (PROPOSED)
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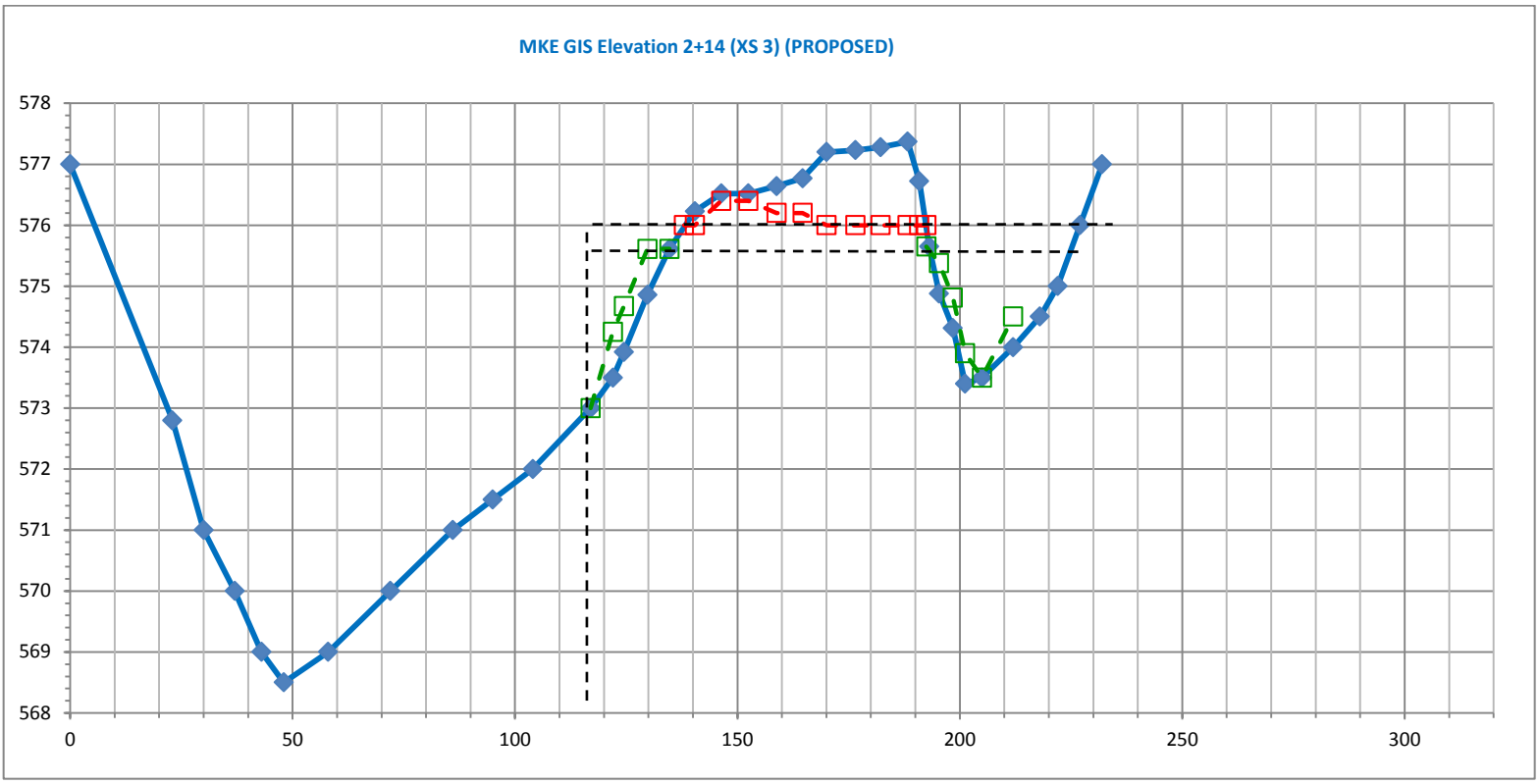
MKE GIS Elevation 2+14 (XS 3) (PROPOSED)
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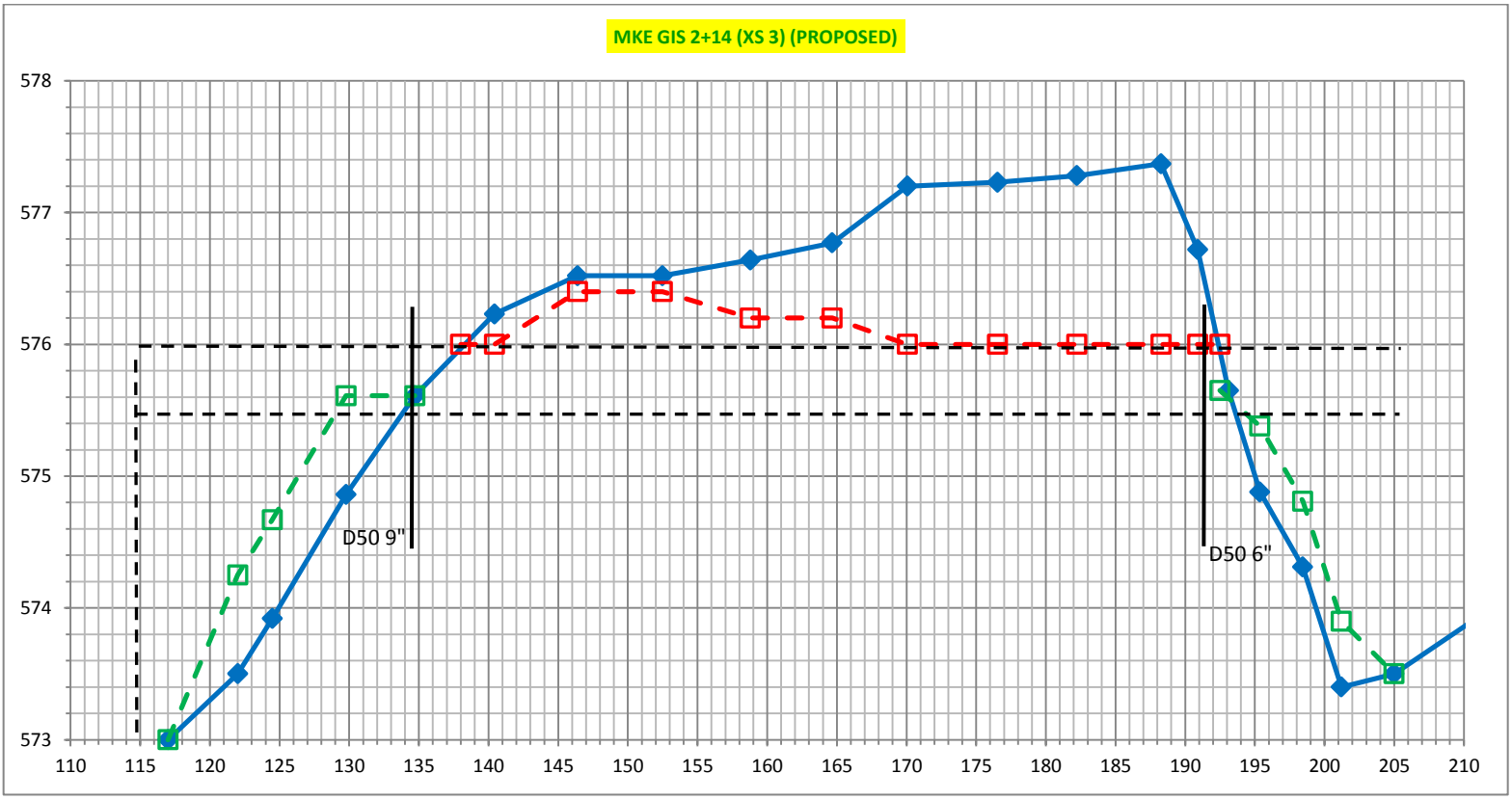
MKE GIS 2+14 (XS 3) (PROPOSED)
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D50 6"
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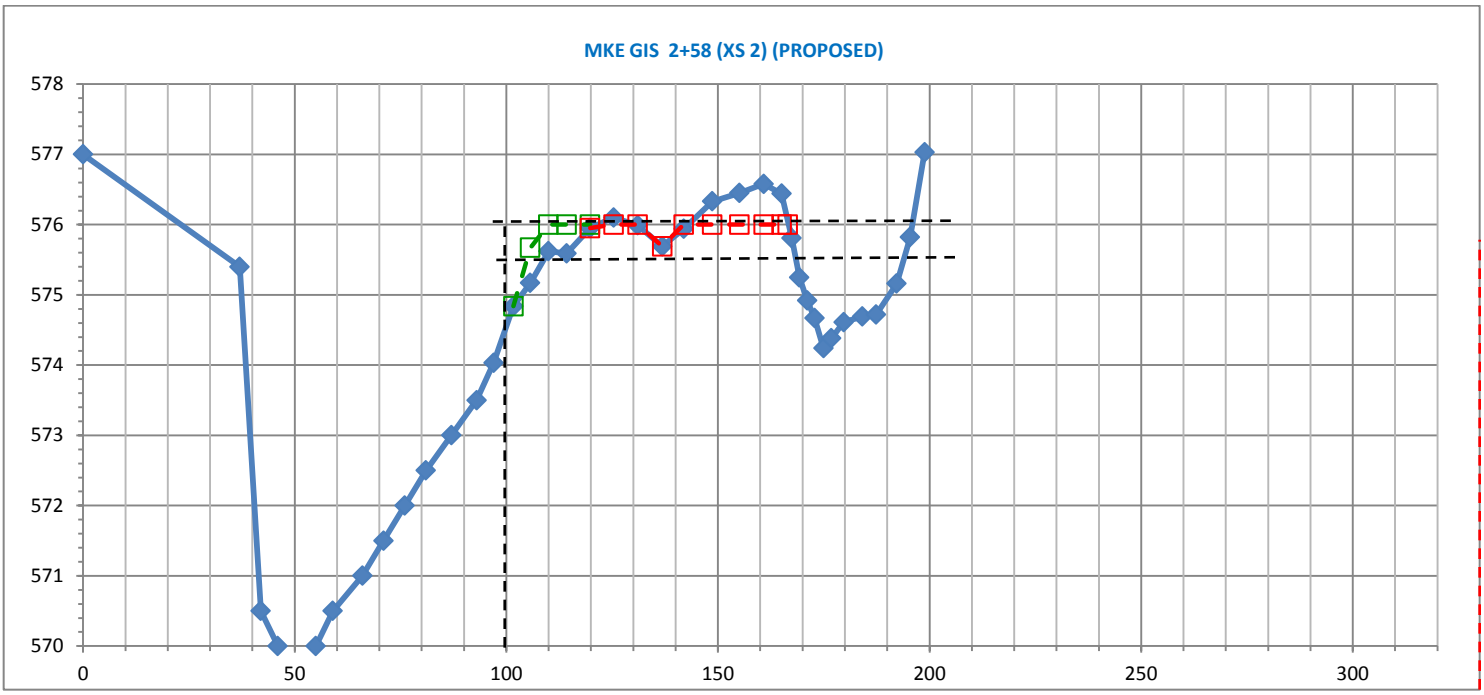
MKE GIS 2+58 (XS 2) (PROPOSED)
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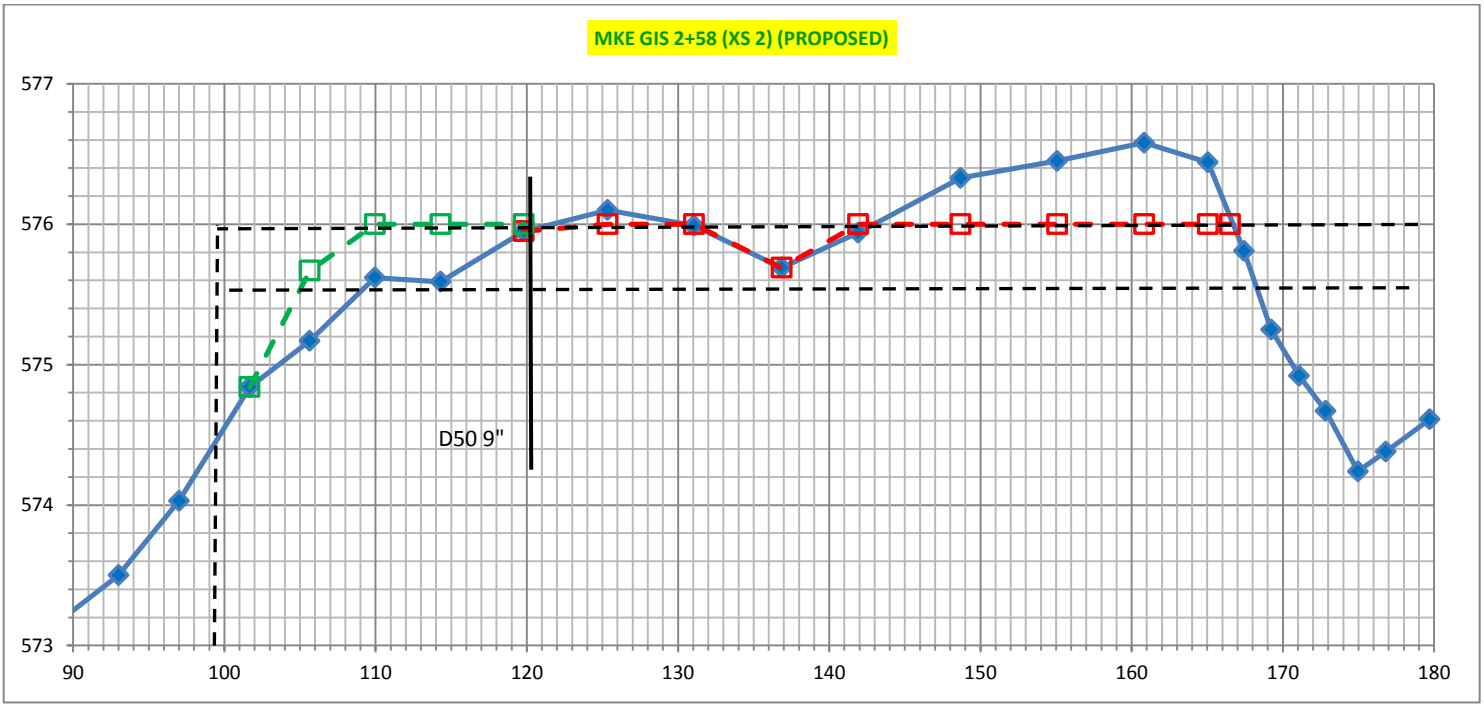
MKE GIS 2+58 (XS 2) (PROPOSED)
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D50 9"
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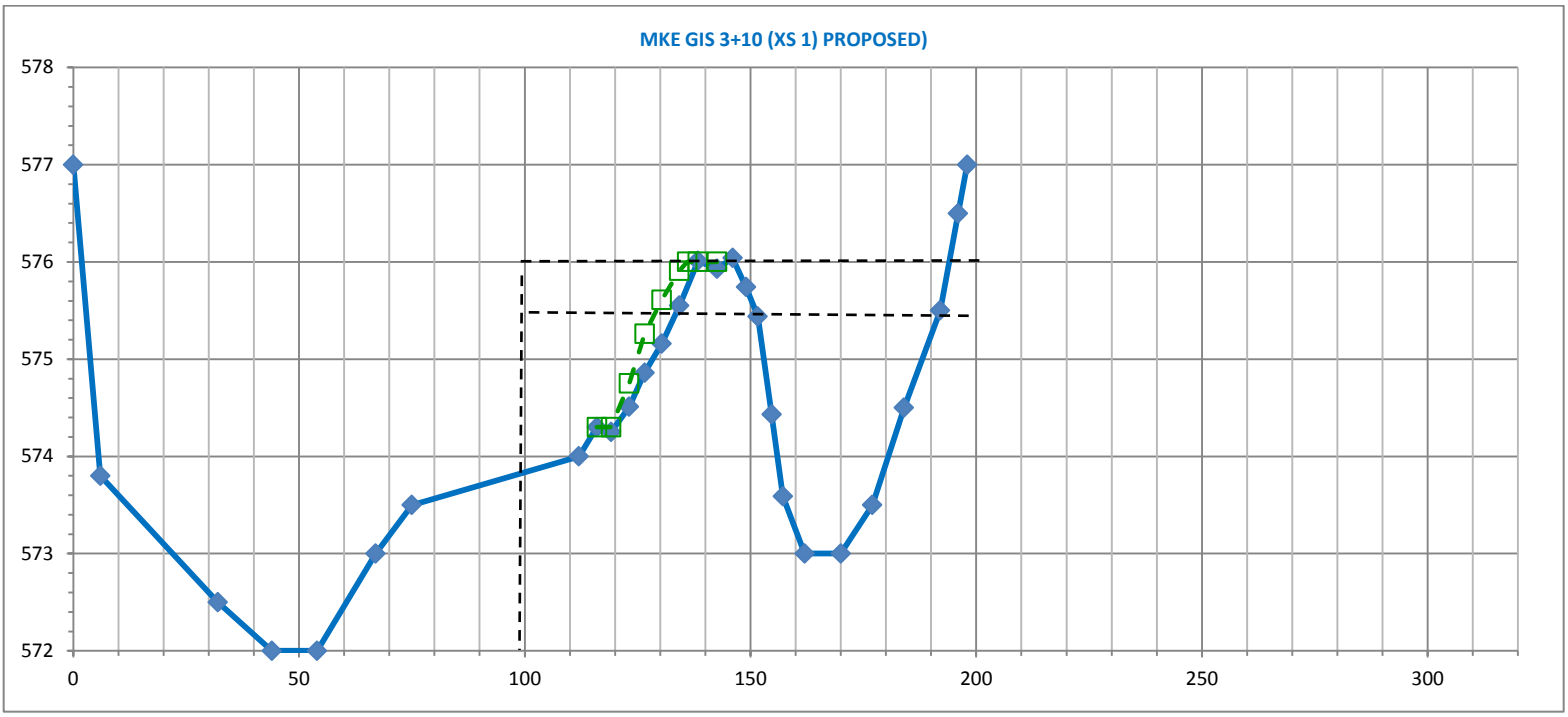
MKE GIS 3+10 (XS 1) PROPOSED)
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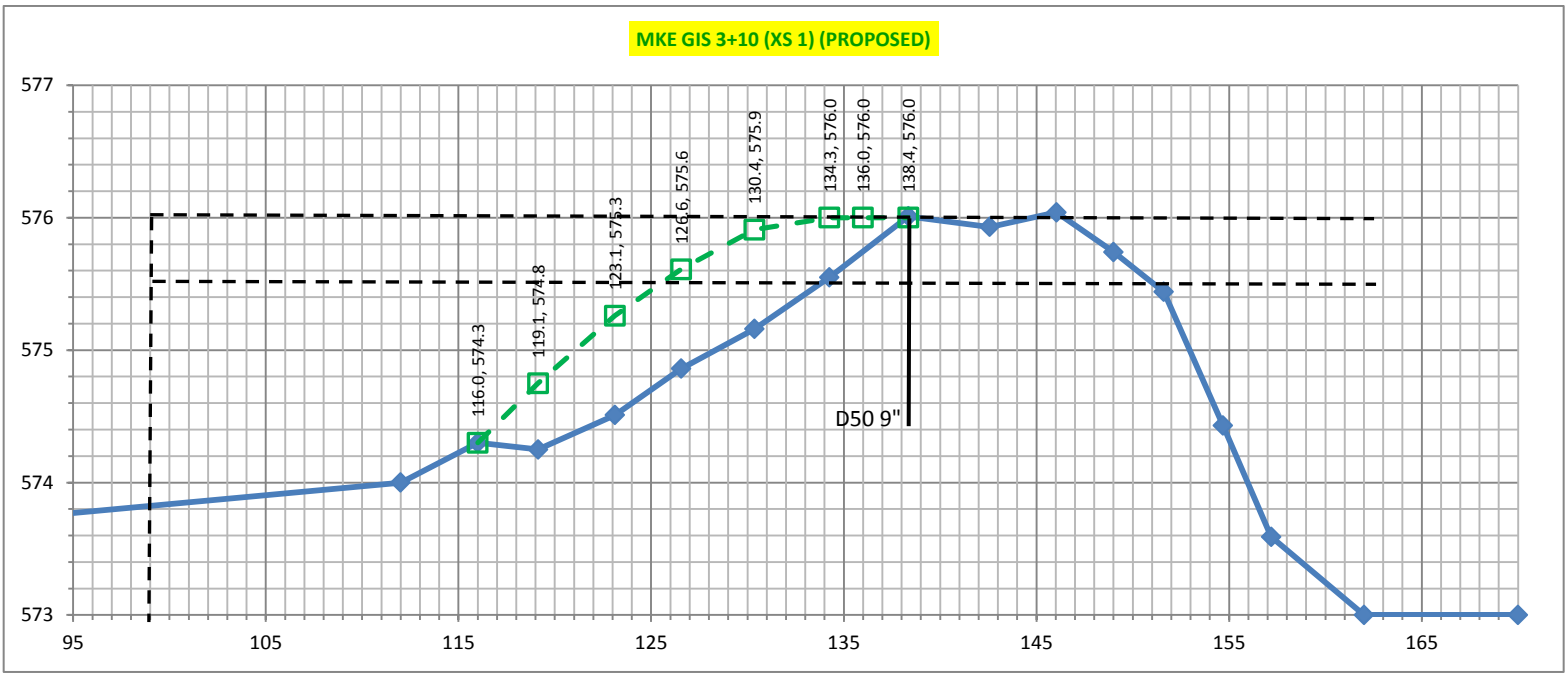
MKE GIS 3+10 (XS 1) (PROPOSED)
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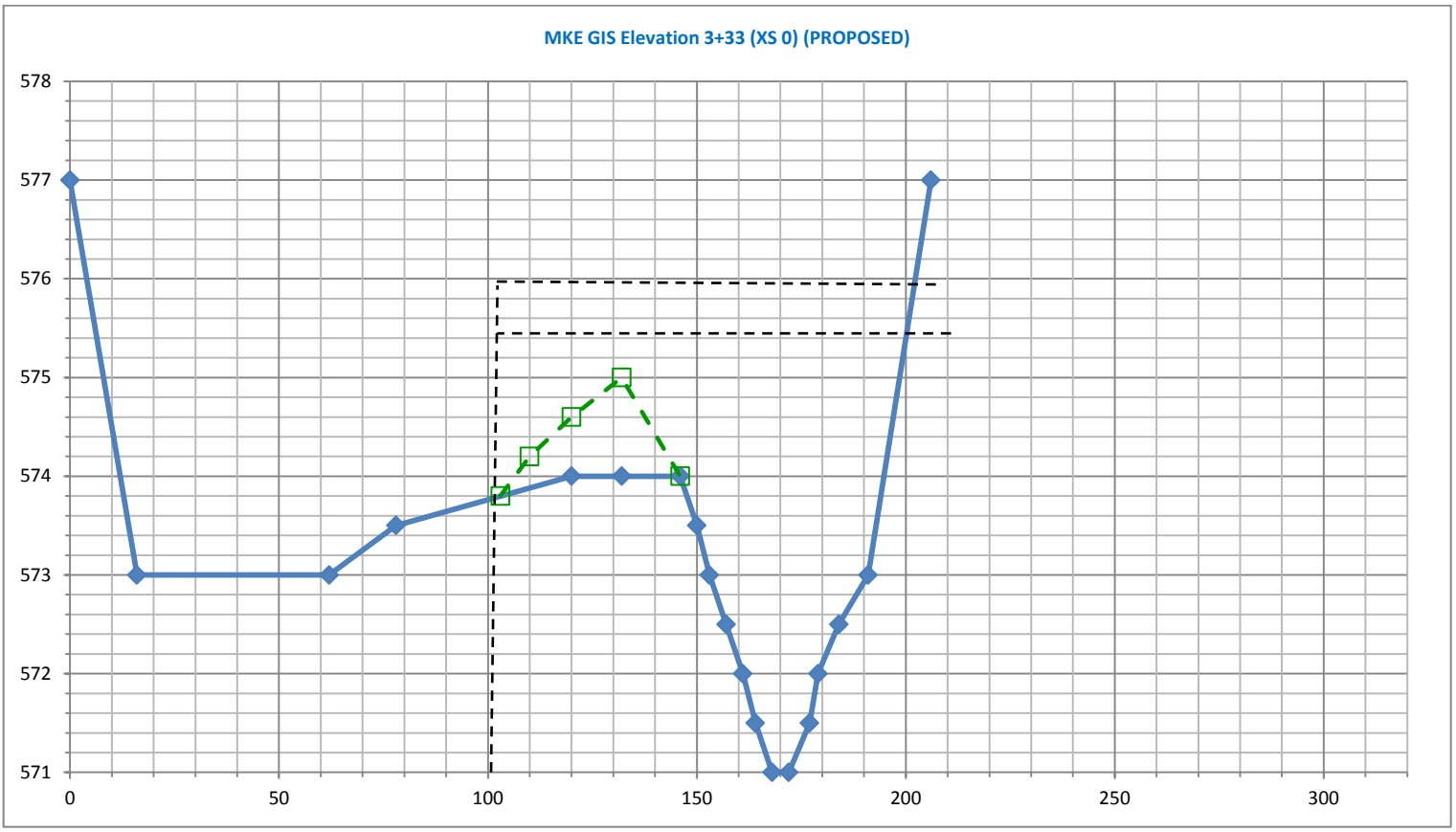
116.0, 574.3
119.1, 574.8
123.1, 575.3
126.6, 575.6
130.4, 575.9
134.3, 576.0
136.0, 576.0
138.4, 576.0
D50 9"


MKE GIS Elevation 3+33 (XS 0) (PROPOSED)
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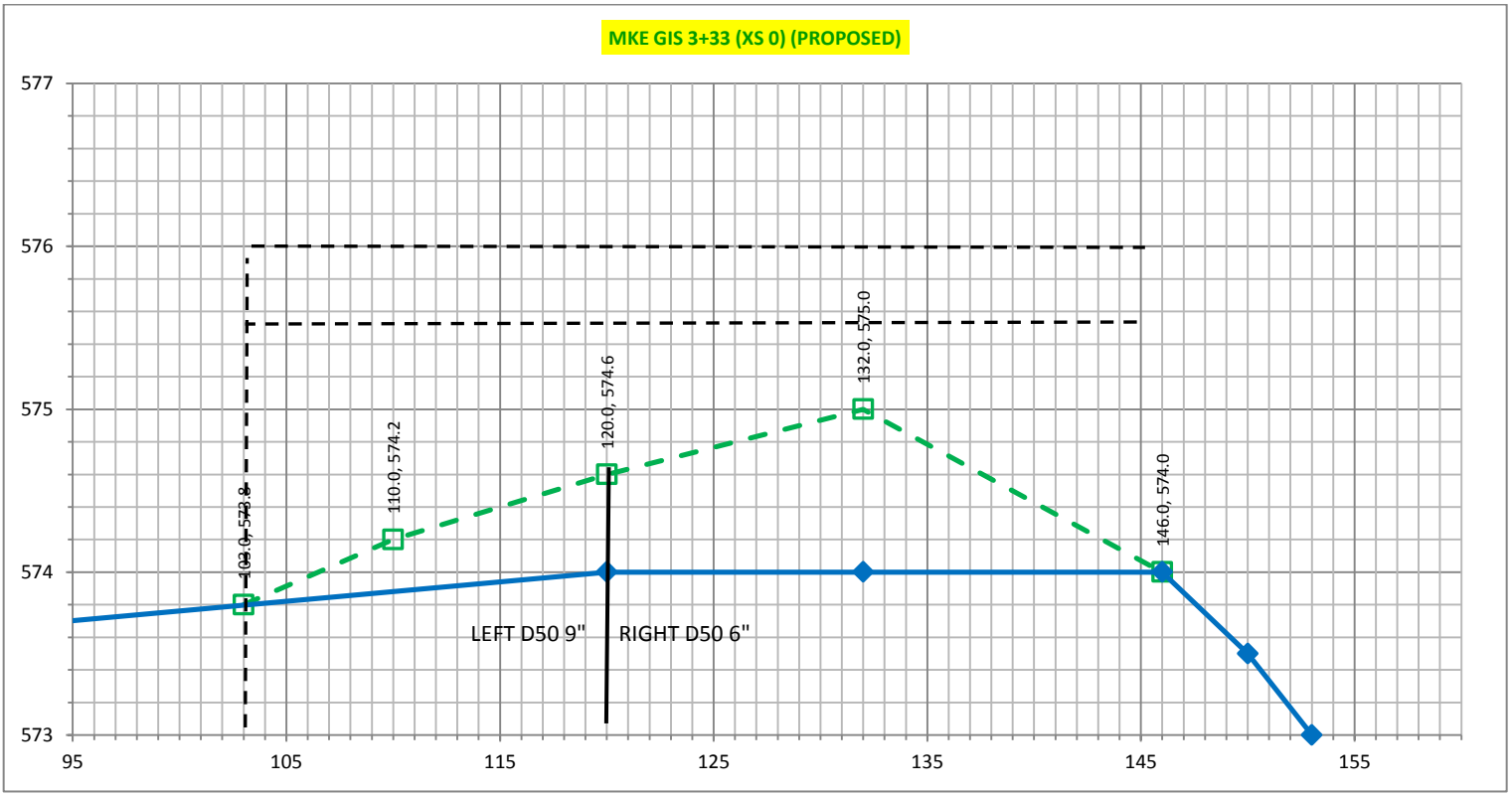
MKE GIS 3+33 (XS 0) (PROPOSED)
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145
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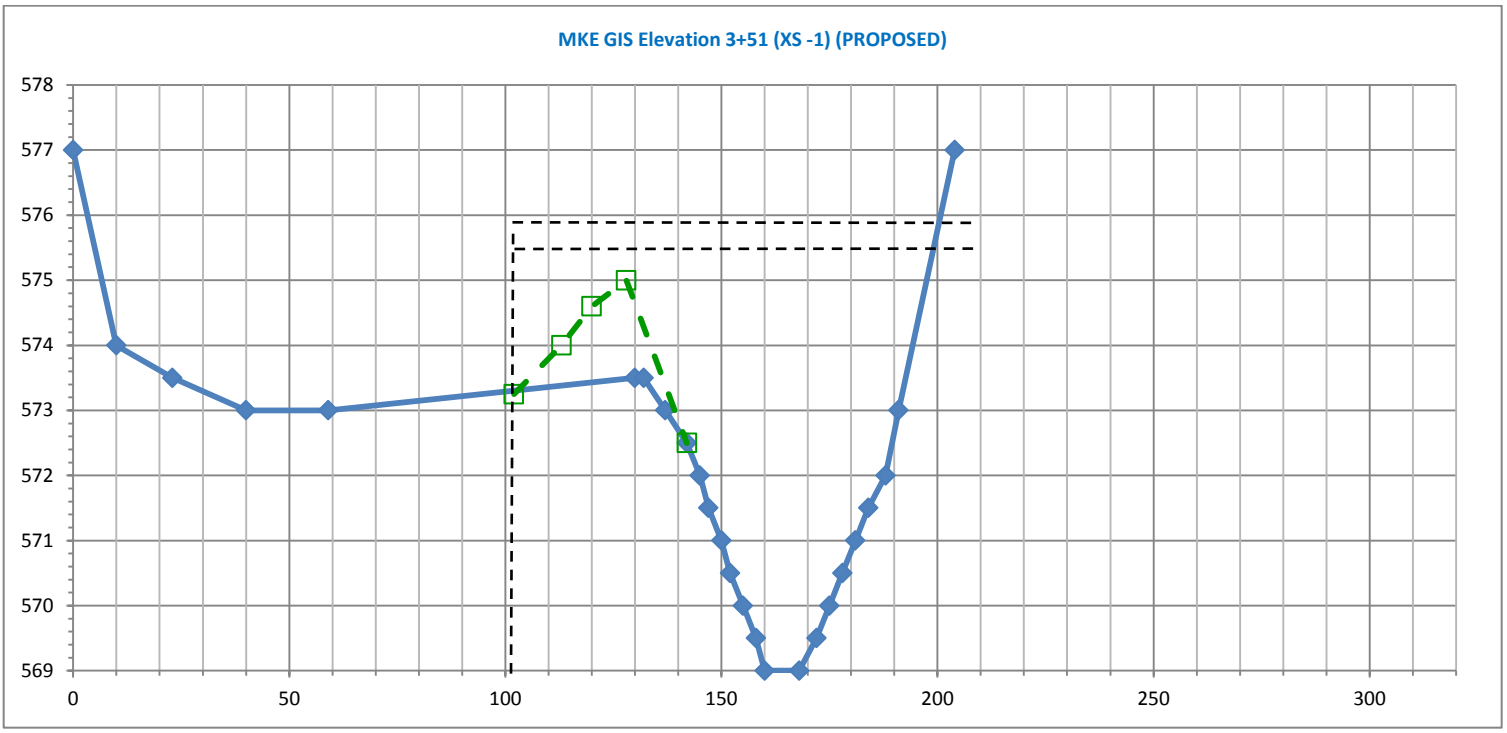
110.0, 574.2
120.0, 574.6
132.0, 575.0
146.0, 574.0
LEFT D50 9"
RIGHT D50 6"


MKE GIS Elevation 3+51 (XS -1) (PROPOSED)
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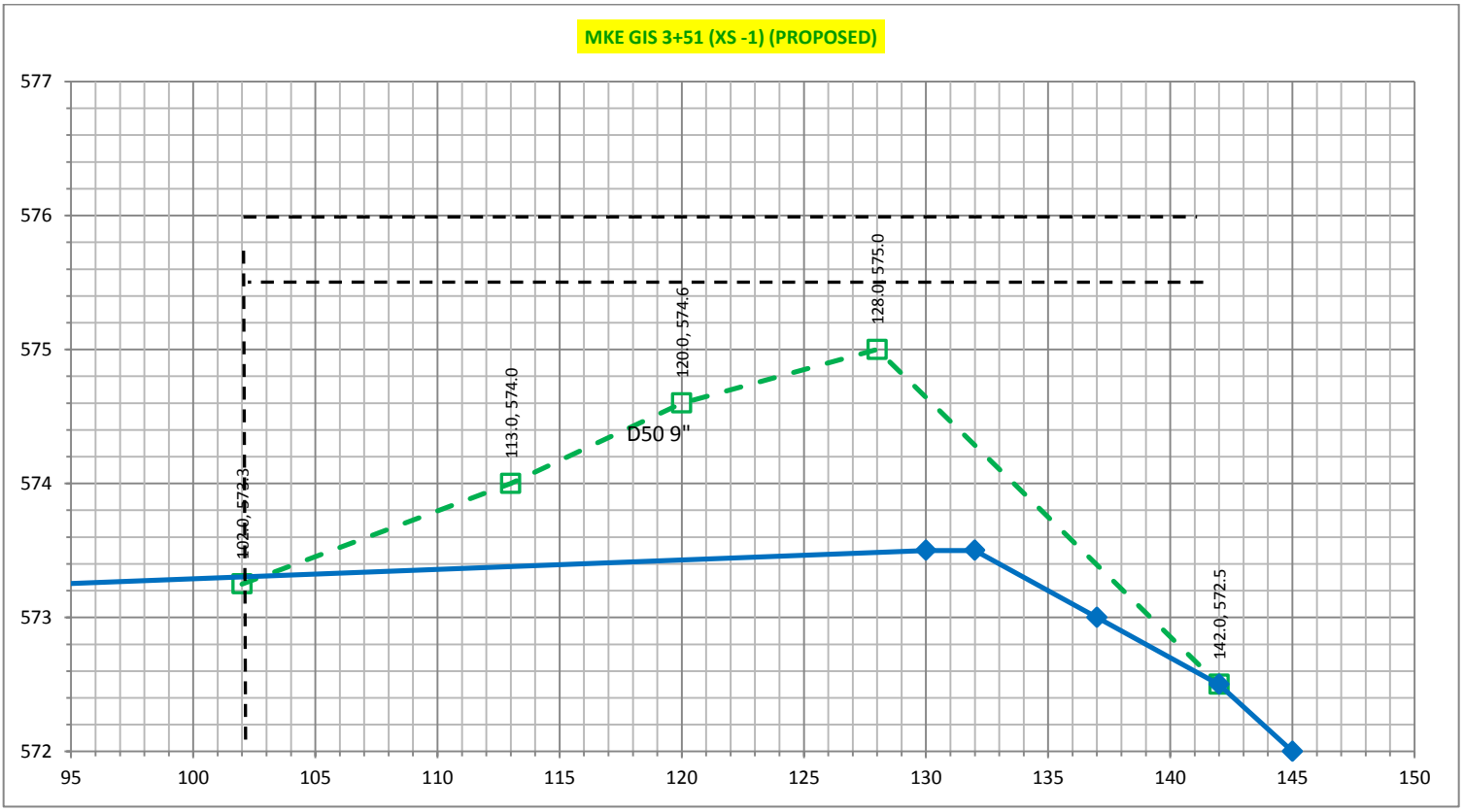
MKE GIS 3+51 (XS -1) (PROPOSED)
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130
135
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102.0, 574.3
113.0, 574.0
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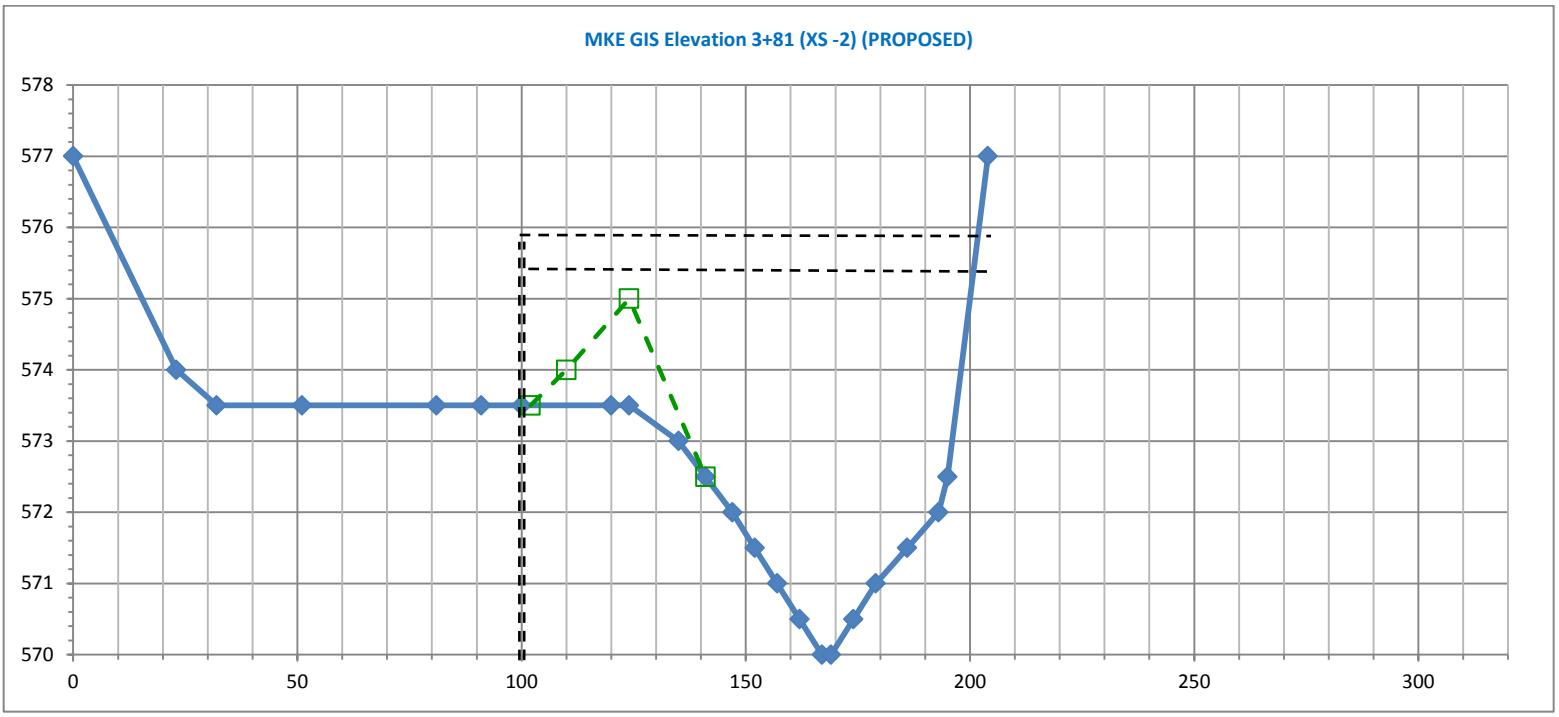
128.0, 575.0
142.0, 572.5
D50 9"


MKE GIS Elevation 3+81 (XS -2) (PROPOSED)
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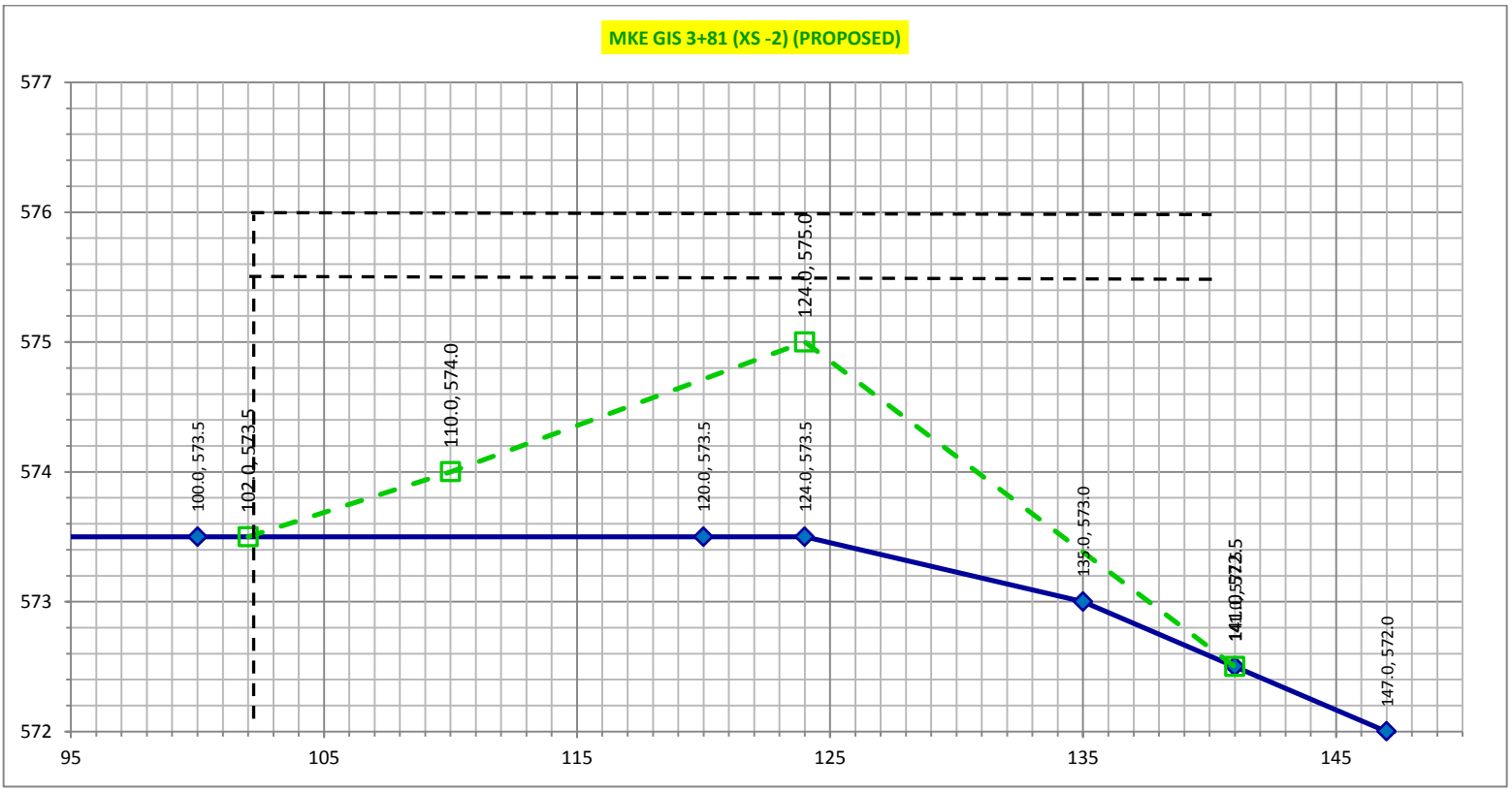
MKE GIS 3+81 (XS -2) (PROPOSED)
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100.0, 573.5
102.0, 573.5
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124.0, 573.5
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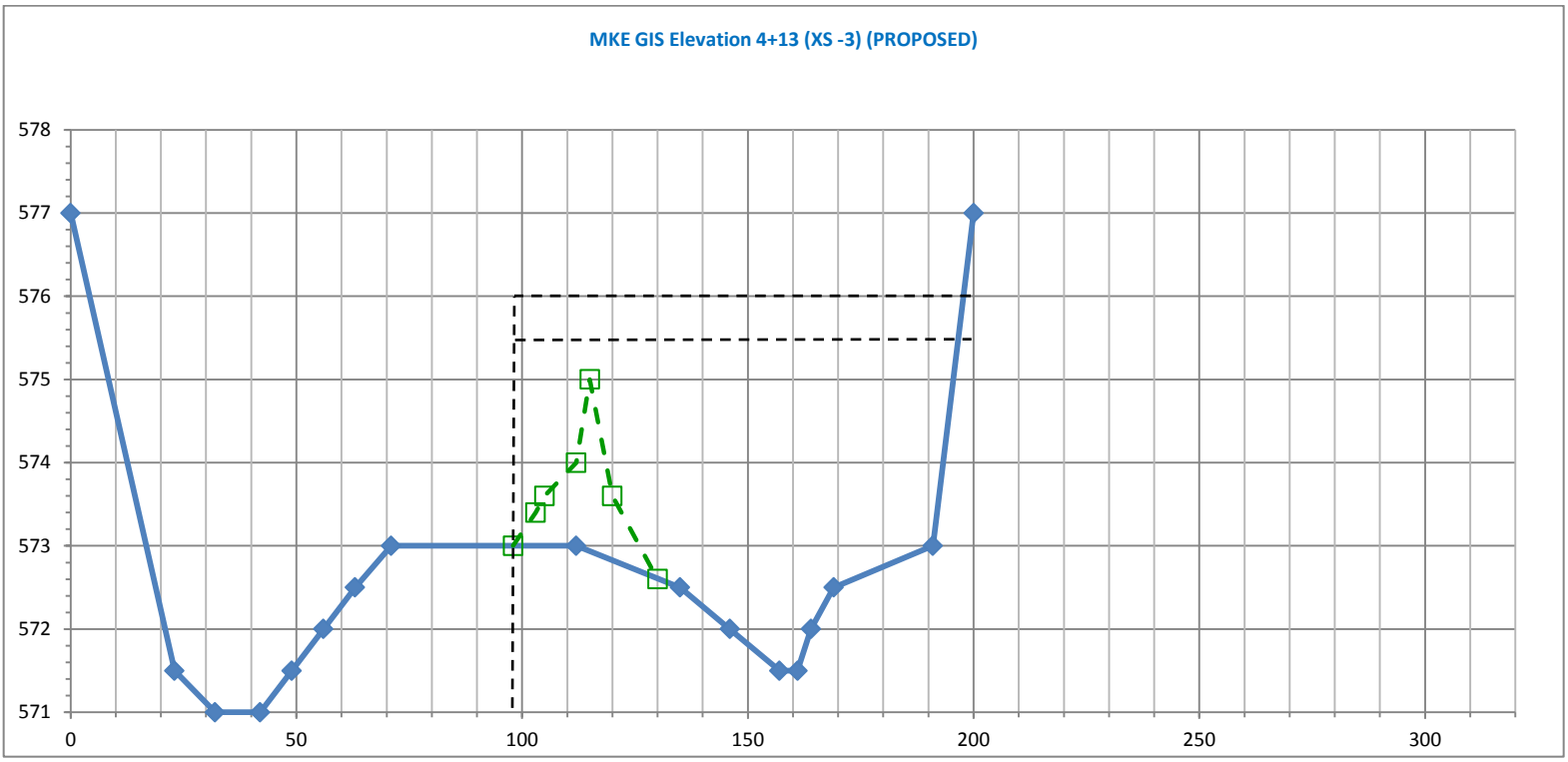
135.0, 573.0
147.0, 572.0


MKE GIS Elevation 4+13 (XS -3) (PROPOSED)
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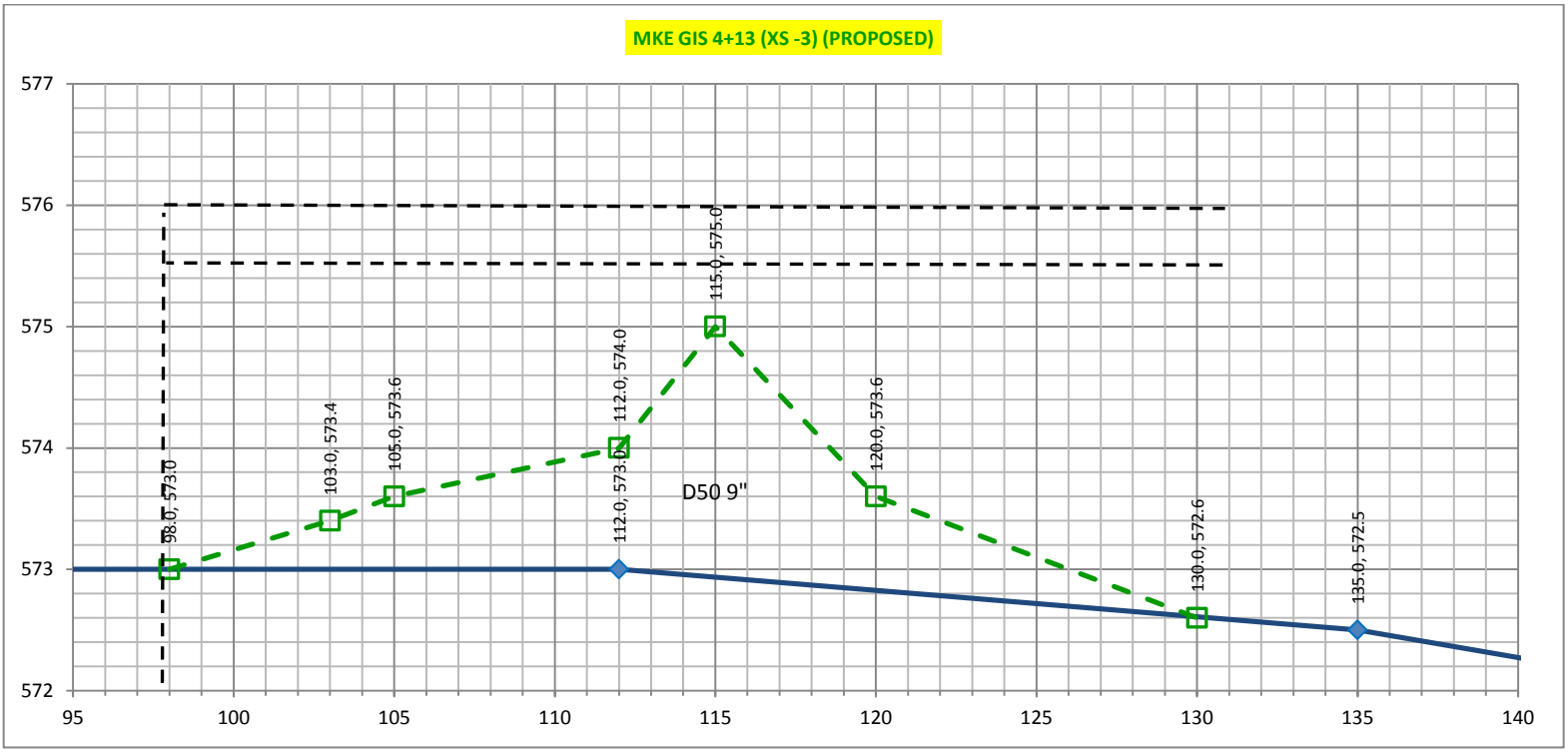
MKE GIS 4+13 (XS -3) (PROPOSED)
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130
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98.0, 573.0
103.0, 573.4
105.0, 573.6
112.0, 573.6
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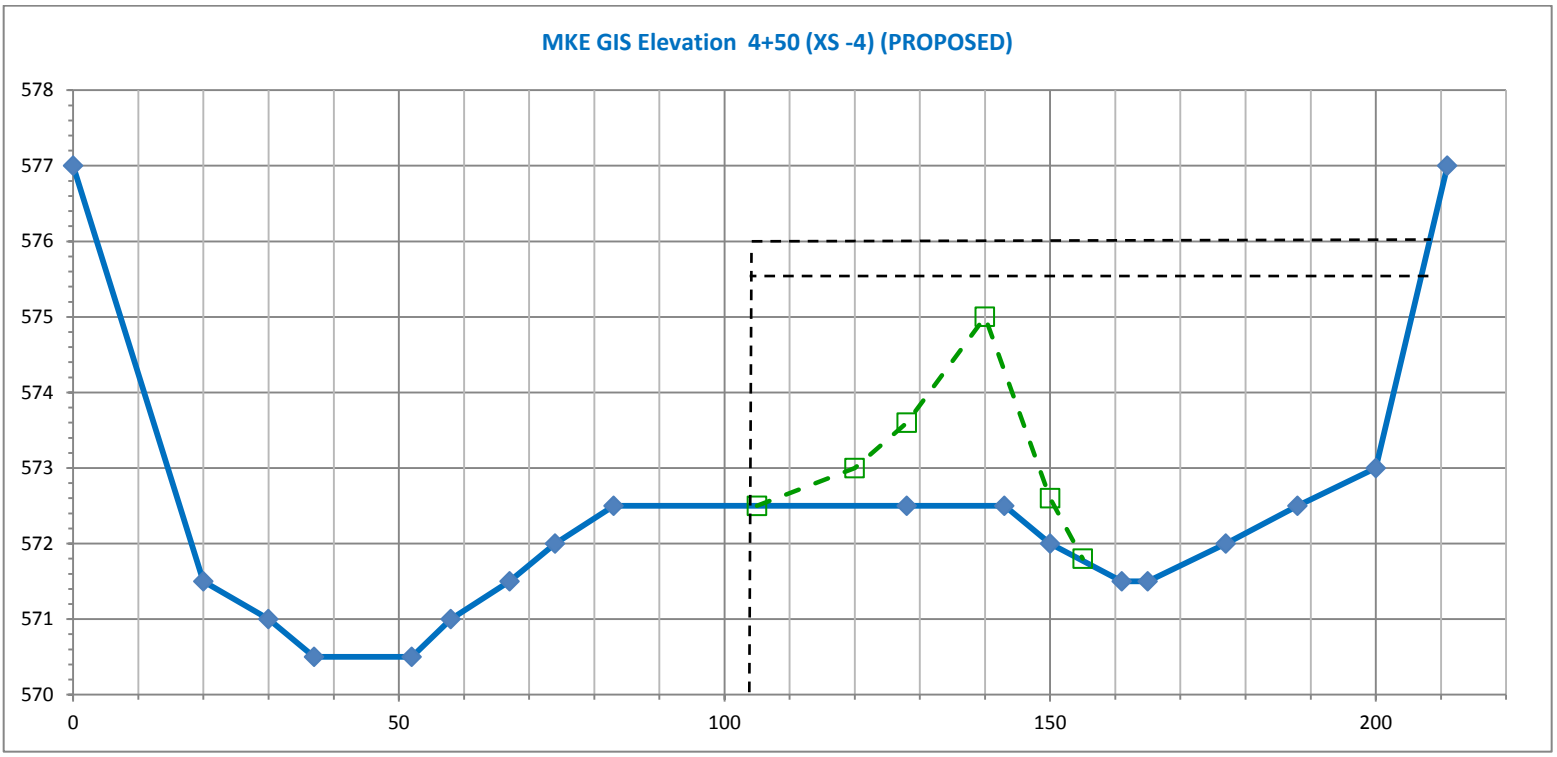
115.0, 575.0
120.0, 573.6
130.0, 572.6
135.0, 572.5
D50 9"


MKE GIS Elevation 4+50 (XS -4) (PROPOSED)
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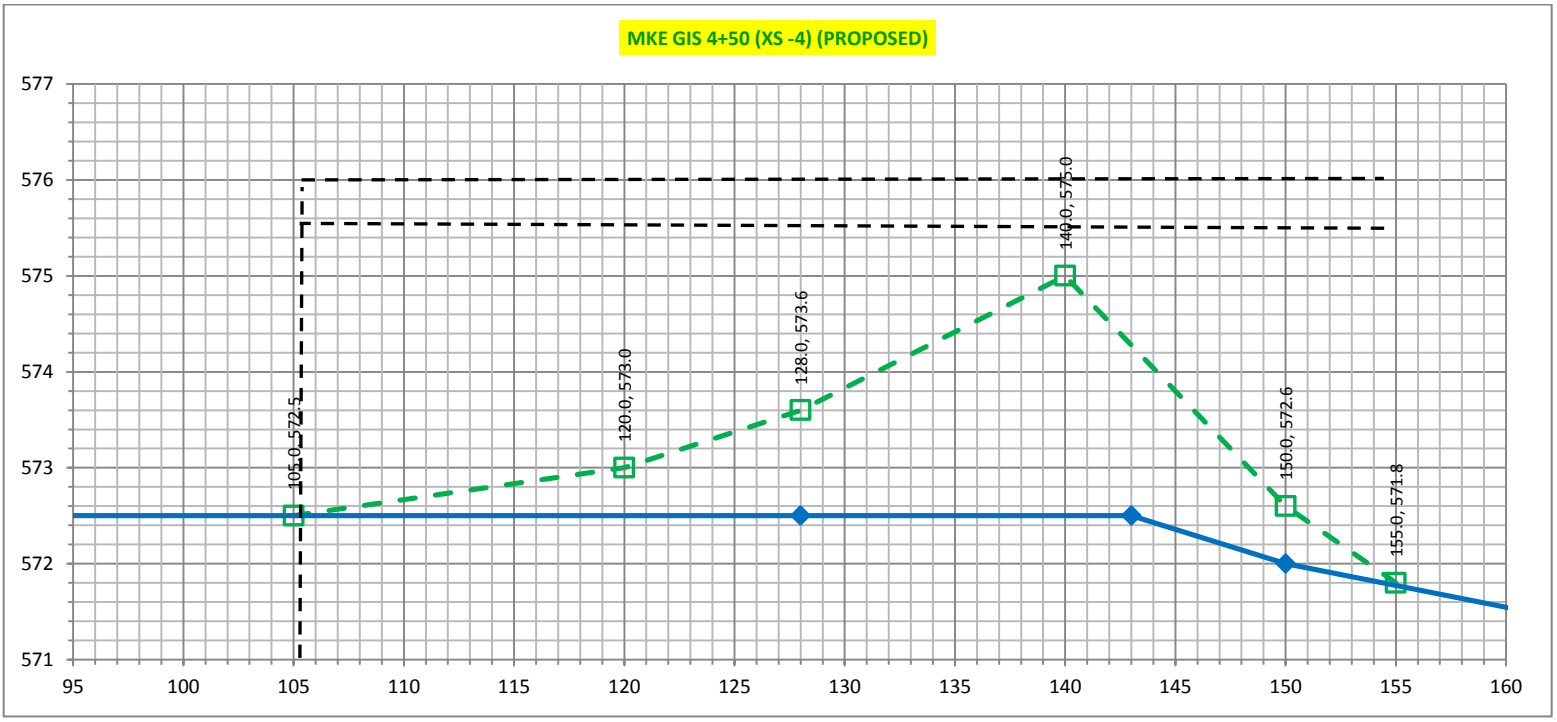
MKE GIS 4+50 (XS -4) (PROPOSED)
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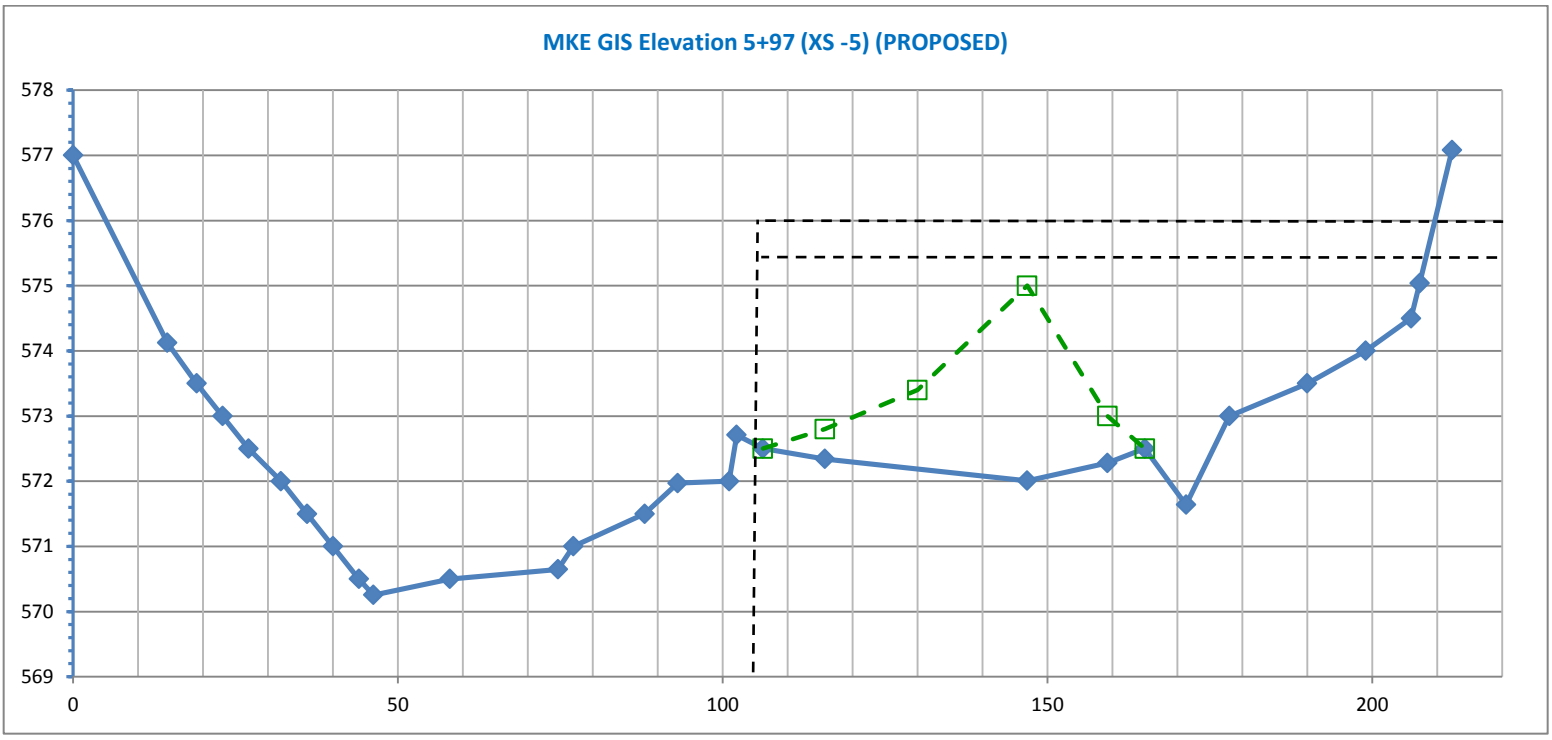
155.0, 571.8


MKE GIS Elevation 5+97 (XS -5) (PROPOSED)
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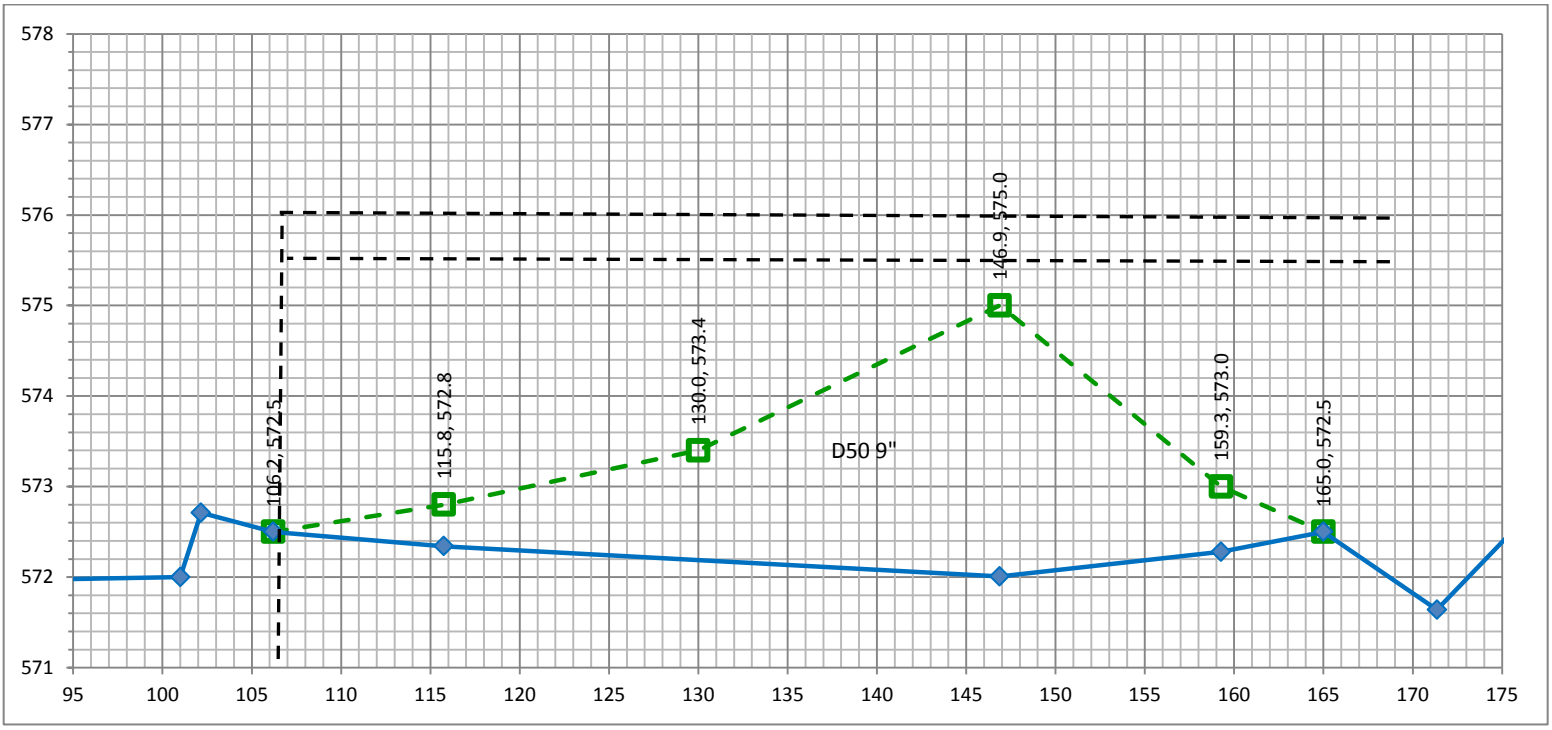
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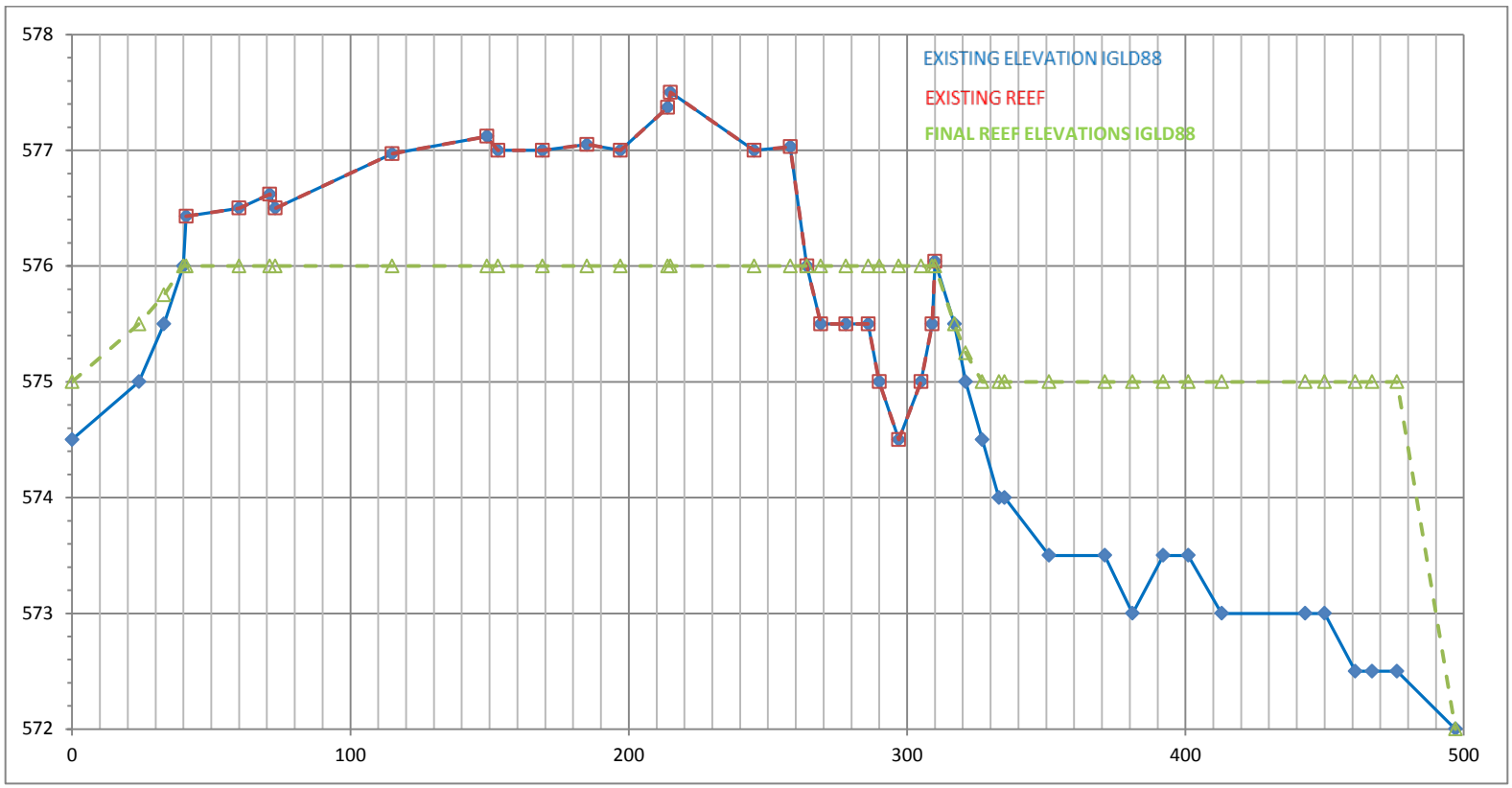
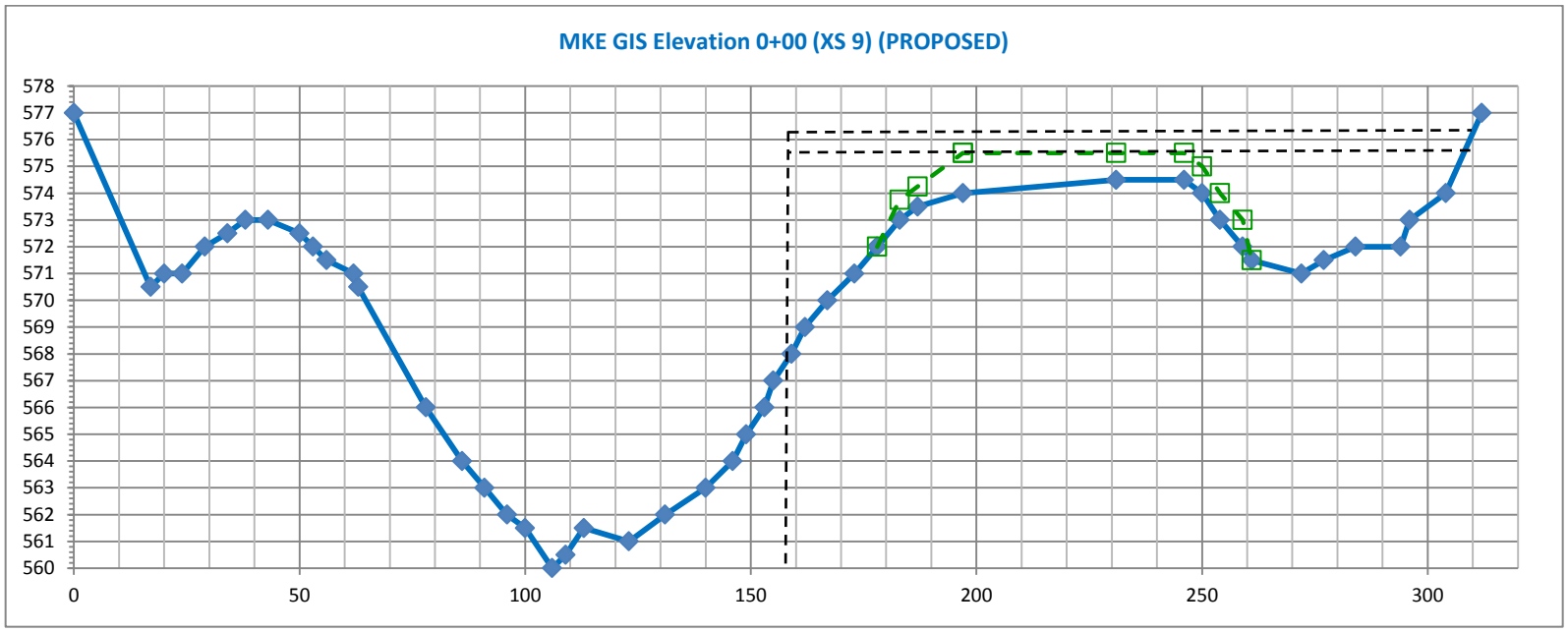
170
175
106.2, 572.5
115.8, 572.8
130.0, 573.4
146.9, 575.0
159.3, 573.0
165.0, 572.5
D50 9"

Profile view of existing river bed and reef, and proposed reef.




MKE GIS Elevation 0+00 (XS 9) (PROPOSED)
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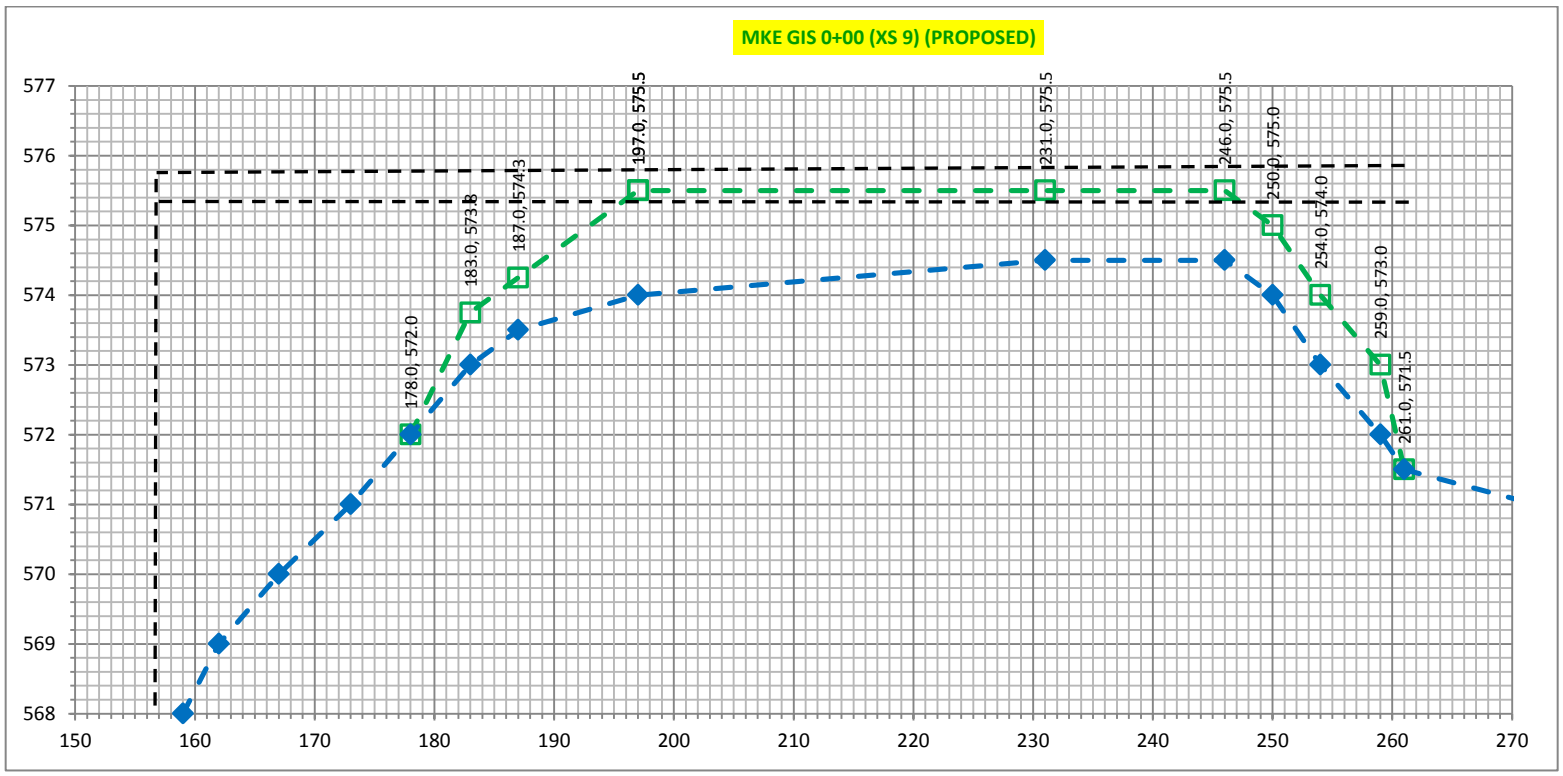
MKE GIS 0+00 (XS 9) (PROPOSED)
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178.0, 572.0
183.0, 573.8
187.0, 574.3
197.0, 575.5
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246.0, 575.5
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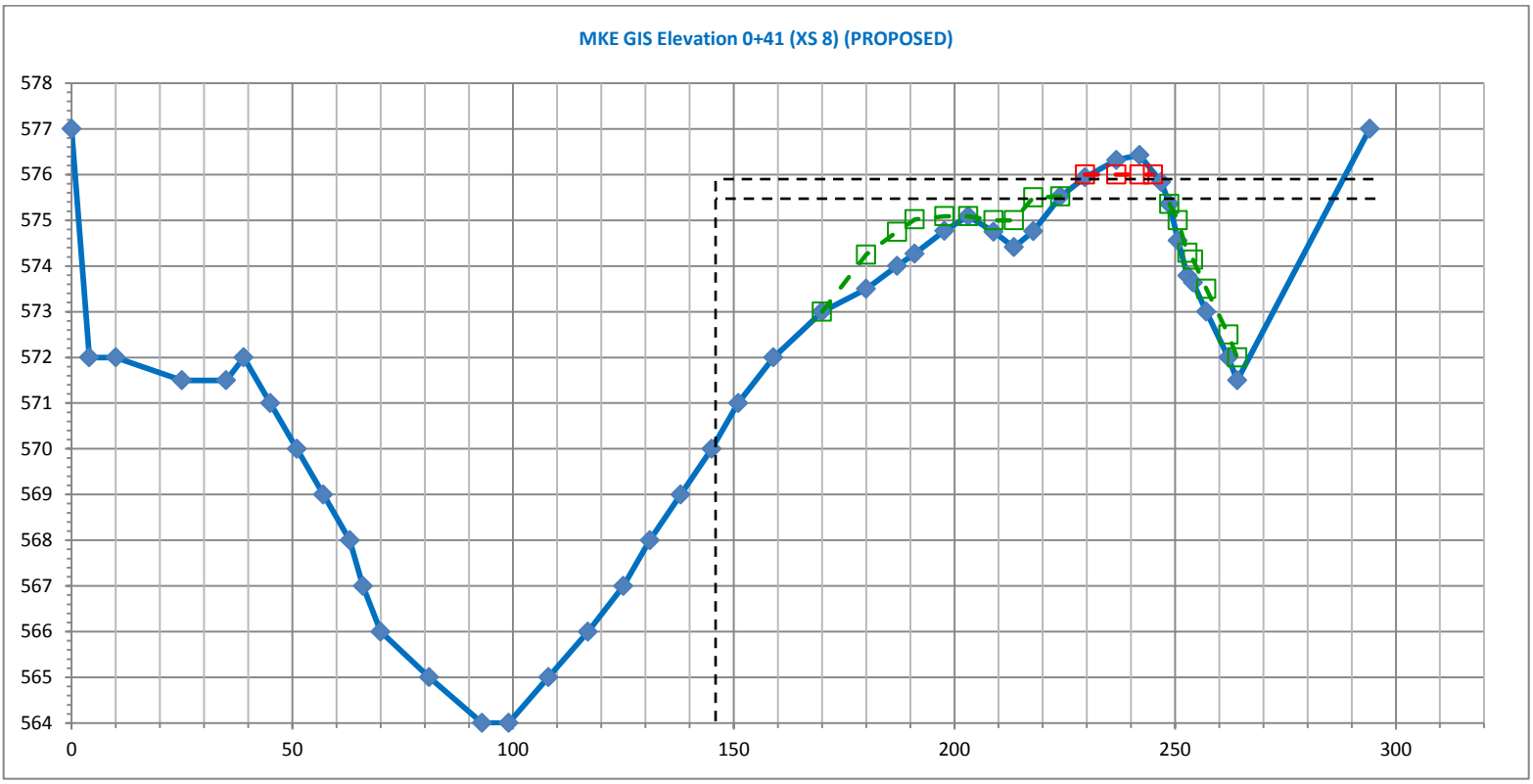
254.0, 574.0
259.0, 573.0
261.0, 571.5


MKE GIS Elevation 0+41 (XS 8) (PROPOSED)
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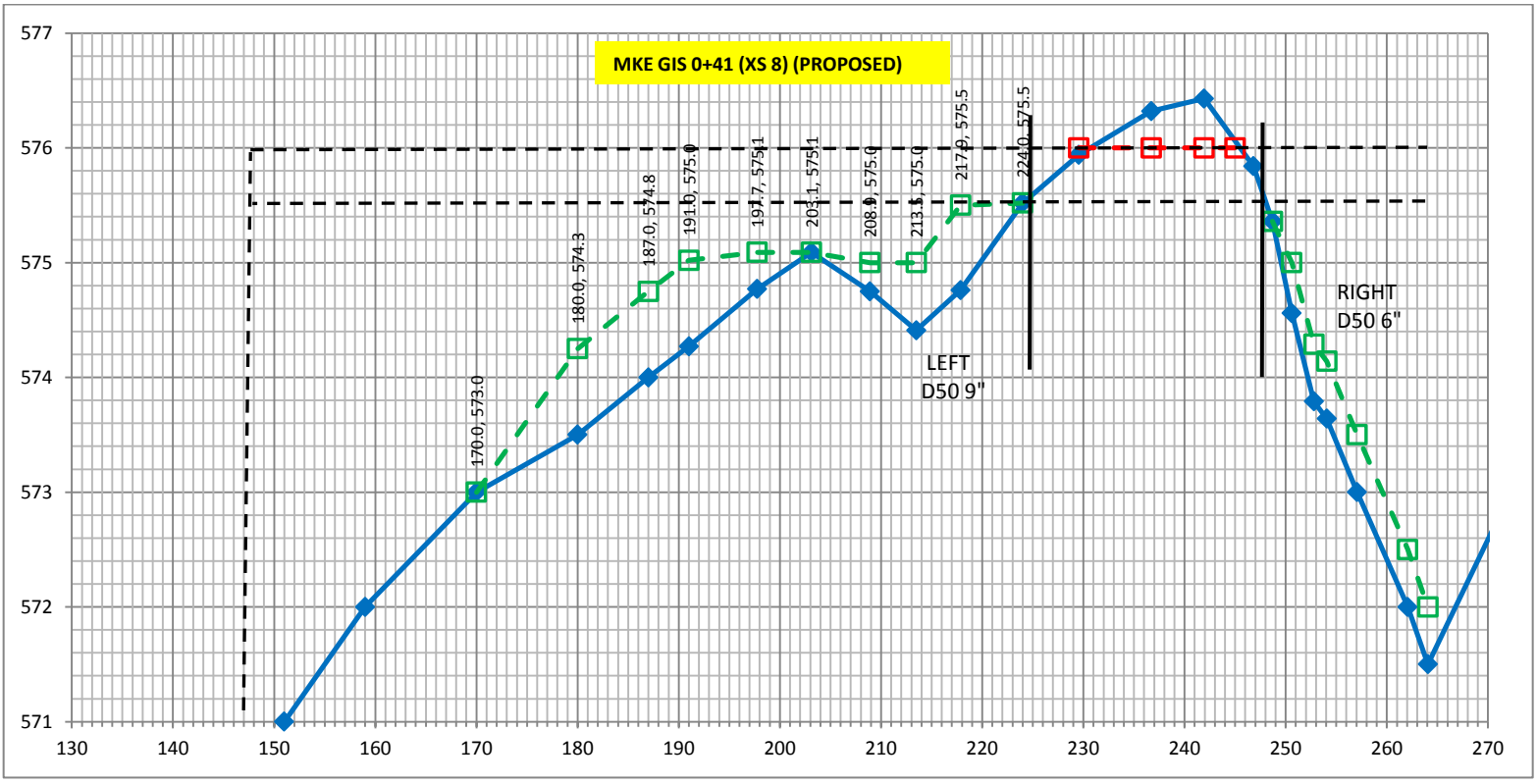
MKE GIS 0+41 (XS 8) (PROPOSED)
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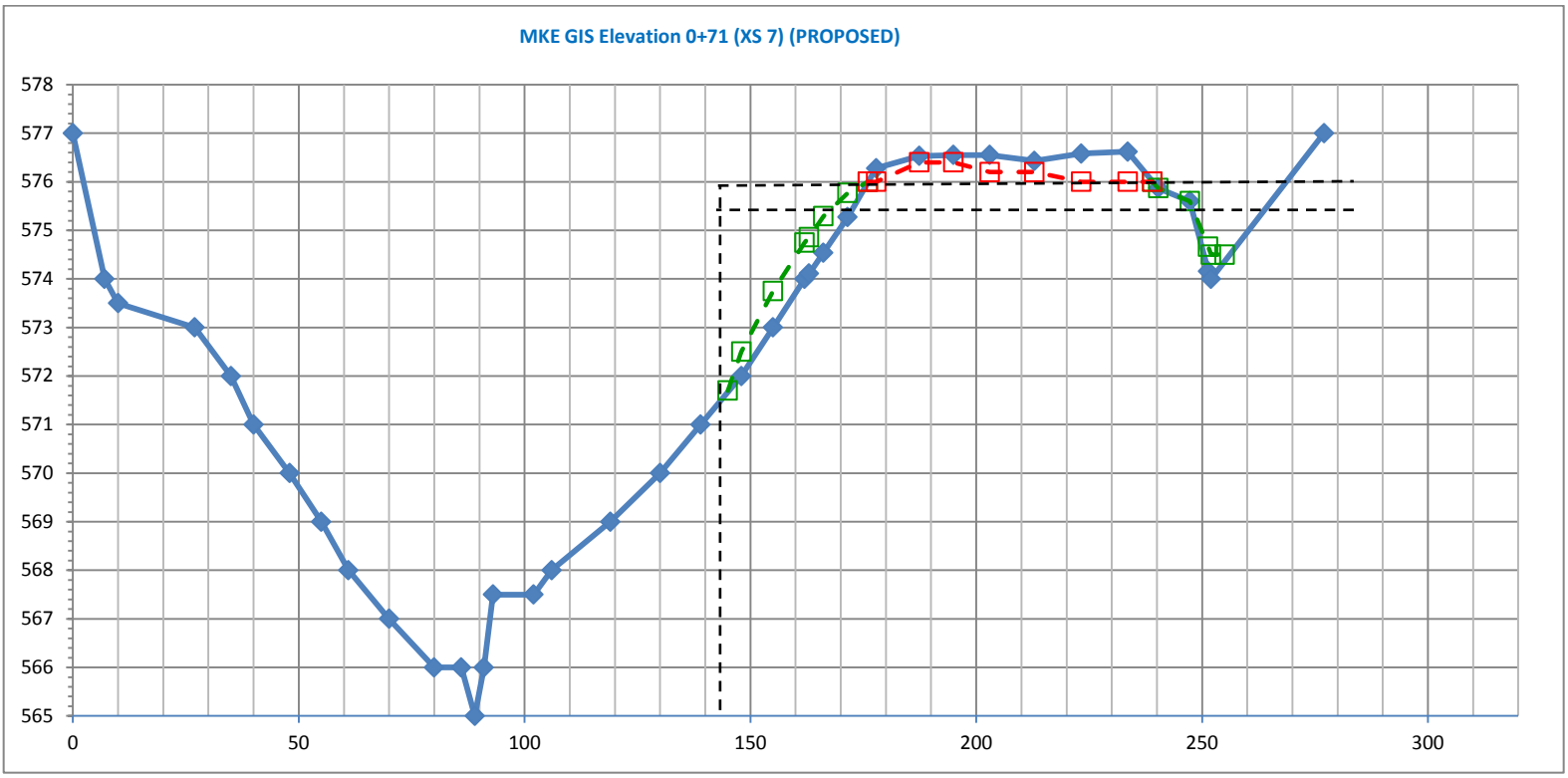
170.0, 573.0
180.0, 574.3
187.0, 574.8
191.0, 575.0
197.7, 575.1
203.1, 575.1
208.9, 575.0
213.5, 575.0
217.9, 575.5
224.0, 575.5
LEFT
D50 9"
RIGHT
D50 6"


MKE GIS Elevation 0+71 (XS 7) (PROPOSED)
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250
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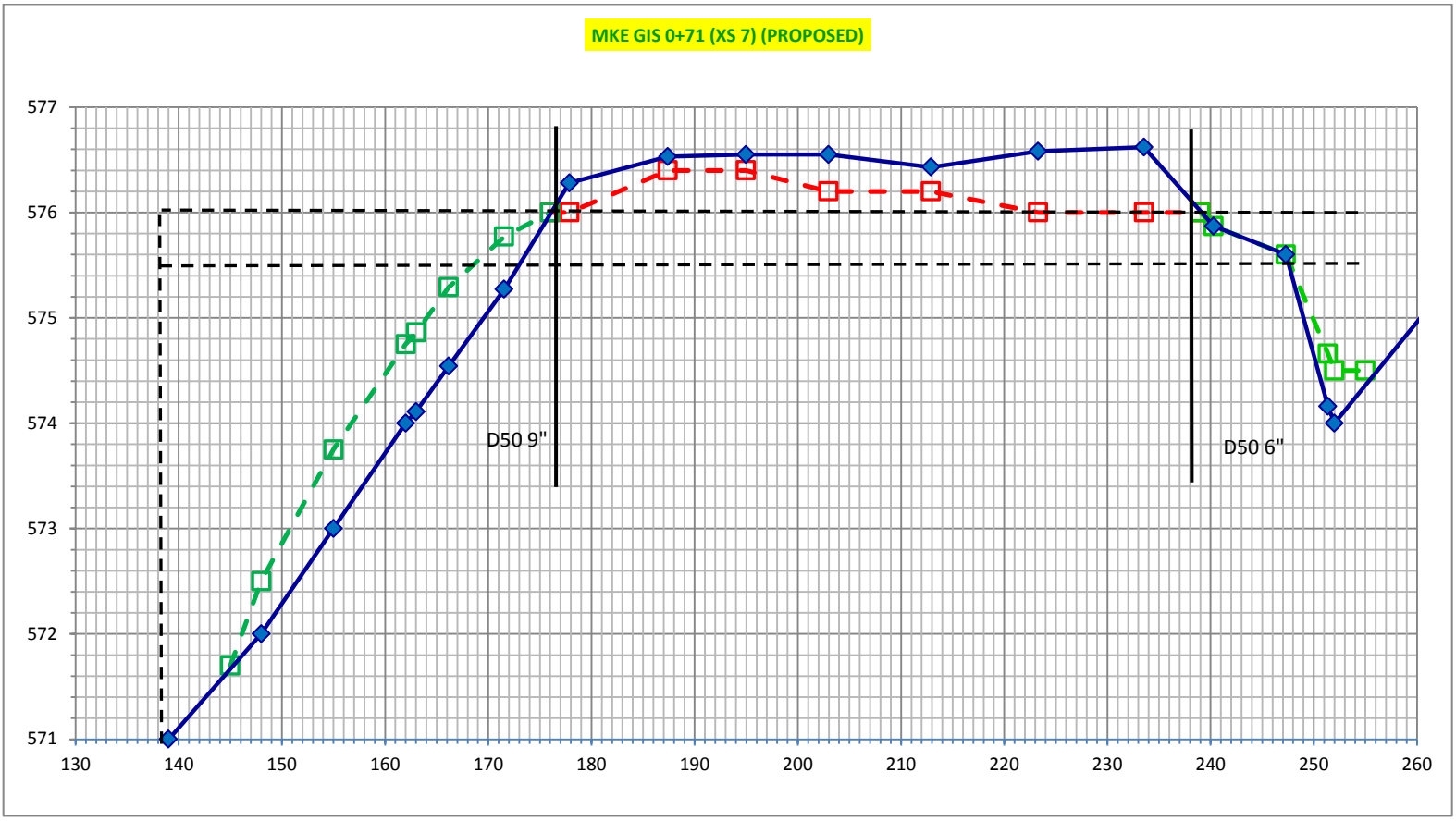
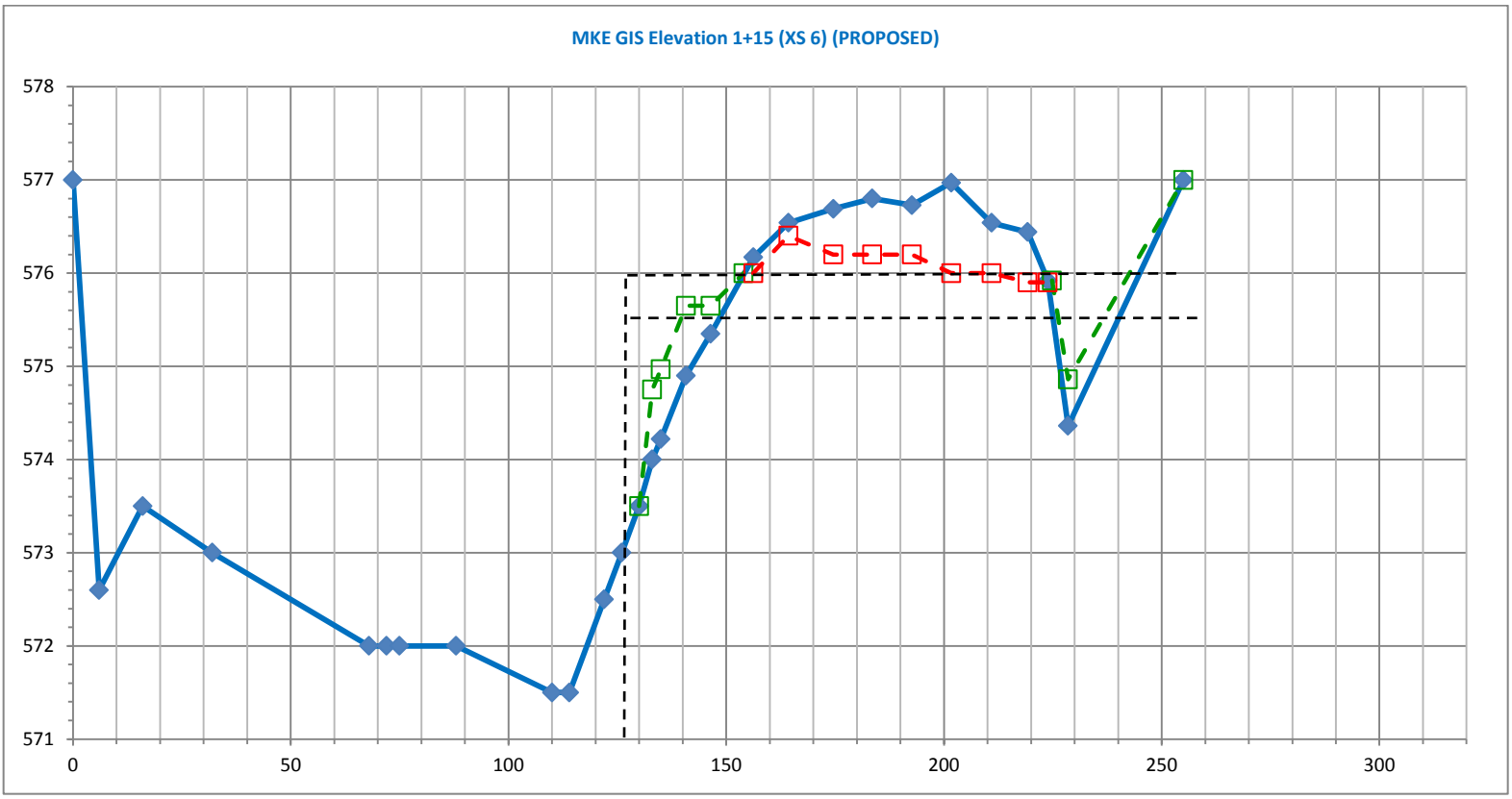

MKE GIS 0+71 (XS 7) (PROPOSED)
577
576
575
574
573
572
571
D50 9"
D50 6"
130
140
150
160
170
180
190
200
210
220
230
240
250
260


MKE GIS Elevation 1+15 (XS 6) (PROPOSED)
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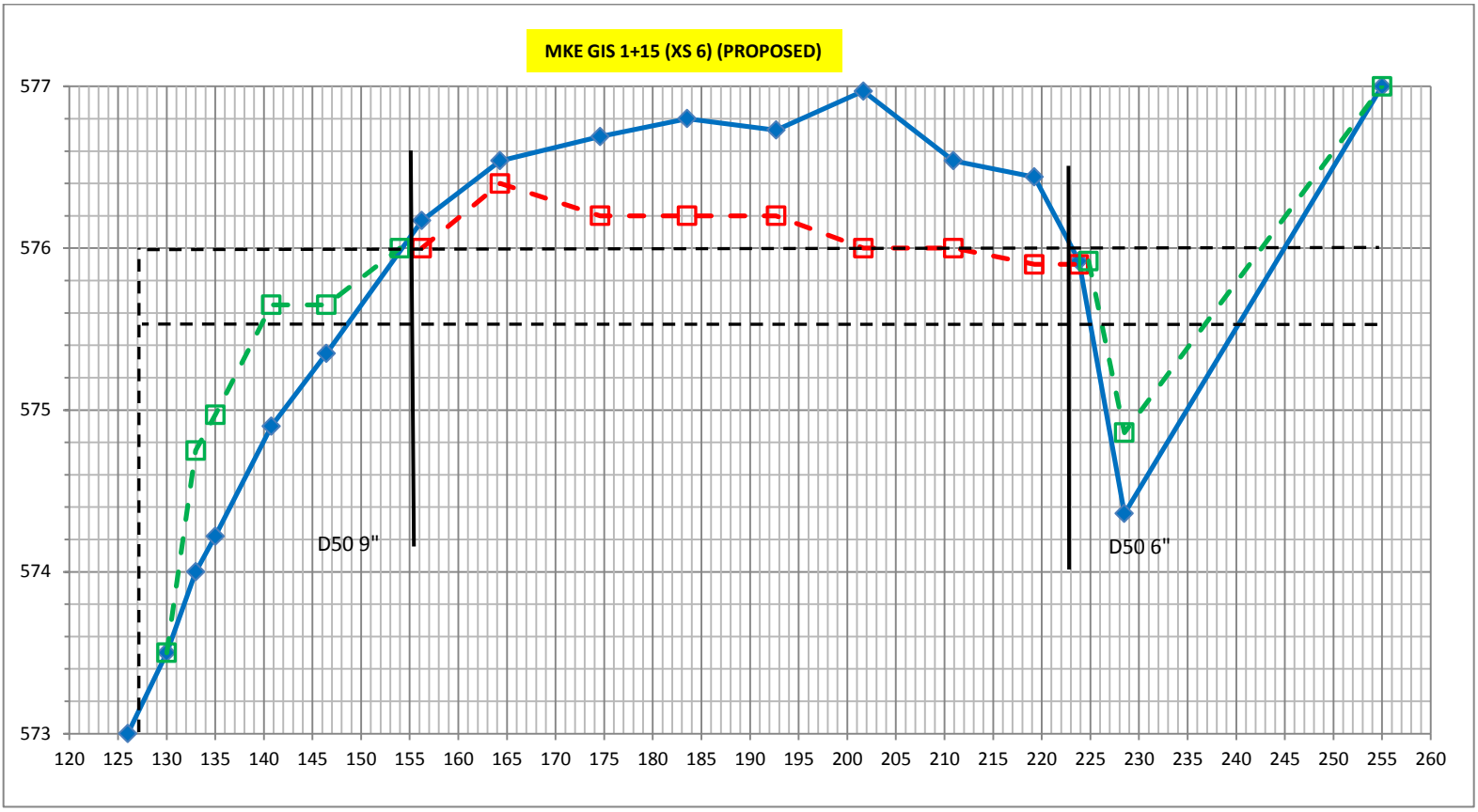
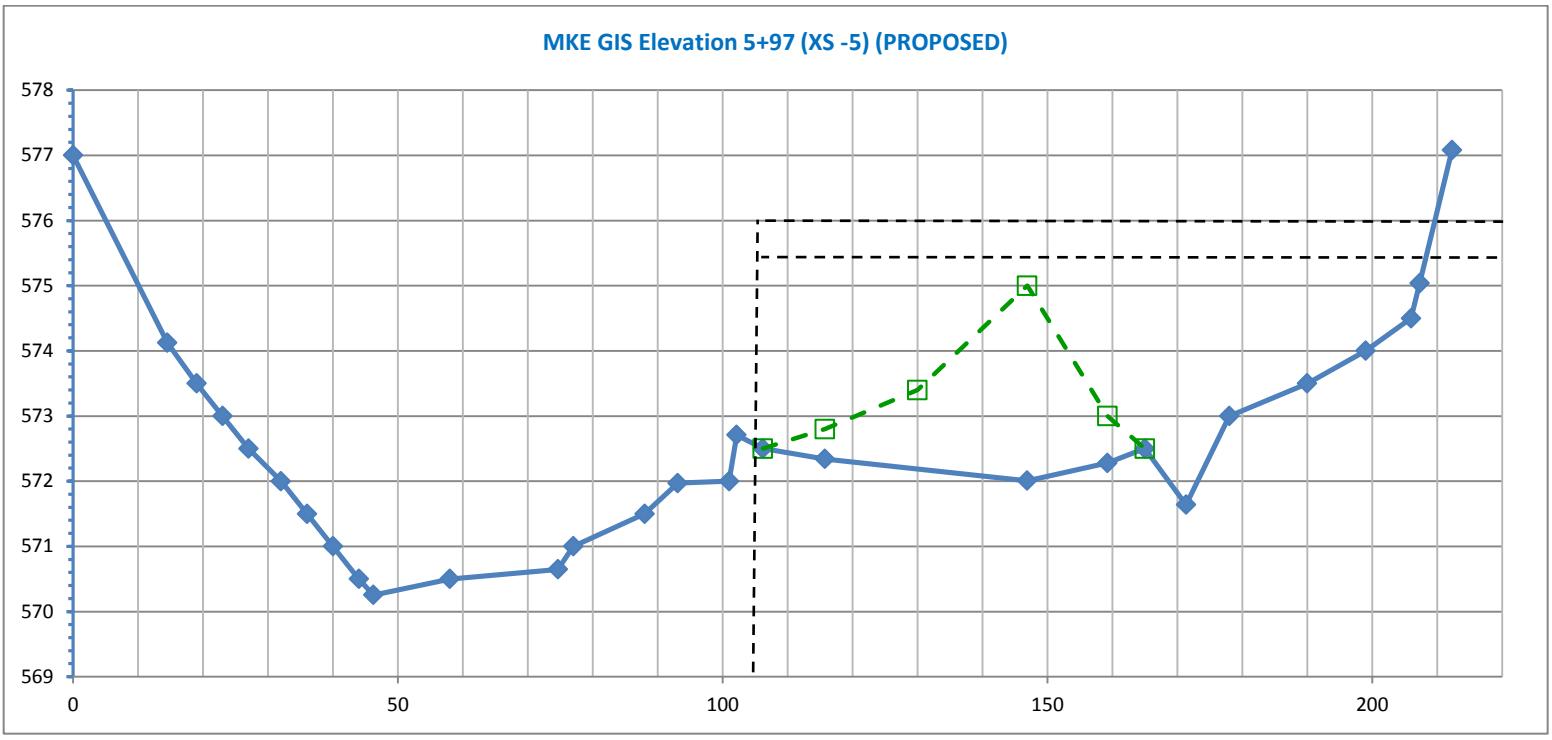
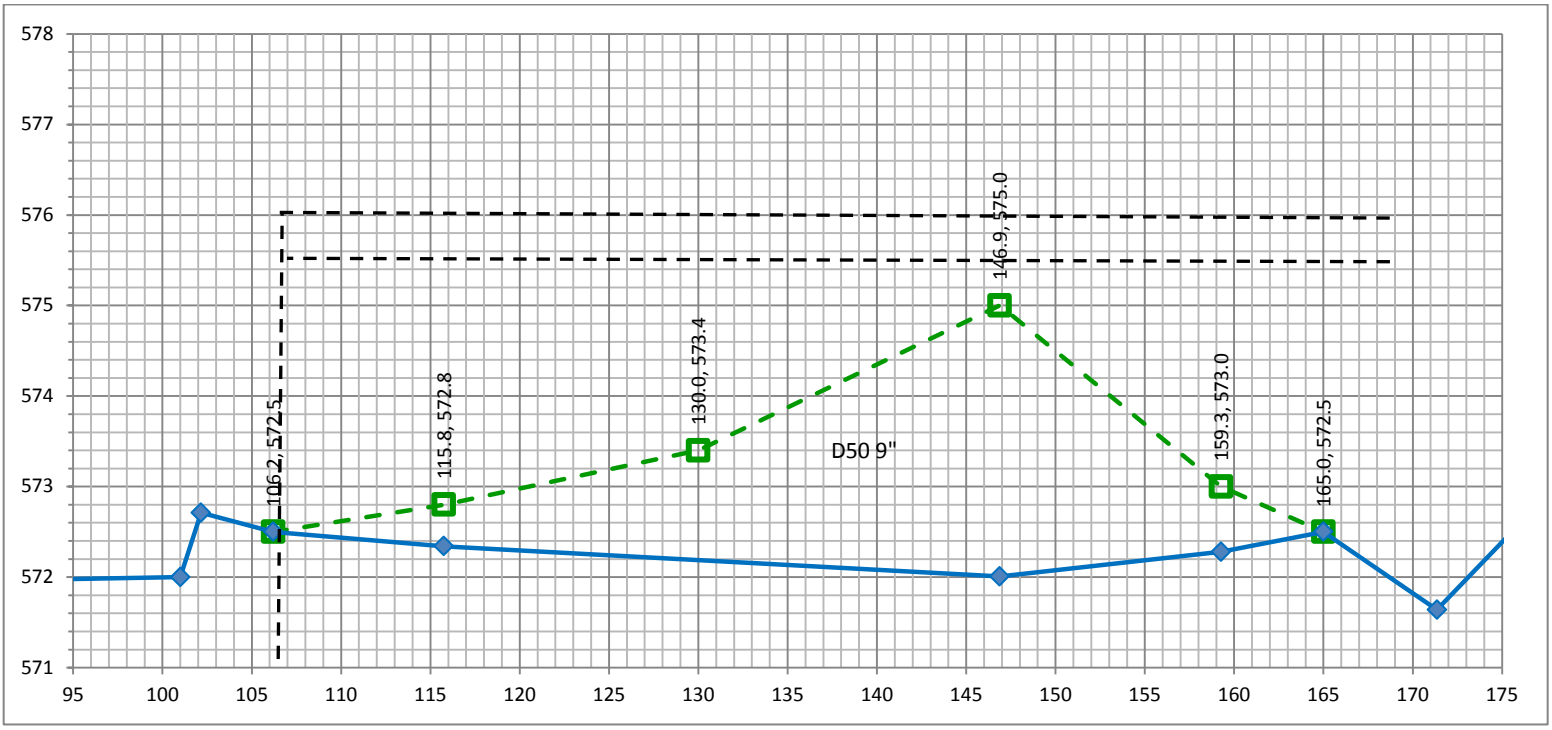
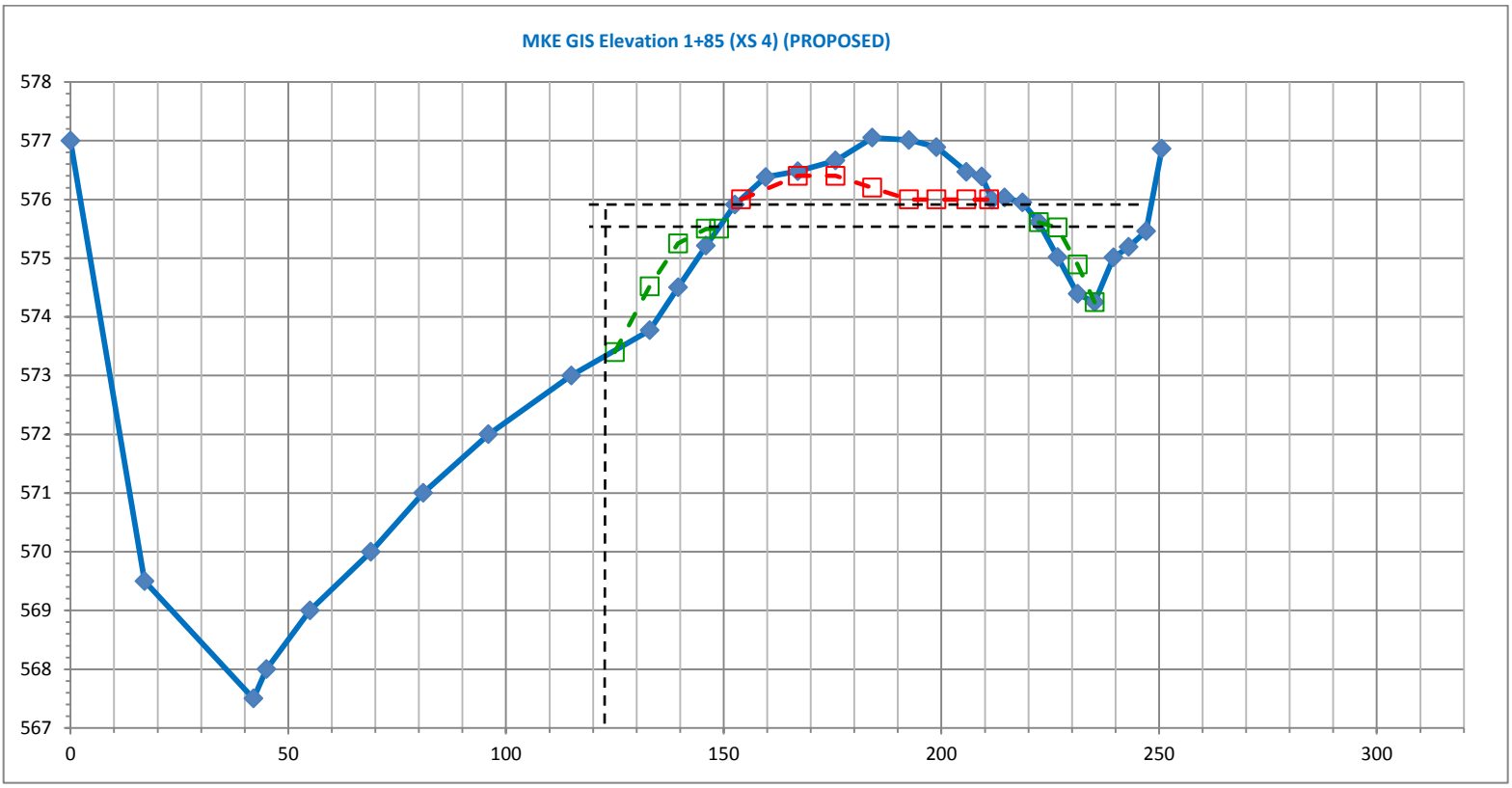
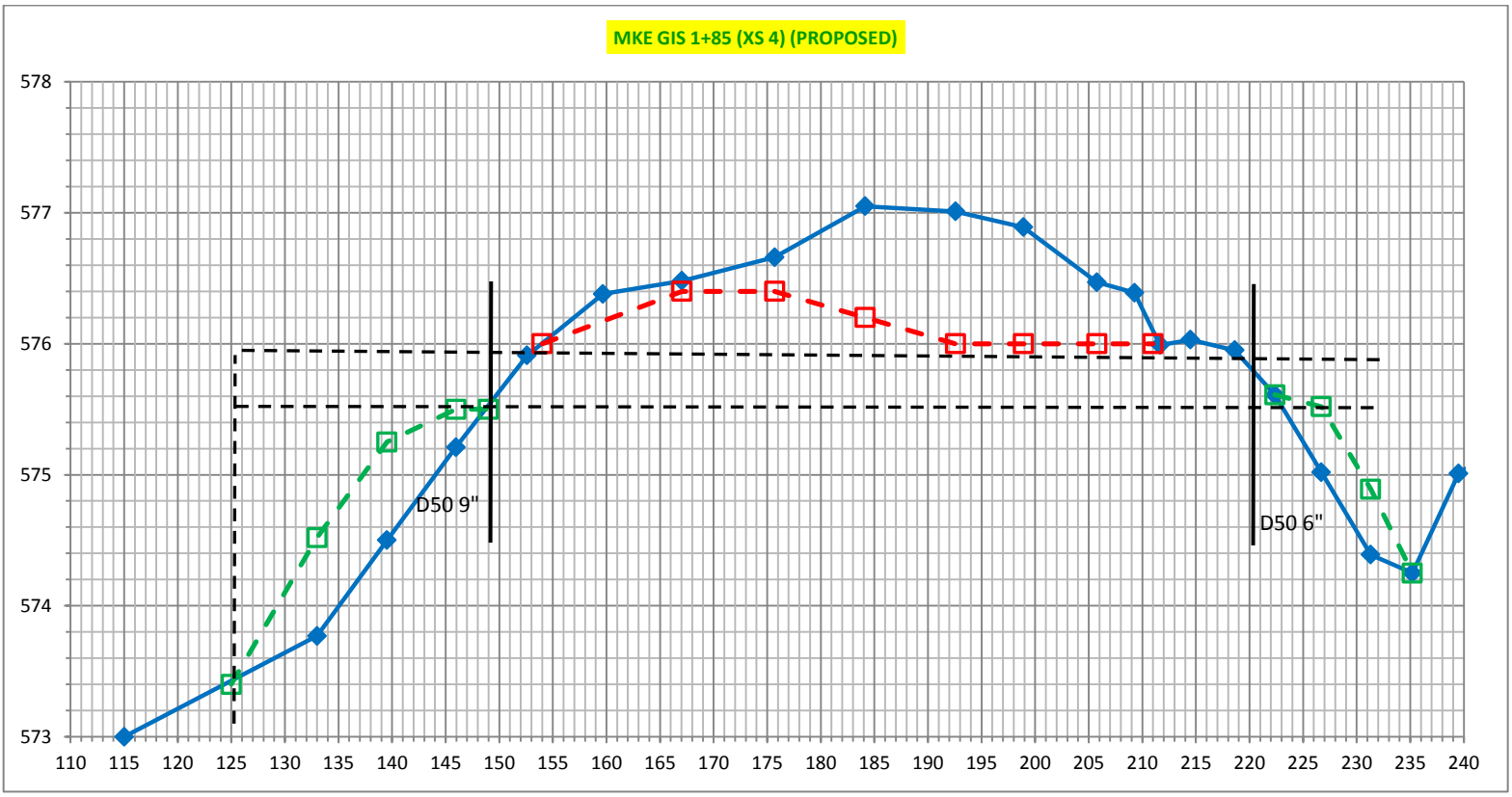
577
576
575
574
573
572
571
0
50
100
150
200
250
300

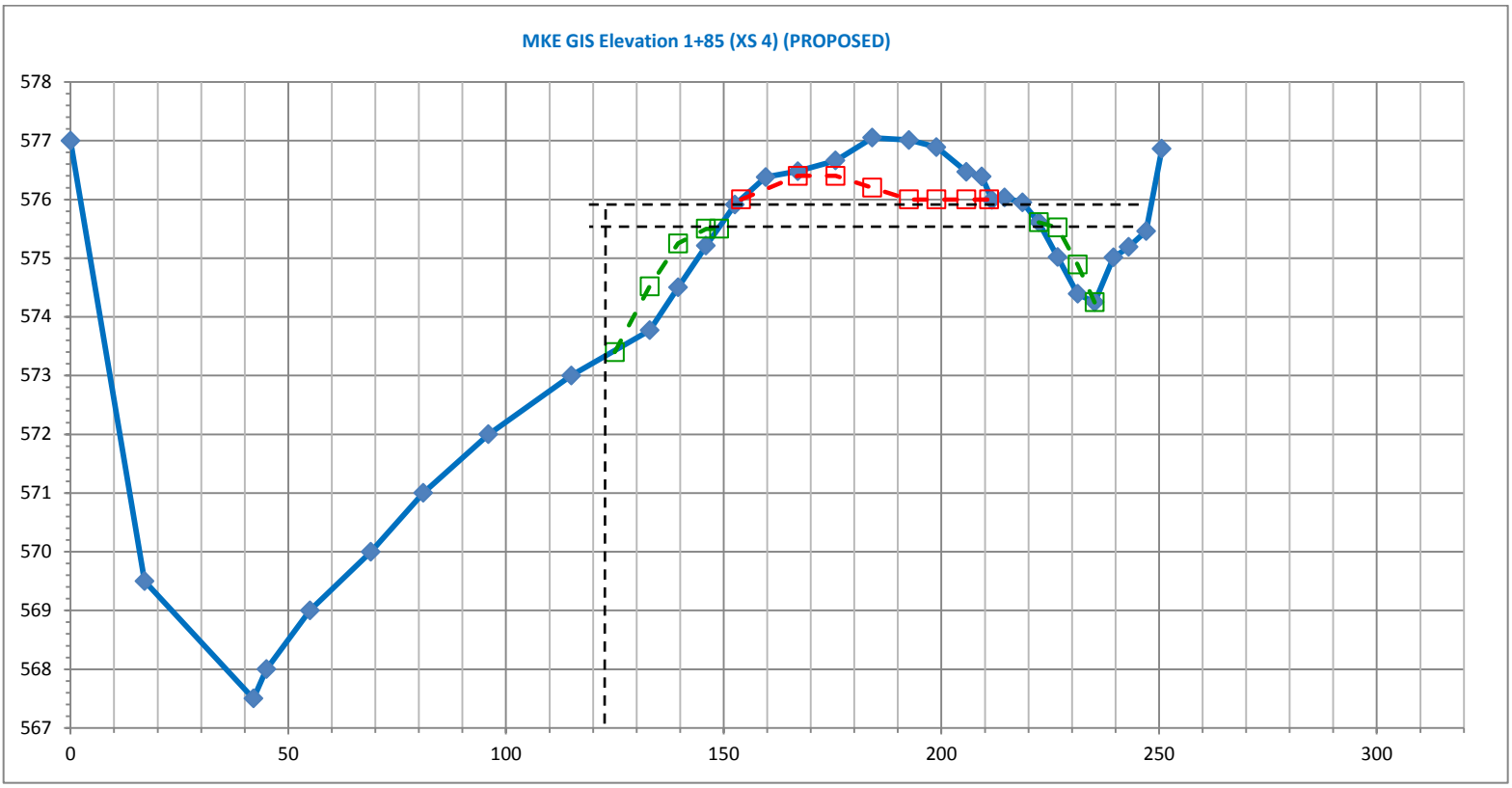

MKE GIS 1+15 (XS 6) (PROPOSED)
577
576
575
574
573
D50 9"
D50 6"
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260

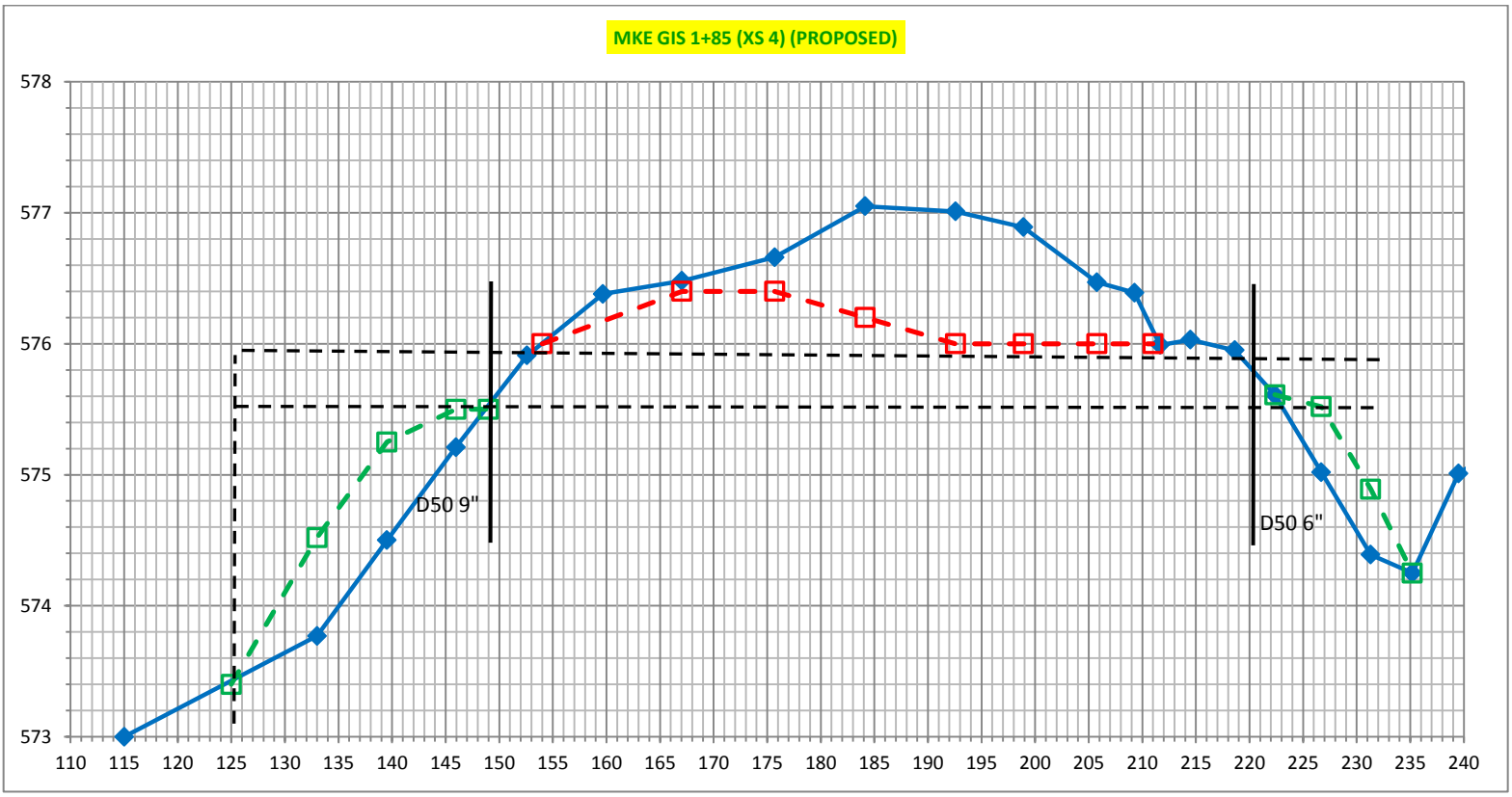

MKE GIS Elevation 5+97 (XS -5) (PROPOSED)
578
577
576
575
574
573
572
571
570
569
0
50
100
150
200

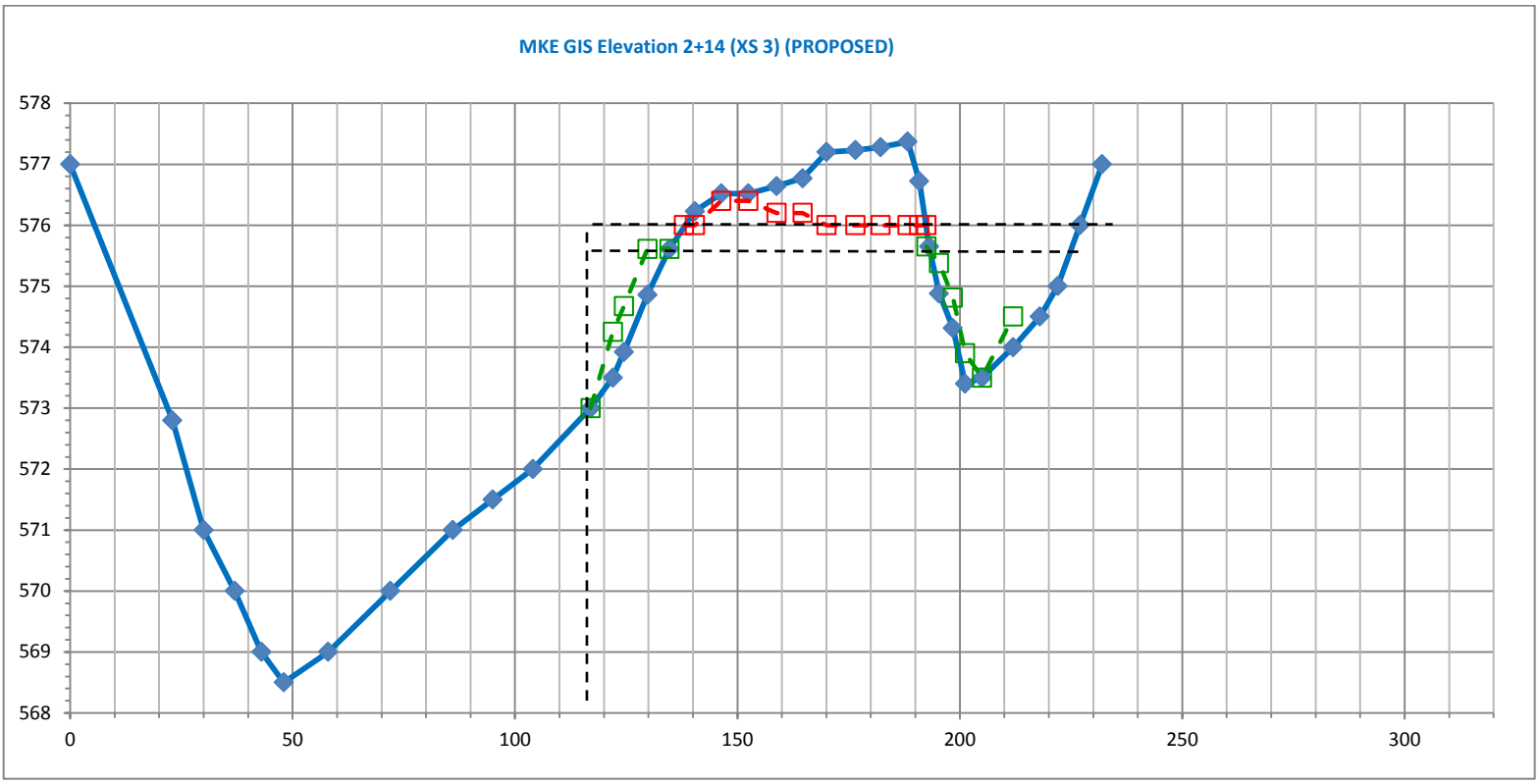

578
577
576
575
574
573
572
571
95
100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
106.2, 572.5
115.8, 572.8
130.0, 573.4
146.9, 575.0
159.3, 573.0
165.0, 572.5
D50 9"

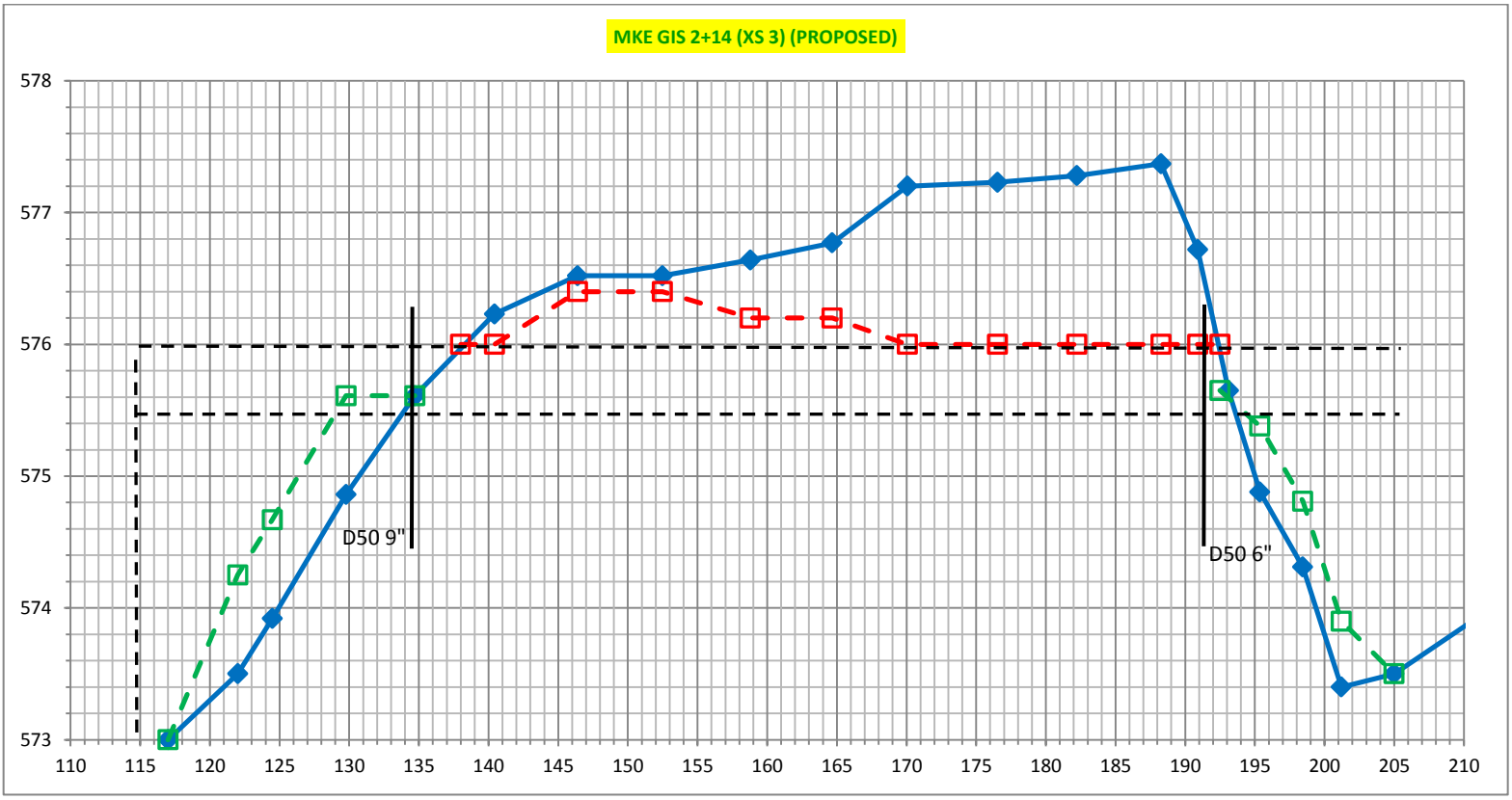

MKE GIS Elevation 1+85 (XS 4) (PROPOSED)
578
577
576
575
574
573
572
571
570
569
568
567
0
50
100
150
200
250
300

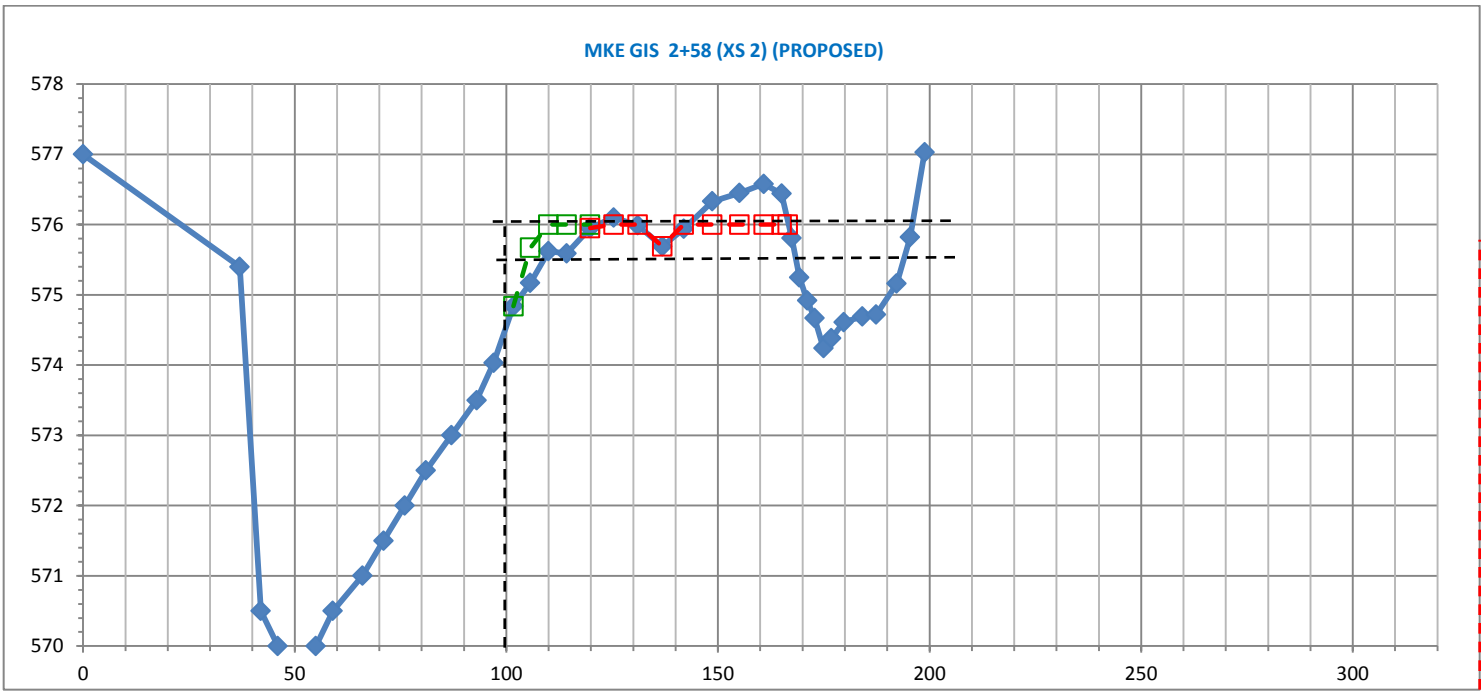

MKE GIS 1+85 (XS 4) (PROPOSED)
578
577
576
575
574
573
D50 9"
D50 6"
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240

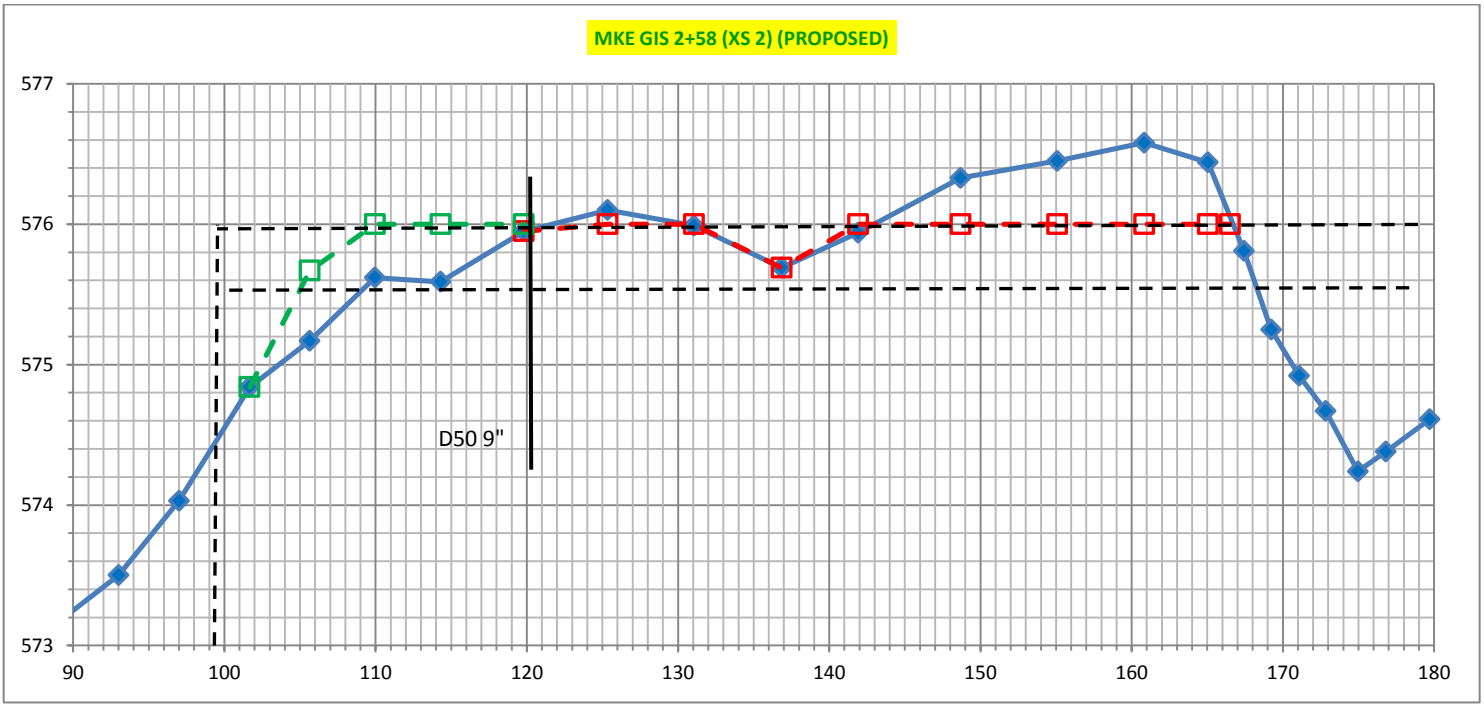

MKE GIS Elevation 1+85 (XS 4) (PROPOSED)
578
577
576
575
574
573
572
571
570
569
568
567
0
50
100
150
200
250
300

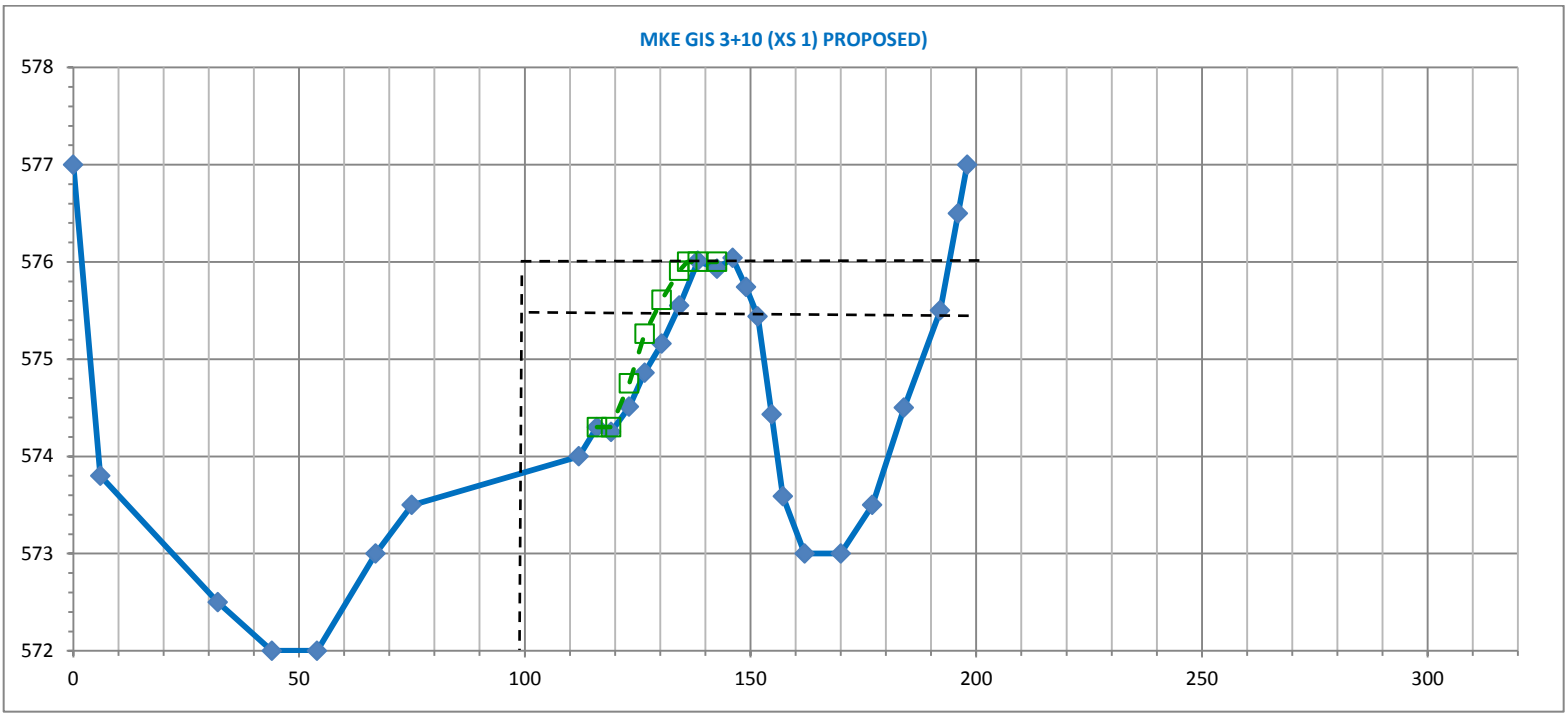

MKE GIS 1+85 (XS 4) (PROPOSED)
578
577
576
575
574
573
D50 9"
D50 6"
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240

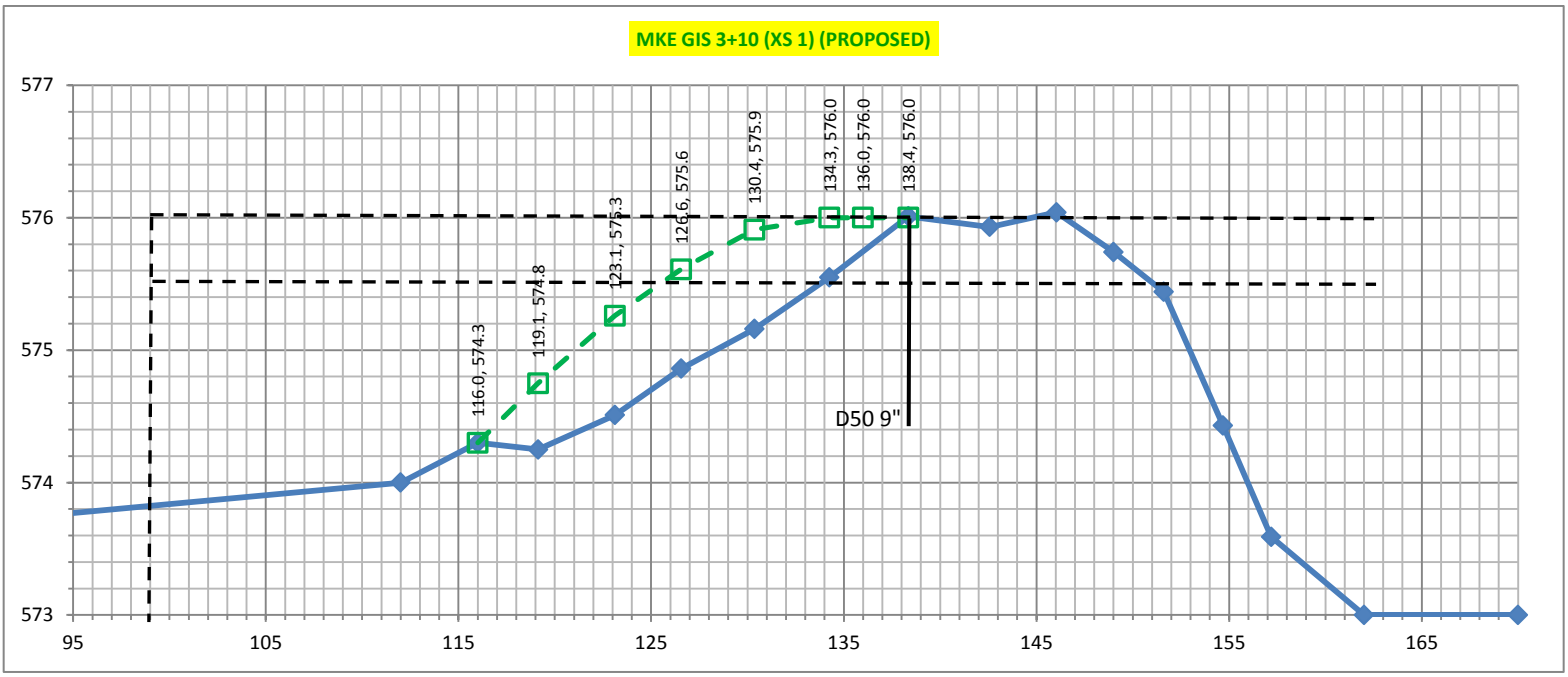

MKE GIS Elevation 2+14 (XS 3) (PROPOSED)
578
577
576
575
574
573
572
571
570
569
568
0
50
100
150
200
250
300

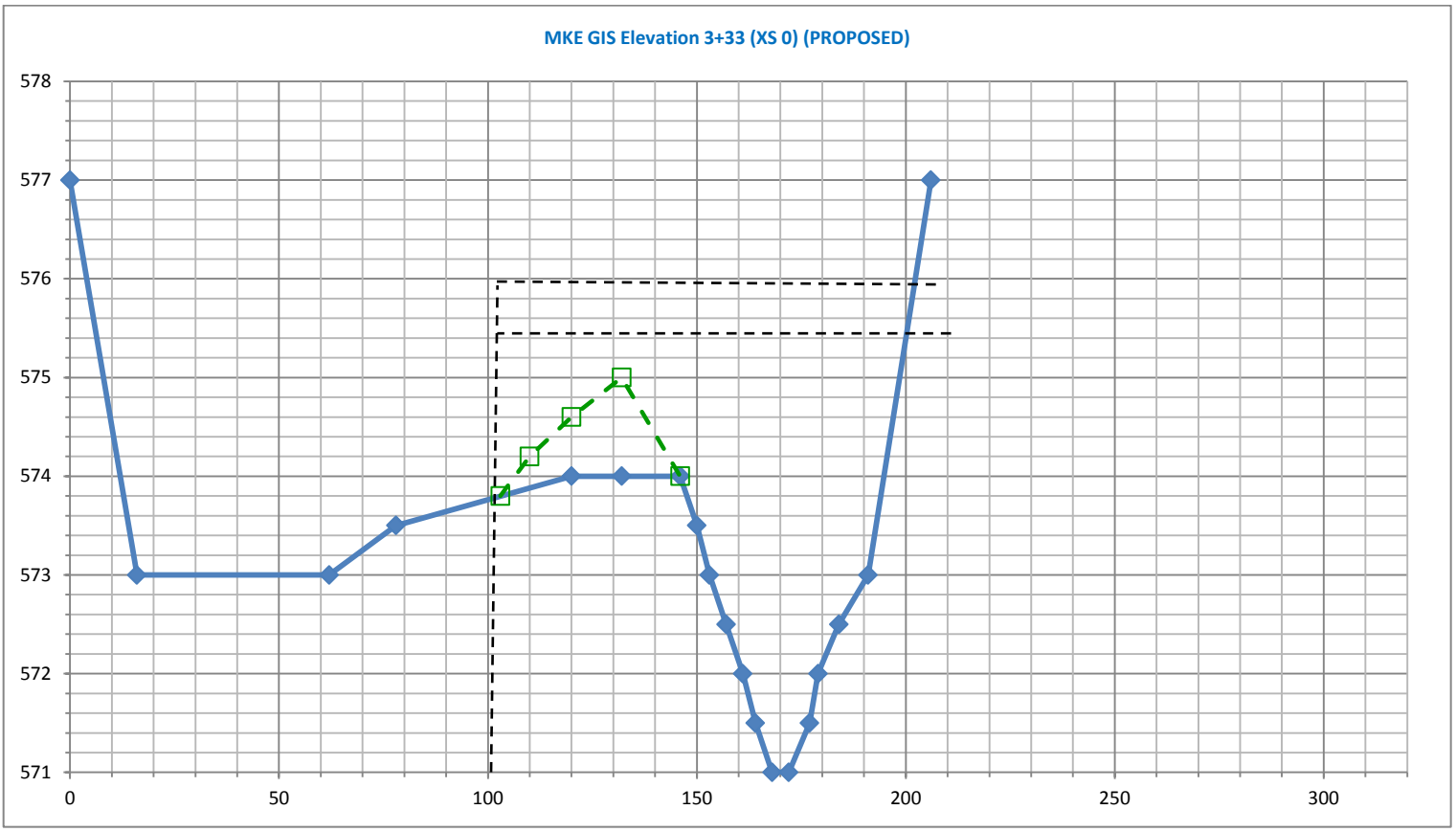

MKE GIS 2+14 (XS 3) (PROPOSED)
578
577
576
575
574
573
D50 9"
D50 6"
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210

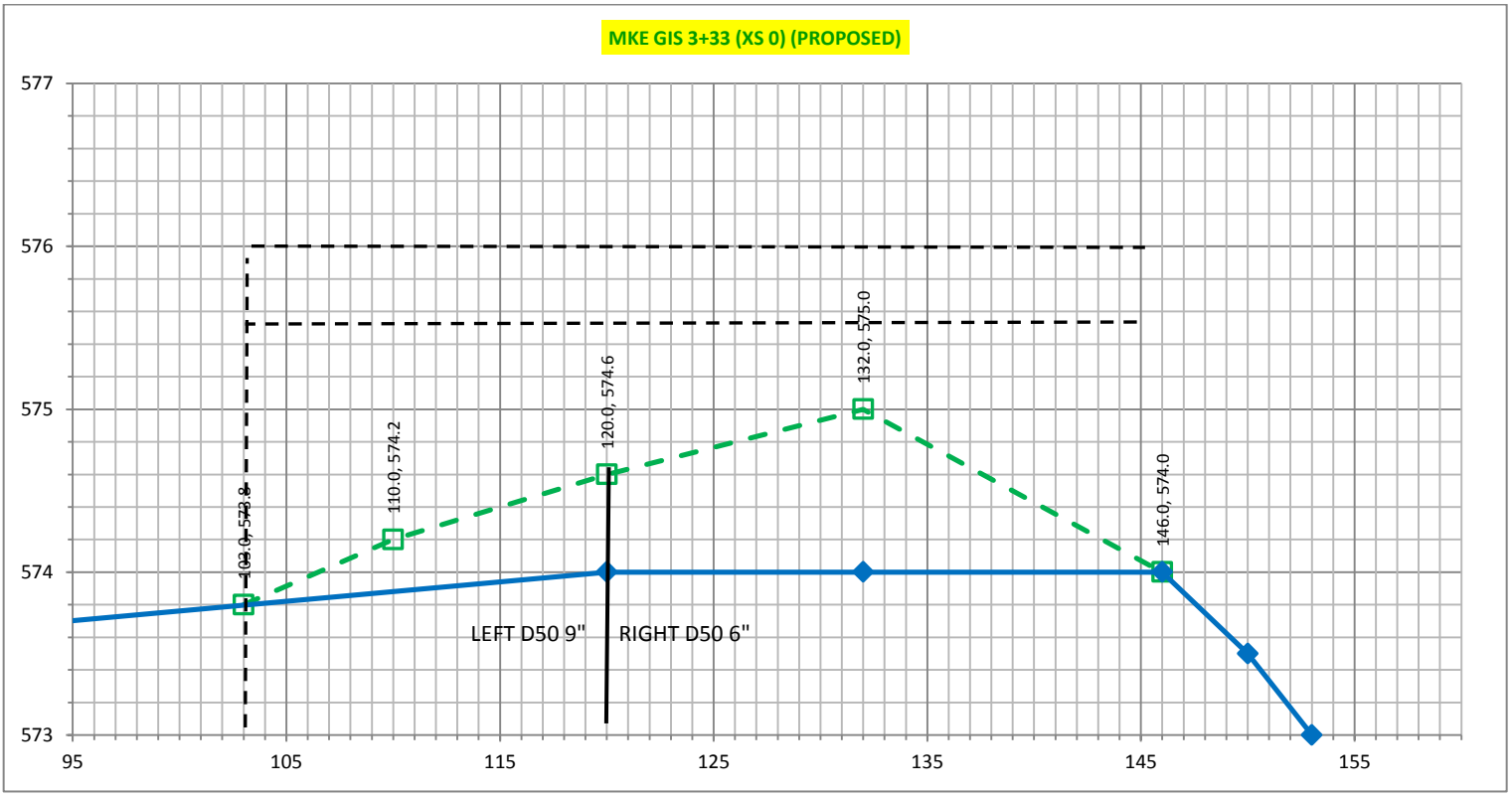

MKE GIS 2+58 (XS 2) (PROPOSED)
578
577
576
575
574
573
572
571
570
0
50
100
150
200
250
300

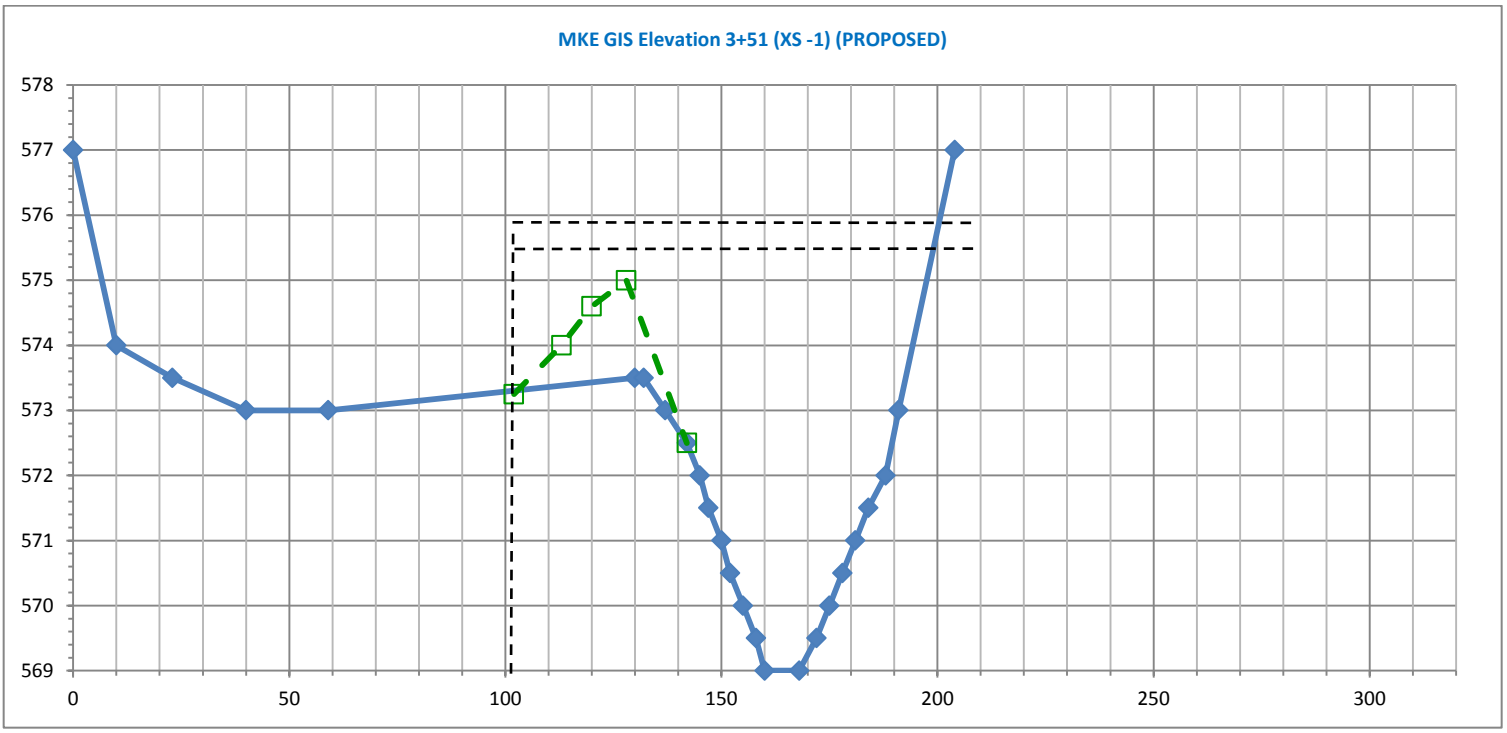

MKE GIS 2+58 (XS 2) (PROPOSED)
577
576
575
574
573
D50 9"
90
100
110
120
130
140
150
160
170
180

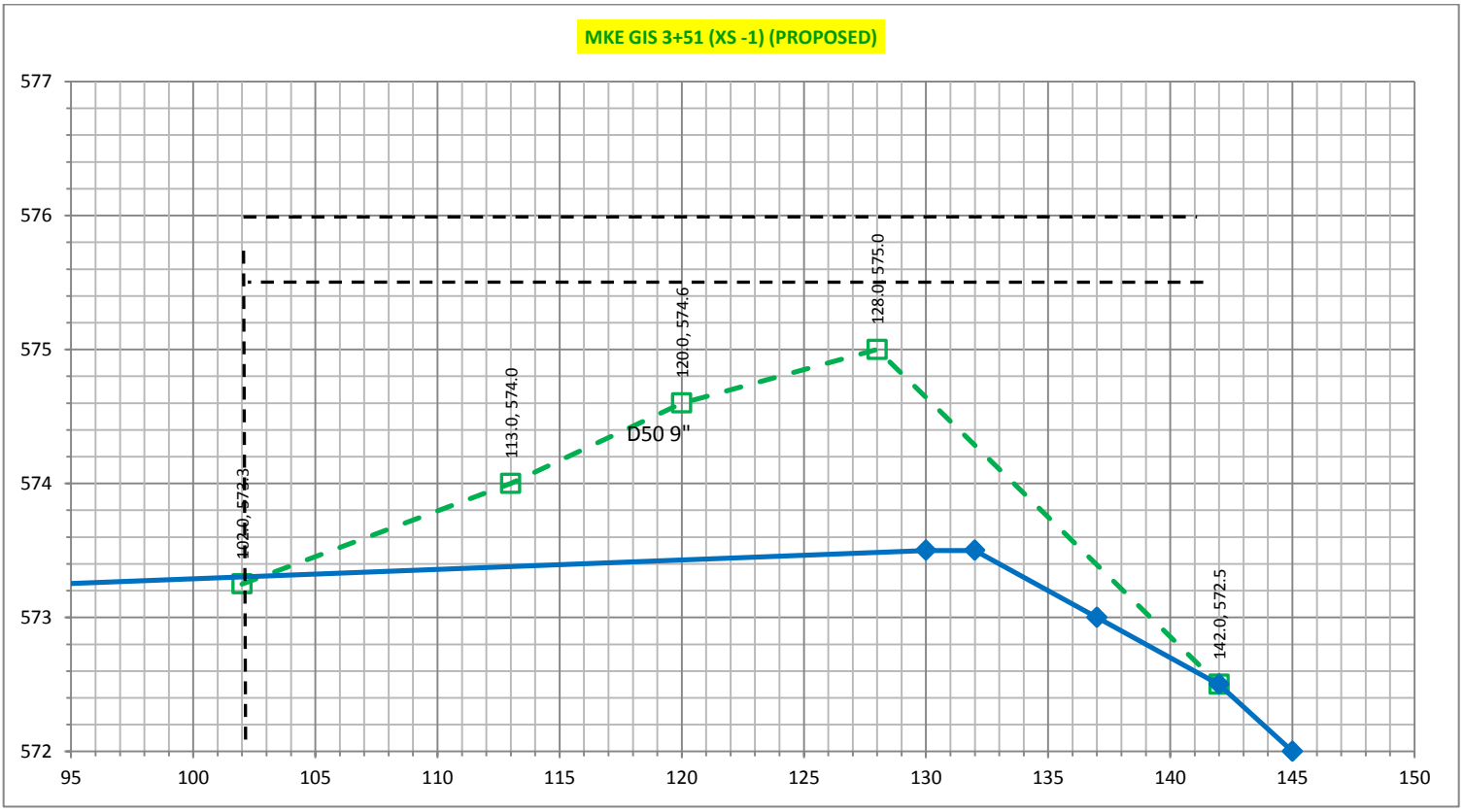

MKE GIS 3+10 (XS 1) PROPOSED)
578
577
576
575
574
573
572
0
50
100
150
200
250
300

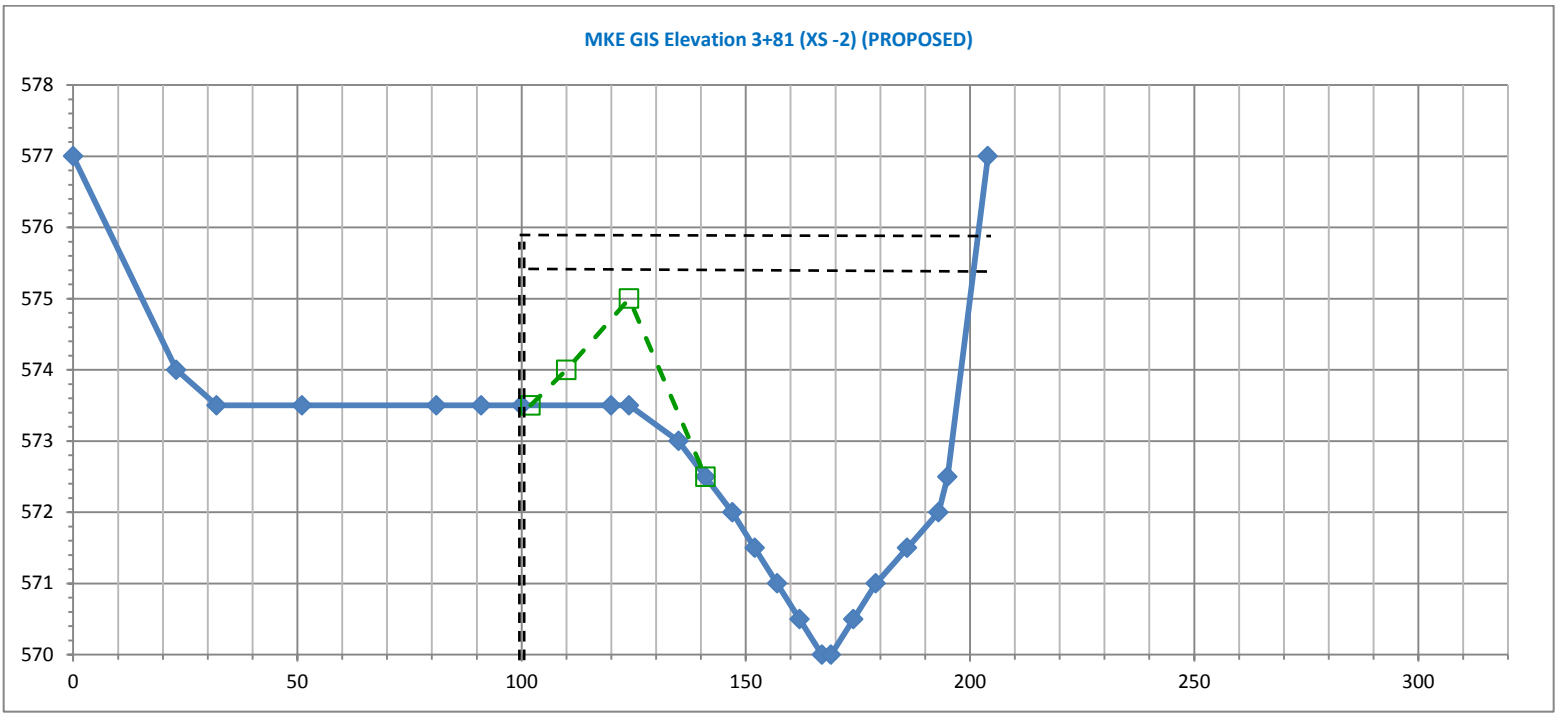

MKE GIS 3+10 (XS 1) (PROPOSED)
577
576
575
574
573
95
105
115
125
135
145
155
165
116.0, 574.3
119.1, 574.8
123.1, 575.3
126.6, 575.6
130.4, 575.9
134.3, 576.0
136.0, 576.0
138.4, 576.0
D50 9"

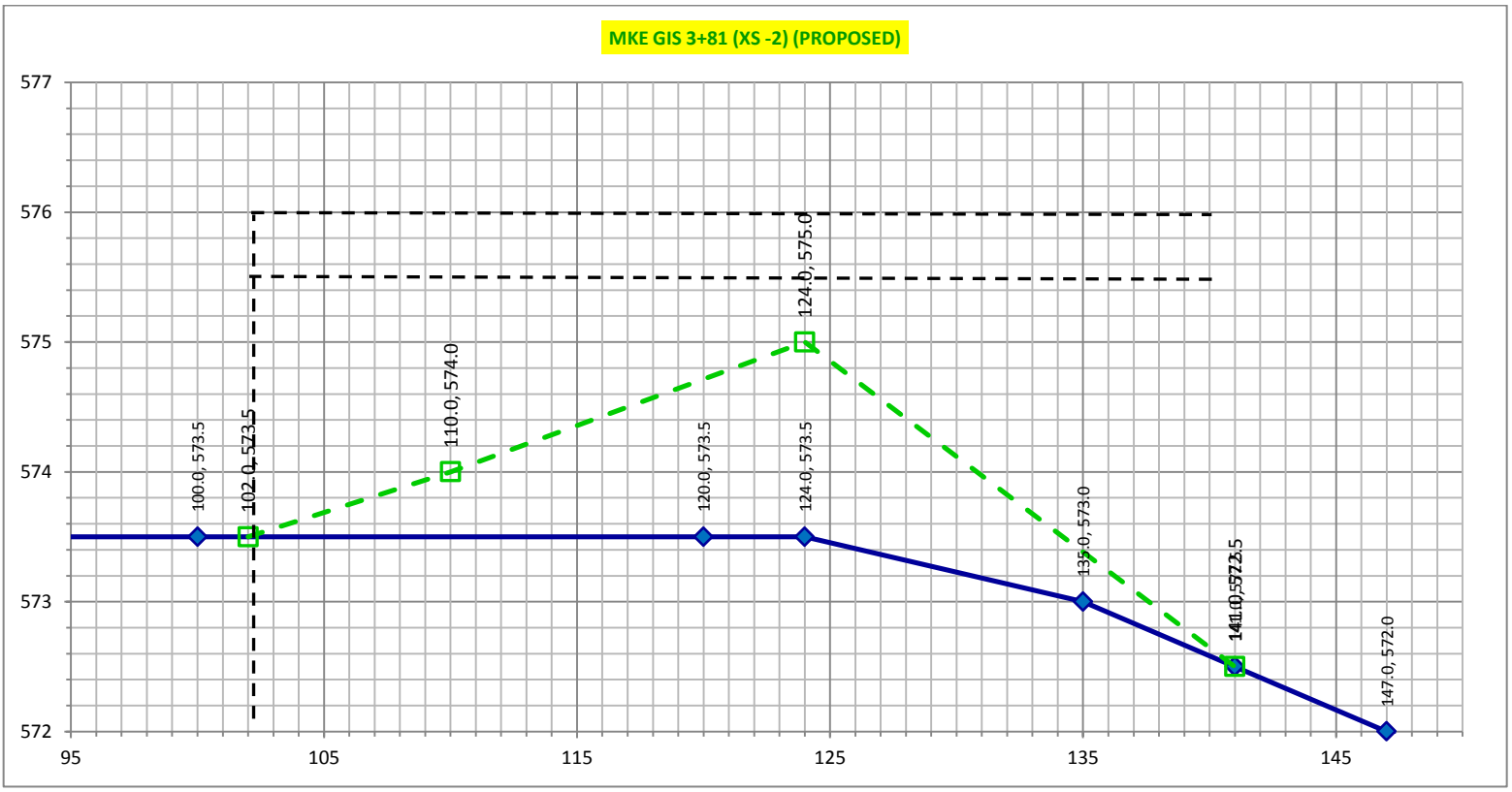

MKE GIS Elevation 3+33 (XS 0) (PROPOSED)
578
577
576
575
574
573
572
571
0
50
100
150
200
250
300

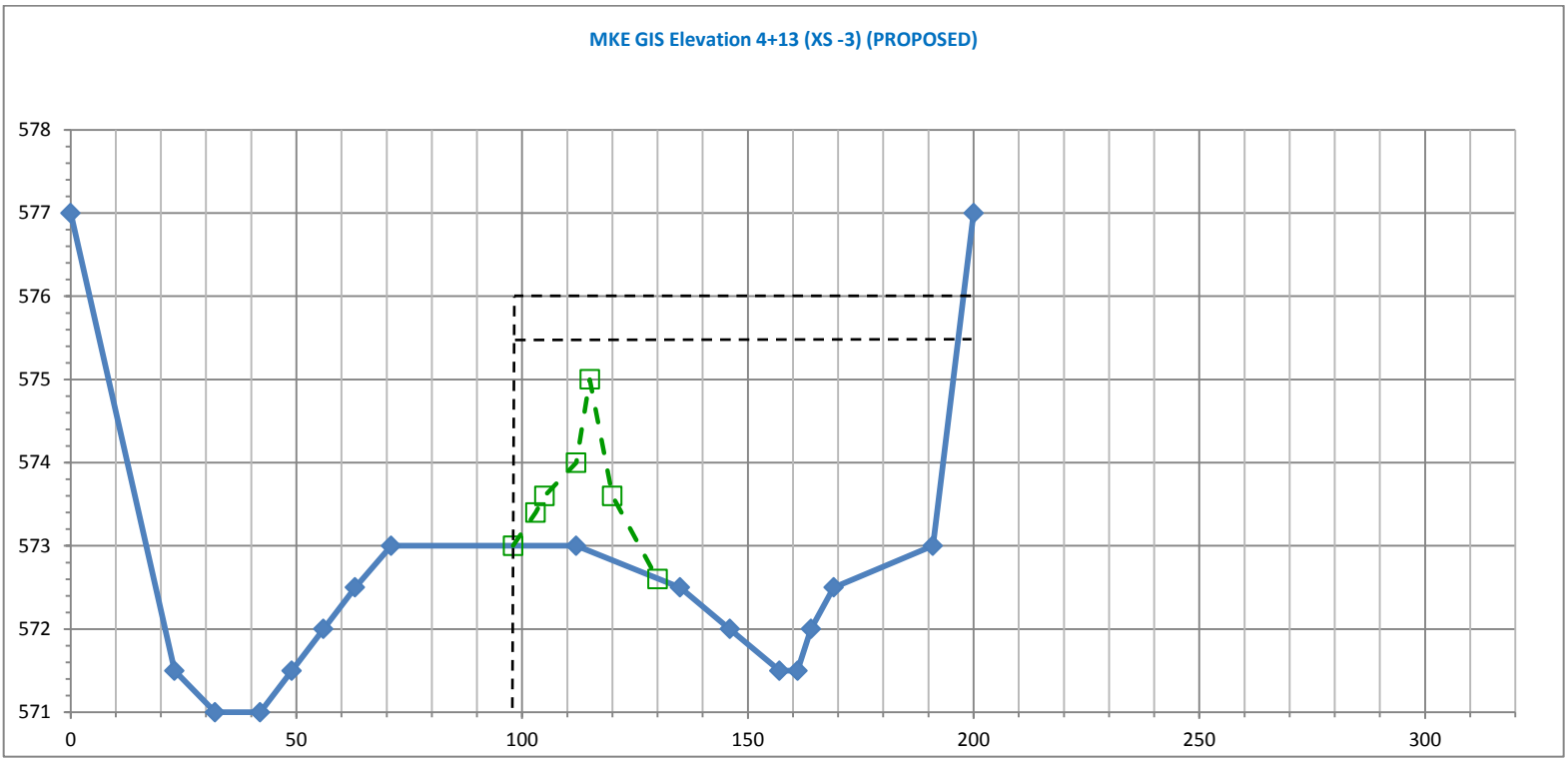

MKE GIS 3+33 (XS 0) (PROPOSED)
577
576
575
574
573
95
105
115
125
135
145
155
104.0, 573.8
110.0, 574.2
120.0, 574.6
132.0, 575.0
146.0, 574.0
LEFT D50 9"
RIGHT D50 6"

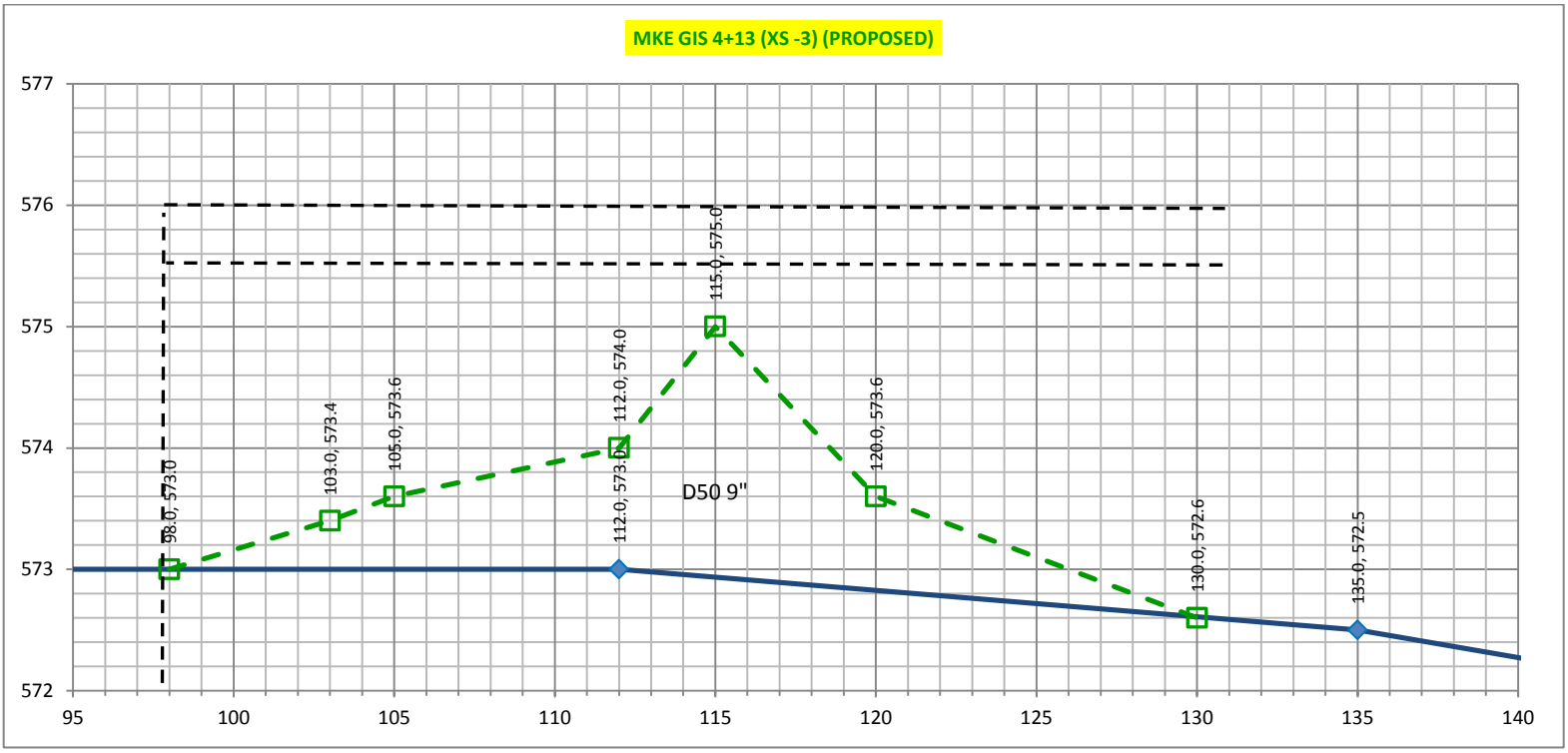

MKE GIS Elevation 3+51 (XS -1) (PROPOSED)
578
577
576
575
574
573
572
571
570
569
0
50
100
150
200
250
300

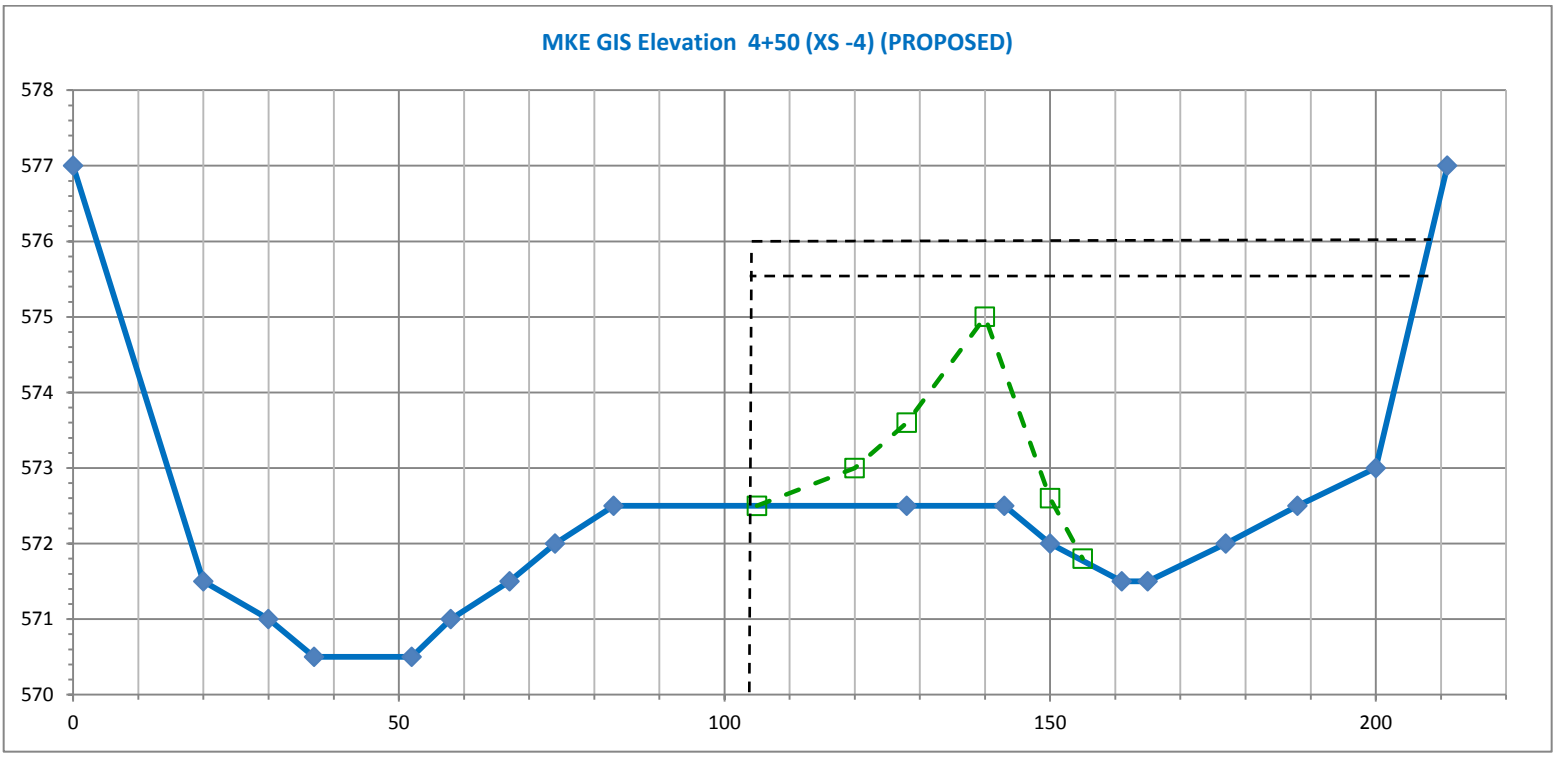

MKE GIS 3+51 (XS -1) (PROPOSED)
577
576
575
574
573
572
95
100
105
110
115
120
125
130
135
140
145
150
102.0, 574.3
113.0, 574.0
120.0, 574.6
128.0, 575.0
142.0, 572.5
D50 9"

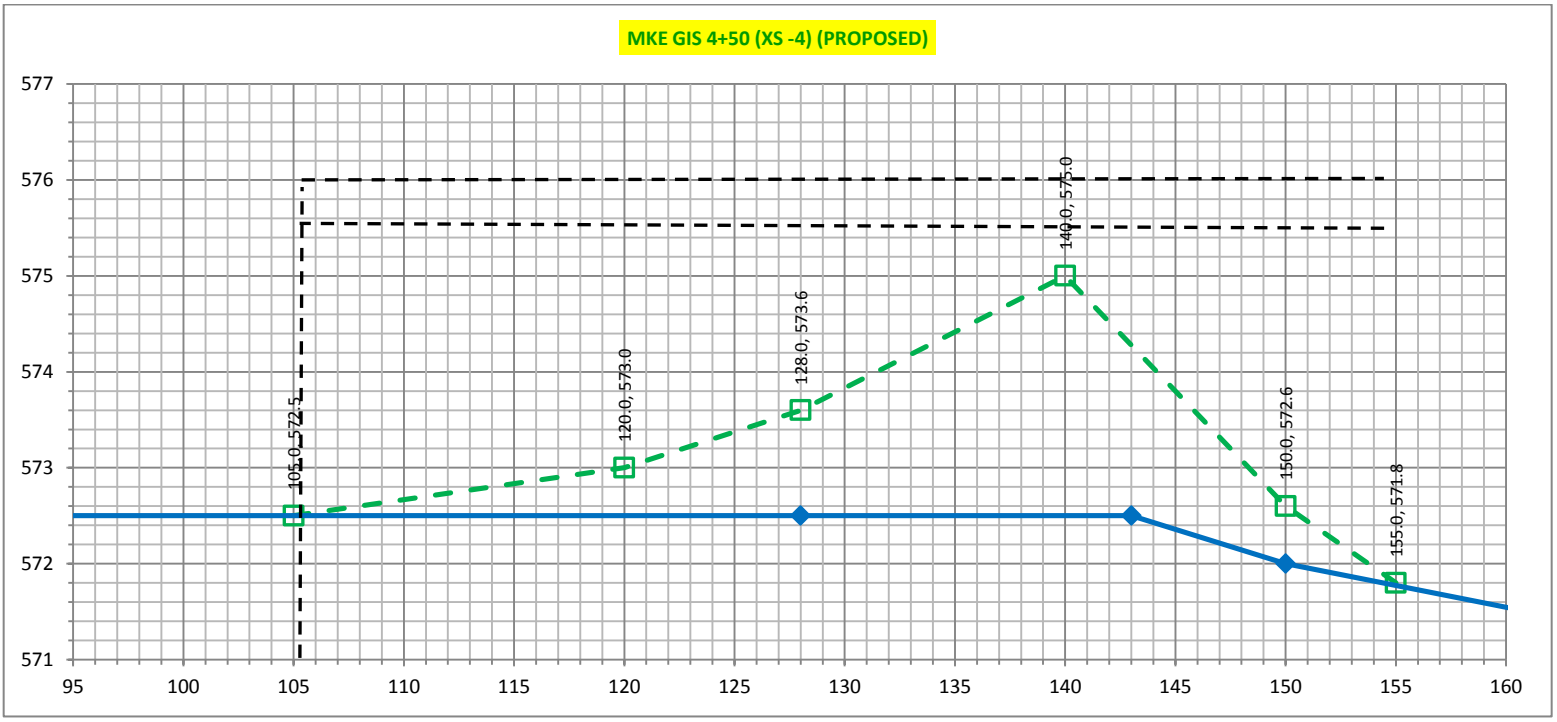

MKE GIS Elevation 3+81 (XS -2) (PROPOSED)
578
577
576
575
574
573
572
571
570
0
50
100
150
200
250
300

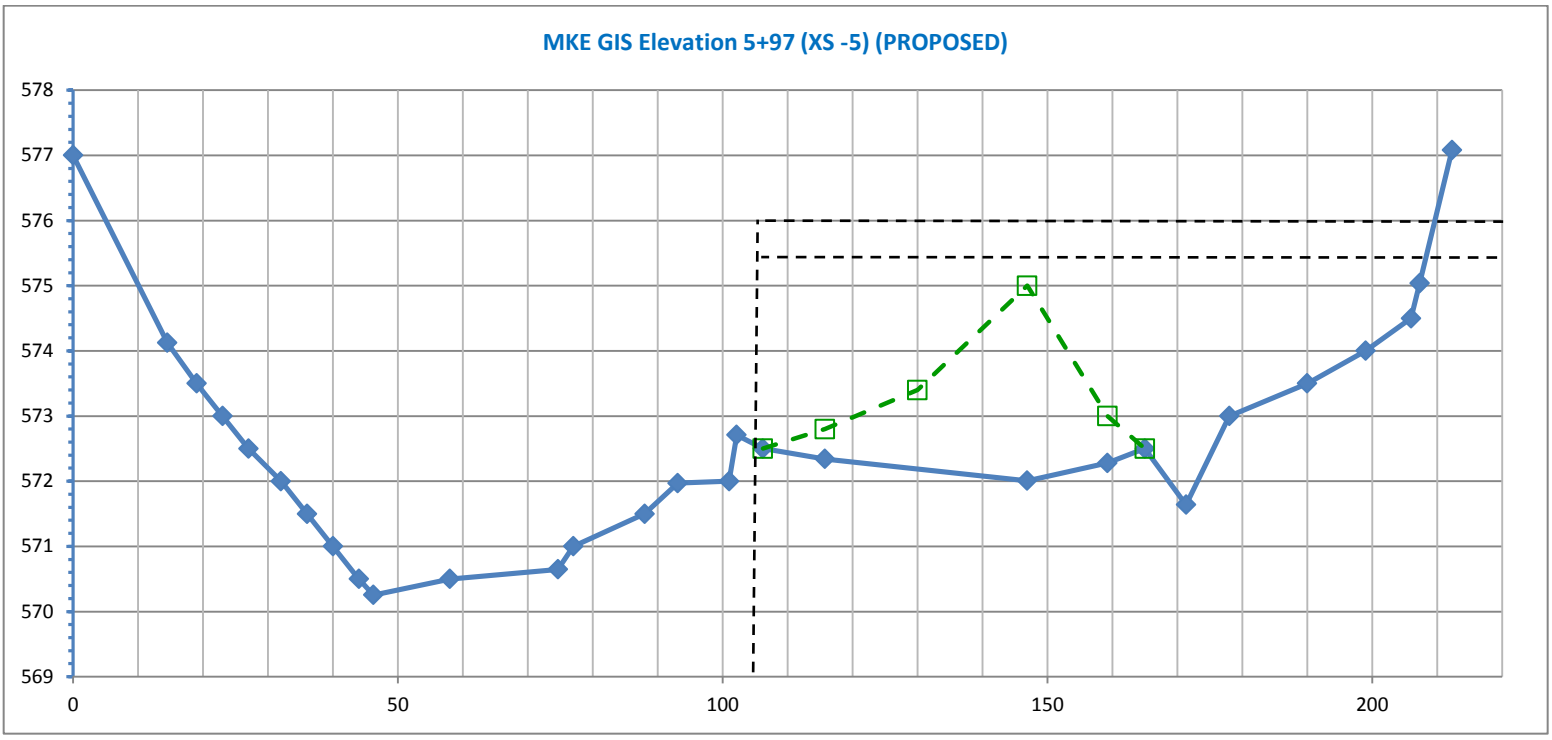

MKE GIS 3+81 (XS -2) (PROPOSED)
577
576
575
574
573
572
95
105
115
125
135
145
100.0, 573.5
102.0, 573.5
110.0, 574.0
120.0, 573.5
124.0, 573.5
124.0, 575.0
135.0, 573.0
147.0, 572.0

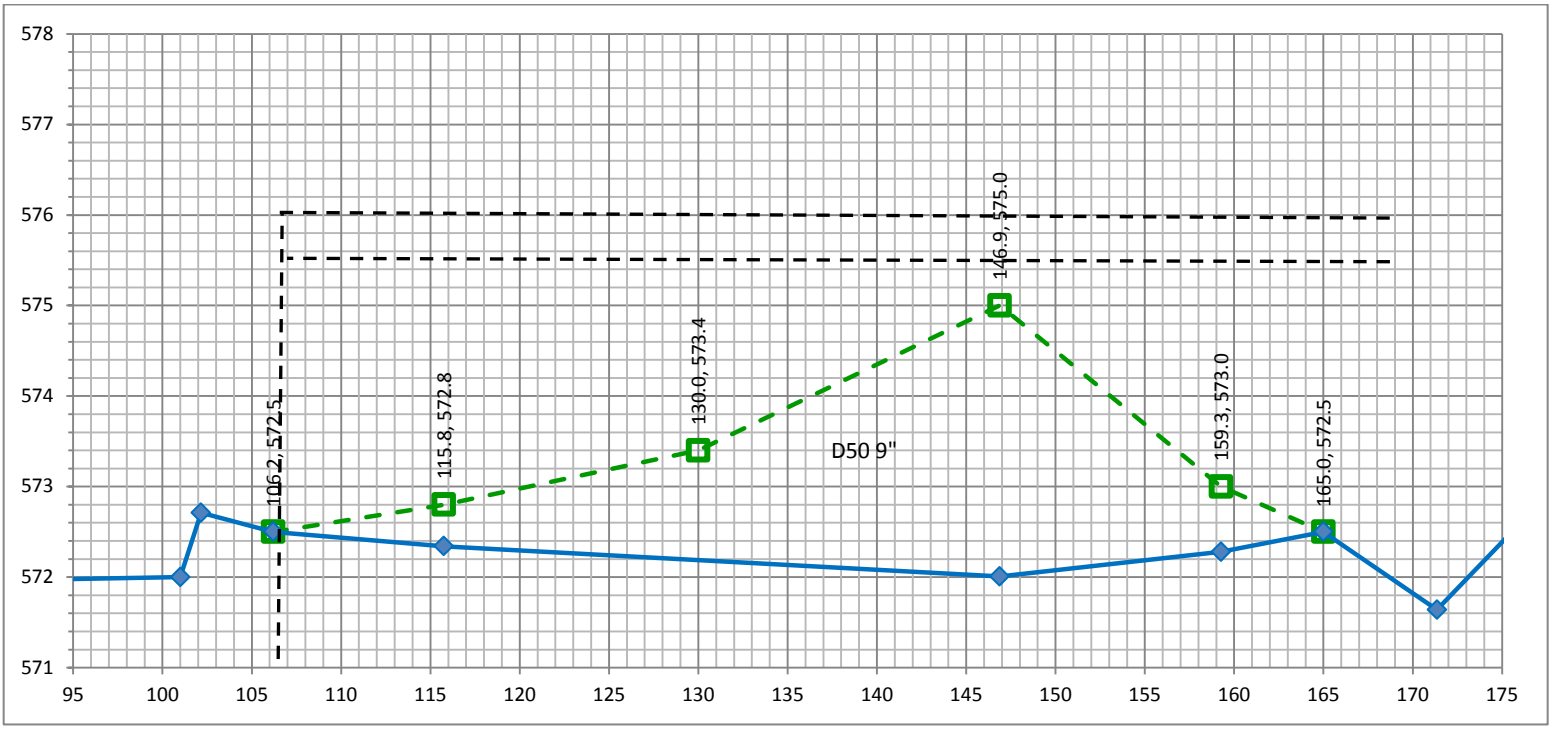

MKE GIS Elevation 4+13 (XS -3) (PROPOSED)
578
577
576
575
574
573
572
571
0
50
100
150
200
250
300


MKE GIS 4+13 (XS -3) (PROPOSED)
577
576
575
574
573
572
95
100
105
110
115
120
125
130
135
140
98.0, 573.0
103.0, 573.4
105.0, 573.6
112.0, 573.6
112.0, 574.0
115.0, 575.0
120.0, 573.6
130.0, 572.6
135.0, 572.5
D50 9"


MKE GIS Elevation 4+50 (XS -4) (PROPOSED)
578
577
576
575
574
573
572
571
570
0
50
100
150
200


MKE GIS 4+50 (XS -4) (PROPOSED)
577
576
575
574
573
572
571
95
100
105
110
115
120
125
130
135
140
145
150
155
160
105.0, 572.5
120.0, 573.0
128.0, 573.6
140.0, 575.0
150.0, 572.6
155.0, 571.8


MKE GIS Elevation 5+97 (XS -5) (PROPOSED)
578
577
576
575
574
573
572
571
570
569
0
50
100
150
200


578
577
576
575
574
573
572
571
95
100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
106.2, 572.5
115.8, 572.8
130.0, 573.4
146.9, 575.0
159.3, 573.0
165.0, 572.5
D50 9"