City of Jordan MN

Flood Protection Analysis

Structural Flood Mitigation Feasibility Study for Sand Creek

Certification

Feasibility Report

For

Jordan Flood Protection Analysis

City of Jordan MN
T14.108921

5/2/2019

I hereby certify that this plan, specification or report was prepared by me or under my direct supervision, and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

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Date: 5/2/2019

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I. Executive Summary

The following report details the findings of the Jordan Flood Protection Analysis. The first portion of the analysis consisted of updating the existing conditions hydraulic model of Sand Creek into a more robust and accurate 2-dimensional flood model. The remainder of the study focused on three different flood mitigation projects that were most likely to reduce the risk of flooding to the residents and business owners in the City of Jordan. Flood risk reduction strategies included the following:

1. Construction of levees along Sand Creek's east bank to protect the City. The levees are described in 3 sections separated by major bridges as:
    - Section 1 – Between Varner St. and HWY 282
    - Section 2 – Between HWY 282 and HWY 169
    - Section 3 – Between HWY 169 and the second Syndicate St. Bridge
2. Construction of a flood diversion structure on the west bank of Sand Creek above the HWY 282. Bridge to divert floodwaters into the nearby wetland and around the City.
3. Analyze existing bridge crossing along Sand Creek to explore bridge modifications options to reduce flood elevation.

One alternative considered was to replace the proposed earthen embankments along Section 1 with a sheet pile flood wall. This was considered as an option to reduce the levee footprint on adjacent properties and reduce potential acquisitions.

Cost estimates of the various options were completed along with an estimate of properties removed from the Zone AE floodplain. Cost estimates for the levees also included options for internal drainage of the City's stormwater when Sand Creek is at flood stages. The internal drainage options are summarized below in Table 1.

Table 1 Internal Drainage Summary

Internal Drainage Options Summary				
	Footprint (ac)	**Storage Volume** (ac-ft)	**Excavation Volume** (CY)	**Pump Requirements** (gpm)
Option 1	8.2	33	47500	N/A
Option 2	6.8	22	40000	20000
Option 3	3.1	9	17000	30000

Upon review of the analysis, it was concluded that the flood diversion structure cost was too great for the relatively small impact it would have on the base flood elevations. Similarly, it was determined that the bridges did not impact the flood elevations on the scale predicted in previous modeling effort and that bridge modifications were not a cost-effective way to minimize flood risk.

The remaining levee options and pond options are summarized in Table 2 below. The basic levee option consists of a floodwall for the first 500' of Section 1 and earthen embankments for the remaining levee sections. The levee Alternate assumes the floodwall is extended through all of Section 1 with new earthen embankments in Sections 2 and 3.

Table 2 Summary of Feasible Alternatives

Summary of Feasible Alternatives		
Levee with Pond Option 1	$	5,658,600
Levee with Pond Option 2	$	7,393,400
Levee with Pond Option 3	$	7,634,600
Levee Alternate with Pond Option 1	$	7,497,600
Levee Alternate with Pond Option 2	$	9,232,400
Levee Alternate with Pond Option 3	$	9,473,600

The recommended mitigation projects are the construction of the 3 levee sections in conjunction with Option 1 of the internal drainage options. This scenario offers a high of flood protection while minimizing the expected costs.

Table 3 Summary of Estimated Project Costs

Summary of Estimated Project Cost		
		Est. Cost
Internal Drainage - Storm Sewer & Pond Construction	$	1,023,600
Certified Levee Construction	$	2,052,000
Estimated Construction Cost	**$**	**3,075,600**
20% Est. Soft Costs	$	615,000
Land Acquisition	$	1,968,000
Estimated Cost - Levee Construction	**$**	**5,658,600**

Due to funding requirements, the project proposed here will likely be constructed in several phases. The recommended phases are as follows:

Phase 1 – Preliminary Design of levees and internal drainage

Phase 2 – Construct Levee Section 1

Phase 3 – Construct Levee Section 3 and internal drainage basin

Phase 4 – Construct Levee Section 2 and reroute stormwater under HWY 169

The phases above do not need to be completed individually. If funding is available multiple phases may progress simultaneously.

II. Study Background

A. 2014 DFIRM Appeal

In 2014 the City of Jordan began an investigation into the preliminary effective Flood Insurance Rate Maps (FIRM) released by FEMA in 2006 for Sand Creek. In a previous memo by Bolton & Menk to the MN DNR Floodplain team dated November 11th, 2014, it was noted that the modeling used to produce the 2006 maps contained several recommended modifications in the hydrologic study that produced a flood elevation above previous records and estimates. The DNR agreed with the findings and aided the City in petitioning FEMA to reduce the flood flows from the higher rates back to the previously used flow rates. DNR staff completed a 2-station comparison in 2014 which estimated the flood flows at approximately 30% lower than those that were used to produce the preliminary effective maps. FEMA reviewed the submissions and concluded that while the data did support the reduction of flow, the flow rates still fell within the 50% confidence interval of the previous study. In compromise, FEMA agreed to reduce the flow rates to the previous FIS flows of 8100 cubic feet per second (cfs) for the 1% recurrence (also referred to as the 100-year flood). Table 4 below summarizes all the hydrologic study flow rates.

Table 4 Hydrologic Comparisons

Hydrologic Model Results	
Study	**1% Flow rate (cfs)**
2006 FIS	9716
1982 FIS	8100
HEC-1 Model (1985)	8725
USGS Regression Equation (1985)	7941
2014 2-Station Comparison	6860

Water surface elevation discrepancies were also noted at several locations on the 2006 FIRM maps as well. Two notable locations were along HWY 169 west of Sand Creek and within the City limits between HWY 282 and HWY 169. At HWY 169 west of Sand Creek it was noted that the water surface elevation listed on the map would have the highway overtopping by approximately 2ft and the highway was not shown as being inundated. Similarly, in town the floodplain elevations on the map did match the ground elevations and substantially reduced the mapped floodplain. Exhibit 1 below shows the mapped floodplain as proposed by FEMA in yellow vs. the remapped floodplain in blue. No changes were made to the model for this figure, only the floodplain was accurately projected onto county LiDAR topographic data to give an accurate representation of the floodplain.

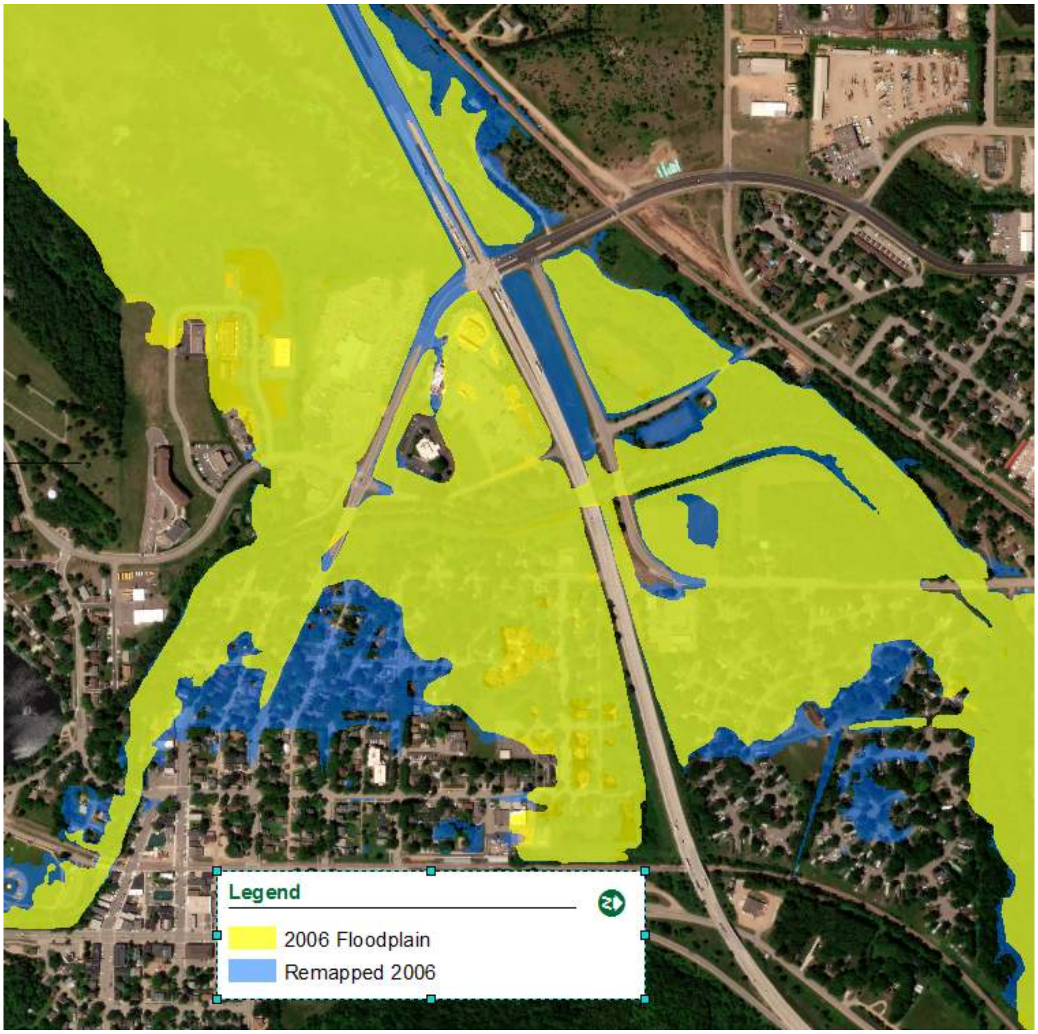


Exhibit 1 Flood Map Discrepancies

After identifying issues with both the mapping and the hydrology data used to produce the maps, the City of Jordan authorized Bolton & Menk, Inc to revise the models and maps and submit the results to FEMA to be included in the new floodplain maps.

In July of 2018, the new preliminary effective maps were issued by FEMA showing the updated floodplain extents for Sand Creek as submitted by the City of Jordan. The proposed floodplain reduced the flood elevation in the City by approximately 1-2ft for the 1% recurrence interval flood (100yr Flood). Despite the reduction in flood elevation, the actual number of affected structures remained the same between the 2018 Preliminary Effective maps and the 2006 maps. Table 5 below summarizes the number of structures in the floodplain for each mapping iteration to date.

Table 5 Inundated Structures

Structures in Mapped Floodplain	
Map Date	**Structures in Floodplain**
1982 FIRM	352
2006 Preliminary Effective	358
2006 Accurately Mapped	474
2018 Preliminary Effective	361

B. Costs of Flood Insurance

As shown in Table 5, the City of Jordan currently has 361 structures that are located within the mapped preliminary effective mapped floodplain. As of August 2018, there were 77 structures carrying flood insurance in the City at an average cost of approximately $1850 per year. Nationwide, FEMA expects that flood insurance rates will increase an average of 8% annual[1]. Table 6 below summarizes the expected average cost of flood insurance in the City of Jordan through 2030

Table 6 Flood Insurance Premiums

Flood Insurance Premiums	
2018 Average Insurance Cost	$ 1,900
2020 Estimated Flood Insurance Cost	$ 2,200
2030 Estimated Flood Insurance Cost	$ 4,700

Per federal regulations, all houses purchased using a federally backed mortgage must carry flood insurance through the life of the mortgage. Rates vary based on flood risk, however the requisite of flood insurance make selling a home significantly harder due to the added costs associated with it. Studies have also shown that being in a mapped floodplain may reduce your property values by 7.3% in comparison to similar homes located outside of the designated floodplain area[2].

By 2020, the cost of current flood insurance policies within the City of Jordan are estimated to be nearly $170,000 annually.

C. Project Goals

With such a large portion of the City within the mapped floodplain and heavy, growing costs, the City was interested in possible risk mitigation efforts. This feasibility study was proposed to gage which flood protection efforts would provide the greatest risk reduction for the Jordan residents and businesses. Three mitigation efforts were reviewed in this preparation of this report:

1. Levees on the east bank of Sand Creek
2. Bridge widening
3. Flood bypass options

To effectively and accurately evaluate these options, the model was transitioned from a 1-dimensional (1D) flood model into a more accurate 2-dimensional model (2D). The 2D model allows for the flood model to be built over the high detail LiDAR data available to the City and provide a high-resolution output for future planning.

[1] Wright, Roy E. (9/29/2018) *Write Your Own (WYO) Principal Coordinators and the National Flood Insurance Program (NFIP) Servicing Agent.* https://nfipservices.floodsmart.gov/2017/w-17061

[2] Bin, O., Kruse, J., & Landry, C. (2008). Flood Hazards, Insurance Rates, and Amenities: Evidence from the Coastal Housing Market. *The Journal of Risk and Insurance, 75*(1), 63-82. Retrieved from http://www.jstor.org/stable/25145263

III. Project Scope

The goal of this study is to analyze which combination of the three potential flood mitigation projects offers the greatest reduction of flood hazards to the City while remaining cost effective. A summarized scope of each option has been summarized below

A. Model Update

The existing 1D unsteady model was transitioned into the new 2D model to better understand the flow patterns of Sand Creek and provide a more accurate representation of flooding conditions.

Maps will be produced showing the effects of the various options on the mapped floodplain

B. Levee Analysis

1. Levee Options

Levees along the east bank of Sand Creek were considered individually. The existing levees are not accredited and may not be included in the current Flood Insurance Rate Maps (FIRMs).

Maps were updated to show the resulting floodplains for the proposed levees and to account for the number of structure that are removed from the floodplain.

2. Internal Drainage

Drainage of the developed areas behind the proposed levees, or the internal drainage, must be considered in the design of the levees. The storm sewer in the City of Jordan will need to be modified to allow it to drain by gravity during normal river stages and to be pumped out if necessary during flood scenarios.

Options for internal drainage will contain both pump and no pump scenarios.

C. Bridge Alterations

Based on previous modeling efforts, several bridges create a backwater effect on Sand Creek and raised the base flood elevations. As part of this study, bridges were reanalyzed in the 2D model to check bridge capacity and provide recommendations for potential modifications to bridge openings

D. Flood Diversion

Currently Sand Creek overtops Creek Lane just upstream of the HWY 282 Bridge crossing. This overtop location was previously considered by the Corps of Engineers as a location to possibly route excess flood water into the large wetland complex to the west and bypass a large section of the City.

A new bypass option was considered to reduce the base flood elevation in Sand Creek and reduce the amount of fill necessary for the levees.

E. Cost Estimates

Once all options have been identified and analyzed, a matrix of options and associated costs was developed to aid the City in choosing the most cost-effective way of protecting as many properties as possible

IV. Flood Model Updates

A. Existing FEMA Approved Model

The model used to generate the current Preliminary Approved FIRMs was developed by Bolton & Menk, Inc. for the City of Jordan as part of the open comment period of the recent flood map updates. This 1D unsteady model was chosen at the time because it was the only viable option at the time for a volumetric flood model that FEMA would approve for the flood map.

Traditional steady-state 1D models assume that Sand Creek is at its peak flood flows for an infinite time period. The model calculates the water surface elevation at each cross-section and does not account for flood storage in the system. It could be compared to turning on the tap in a tub and letting it run for an hour. The tub will eventually fill up and overflow, but once the flow down the drain and over the tub equals the flow coming in from the faucet, the water surface elevation in the tub remains constant. Similarly, in a 1D model the water surface is raised until the flow out of the channel equals the flow into the channel.

The unsteady model used in previous efforts is volumetric and uses synthetic hydrographs to account for a finite volume of water flowing down the stream. This would be more analogous to turning on the tap in a tub for several minutes before shutting it off again. The water surface in the tub would rise and then fall but not necessarily overtop.

This analogy is important because of the split in flow that occurs just upstream of the HWY 282. bridge where water leaves the main channel and flows west into the nearby wetland complex (located behind Wolf Motors). In a steady state model, this large wetland complex fills up until the highways overtop. The hydrology model however indicated that the flow into the wetland would only occur for several hours during the 100-year flood and would likely not have enough volume to cause the highway to overtop. For this reason, the unsteady model was developed to account for the flood storage present in the wetland.

The preliminary FIRMs were issued by FEMA in July of 2018 and are expected to become effective in 2019. The FIRMs are used by the National Flood Insurance Program for flood insurance policies and regulations. The FIRMs in this region are based solely on riverine flooding due to rainfall and do not account for ice jams or other potential sources of flooding.

B. Proposed 2D Model

Previous modeling efforts on Sand Creek were all completed using the 1D flood modeling approach. A 1D model uses a series of stream cross-sections, estimating the flood depth at each cross section, and then assuming averaged (interpolated) depths between the two cross sections. The 1D model assumes that flow is only going in 1 direction, in this case downstream. The 1D model could not calculate where flow would split and flow around an obstruction or changes in flow under bridge crossings. Exhibit 2 below shows an example of a cross-section from the 1D flood model. The area in blue illustrates the expected flood depth while the grey area illustrates the area blocked by HWY 282.

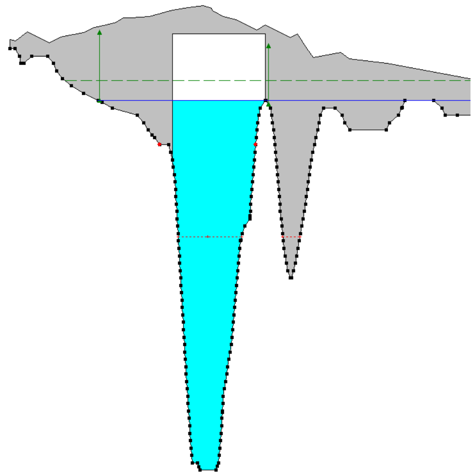


Exhibit 2 HWY 282 Bridge Cross-section

When using 1D models, users must also estimate the changes in flow direction at bridges. In the traditional 1D methodology, it was assumed that contraction and expansion of flow through a bridge opening would always occur at a constant rate through the opening as illustrated in Exhibit 3 below. The change in water surface elevation through the bridges were also accounted for through expansion and contraction coefficients which are assumed for each individual cross section. These coefficients were used to describe turbulent nature of water that is expanding or contracting its flow path to fit through bridge crossings. The expansion /contraction rates and loss coefficients are based on lab testing results for various types of stream crossings and have a range of acceptable values.

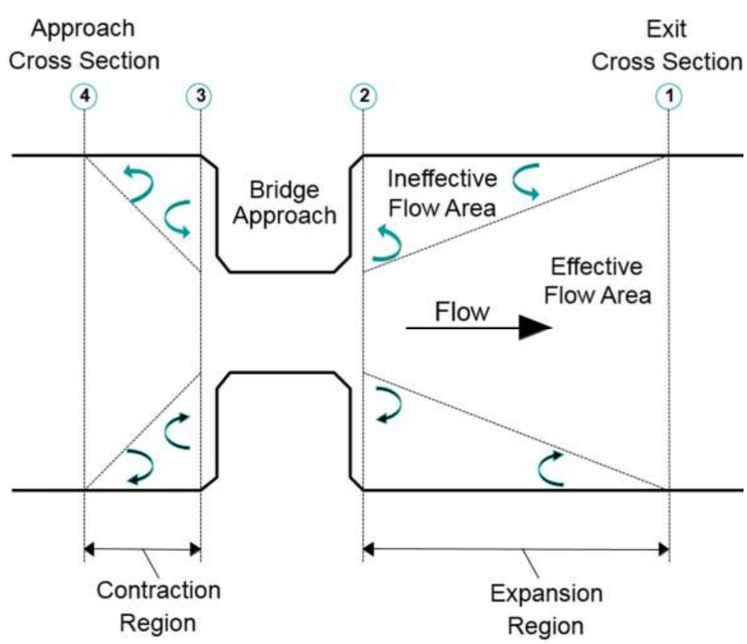


Exhibit 3 Expansion & Contraction of Flow

The most significant difference between the older 1D model and the newer 2D model is that the 2D model provides a continuous stream instead of the cross-section by cross-section approach. Instead of single "slices" of the stream, a terrain model that shows the full stream geometry in 3D is loaded into the model and the flood flow data is "poured" into the river channel.

The 2D model allows the water to flow in any direction – removing the assumptions the modeler must make in a 1D model to describe the flow through bridge openings. This provides a more accurate representation of what the flow will do through a bridge crossing. Exhibit 4 to the right illustrates the HWY 282 bridge crossing of Sand Creek as it appears in the 2D flood model. The red arrows and white lines illustrate the direction and magnitude of the Sand Creek 100-year flows.

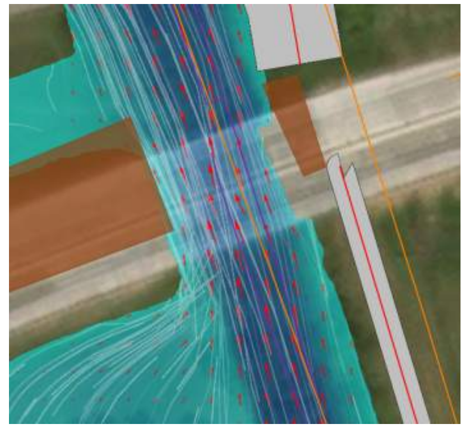


Exhibit 4 2D HWY 282

Like the 1D unsteady model used to generate the maps for the preliminary effective FIRMs, a 2D model is also volumetric and accounts for flood storage within the floodplain. However, storage calculated in 2D is more accurate as it allows the model to identify where the water will be stored.

In an effort to provide the City of Jordan the best product, all 3 mitigation efforts were modeled in a fully 2D HEC-RAS model.

C. Evaluation of Existing Conditions

The existing conditions model was created to show the realistic flooding of Sand Creek with the levees as they currently exist. The existing levees do not meet FEMA requirements for flood protection and cannot be incorporated into the maps. However, they have offered the City some protection in historical floods. Exhibit 5 below shows the 2D existing conditions flood extents within the City in yellow and the Preliminary approved floodplain in blue. The areas where they overlap appear green.

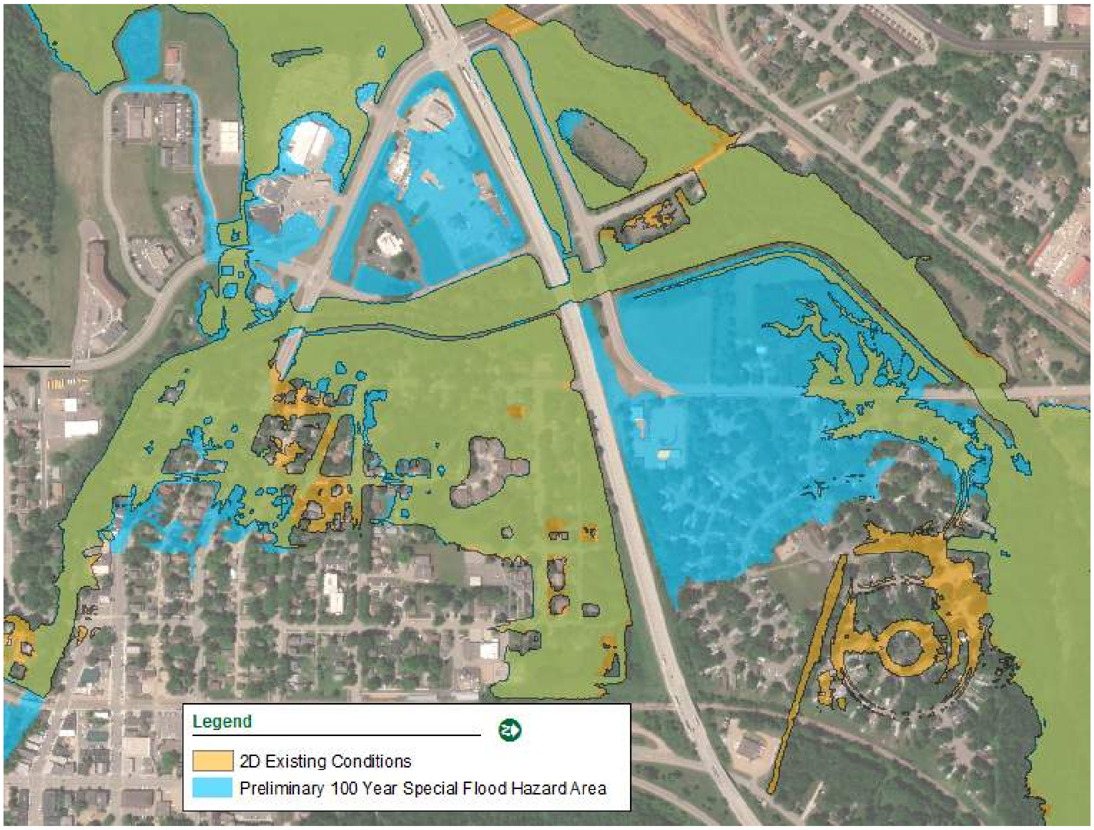


Exhibit 5 2D Existing Conditions

As seen above, the existing levees reduce the flooding downstream of HWY 169. However, they do not provide much protection upstream of the bridge. Flood waters leave the banks of Sand Creek upstream of the HWY 282 bridge on the east bank of the stream and flow downstream behind the existing levee causing most of the inundation seen in Exhibit 5. Neither of the existing levees are expected to overtop in the model. However, the existing levees do not have enough freeboard height to meet FEMA requirements.

One section added into the model was the drainage ditch in the northern portion of Jordan. The ditch's contributing drainage area is small enough that FEMA does not typically include it in their flood models and it was excluded from the previous mapping effort. However, since this model shows the realistic flood hazards, it was included in the model.

It is important to note that while this map does show a likely outcome of the 100-year flood within the City of Jordan, it does not meet the requirements of FEMA for use in the National Flood Insurance Program (NFIP). Regulations would require that both existing levees be removed from the model and water be allowed to flow freely through the City. As such, this map may be a useful planning tool for the City but it should not be used in any official capacity in administering the NFIP.

V. Levee Analysis

Flood control levees are strictly regulated by FEMA to ensure that properties and people protected by the levees are reasonably safe from a catastrophic failure during a flood event caused by stormwater runoff. FEMA requires that levees have 3ft of freeboard above the base flood elevation and an additional 1ft of freeboard for levees within 100ft of a constriction point such as bridge or culvert crossings.

Some sections of the proposed levee will be constructed as a flood wall to reduce the impact on surrounding properties. Floodwalls typically have a higher cost per lineal foot than a traditional earthen embankment. However, they have a drastically lower footprint for the same level of flood protection. Exhibit 6 below illustrates the typical flood wall cross-section used in this feasibility study.

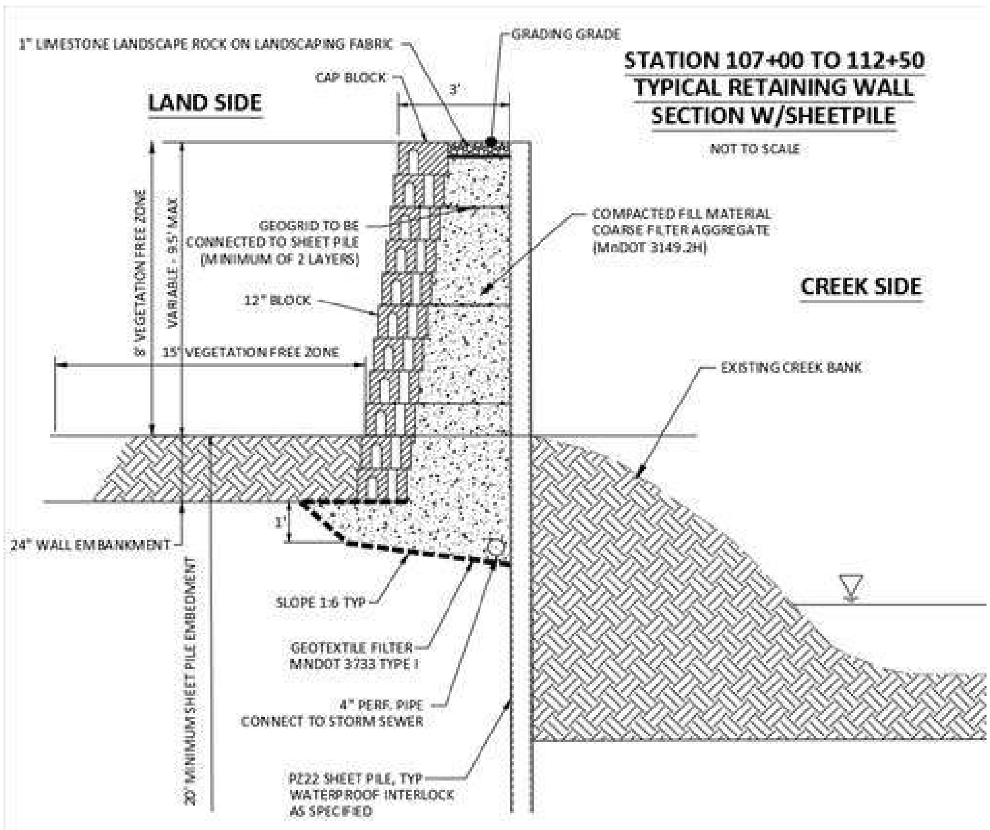


Exhibit 6 Typical Flood Wall Detail

Most of the existing levee consists of an earthen embankment that was constructed out of native materials and that likely do not meet stability requirements for accreditation. In these locations, it was assumed that the levee would have to be fully reconstructed using the typical cross-section see below in Exhibit 7. Levees of this design are typically the most cost-effective option for providing flood protection although they may impact local properties due to the large footprint.

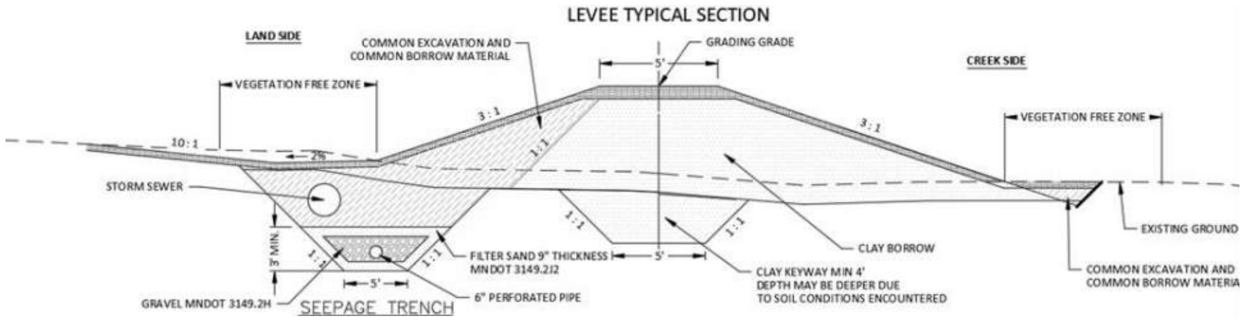


Exhibit 7 Typical Earthen Levee Detail

For this portion of the report, the focus will be on the location of the levees and their effects on the flood surface, but not specifically on levee elevations. Because the elevations are based on freeboard requirements, the options explored as part of the flood diversion and bridge modifications section will affect the final levee elevations.

A. Levee Section 1

Levee section 1 runs from the Varner St. Bridge to the HWY 282 bridge on the east bank of Sand Creek. This is the only section existing non-accredited levees do not exist. This section must be constructed to prevent flood waters from passing behind levee 2 and inundating the the bulk of lowertown Jordan.

If constructed, the area in green seen in Exhibit 8 would be removed from the mapped floodplain. This section of levee would remove approximately 77 structures from the mapped floodplain if constructed.

Exhibit 8 Levee Section 1

Section 1 has existing development located close to the Sand Creek corridor and therefore required a varied approach to the levee design to minimize impacts to the existing structures. The preliminary easterly (upstream) 500' of levee is proposed as a vertical floodwall instead of a typical earthen embankment. This dramatically reduces the foot print of the levee and protects the businesses located nearby. Beyond that stretch, the levee would transition into an earthen embankment until it ties into to the embankments of the HWY 282 bridge. Preliminary grading plans for the levee embankment can be found in Appendix B.

The proposed levee would likely require the partial acquisition of 14 properties and full acquisition of an additional 3 properties along the embankment corridor. In total, it is expected to impact 8 existing structures. A map of the projected corridor alignment and the impacted properties can be found in Appendix C.

One alternative option was to construct a floodwall for the entire length of this section. This reduces the impact to neighboring properties and reduces the acquisitions but does come at a substantially higher cost.

B. Levee Section 2

Section 2 follows the existing embankment corridor between the HWY 282 bridge and HWY 169. The existing non-accredited levee along this alignment does not have enough freeboard to meet FEMA requirements and will need to be reconstructed to meet standards. Exhibit 9 illustrates in purple the portion of the floodplain that may be removed by the construction of the section 2 levee.

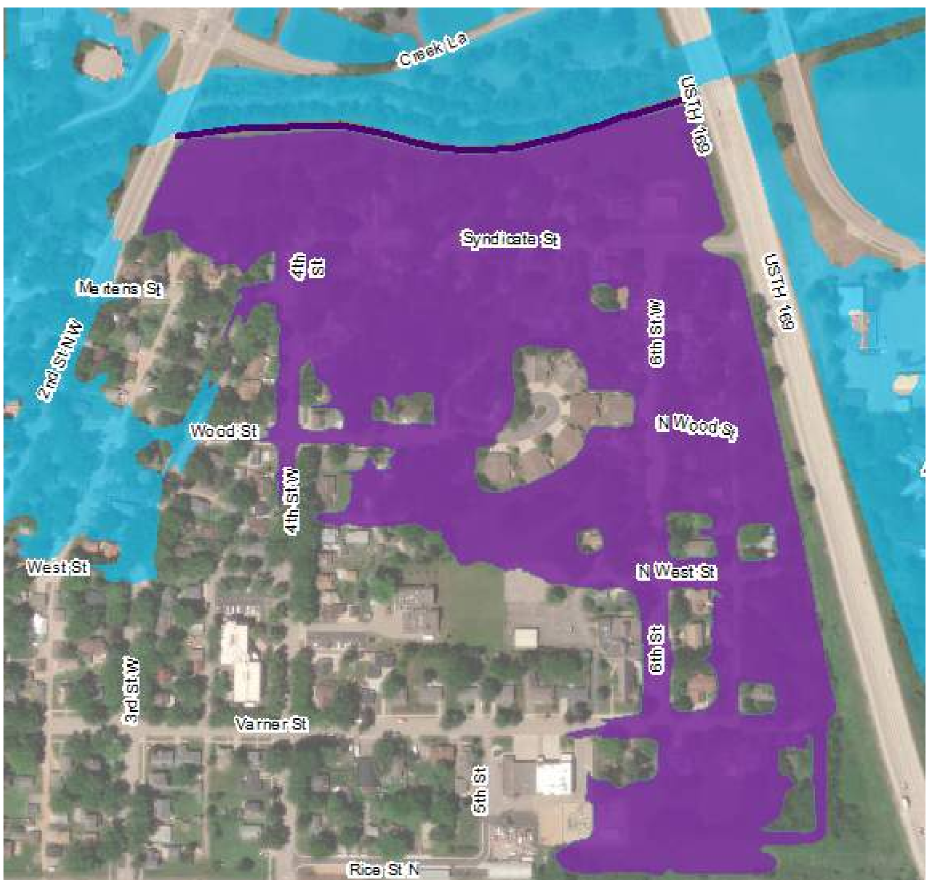


Exhibit 9 Levee Section 2

If levee section 2 is reconstructed and accredited, approximately 103 structures may be removed from the mapped floodplain. As previously show in Exhibit 5, a portion of the flooding behind section 2 consists of water flowing behind the levee along Mertens St. and Wood St. For the areas behind section 2 to be adequately protected, section 1 will also have to be constructed.

Due to the existing levee, there are no expected impacts to adjacent properties for this section of levee. A map of the projected corridor alignment can be found in Appendix C. Preliminary grading plans for the levee embankment can be found in Appendix B.

C. Levee Section 3

Section 3 follows the existing levee embankments between the HWY 169 bridge and terminates at the second Syndicate St. bridge. Options were considered to move the levee closer to Sand Creek in an effort to increase the developable land behind the levee, however this constricted the flow in Sand Creek and increased the streams flood elevations. This would have also altered the existing floodway delineation and would require extensive vetting by FEMA before approval for the levee could be secured. For this reason, it was proposed to follow the existing levee alignment.

The existing non-accredited levee along this alignment does not have enough freeboard to meet FEMA requirements and will need to be reconstructed to meet standards. Exhibit 10 below illustrates the area that could be protected by the proposed section 3. Preliminary grading plans for the levee can be found in Appendix B.

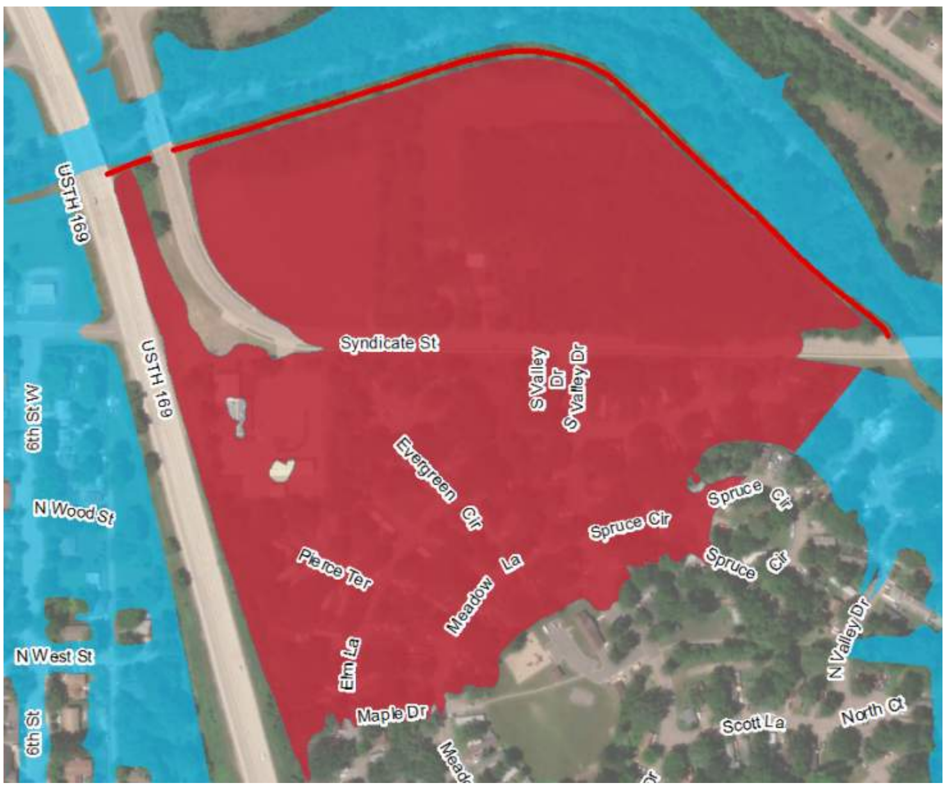


Exhibit 10 Levee Section 3

If section 3 is reconstructed and accredited approximately 115 structures may be removed from the mapped floodplain and 4 properties would have to be partially acquired to expand the proposed levee. However, no structures would be impacted by the alignment. A map of the projected corridor alignment and affected properties can be found in Appendix C.

VI. Internal Drainage

'Internal drainage' is the term used by FEMA to describe the stormwater that may be trapped behind the proposed levees during flood events. Under normal conditions the stormwater from Jordan flows by gravity directly into Sand Creek. During a flood event the Sand Creek elevations are high enough that the water must be either stored behind the levee in storage basins or it must be mechanically pumped into the river.

The basic internal drainage requirements are prescribed by HEC-22. Due to Sand Creek's watershed size, the internal drainage system must be capable of pumping out water from a 10-year rainfall event over the City when Sand Creek is at its 100-year flood elevation. The system also must adequately store and pass the 100-year design storm over the City when Sand Creek is at its 10-year flood elevation.

Unfortunately, the flood elevation in Sand Creek at the 10-year storm is high enough that the existing City storm sewers' internal drainage system cannot gravity drain into Sand Creek. As such, the internal drainage basin must be either capable of storing the runoff from the 100-year rain event or must be capable of pumping the excess water. To meet these requirements, three options have been proposed. All three options propose placing the basin the undeveloped area between levee section 3 and Syndicate St. The storm sewer from Levee Sections 1 & 2 will be collected in the same ditch system the currently drain to and pass under HWY 169 in a 48" RCP and into the drainage basins. The general footprint for all basins can be seen in Exhibit 11.

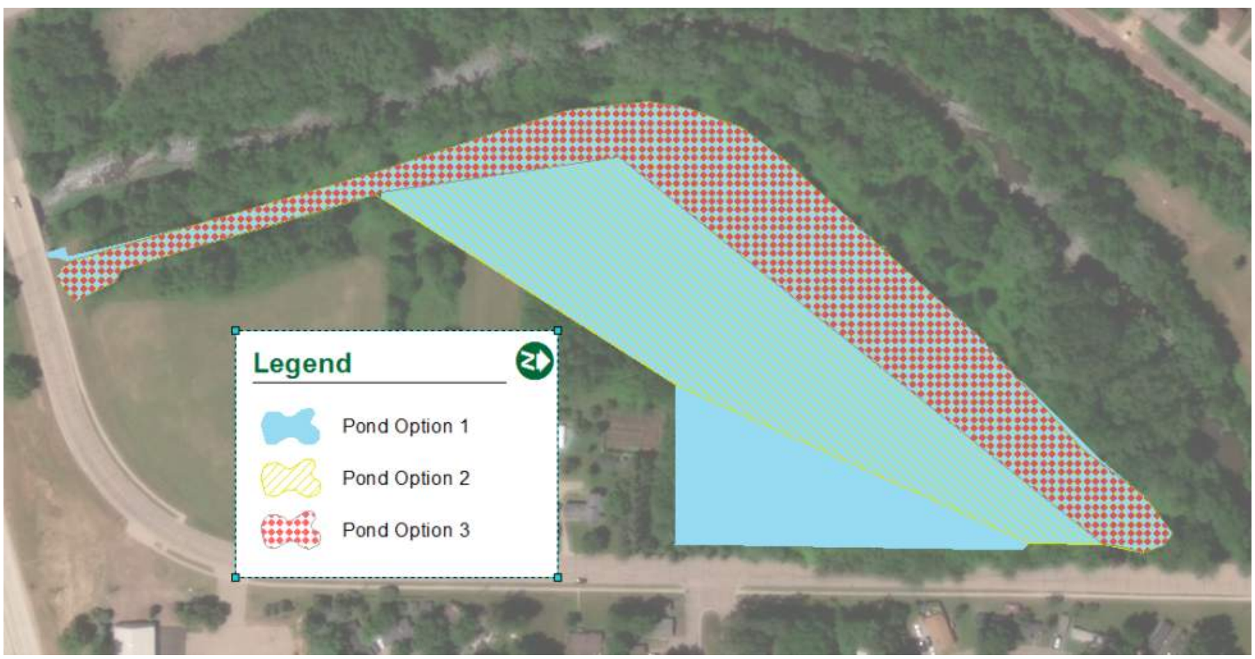


Exhibit 11 Internal Drainage Pond Options

Pond Option 1 requires the largest footprint at 8.2 acres. However, it does not require any pumps to manage the stormwater. The basin has been sized large enough to completely contain the 100-year design storm from the City of Jordan with no gravity outlet. In this option the stormwater would be detained behind the dam until the water in Sand Creek recedes enough to allow the outlet to gravity drain again.

Pond Option 2 reduces the proposed footprint to approximately 6.8 acres but it does require two 10,000gpm pumps to be able to manage the incoming stormwater without causing flooding upstream of the basin. FEMA also requires that the lift station have an emergency power source, such as a generator, in case of power outages during floods as well as redundancy in the pumping capacity in case one of the pumps was to fail. For all cost estimates it was assumed that there would be 1 additional pump beyond what was required and a dedicated onsite generator.

Pond Option 3 reduces the proposed footprint to 3.1 acres and will require three 10,000gpm pumps to manage the stormwater. As with Option 2, a redundant pump and backup power generator will be included with the construction cost of this basin.

Table 7 below summarizes the basin size and pumping requirements for all three options.

Table 7 Internal Drainage Options

Internal Drainage Pond Options				
	Footprint (ac)	**Storage Volume** (ac-ft)	**Excavation Volume** (CY)	**Pump Requirements** (gpm)
Option 1	8.2	33	47500	N/A
Option 2	6.8	22	40000	20000
Option 3	3.1	9	17000	30000

VII. Flood Diversion

The second mitigation effort that was analyzed for this report was the possibility of constructing a flood bypass system to reduce the peak flow rate in Sand Creek along the levee corridor. Just upstream of the HWY 282 bridge there is a low point on the left overbank of Sand Creek where water can spill out of the river and flow west into the nearby wetland complex as seen in Exhibit 12.

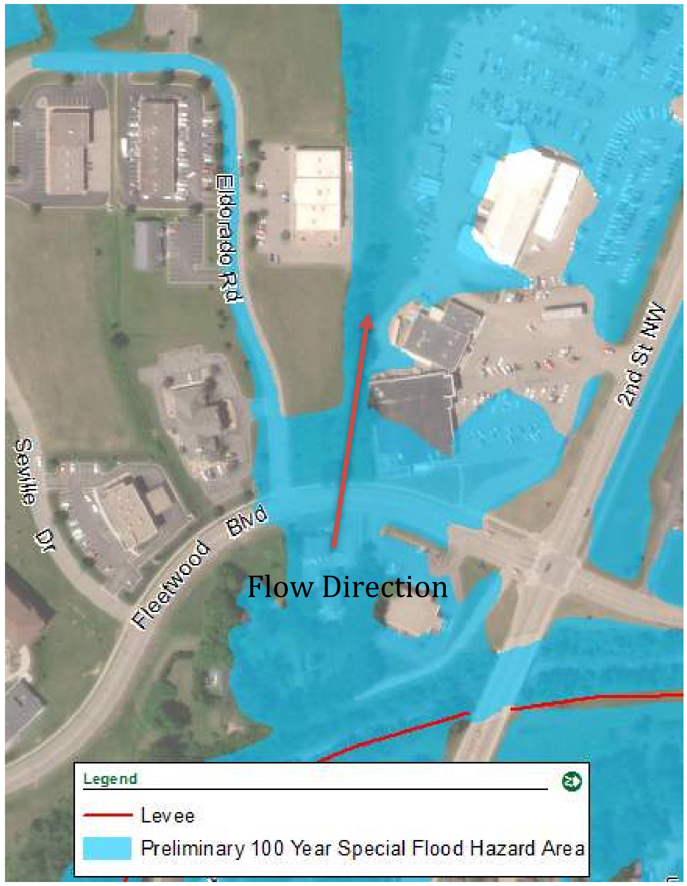


Exhibit 12 Existing Overland Route

In a previous study by the USACE, it was noted that the wetland complex had enough storage to temporarily store the water flowing out of Sand Creek and reduce the effects of flooding. The wetland complex has watershed area of approximately 7.9 square miles in comparison to Sand Creek's 236.3 square mile watershed. The resulting runoff from the wetland watershed largely passes through the system well before Sand Creek reaches flood levels leaving large volumes of storage available for flood waters from Sand Creek. Figure 1 shows the difference in scale of the two hydrographs.

Using this overland route as the starting point, two different culvert configurations were considered with 2 different alignments. Both alignments have an inlet structure located along Creek Ln South. The road along this location would have to be raised approximately 5ft to provide cover for the culverts. However, this would have the added benefit of removing the nearby properties from the floodplain as well. Inlets would be placed just above the 10-year flood to prevent low flow events from passing water into the wetland.

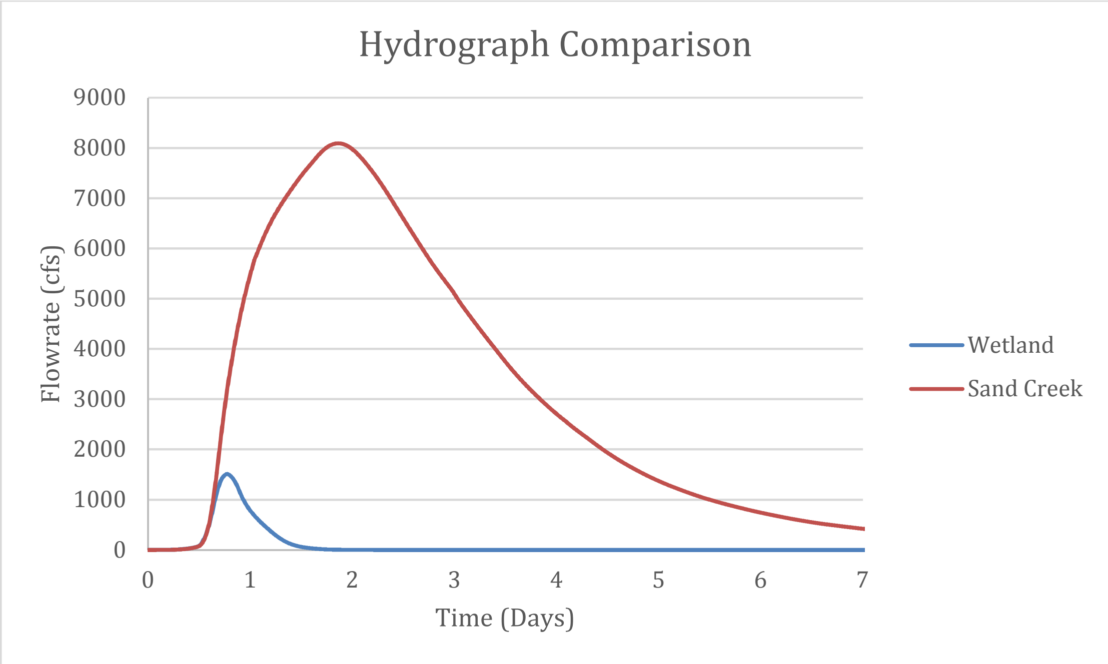


Figure 1 Hydrograph Comparison

To pass this additional flow the culverts downstream of the wetland would also need to be upsized to handle the additional flow. The first stream crossing at HWY 169 will require 2 additional 60" CMP culverts. The culverts under HWY 282 and Creek Ln should be replaced with dual 8'x8' box culverts. If these culverts are not upsized in conjunction with the bypass being installed, the houses and roads in the area are highly likely to overtop during flood events. In particular, the culvert under Creek Ln dramatically restricts flow in the wetland area.

A. Route Options

Route 1 routes the bypass culverts under Eldorado Dr. and into the adjacent wetland. This route keeps the alignment on existing roadway and right-of-way as much as possible, keeping new easements at a minimum. It does however require several bends in the culverts and a much longer flow length.

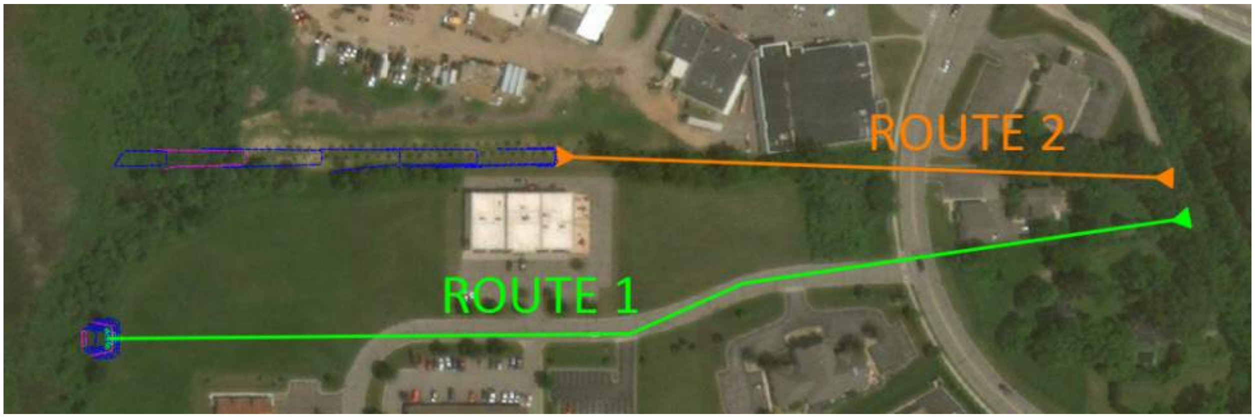


Exhibit 13 Bypass Routes

Route 2 is located north of Route 1 and takes the shortest route to a feasible outlet location. The existing low point adjacent to Wolf Motors allows for the bypass route to be shortened by nearly 700' in comparison with Route 1 but would require purchasing additional easement rights.

B. Size Options

Two different options were considered for this portion of the analysis. The first option considered placing dual 6’x8’ box culverts as they would be on the smaller end of the feasible culvert size. The second option was to assess the other extreme by placing a triple 8’x10’ box culvert along the same alignments.

C. Bypass Results

Both options were modeled in the 2D model described in section IV of this report. It was noted that the change in WSEL between the 2 route options was virtually identical. For that reason, the results shown below in Table 8 are summarized only by the differences in the base flood elevation of Sand Creek.

Table 8 Bypass Comparison

Bypass Flood Reduction Comparison		
Alternative	**Water Surface Elevation (ft)**	**Flood Reduction (ft)**
Levees	753.47	N/A
Dual 6x8	753.36	0.11
Triple 8x10	753.14	0.33

The Flood Reduction height resulting from each bypass option indicates the decrease in levy elevation that could be achieved under that scenario. With three 8x10 box culverts bypassing flow, a levy height reduction of 0.33’ (4”) could be achieved.

VIII. Bridge Alterations

Bridges and culvert crossing are common sources of concern during high water events in streams. The crossings create sites that are more likely to restrict flows and create dangerous flood conditions in the upstream area.

The slope of the water surface along a stream is called the hydraulic grade line (HGL). In a general sense, the HGL of the stream is similar in slope to the slope of the stream bed. Traditionally, bridges and culvert crossings were designed to not impact the HGL of the stream at normal flowrates but were not necessarily designed to pass larger flood events. In a clear stream channel, the depth of water in the channel would increase until the channel's conveyance is able to carry the flood flows at a constant HGL. At a stream crossing, the stream's conveyance capacity is reduced being partially blocked by the crossing structure. This causes water to build up behind the structure until the upstream water pressure forces the water through at higher velocities, creating what is commonly referred to as a backwater effect.

Any stream crossing is a point of concern during a flood event. At any crossing, the stream is forces to contract its flow through the bridge or culvert opening which simultaneously increases the velocity in the channel and reduces the conveyance capacity of the channel creating a backwater effect where the water immediately upstream of the crossing does not match the slope of the stream bed.

Newer bridges are constructed to pass the 50yr or 100yr flood flows with minimal impact to the HGL. This is usually accomplished by constructing the bridge as a clear span bridge with no piers or pilings within the channel and by keeping the low chord of the bridge above the 100yr flood elevations.

The goal of this section of the analysis was to consider the effects the existing bridges have on Sand Creek. The results of the 1D unsteady model used in the most recent FEMA remapping process indicate that several bridges may create backwater conditions that raise the water surface elevations during the 100 yr flood event created by the 100yr design storm (8100cfs). Alternative flooding scenarios, such as debris or ice jams, were not considered as part of this analysis.

A. Comparison of Existing to 2D model

Figure 2 below shows the comparison of the older 1D model's expected flood elevations to the preliminary 2D model results. As progress was made in the levee and diversion analysis components of the feasibility study, including conceptual modification of the existing bridges over Sand Creek, it became apparent that modifying these bridge openings will not yield a significant benefit and thus not be a cost-effective part of the flood control solution for Jordan.

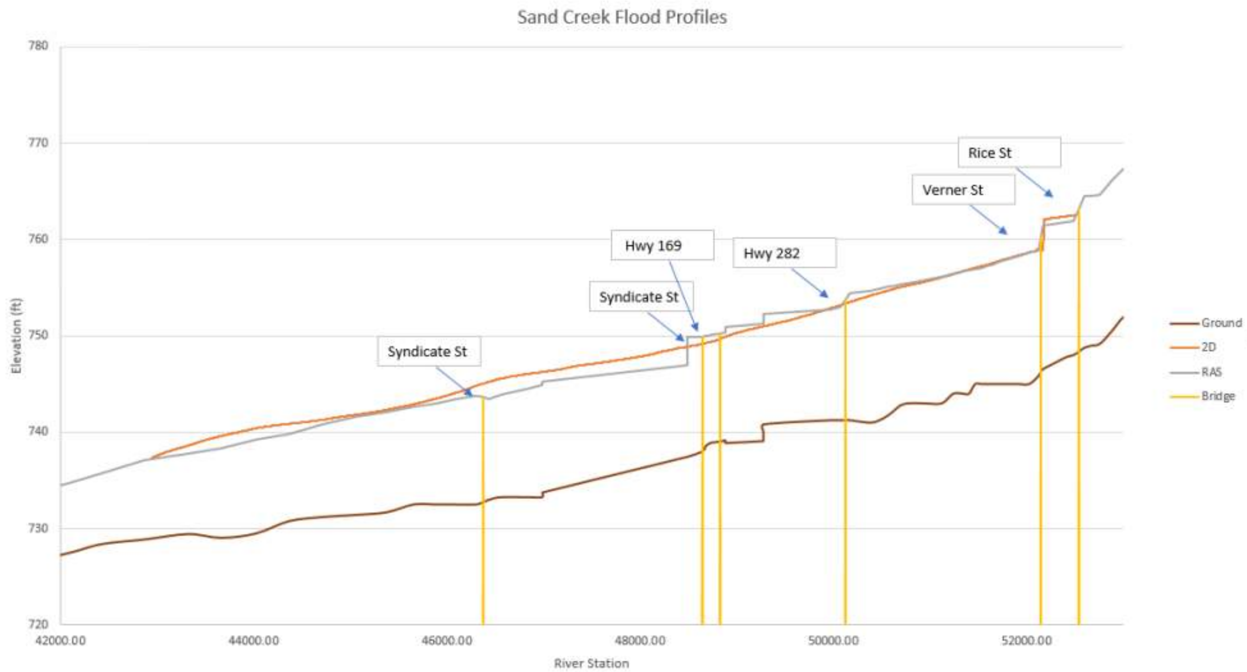


Figure 2 Flood Profile Comparison

Figure 2 demonstrates the estimated Sand Creek elevation along its length comparing the two models.

- The orange line labeled as "2D" illustrates the Sand Creek surface water elevation along its length based on the new two-dimensional model.
- The blue line labeled "RAS" illustrates the Sand Creek surface water elevation along its length based on the old one-dimensional HEC-RAS model.
- The brown lined labeled the "Ground" elevation – essentially the bottom of Sand Creek along its length.
- The yellow lines indicate bridges for reference along the length of Sand Creek.

The 1D "RAS" model formerly illustrated steep drop-offs in the Sand Creek surface water profile, almost steps downward, at the downstream end of each bridge. With more detailed accounting for how the Creek floodwater is flowing near and through these bridges, the 282-169-Frontage Road bridges in the 2D model do not appear to be 'holding back' Sand Creek flood water – note how there are no longer steps downward in the "2D" surface water profile at the bridges. As a result, the new 2D model indicates the flood elevations decreasing slightly upstream of the existing bridges and increasing slightly downstream of the bridges. More importantly, the lack of these 'steps' indicates limited restriction is occurring at the bridges based on the two-dimensional model

B. Conclusions

Through development of improved modeling and comparison of different bridge openings, the existing bridge crossings appear to have sufficient capacity to pass the 100-year flood flows (8100cfs) with limited benefit being created by the costly widening. While the TH 282, US 169, and Frontage Road bridges have an influence on the 100-year flood elevations, benefits of widening are not significant.

Alternative flood scenarios such as ice jams or debris jams may still occur the bridge crossings. These scenarios are further discussed in Section XI of this report.

IX. Preliminary Engineering Estimates

A. Levee

Table 9 Levee Costs

Levee Construction Cost Estimate										
			Estimated Quantity				**Estimated Cost**			
	Unit	**Est. Unit Price**	Section 1	Section 2	Section 3	Total	Section 1	Section 2	Section 3	Total
Common Excavation	CY	$ 10	5200	10300	14400	29900	$ 52,000	$ 103,000	$ 144,000	$ 299,000
Clay Borrow	CY	$ 40	4800	6300	7800	18900	$ 192,000	$ 252,000	$ 312,000	$ 756,000
Coarse Filter Aggregate	CY	$ 24	700	600	1100	2400	$ 16,800	$ 14,400	$ 26,400	$ 57,600
6" Perforated Pipe	LF	$ 10	1380	1650	2110	5140	$ 13,800	$ 16,500	$ 21,100	$ 51,400
4" Perforated Pipe	LF	$ 8	470	0	0	470	$ 3,760	$ -	$ -	$ 3,760
Modular Block Retaining Wall	SF	$ 45	3800	0	0	3800	$ 171,000	$ -	$ -	$ 171,000
Course Filter Aggregate (Wall)	TON	$ 30	425	0	0	425	$ 12,750	$ -	$ -	$ 12,750
Seeding	AC	$ 950	1.6	1.7	1.4	5	$ 1,533	$ 1,639	$ 1,351	$ 4,524
24" FES	EA	$ 1,500	1		0	1	$ 1,500	$ -	$ -	$ 1,500
28" Concrete Arch Apron	EA	$ 2,000	0	1	0	1	$ -	$ 2,000	$ -	$ 2,000
PZ22 Sheetpile Floodwall	SF	$ 35	10000	0	0	10000	$ 350,000	$ -	$ -	$ 350,000
Subtotal							**$ 815,000**	**$ 390,000**	**$ 505,000**	**$ 1,710,000**
20% Contingency							$ 163,000	$ 78,000	$ 101,000	$ 342,000
Estimated Construction Cost							**$ 978,000**	**$ 468,000**	**$ 606,000**	**$ 2,052,000**
20% Est. Soft Costs							$ 196,000	$ 94,000	$ 121,000	$ 411,000
Land Acquisition							$ 1,755,000	$ -	$ -	$ 1,755,000
Estimated Cost - Certified Levees							**$ 2,929,000**	**$ 562,000**	**$ 727,000**	**$ 4,218,000**

Table 10 Section 1 Floodwall Alternative

Sheet Pile Alternative Construction Cost Estimate											
			Estimated Quantity				Estimated Cost				
	Unit	Est. Unit Price	Section 1	Section 2	Section 3	Total	Section 1	Section 2	Section 3	Total	
Common Excavation	CY	$ 10	0	10300	14400	29900	$ -	$ 103,000	$ 144,000	$ 247,000	
Clay Borrow	CY	$ 40	0	6300	7800	18900	$ -	$ 252,000	$ 312,000	$ 564,000	
Coarse Filter Aggregate	CY	$ 24	0	600	1100	2400	$ -	$ 14,400	$ 26,400	$ 40,800	
6" Perforated Pipe	LF	$ 10	0	1650	2110	5140	$ -	$ 16,500	$ 21,100	$ 37,600	
4" Perforated Pipe	LF	$ 8	1850	0	0	470	$ 14,800	$ -	$ -	$ 14,800	
Modular Block Retaining Wall	SF	$ 45	14800	0	0	3800	$ 666,000	$ -	$ -	$ 666,000	
Course Filter Aggregate (Wall)	TON	$ 30	1665	0	0	425	$ 49,950	$ -	$ -	$ 49,950	
Seeding	AC	$ 950	0.2	1.7	1.4	5	$ 190	$ 1,639	$ 1,351	$ 3,180	
24" FES	EA	$ 1,500	1	0	0	1	$ 1,500	$ -	$ -	$ 1,500	
28" Concrete Arch Apron	EA	$ 2,000	0	1	0	1	$ -	$ 2,000	$ -	$ 2,000	
PZ22 Sheetpile Floodwall	SF	$ 35	38850	0	0	10000	$ 1,359,750	$ -	$ -	$ 1,359,750	
Subtotal							**$ 2,092,000**	**$ 390,000**	**$ 505,000**	**$ 2,987,000**	
20% Contingency							$ 418,000	$ 78,000	$ 101,000	$ 597,000	
Estimated Construction Cost							**$ 2,510,000**	**$ 468,000**	**$ 606,000**	**$ 3,584,000**	
20% Est. Soft Costs							$ 502,000	$ 94,000	$ 121,000	$ 717,000	
Land Acquisition							$ 1,755,000	$ -	$ -	$ 1,755,000	
Estimated Cost - Certified Levees							**$ 4,767,000**	**$ 562,000**	**$ 727,000**	**$ 6,056,000**	

B. Internal Drainage Cost

Table 11 Internal Drainage Costs

Estimated Internal Drainage Cost								
			Est. Quantity			Est. Cost		
	Unit	Est. Unit Cost	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
48" RC Storm Pipe (Jacked)	LF	$875	300	300	300	$ 262,500	$ 262,500	$ 262,500
Common Excavation	CY	$10	47500	40000	17000	$ 475,000	$ 400,000	$ 170,000
Seeding	AC	$950	8.2	6.8	3.1	$ 7,790	$ 6,460	$ 2,945
48" RC Safety Apron Design 3132	EA	$3,800	2	2	2	$ 7,600	$ 7,600	$ 7,600
Lift Station Structure	LS	N/A*	0	1	1	$ -	$ 400,000	$ 500,000
Submersible Axial Flow Pumps	LS	N/A*	0	3	3	$ 100,000	$ 600,000	$ 890,000
Generator	EA	$200,000	0	1	1	$ -	$ 200,000	$ 200,000
Electrical, Instrumentation, & Control	LS	N/A*	1	1	1	$ -	$ 160,000	$ 220,000
Force Main	N/A	N/A*	0	1	1	$ -	$ 50,000	$ 60,000
*Costs related to lift stations are specific to each option			**Subtotal**			**$ 853,000**	**$2,087,000**	**$2,313,000**
			20% Contingency			$ 170,600	$ 417,400	$ 462,600
			Est. Construction Cost			**$1,023,600**	**$2,504,400**	**$2,775,600**
			20% Est. Soft Costs			$ 205,000	$ 501,000	$ 555,000
Land Acquisition	AC	$ 30,000	7.1	5.7	2.9	$ 213,000	$ 171,000	$ 87,000
			Est. Cost - Internal Drainage			**$1,441,600**	**$3,176,400**	**$3,417,600**

C. Bypass Cost

Table 12 Bypass Option 1 Costs

Estimated Option 1 6' x 8' Box Bypass Costs						
			Est. Quantity		Est. Cost	
	Unit	Cost	Route 1	Route 2	Route 1	Route 2
Road Reconstruct	LF	$ 500	800	80	$ 400,000	$ 40,000
Utility Reconstruct	LF	$ 500	800	0	$ 400,000	$ -
Common Excavation	CY	$ 20	18000	10200	$ 360,000	$ 204,000
6'x8' Box Culvert	LF	$ 600	3000	1720	$ 1,800,000	$ 1,032,000
			Subtotal		**$ 2,960,000**	**$ 1,276,000**
			20% Contingency		$ 592,000	$ 255,200
			Estimated Construction Cost		**$ 3,552,000**	**$ 1,531,200**
			20% Est. Soft Costs		$ 710,000	$ 306,000
			Estimated Cost - Option 2 Bypass		**$ 4,262,000**	**$ 1,837,200**

Table 13 Bypass Option 2 Costs

Estimated Option 1 6' x 8' Box Bypass Costs						
			Est. Quantity		**Est. Cost**	
	Unit	Cost	Route 1	Route 2	Route 1	Route 2
Road Reconstruct	LF	$ 500	800	80	$ 400,000	$ 40,000
Utility Reconstruct	LF	$ 500	800	0	$ 400,000	$ -
Common Excavation	CY	$ 20	28000	16000	$ 560,000	$ 320,000
8'x10' Box Culvert	LF	$ 600	4500	2580	$ 3,150,000	$ 1,806,000
			Subtotal		**$ 4,510,000**	**$ 2,166,000**
			20% Contingency		$ 1,353,000	$ 649,800
			Estimated Construction Cost		**$ 5,863,000**	**$ 2,815,800**
			20% Est. Soft Costs		$ 1,172,600	$ 563,160
			Estimated Cost - Option 2 Bypass		**$ 7,035,600**	**$ 3,378,960**

X. Recommendations

A. Levee Recommendation

It is recommended that the City of Jordan pursue accreditation for all three proposed levee alignments. Table 14 summarizes both the existing and potential future flood insurance premiums for the all properties within the City of Jordan as of August 2018. The alternative option of construction of a flood wall for the entirety of Section 1 is not recommended at this time due to costs. If funding above what is necessary to construct the earthen embankments is identified in the future, the alternative may be reconsidered.

Table 14 Summary of NFIP Policies

Summary of NFIP Policies	
Number of Policies	77
Total Cost	$ 144,905
Policies Removed by Levee	65
Total Premium Reduction	$ 118,534
Remaining Number of Policies	12
Remaining Total Cost	$ 32,517

Completion of the proposed levees will likely over 84% of the structures currently located within the FEMA mapped floodplain. Table 15 shows the potential annual savings possible after the levees have been constructed.

Table 15 Post Levee Flood Insurance Projection

Flood Insurance Premiums			
	Existing Conditions	**With Levee**	**Potential Savings**
Existing 2018 Costs	$ 144,905	$ 32,517	$ 112,388
Estimated 2020 Costs	$ 169,000	$ 37,900	$ 131,100
Estimated 2025 Costs	$ 248,300	$ 55,700	$ 192,600
Estimated 2030 Costs	$ 364,900	$ 81,900	$ 283,000

Within 15 years, the 65 property owners who would no longer be required to purchase flood insurance would see a total savings of approximately $3.4 million assuming flood insurance continues to rise at 8% per year.

Houses behind the levee may still choose to purchase flood insurance at reduced rates if the homeowner prefers.

Houses located outside of the floodplain are likely to have property values 5-10% higher than similar houses within the special flood hazard area. Based on the estimated property values of the inundated properties, this would increase the total taxable value of the properties by $1.4-2.9 Million dollars. A benefits appraisal of the affected properties is recommended to better quantify the anticipated increase in property value for the purposes of special assessments.

B. Internal Drainage Recommendations

It is recommended that the City pursue Option 1 of the internal drainage designs. Provides a high level of safety to City while minimizing costs. While Option 1 would meet the minimum requirements without any pumping options, it is recommended that at least 1 5000gpm be on site to help draw down the pond after rain events during periods when Sand Creek remains at flood stage for long periods.

Future consideration may also be given to developing the large area inside the basin as a City park or another open space use. The area would be mapped as a zone A floodplain by FEMA as park of the flood control structure, however FEMA does allow for open space uses in the flood zones. Public spaces such as baseball or soccer fields may be constructed as long as all utilities are adequately flood proofed and structures are not susceptible to damage by long periods of inundation.

C. Bypass Recommendations

Given the high costs and low impacts to the Sand Creek flood elevations, it is recommended that neither option be pursued.

It is however recommended that the City still pursue replacing and upsizing the existing culvert under Creek Ln. The existing culvert consists of a box culvert on the upstream side of the crossing and a corrugated metal pipe on the downstream side. The crossing commonly backs water back up into the wetland and could create hazardous conditions during flooding.

XI. Alternative Flood Scenarios

The focus of this feasibility study was to estimate the effects of a flood created by a 100yr 24hr design storm rain event on the Sand Creek and Wetland watersheds resulting in peak flowrate of 8100cfs. This methodology is the industry standard when modeling flood scenarios for riverine systems. This design methedology is based off of the statical probability that the design flood scenario has a 1% chance of occuring in any given year and is the most probable cause of flood damage along the river system. It is possible that flood elevations may exceed the design storm based on other scenarios that are not accounted for in a standard flood analysis required for FEMA mapping purposes.

Other flood protection efforts can be taken to monitor for and prevent alternative flooding scenarios. In general, the best protection is to regularly inspect and maintain all culvert and bridge crossings and monitor the stream for any rapidly changing conditions.

A few possible alternative flooding scenarios are described below. This does not represent a complete list of events that may cause flooding in Sand Creek but serves to highlight a few potential scenarios.

A. Cumulative Rainfall

Multiple days of rain in short succession may create conditions that exceed the 100 yr design storm flooding even though any individual storm does not meet the 100yr design storm rainfall depth. Small rainfalls will fill the surface depression storage in the watersheds and may create saturated soils. These conditions create near impervious conditions across the watershed that greatly increase runoff. The resulting runoff may drastically increase the projected runoff rates for smaller rainstorm events.

In the event of multiple days of rain, the river gage near the City of Jordan should be monitored closely as river levels may rise rapidly.

B. Coincidental Peaks

The hydrographs for Sand Creek and the Wetland are shown in Figure 1 in section VII of the report. Here it is apparent that identical rainfall events occuring simultaneously over 2 different watersheds can create very different hydrographs that peak at different times. Due to their proximity, it was assumed that the wetland area and Sand Creek will flood simultaneously, however that assumption is not made for all rivers.

In the case of Sand Creek, it is assumed that the Minnesota river will not be at flood stage when Sand Creek floods. This is because the Minnesota River watershed near Jordan is approximately 16,200 square miles while the Sand Creek Watershed is only 274 square miles. It is unlikely that a storm event would be large enough across both watersheds to create an incident where the rivers flood simultaneously.

Due to the size of the Minnesota river watershed, in the event of an extreme rainfall, it is likely that there would be a couple of days of lag time between the storm event and when the river reaches it peak stage. During this lag period, it is important to carefully watch the Sand Creek watershed for any additional large storm events or rapidly changing river conditions as the higher water levels in the Minnesota river may increase the water surface elevations in Sand Creek near Jordan.

C. Debris Blockages

During large storm events it is common for debris to be washed out into the flood channels creating additional hazards in the stream channel. Debris carried by the rivers during large storm events can easily obstruct stream crossings such as a culverts and bridges. Even a minor restriction in a culvert can substantially reduce the culverts conveyance capacity and increase the water surface elevations upstream of the crossing. During a flood it may not be possible to clear debris however once waters recede is important to clear debris from the channel and stream crossings.

D. Dam Failure

Sand Creek has a run of river dam located just upstream of the Rice St. bridge at the mill pond park. The dam diverts water into the mill pond but does not maintain a substantial pool in the river channel. The dam was modeling in place during the FEMA flood study but does not offer the City and form of flood protection. The water stored in the mill pond is retained by a second dam located to the north. The locations of both dams can be seen in Exhibit 14 below

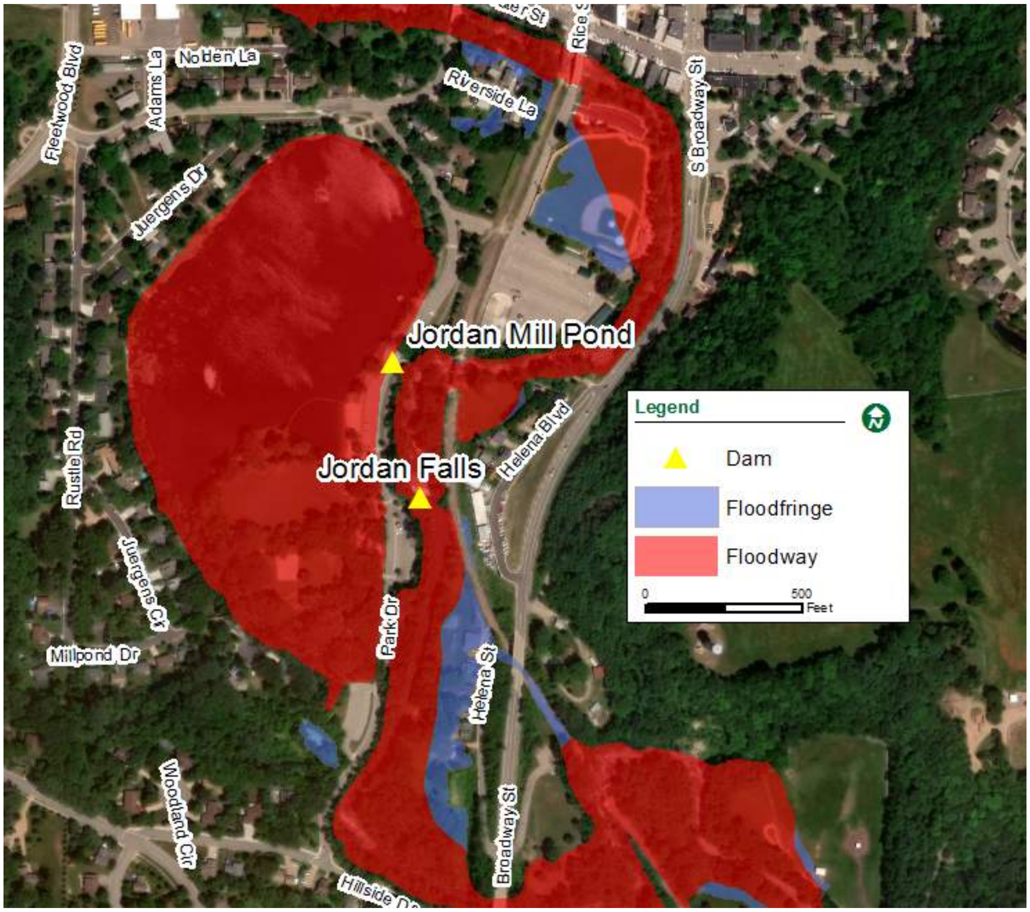


Exhibit 14 Dam Locations

Since the dam is a run of river dam and does not store a “pool” upstream of the dam, during a dam failure scenario there should not be a substantial increase in flow. The change in the hydraulic grade line however may carry a large amount of sediment and debris downstream which may damage infrastructre.

The dam should be inspected annually for structural stability.

E. Ice Jams

Ice jams (also called ice dams) form in rivers during the spring melt.Typically, in rivers like Sand Creek, they form when melt occurs rapidly and water levels rise and break up the upstream ice before the ice is able to melt in place. The ice is carried downstream by the water where it may jam together to form an ice jam.

It is difficult to estimate exactly where an ice jam may form. They are most likely to jam near constrictiction points such as narrow bridge widths and culverts or where stream slopes flatten out and the velocity in the channel reduces. As stated in Section 2, Bridge Widening, the bridges throughout the study area do not cause any constriction points generating a headwater condition that increased flood elevation or reduced velocities. It is possible that ice and other debris could get caught on piers or in the channels near the bridges, however widening the bridges would not change the reduce the possibility of this occurring.

The most likely area that ice jams would occur is in the area downstream of the second Syndicate St. bridge where the stream flattens out. The section of Sand Creek between the Varner St. bridge and the downstream Syndicate St. bridge has an average slope of approximately 0.26% and during the 100yr flood an expected average channel velocity of 8.6ft/sec. In the section downstream of Syndicate to the confluence with the Minnesota floodplain, Sand Creek has a slope of approximately 0.13% with an average channel velocity of 3.9 ft/sec during the 100yr flood. This dramatic change in slope and velocity reduces the ability of the stream to carry the large ice flows during the spring melt. The channel downstream of the Syndicate St. bridge also widens into a braided stream with intermittent islands and a heavily wooded overbank. These islands and woods give the ice flows many different obstacles for ice to get hung up on and create ice jams during the spring melt.

During spring runoff the river gage along Sand Creek near 169 should be monitored for rapidly increased water surface elevation as this is indicitive of an ice jam forming. The ice jam should be cleared as quickly as possible to prevent uspstream flooding.

Ice jams that form downstream of a bridge may back water up behind the dam impacting upstream bridges. When the downstream dam forms, it reduces the velocity of the water which in turn makes it more likely that additional ice will jam upstream. However, widening the bridges would not change the likelyhood of ice jams forming during these conditions. Options for enabling expedited clearing of jams should be investigated.

A ice jam analysis of Sand Creek may also be completed. Since FEMA has not had enough claims related to ice jam flooding they did complete one during the last remapping process. The Community can undertake one if it desires to implement additional regulations and protections.

XII. Next Steps

A. FEMA Benefit Cost Analysis

Many federally funded grant opportunities will require a FEMA Benefit Cost Analysis (BCA). The BCA quantifies the value of the proposed flood mitigation plan as a function of cost of the project vs. the reduced damage potential. If the ratio is found found to be greater than 1:1 the project is considered fundable by FEMA and other government agencies.

Additional details are required to complete the BCA. This report provides an estimate of the costs for the BCA but does not address the benefits details that are required by the BCA toolkit. The following details are required for each structure that is currently located in the special flood hazard area for the BCA to be completed, which are not currently available in full:

- First Floor Elevations
- Square footage
- Replacement value
- Number of stories and basement
- Foundation type
- Population of structure

FEMA prefers that this data be collected and registered with the local NFIP administrator as an elevation certificate. Multiple structures on the same property may require multipe elevation certificates (eg. Detached garages). The structure data is then matched with the corresponding flood data for the 10-, 50-, 100-, and 500 year flood elevations from the most recent flood insurance study.

Currently there are an estimated 361 structures within the mapped 100 year floodplain and and additional 150 within the 500 year floodplain that would require an elevation certificate to complete the BCA.

FEMA will also consider social costs into the BCA calculations based on mental stress for flood affected individuals and loss of productivity. Costs also include displacement costs for occupants of any residential structures.

B. Geotechnical Analysis

This study assumes that the existing levee system in Sections 2 & 3 must be completely removed in order to certify the proposed levees. This was considered to be the most fiscally conservative option.

Data regarding the construction of these levees is sparse and little is known outside of 4 preliminary borings that ere completed in 2017. A more detailed exploration of the in place soils may yield results favorable to the levee construction that would allow the existing levees to be expanded instead of replaced. This could reduce construction costs considerably.

Braun Intertec has begun a high level study to determine the usefulness of the existing materials and to provide a more detailed typical cross-section of the proposed levees. Once completed, the prelminary findings of this report should be updated to incorporate their data.

C. Potential Funding Partnerships

1. FEMA Hazard Mitigation Grant Program

The Hazard Mitigation Grant Program (HMGP) purpose is to help communities implement hazard mitigation measures follwing a Presidential Major Disaster Declaration. It's main goal is to enact mitigation measures that reduce the rist of loss of life and property from future disasters.

The grant program favors long term solutions to hazard mitigation such as purchasing repetative loss structure or construction of permanent flood mitigation projects such as levees.

FEMA provides up to 75% of the fund for mitigation projects and the remaining 25% must be provided by other sources such as the City or donations.

To apply, the City must complete the notice of intent (NOI) form and send it to the Homeland Security and Emergency Management (HSEM) to being their review. The project should be incorporated into the City's Hazard Mitigation Plan and must pass FEMA's BCA.

FEMA requires that separate consultants work on the feasibilty study and the final design of the mitigation projects.

Currently, the HMGP has approximately $2.5 million available for Scott County. The due date for the NOI for the current grant cycle is December 28, 2018.

2. DNR Hazard Mitigation Grant

The MN DNR manages a separate hazard mitigation grant that Cities may apply for. Eligible projects include physical mitigation efforts such as the levees recommended in this report. Applications are reviewed on a statewide basis. The Department prioritizes grant requests based on several considerations, including need, feasibility, and financial situation, with an emphasis placed on activities that reduce flood damages and enhance environmental benefits.

Grant requests in excess of $150,000 must be approved by the Legislature and applicants are eligible to receive more than one grant. It is recommmending that application for funding be submitted to the DNR Division of Waters before June 1 of the year you wish to apply.

3. Continuing Authorities Program

The U.S. Army Corps of Engineers (USACE) manages the Continuing Authorties Program (CAP). Any flood mitigation project under $10 million can be submitted to the USACE as a potential CAP. The initial submittal must include a narrative report to the USACE of the flooding issues along with any substantiating data or studies that apply. If selected, the USACE will partner with the sponsor to complete a feasibility study which the USACE will fund up to $100,000 in federal funds and any exceeding costs are shared 50/50 by the USACE and the sponsor. If the proposed project meets the USACE standards, the design and construction costs are shared 65% by federal funs and 35% by the sponsor.

The sponsor is also required to provide all lands, easements, ROW, relocation, and dredge material disposal sites needed for the project. The sponsor is also required for all operations and maintenance costs once completed.

It is important to note that this program is only authorized when funding is available and may not be funded annually.

D. Current Funding Status

The City has met with the DNR Grant Coordinator to begin the process of applying for a grant request in the next cycle. The DNR has recommended that the future project be broken into several different phases as it is hihgly unlikely that a large flood mitigation project could be funded in once grant cycle. Preliminarily, the City has identified the following phasing

Phase 1 – Final Design of levees and internal drainage, acquisition of Phase 2 property

Phase 2 – Construct Levee Section 1, Acquisition of Phase 3 property

Phase 3 – Construct Levee Section 3 and internal drainage basin for levee sections 2 & 3

Phase 4 – Construct Levee Section 2 and reroute stormwater under HWY 169

Phase 5 – Design and acquisition of Phase 6

Phase 6 – Construct Levee Section 4, Valley Green bypass, and Section 4 internal drainage

Phase 1 will consist of a final design of the internal drainage system and modifications that will bring the new levees into compliance with FEMA regulations. In this phase, permitting will also begin with FEMA for a Conditional Letter of Map Revision to get the conditional approval for the floodplain limits after the construction of the levees is completed. It is recommended acquisition of property for Phase 2 areas (levee segment 1 footprint) be completed during this phase to enable Phase 2 construction immediately upon receipt of funding.

Phase 2 will involve construction of levee section 1, which should be constructed before Levee Sections 2 and 3. This levee's internal drainage will drain naturally to the north and does not require any internal drainage alterations beyond some drainage immediately behind the levee that can be connected to the existing storm sewer. This levee is also necessary to prevent the water from flowing behind Levee Section 2. It is recommended acquisition of property for Phase 3 areas (levee segment 3 footprint and internal drainage land needs) be completed during this phase to enable Phase 3 construction immediately upon receipt of funding.

Phase 3 requires that the new internal drainage pond be constructed and protected from flooding before Section 2 is completed. Without Section 3, stormwater will become trapped behind Sections 1 and 2 and may cause localized urban flooding.

Phase 4 consists of constructing Levee Section 2 and completing Letter of Map Revision for FEMA. This levee is the last to be constructed since it requires the upstream protection of Section 1 and the downstream basins in Section 3 before it could meet FEMA regulations. Once all sections are completed final plans will be submitted to paperwork to apply for a Letter of Map Revision which would formally remove the properties in the City of Jordan from the Zone AE floodplain.

Phases 1 through 4 described above do not necessarily need to be completed individually. If funding is available multiple phases may progress simultaneously. Phases 1 through 4 can also be completed independent of Phases 5 and 6.

Phase 5 involves design and acquisition of land for Phase 6. Phase 6 involves re-routing of flow around the Valley Green mobile home park, construction of levee segment 4 between Valley Green and Sand Creek, and construction of internal drainage systems behind levee segment 4.

Estimated costs per phase are as follows:

Table 16 Phase Construction Cost Estimate

Phase Construction Cost Estimate						
Item	**Estimated Cost**					
	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**	**Phase 6**
Levee Design	$246,600					
Internal Drainage Design	$123,000					
Construct Levee Section 1		$1,056,400				
Property Acquisition Levee Section 1	$1,755,000					
Construct Levee Section 2				$505,600		
Property Acquisition Levee Section 2				$0		
Construct Levee Section 3			$654,400			
Property Acquisition Levee Section 3		$213,000				
Section 3 Internal Drainage Construction			$756,600			
Section 2 Internal Drainage Construction				$349,000		
Valley Green Levee/Ditch/Internal Drainage Design					$414,600	
Valley Green Levee/Ditch/Internal Drainage Construction						$3,732,400
Valley Green Property Acquisition					$429,000	
Subtotal	**$2,124,600**	**$ 1,269,400**	**$ 1,411,000**	**$ 854,600**	**$ 843,600**	**$ 3,732,400**
Total Cost	**$5,659,600**				**$4,576,000**	

Appendix G shows the proposed phasing diagram.

XIII. Future Project Recommendations

During this study period, two additional projects have been identified as possible future considerations for the City of Jordan. Both projects fell outside of the original scope for this report but are recommended future projects for the City to consider.

A. Valley Green Levee

The Valley Green mobile home park has been subjected to several flooding events in the past decade. The cause of the flooding has been both an internal drainage issue with the culverts blocking and backing water up into the park and due to high water levels in Sand Creek..

If levees 1-3 are fully constructed, it will leave approximately 63 mobile homes within the predicted 100yr floodplain as seen below in Exhibit 15.

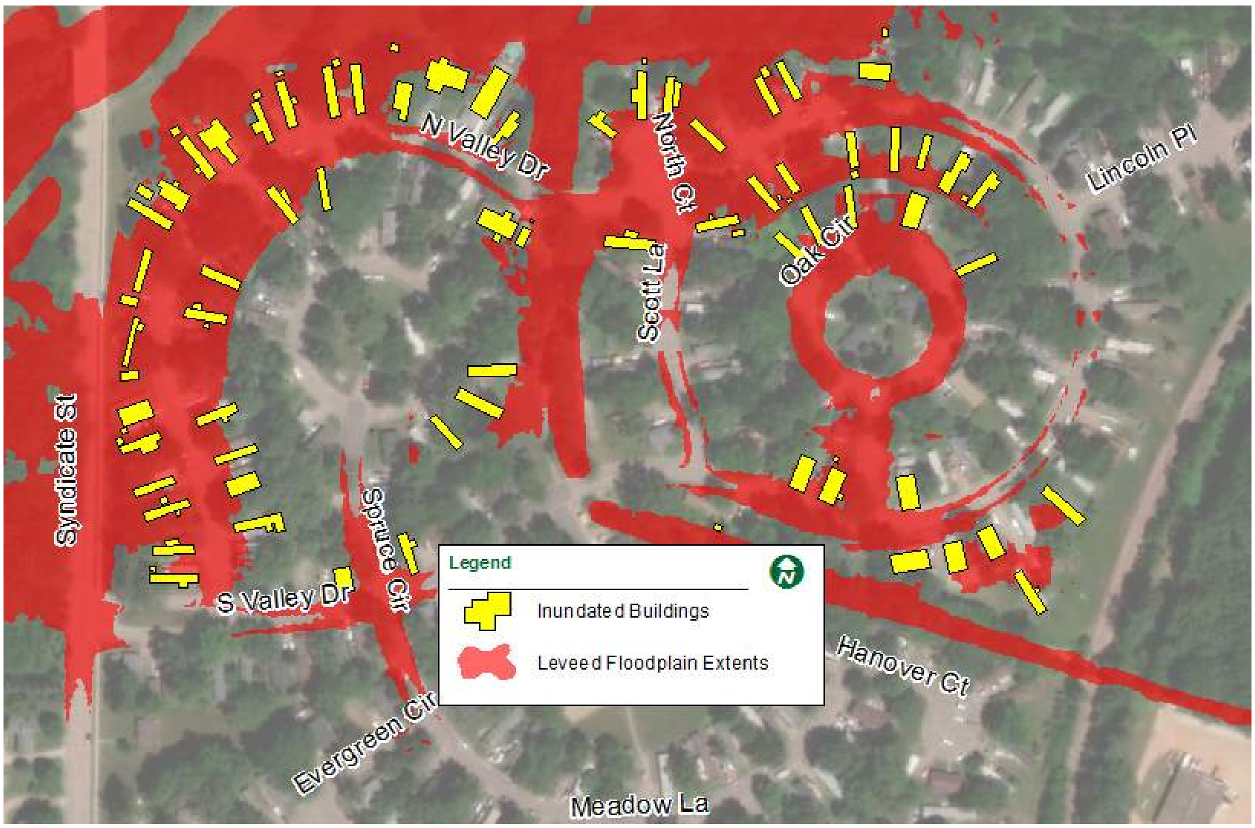


Exhibit 15 Valley Green Inundation Map

A large drainage ditch that flows through the middle of the park is a major design hurdle for this section of levee. This ditch is expected to carry a peak discharge rate of approximately 780cfs during the 100-year flood with a total discharge volume of 473 ac-ft of water. To meet FEMA requirements this discharge would have to be either stored behind a levee, pumped over the levee, or routed around the levee and outside of the mobile home park.

Further, the area between the City and Sand Creek for levee sections 1, 2, and 3 are largely clear of trees and are easily accessible. The area between Valley Green and Sand Creek is heavily wooded and not easily accessible. Any construction along this section will require a large amount of clearing and grubbing since it is a FEMA requirement that the levee and a 25' wide buffer on both sides of the levee be cleared of any woody plants.

Due to recent flood damages however, it was decided that this section of the City should be included in the study to determine the feasibility of future design and construction of a FEMA certified levee. Below is a brief analysis of preliminary design options and estimated costs for the Valley Green levee.

1. Levee Design and Location

The proposed Valley Green levee is located near the downstream end of the drainage ditch along the current FEMA mapped floodway line. The levee is designed using the same typical cross-section used in Levee section 1, 2, and 3 and can be seen in Exhibit 7. The levee ties into the downstream embankment of the Syndicate St. bridge and will wrap along the river bank until it ties into the natural existing high ground on the east side of Valley Green Park. The grading extents and alignment of the proposed levee can be seen below in Exhibit 16

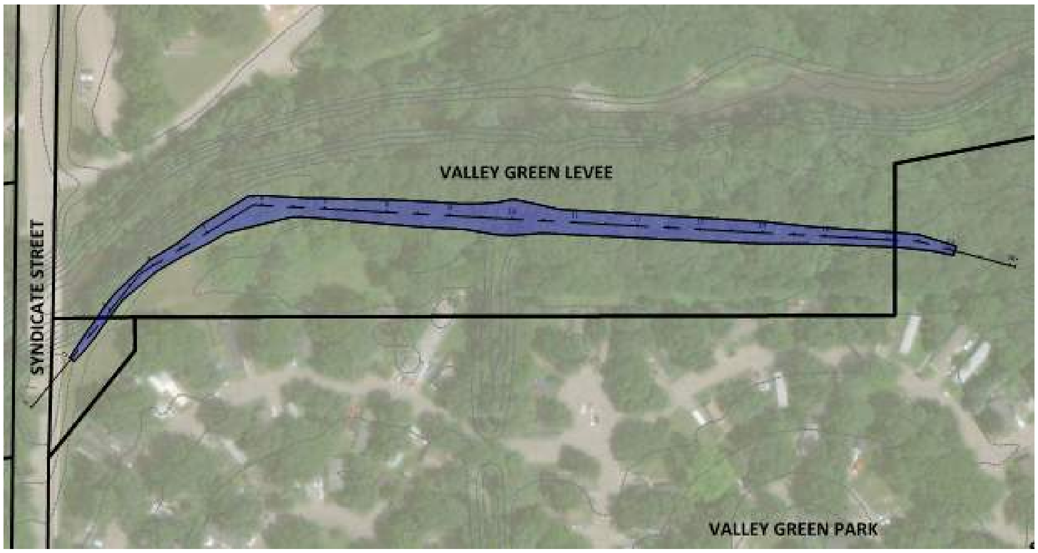


Exhibit 16 Valley Green Levee Alignment

Approximately 1.5 ac of woods will be cleared and grubbed to make room for the levee's clay embankments. The existing ditch channel will be filled and stormwater will be transported by a 24" RCP pipe with a backflow preventer. Details on the outlet of the existing ditch will be detailed in a following section.

The estimated cost for constructing the Valley Green Levee can be seen in Table 17 below.

Table 17 Valley Green Levee Cost

Levee Construction Cost Estimate				
Item	Unit	Cost	Quantity	Cost
Common Excavation	CY	$ 15	5800	$ 87,000
Clearing & Grubbing	AC	$ 8,000	1.50	$ 12,000
Clay Fill	CY	$ 75	4700	$ 352,500
Gravel Fill	CY	$ 24	800	$ 19,200
Common Borrow	CY	$ 10	5300	$ 53,000
6" Perforated Pipe	LF	$ 10	2000	$ 20,000
Seeding	AC	$ 950	1.5	$ 1,425
Est. Land Acquisition	LS	$ 2,310	1	$ 2,310
Subtotal				$ 547,000
Engineering & Legal Costs				$ 109,000
Contingency				$ 164,000
Estimated Total Cost				**$ 820,000**

If constructed, the Valley Green levee and associated ditch bypass and internal drainage improvements would remove the entire Valley Green Park from the FEMA mapped floodplain. The area removed by the proposed levee can be seen in Exhibit 17.

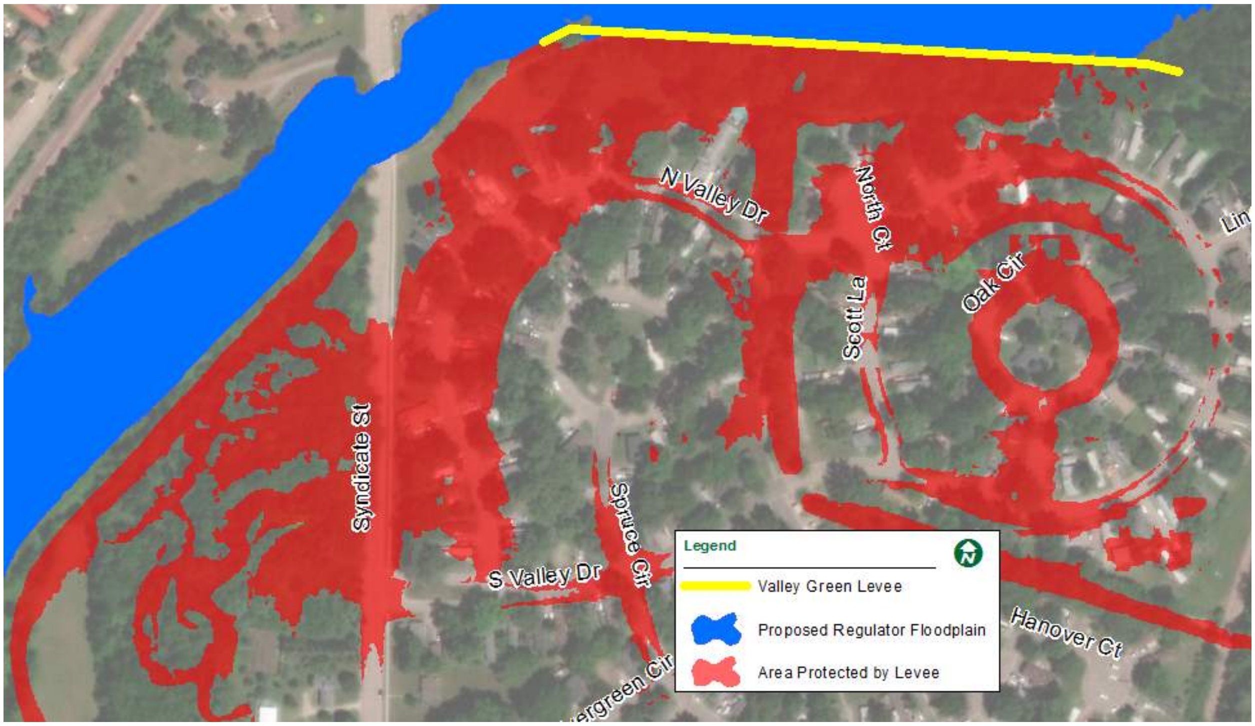


Exhibit 17 Proposed Floodplain at Valley Green Park

2. Ditch Bypass Route

The existing ditch drainage through the Valley Green Park area is a primary concern in the levee design. The current ditch carries around 780cfs during the 100yr design storm with an estimated total stormwater volume of nearly 475ac-ft of water. Unlike the internal drainage of levees 1, 2, and 3 this volume cannot be handled behind the levees. It is proposed that the existing ditch be routed east around the levee where it can gravity drain directly into Sand creek. Two options were considered as potential routes and can be seen in Exhibit 18 below.

Option 1 connects upstream of the current railroad crossing and carries the water east along the tracks. This route minimizes the impact to adjacent properties but will require that a new rail crossing be constructed. The proposed channel is trapezoidal with a 10ft bottom width, 3:1 side slopes and at least 5ft deep. The channel would be constructed at approximately a 1% longitudinal slope. To prevent flooding upstream of the railroad, three 5’x8’ box culverts would be installed under the tracks to convey the 100yr design under the tracks.

Option 2 picks up the existing channel downstream of the railroad tracks. In option 1, the railroad embankment would act as a barrier to prevent any potential overtopping of the channel from flowing down into Valley Green Park. Since option 2 does not have this benefit, a 3ft tall trapezoidal clay embankment is added to the interior side of the channel to prevent water from leaving the channel and flowing behind the levee.

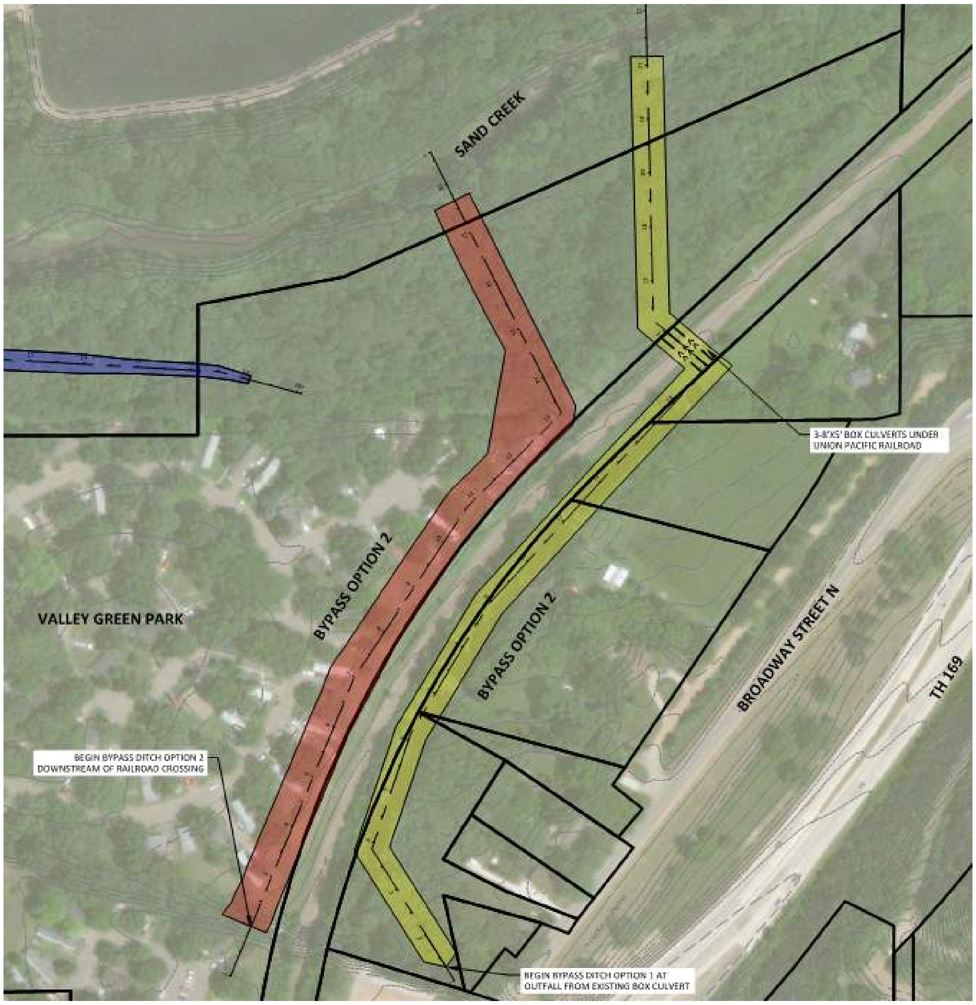


Exhibit 18 Ditch Bypass Alignments

Route 2 uses the same channel geometry as route 1 but is constructed at approximately 0.7% slope leading to slightly lower velocities in the channel. The lower velocities are still high enough to convey most debris downstream without it settling out in the channel but will also help to reduce the potential erosion of the channel during high flow event. Option 2 does not require any modification to the existing railroad crossing but will require that several power transmission poles be relocated.

A summary of costs for both options can be found below in Table 18 and Table 19.

Table 18 Ditch Option 1

Option 1 Ditch Construction Cost Estimate				
Item	Unit	Cost per Unit	Quantity	Cost
Common Excavation	CY	$ 15	10000	$ 150,000
Clearing & Grubbing	AC	$ 8,000	3	$ 24,000
Seeding	AC	$ 950	3	$ 2,850
8'x5' Box Culvert	LF	$ 1,500	300	$ 450,000
Railroad Coordination and Permitting	LS	$ 150,000	1	$ 150,000
Est. Land Acquisition	LS	$ 78,100	1	$ 78,100
Subtotal				$ 855,000
Engineering & Legal Costs				$ 171,000
Contingency				$ 257,000
Estimated Total Cost				**$1,283,000**

Table 19 Ditch Option 2

Option 2 Ditch Construction Cost Estimate				
Item	Unit	Cost per Unit	Quantity	Cost
Common Excavation	CY	$ 15	7100	$ 106,500
Clearing & Grubbing	AC	$ 8,000	1	$ 8,000
Seeding	AC	$ 950	3	$ 2,850
Transmission Pole Relocation	EA	$ 50,000	3	$ 150,000
Est. Land Acquisition	LS	$ 266,250	1	$ 266,250
Subtotal				$ 534,000
Engineering & Legal Costs				$ 107,000
Contingency				$ 160,000
Estimated Total Cost				**$ 801,000**

The MN DNR regulates the alteration of any existing stormwater that outlets to a public water. Either option will likely require a permit from the MN DNR to create an outlet below the OHWL of Sand Creek. The preliminary design relies on the water in the stream to act as the energy dissipater for the channel outlet. If required, an energy dissipater such as a SAF stilling basin or a riprap pool may be required for additional energy dissipation.

3. Interior Drainage

Rerouting the channel from upstream of Valley Green bypasses a large a portion of the stormwater that was conveyed by the existing ditch in the Valley Green Park. The existing ditch will remain in place after levee construction to convey the stormwater that falls between the proposed bypass and the proposed levee. Analogous to the internal drainage analysis for levee section 1, 2, and 3 the internal stormwater from the remaining 63ac behind the proposed levee must either be stored or pumped over the levee in such a way that we do not increase flooding for the 10 and 100-year storm events.

When Sand Creek is at normal water levels, the stormwater runoff originating within the park will still need to be conveyed through the ditch much as it does now. The only change will occur at the levee where a single 24” RCP culvert will convey the flow under the levee and into Sand Creek. This culvert will be fitted with a backflow preventer to prevent flood water from Sand Creek from backing up into the ditch during flooding conditions

When water in Sand Creek is too high and cannot be conveyed through the culvert, a 10,000gpm pump will be required to lift the water up and over the levee into Sand Creek. The existing ditches immediately upstream of the levee will be widened to increase storage capacity for large storm events and to prevent water from overflowing into the park as it does in the existing conditions. The widened ditch will be approximately 10ft deep with 5:1 side slopes for easier maintenance. The bottom half of the ditch will be clay lined to prevent groundwater from filling the ditches. Several mobile homes will have to be relocated to provide room for the proposed ditch widening and lift station. A preliminary sketch of the impacted areas can be seen in Exhibit 19.

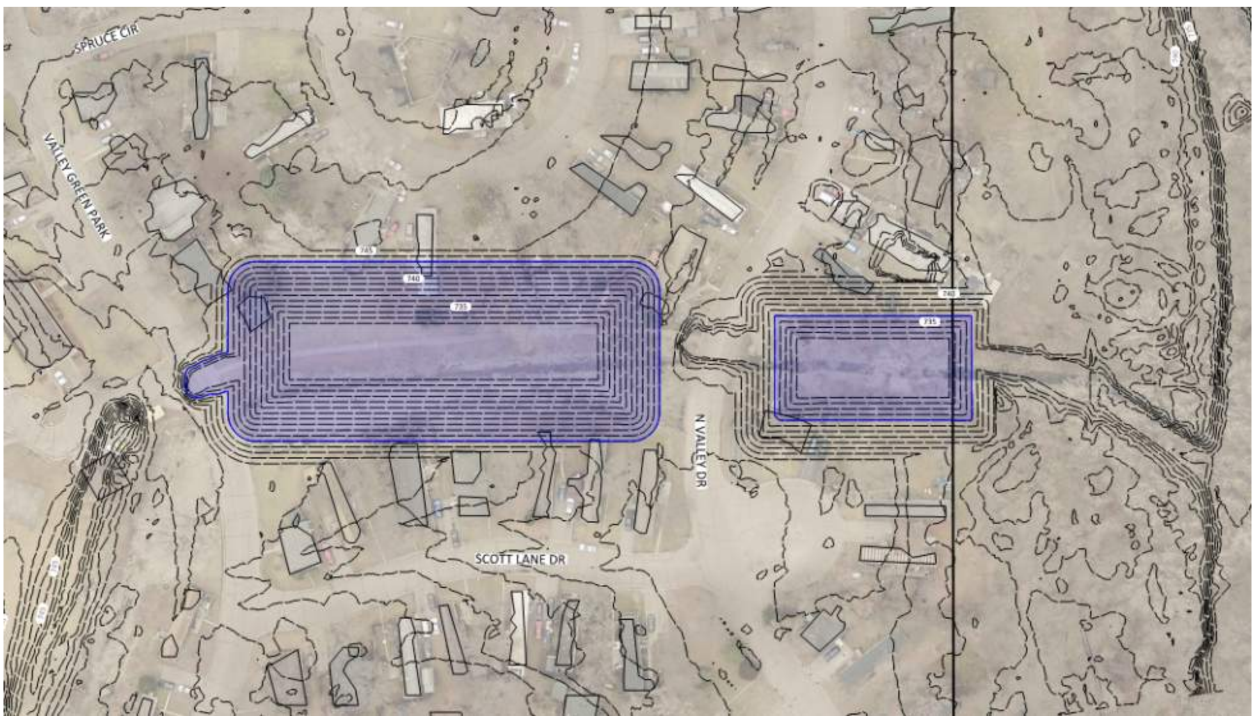


Exhibit 19 Altered Ditch Section

The estimated cost of the internal drainage system is summarized below in Table 20. The cost of the internal drainage makes up a large proportion of the infrastructure costs to protect Valley Green as it exists today. Unfortunately, unlike with levee sections 1,2, and 3, there are no unoccupied areas behind the Valley Green levee large enough to offset the need for large pumps.

Table 20 Valley Green Internal Drainage Cost Estimate

VG Internal Drainage Construction Cost Estimate				
Item	Unit	Cost per Unit	Quantity	Total Cost
Total ex	CY	$ 10	15218	$ 152,180
Clay Liner	CY	$ 75	280	$ 21,000
Lift Station	EA	$ 1,880,000	1	$ 1,880,000
24" RCP	LF	$ 40	320	$ 12,800
24" FES	EA	$ 800	1	$ 800
Backflow Preventer	EA	$ 465	1	$ 465
SEEDING	AC	$ 950	0.35	$ 329
Land Acquisition	LS	$ 160,000	1	$ 160,000
Subtotal				$ 2,228,000
Engineering & Legal Costs				$ 446,000
Contingency				$ 668,000
Estimated Total Cost				**$ 3,342,000**

4. Summary of Flood Protection Costs: Valley Green Area

If flood protection measures are desired to protect Valley Green as it exists today, it is recommended that if the City pursue adding a levee, internal drainage improvements as described above and, option 2 ditch bypass. This option impacts more properties but avoids the costly railroad crossing. The total construction cost summary for this option can be seen below in Table 21. A figure of the proposed levee and the alignment of the bypass options can be found in Appendix F.

Table 21 Summary Cost - Valley Green Levee

Summary of Valley Green Levee Cost	
	Est. Cost
Internal Drainage	$2,228,000
Ditch Bypass	$534,000
Certified Levee Construction	$547,000
Subtotal	**$3,309,000**
Engineering & Legal Costs	$662,000
Contingency	$993,000
Total Estimated Cost of Construction	**$4,964,000**

Given the high cost of this levee, the City may wish to analyze alternative flood mitigation efforts for the residents of Valley Green Park. Other alternatives could include raising the northern portion of the park on fill above the predicted flood elevations or relocating homes that are currently within the mapped floodplain.

B. Ice Jam Analysis

In March of 2019 an ice jam formed in Sand Creek downstream of the Valley Green Park. This ice jam rapidly brought the river levels up near the 100-yr flood elevations near the Park and the waste water treatment facility. The ice jam flooding that occurred is classified as a breakup-type jam[3]. Break-up type jams are frequently associated with rapid increases in runoff and rises in river stage resulting from rainfall and/or snowmelt. Breakup-type jams usually occur in late winter or early spring. Because of the large volumes of ice that may be involved and the higher discharges associated with them, breakup-type ice jams are the most common type of jam to cause flooding.

The preferred approach to ice jam flood modeling is referred to as the direct approach. To use this approach ice jams flooding must be recorded a minimum of 3 times in a 25yr time span where the river conditions have not changed appreciably. The ice jam location, resulting water surface elevations, and discharges should be recorded. The peak water surface elevations are then used to calibrate the normal 100yr flood model to the ice jam events.

Figure 3 Sand Creek and Internal Road Flooding

The alternative approach is referred to as an indirect approach and is applicable in breakup-type ice jams. Under this approach, a discharge frequency analysis would be performed on Sand Creek to calibrate the hydraulic data to record data. Typical ice thicknesses are then calculated and incorporated into the existing hydraulic model and a blockage is manually entered assuming that the channel is between 95-100% blocked. The resulting water surface would then be compared to the normal 100yr floodplain and incorporated into the maps as the new regulatory floodplain.

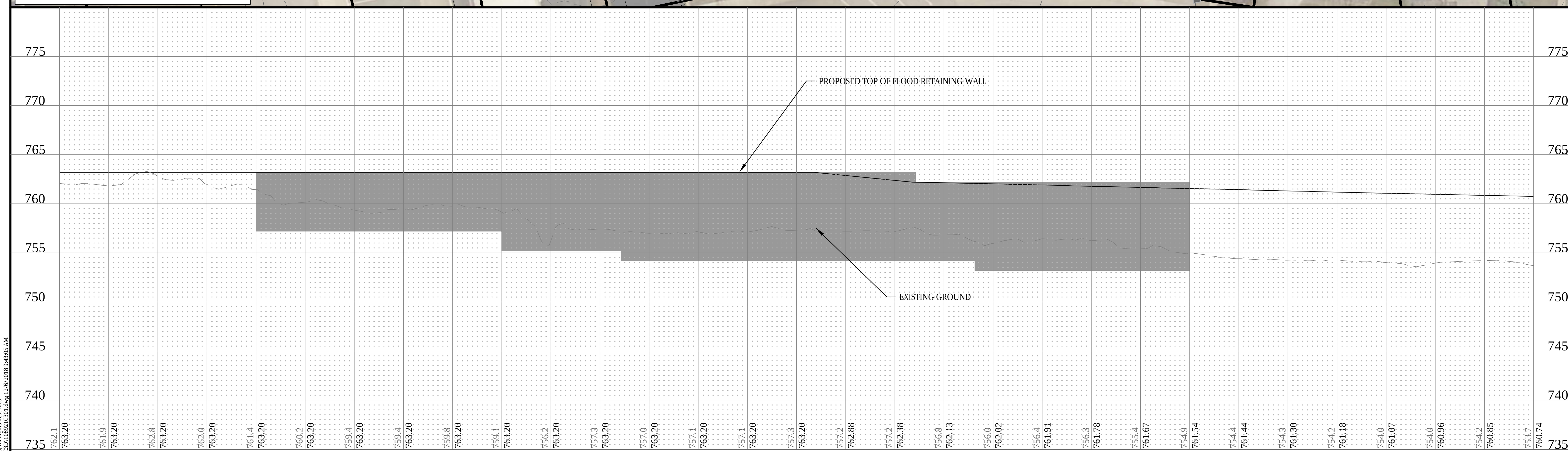
Given the frequency of ice jam flooding around the City of Jordan, the City may consider incorporating this type of study and associated added regulations into their City planning. FEMA grants local floodplain regulators, such as the City the option to regulate their floodplains to a higher standard than what the Federal or State floodplain regulations set as minimum standards. This gives the City the ability to regulate areas outside of the NFIP mapped floodplain to their floodplain development standards without

[3]Federal Emergency Management Agency (2018) Guidance for Flood Risk Analysis and Mapping – Ice Jam Analyses and Mapping, Department of Homeland Security

submitting the mapping to FEMA for incorporation into the NFIP. This would allow the City to enforce new regulations related to ice jams and understand the flood risks in the areas prone to ice jam flooding. This would help mitigate future damages without residents being required to purchase flood insurance. Being outside of the NFIP mapped floodplain also would allow residents within the ice jam zoned areas an opportunity to purchase flood insurance at a reduced rate.

Appendix A: Preliminary Grading Plans

NOTE:
1. EXISTING GROUND TOPOGRAPHIC DATA PER LIDAR RESOURCES. TOPOGRAPHIC SURVEY IS RECOMMENDED PRIOR TO FINAL DESIGN.
2. PARCEL BOUNDARIES PER SCOTT COUNTY GIS DATA. BOUNDARY SURVEY RECOMMENDED PRIOR TO FINAL DESIGN.



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VERT. SCALE 0 5 10 FEET

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CITY OF JORDAN, MINNESOTA

FLOODPLAIN MODELING

PRELIMINARY GRADING PLAN

LEVEE GRADING PLAN AND PROFILE

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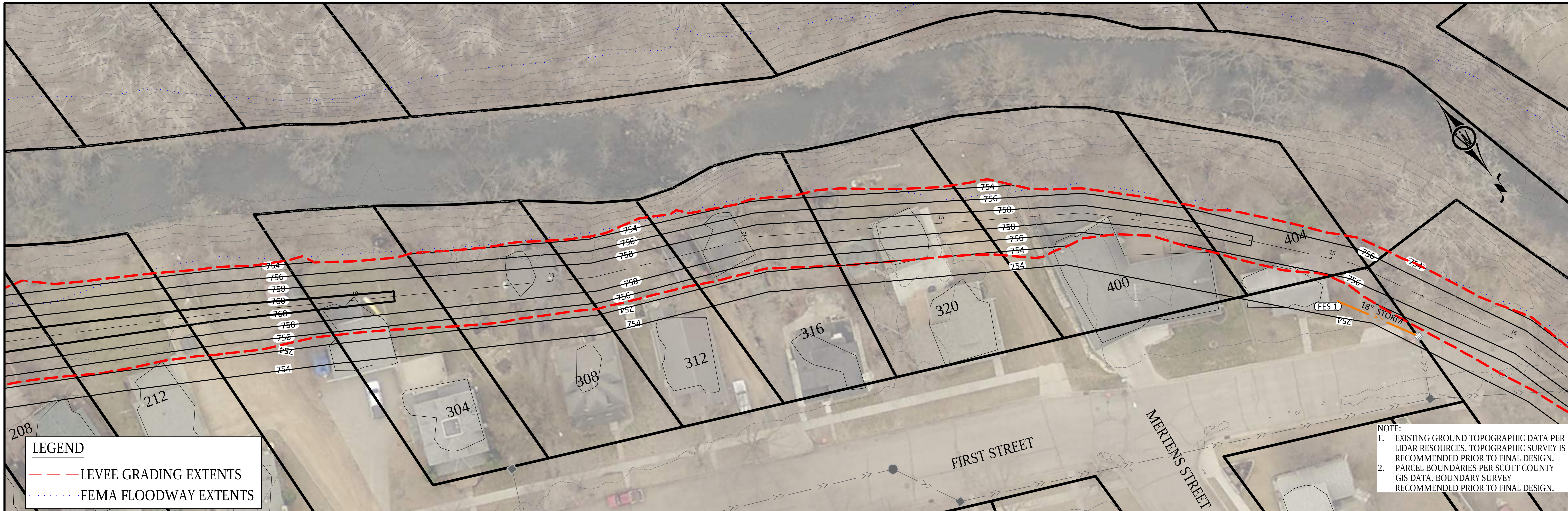

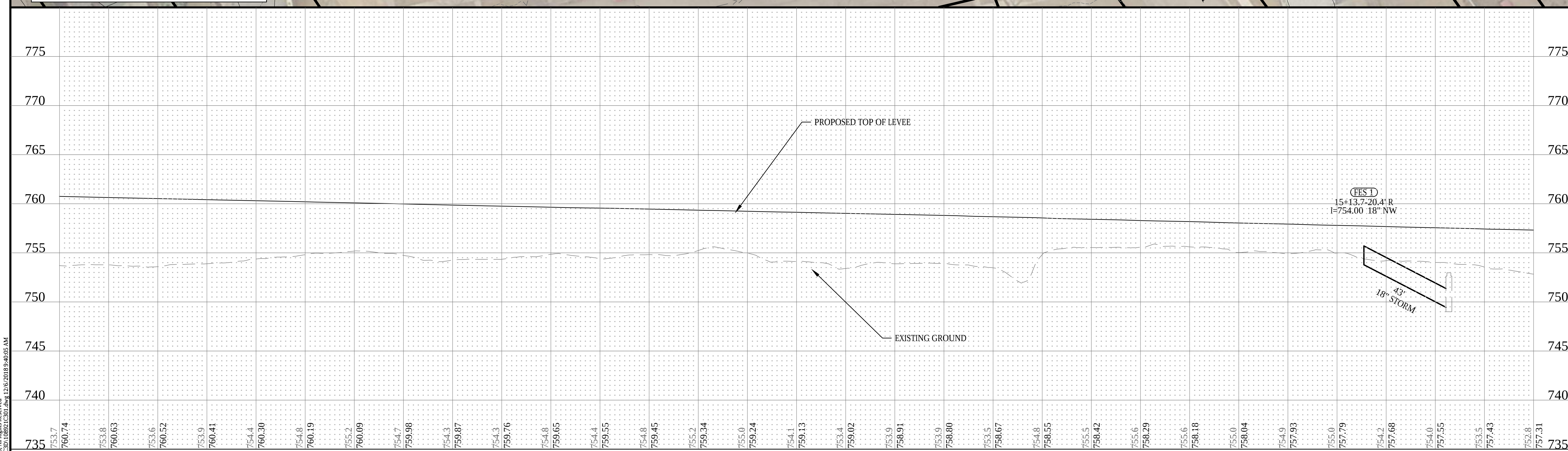

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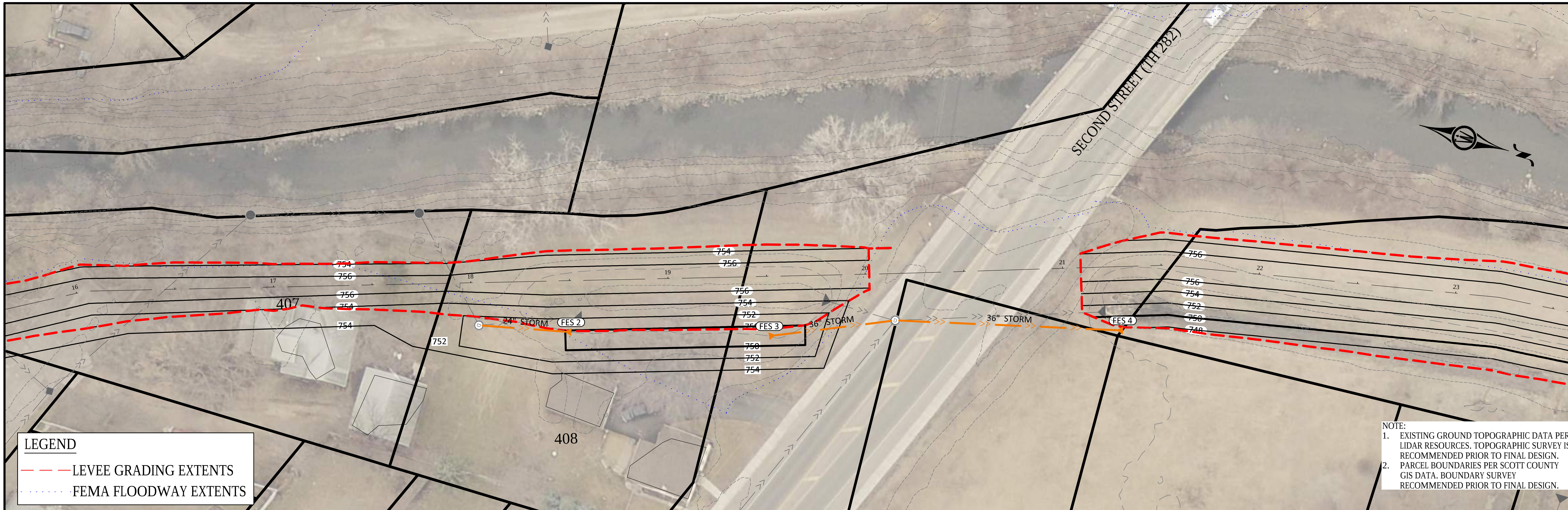

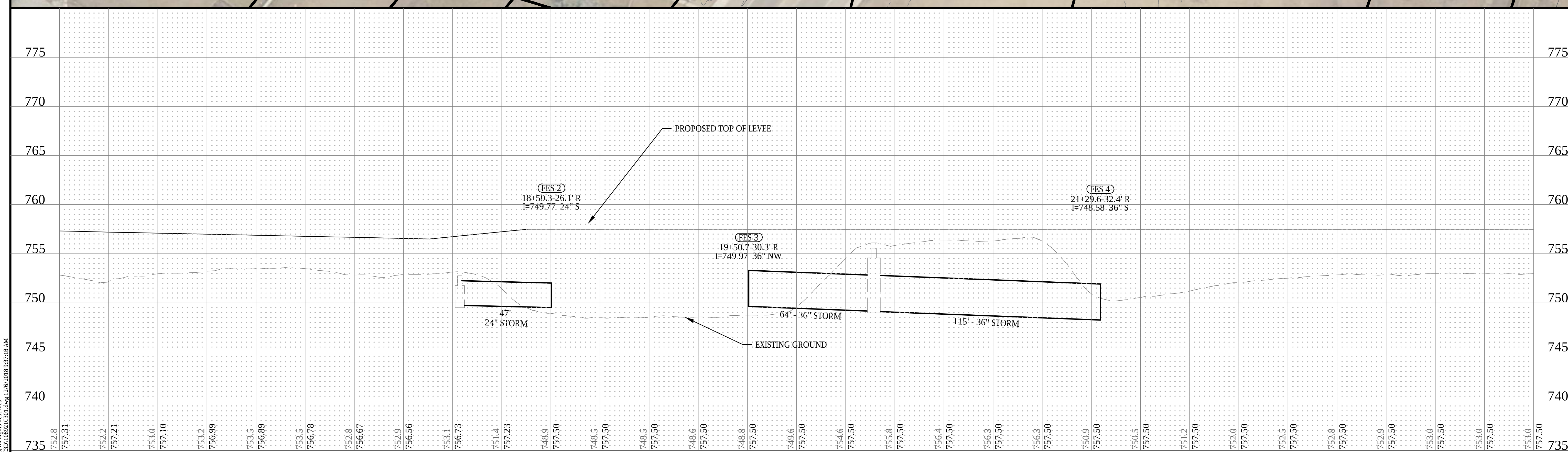

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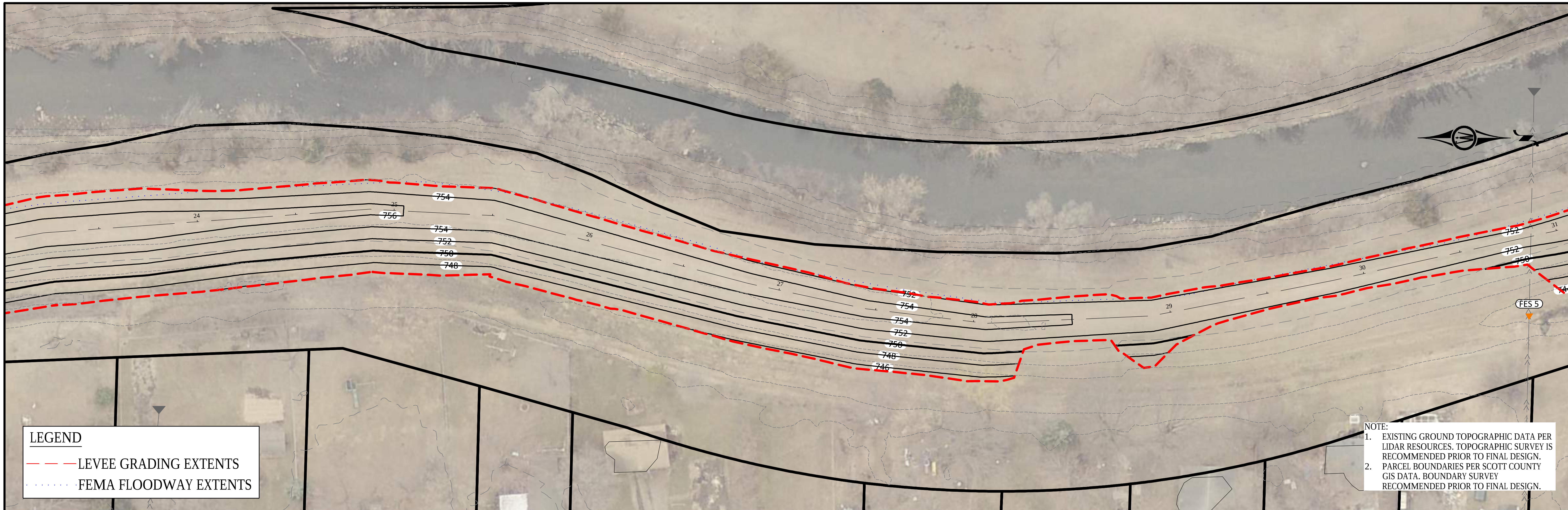

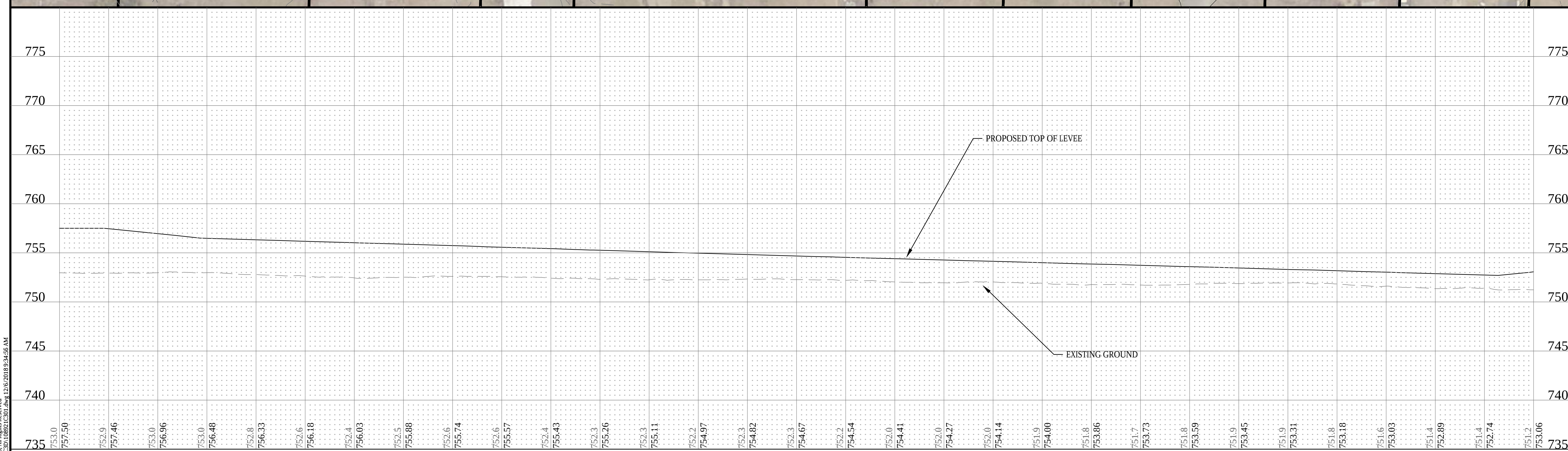

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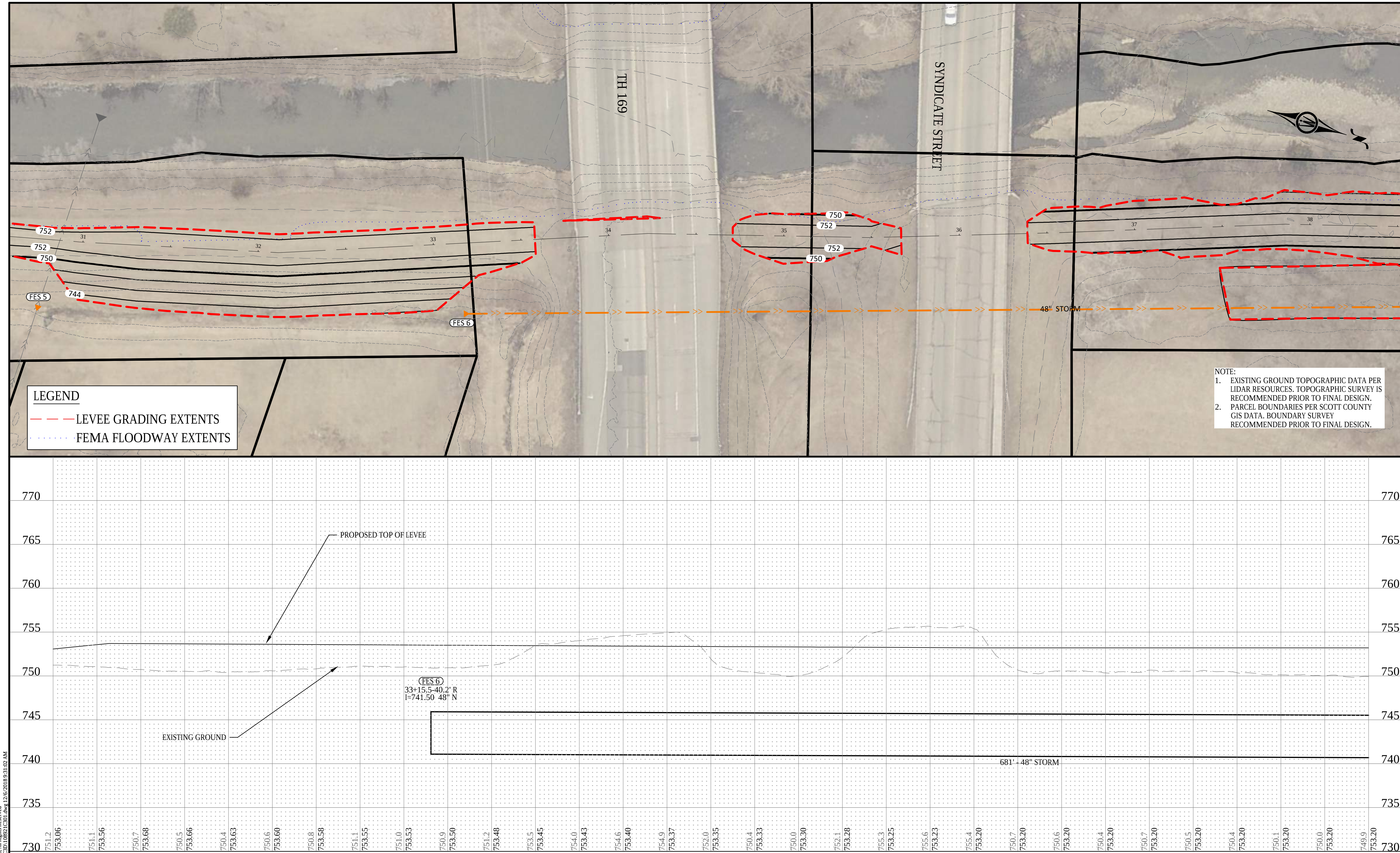

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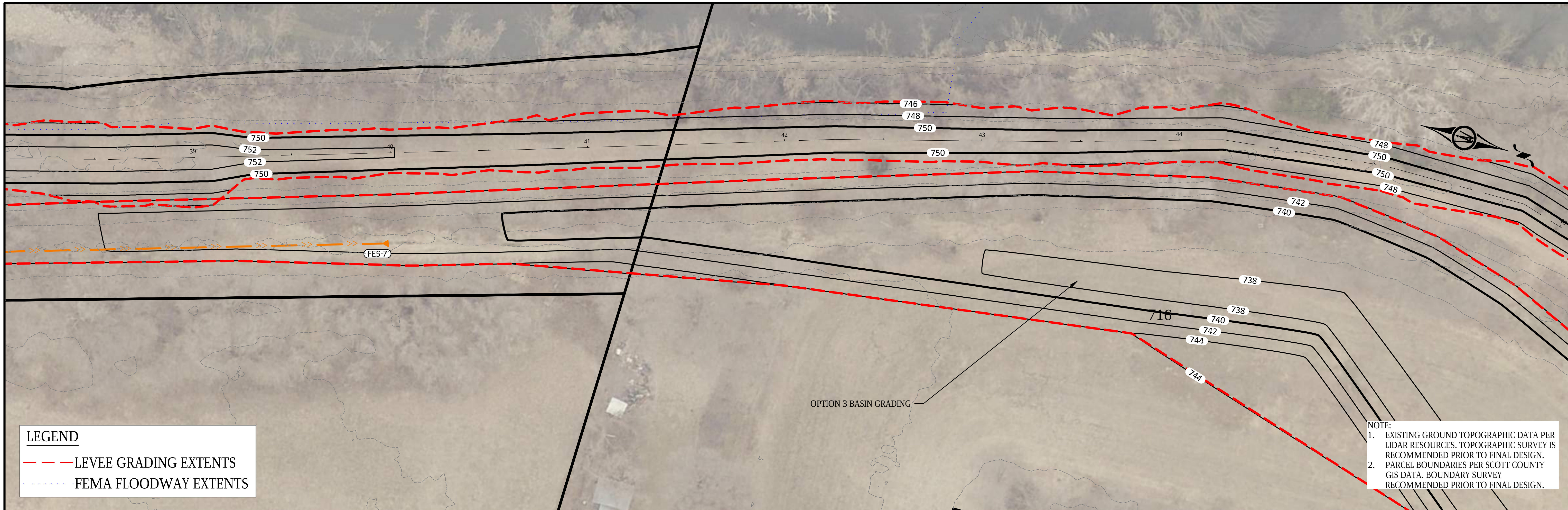

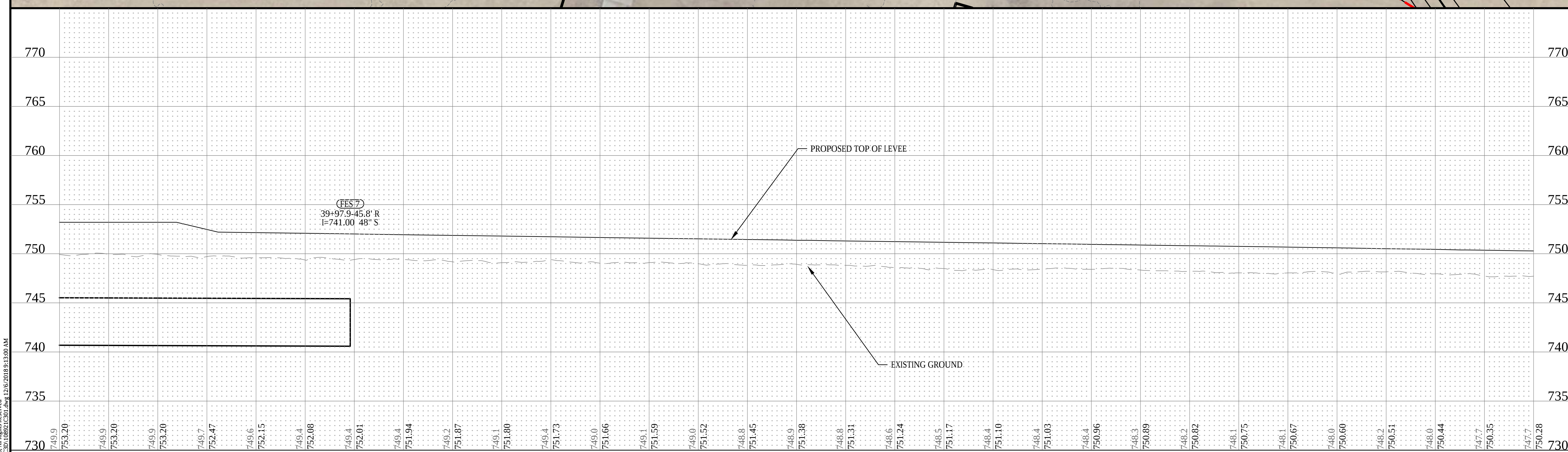

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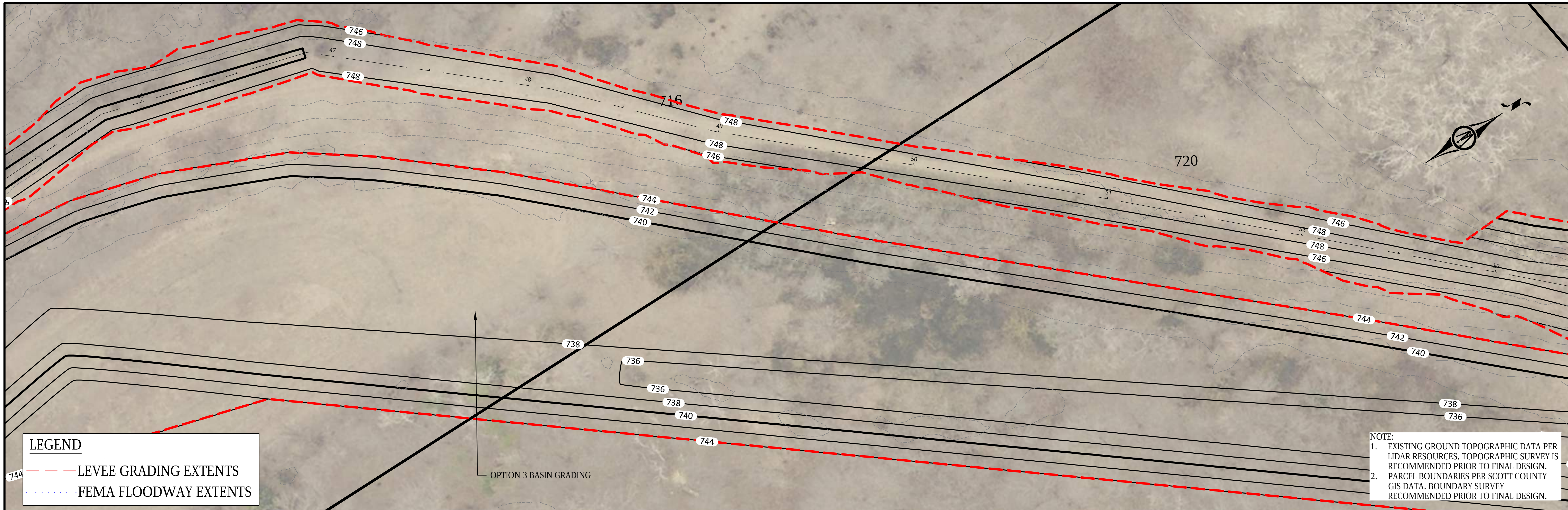

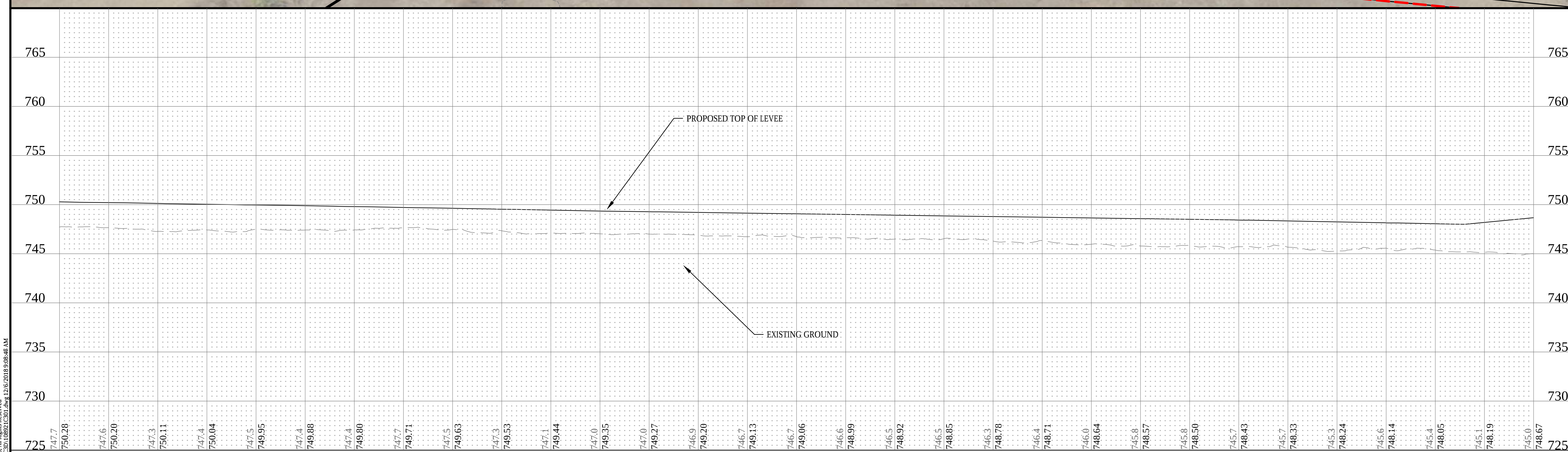

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LEVEE GRADING PLAN AND PROFILE

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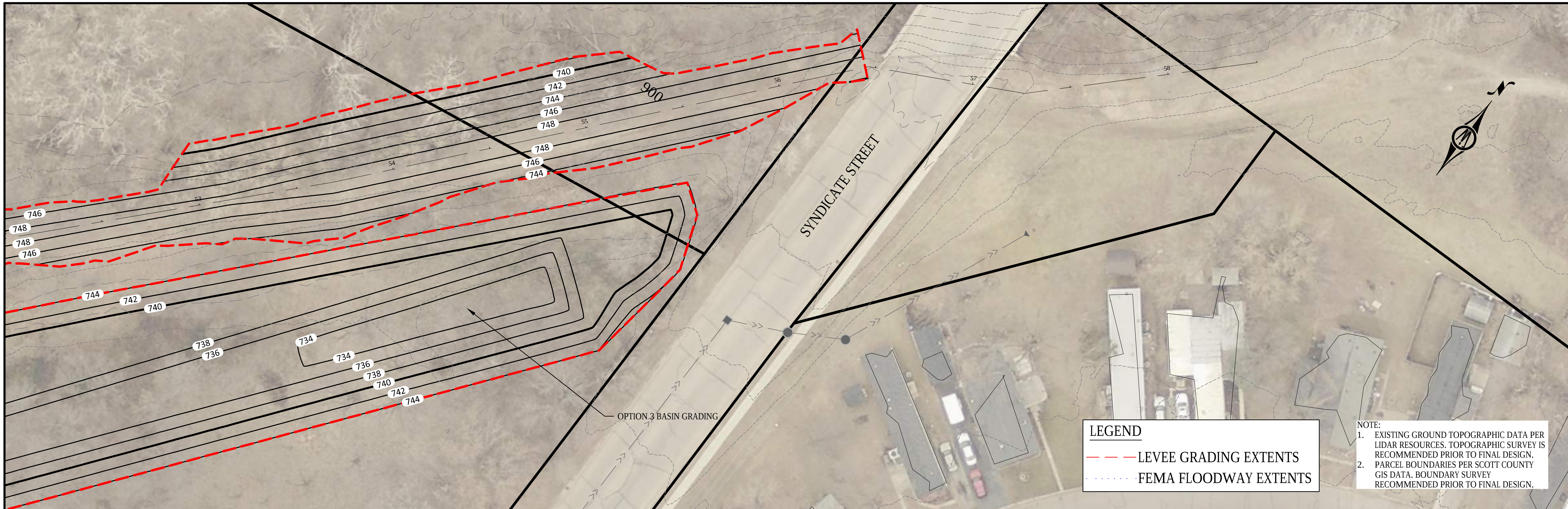

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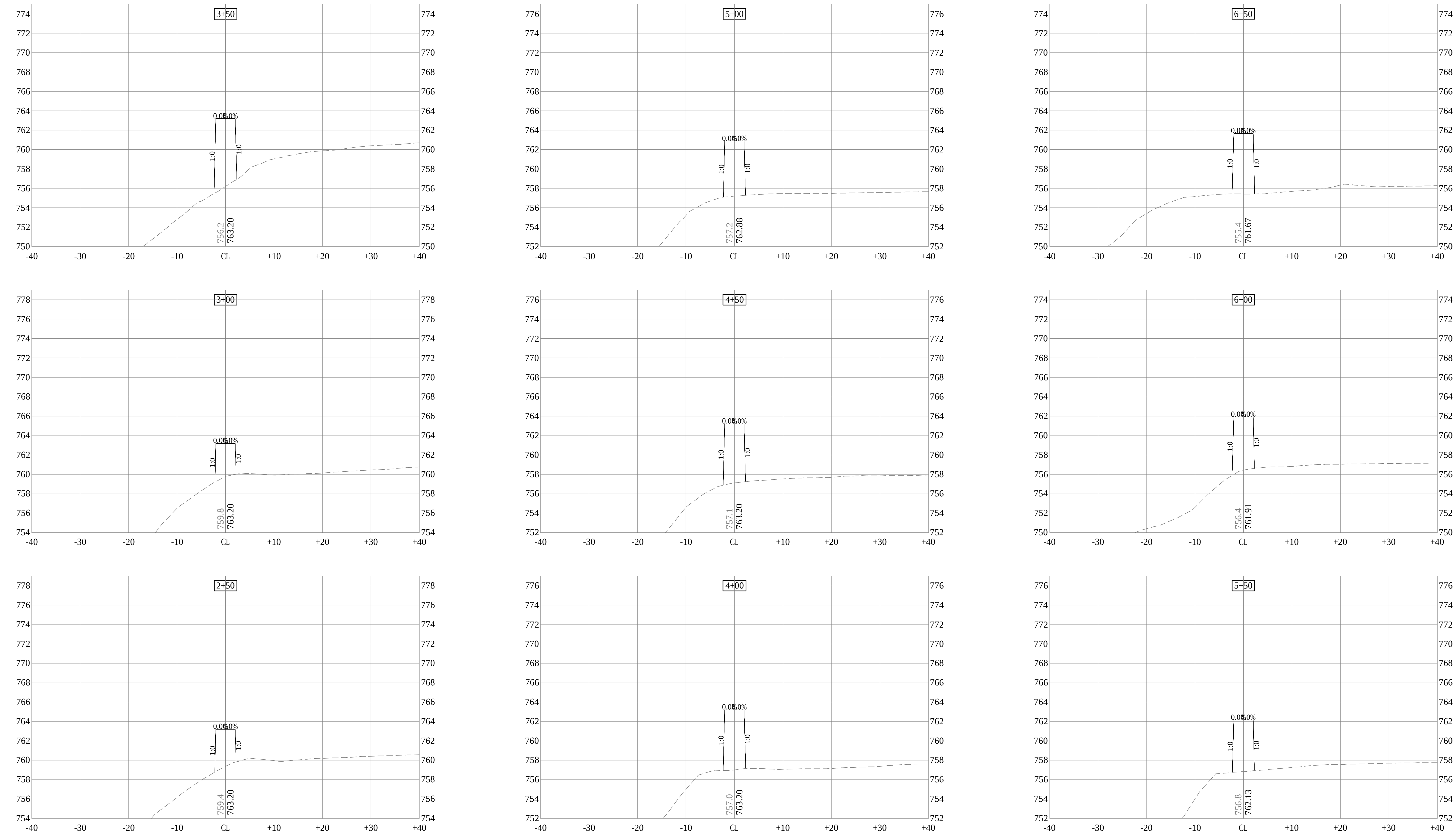

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FLOODPLAIN MODELING

CROSS SECTIONS

LEVEE

SHEET

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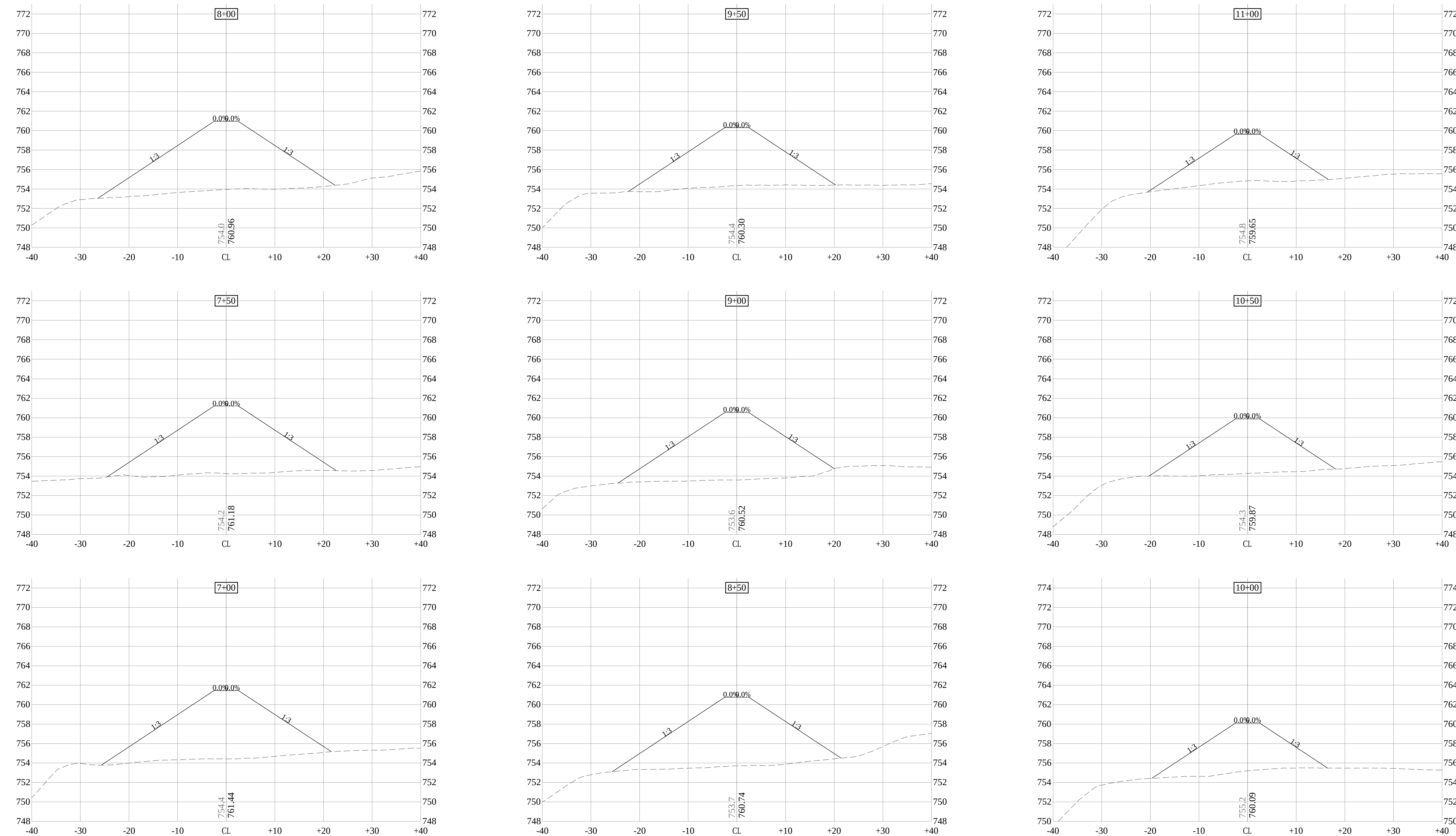

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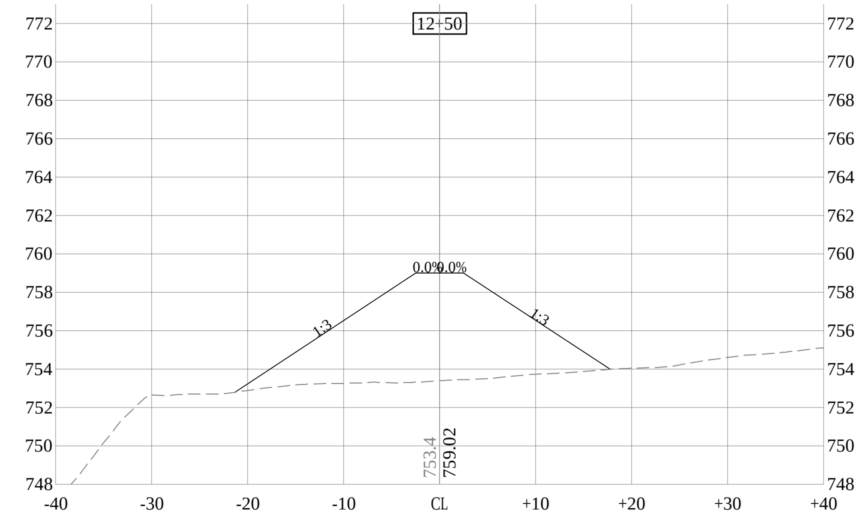
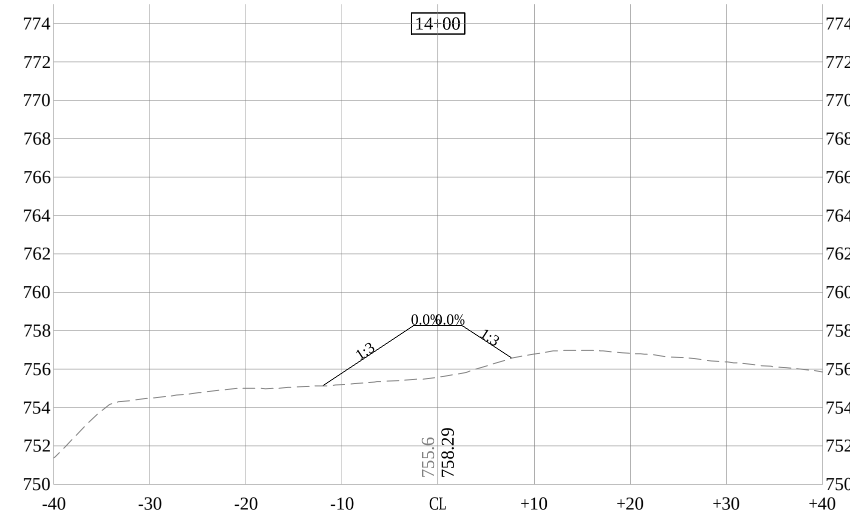
FLOODPLAIN MODELING

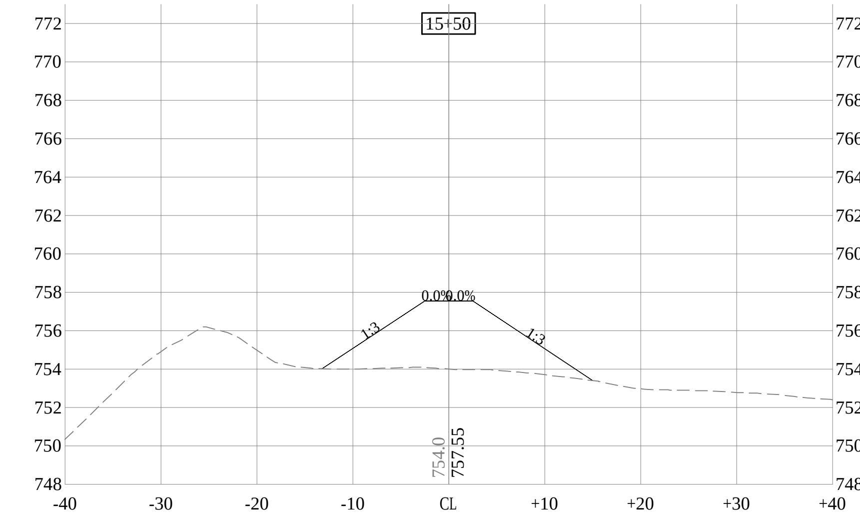
CROSS SECTIONS

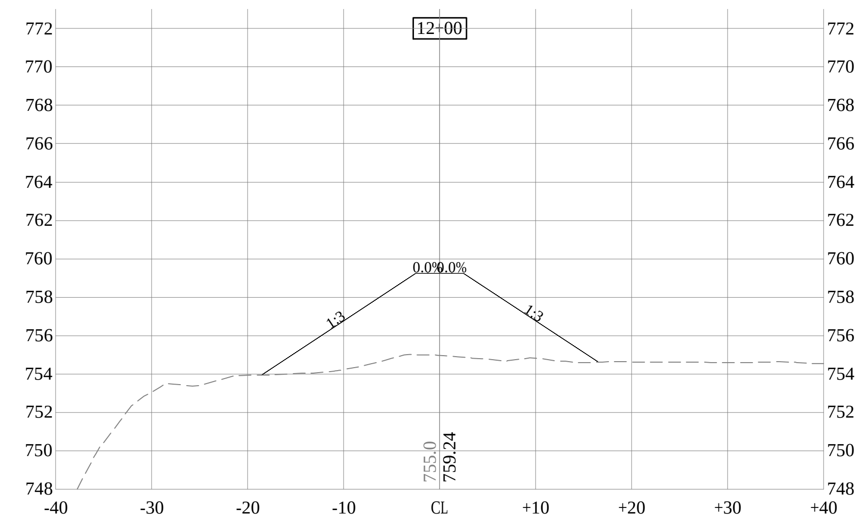
LEVEE

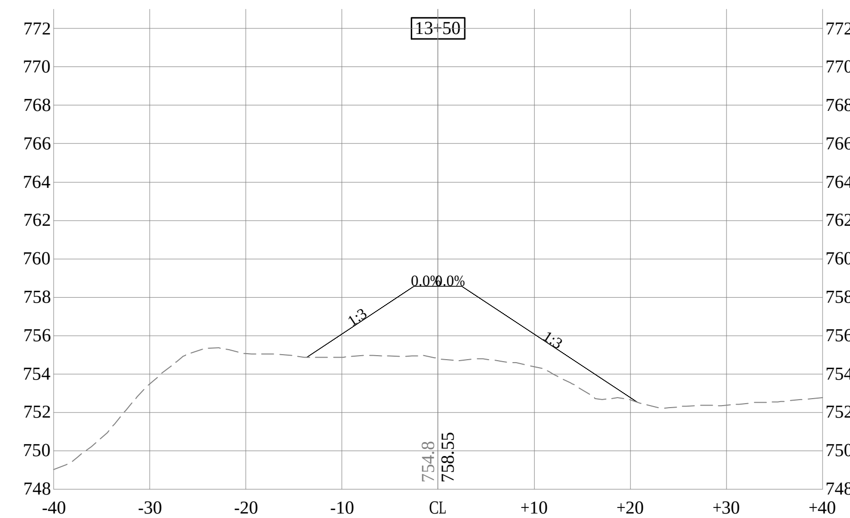
SHEET C9.02

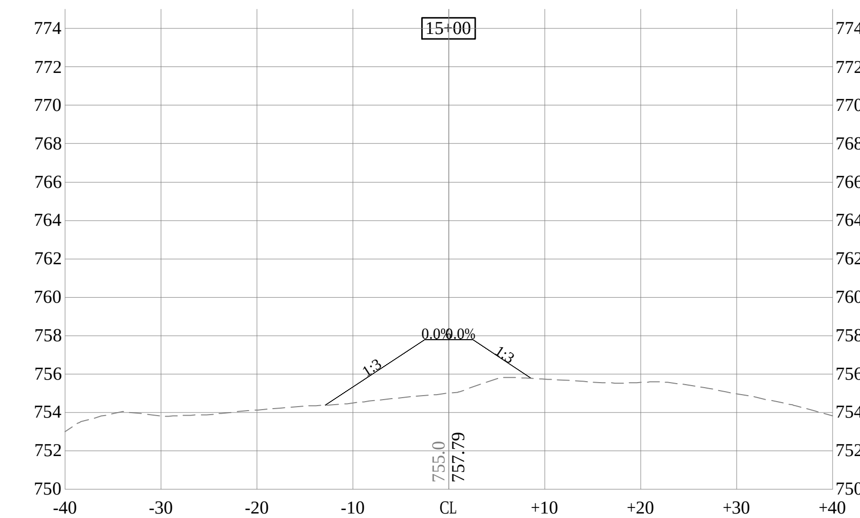


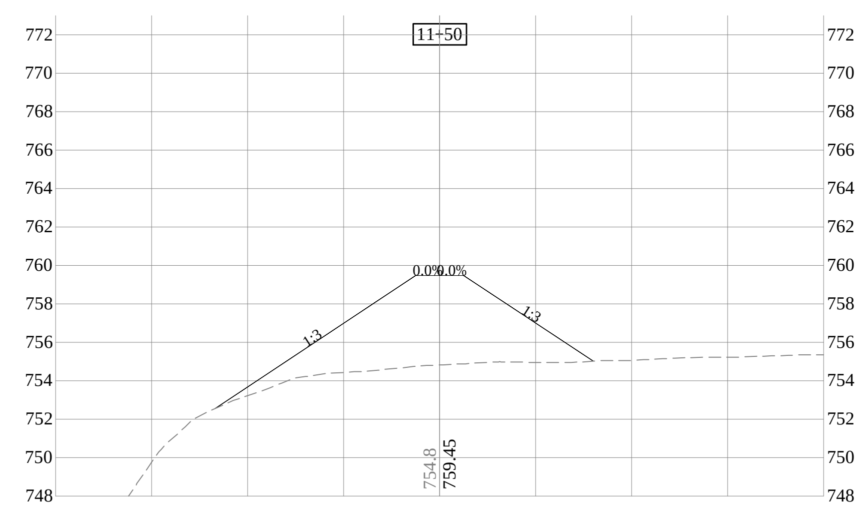


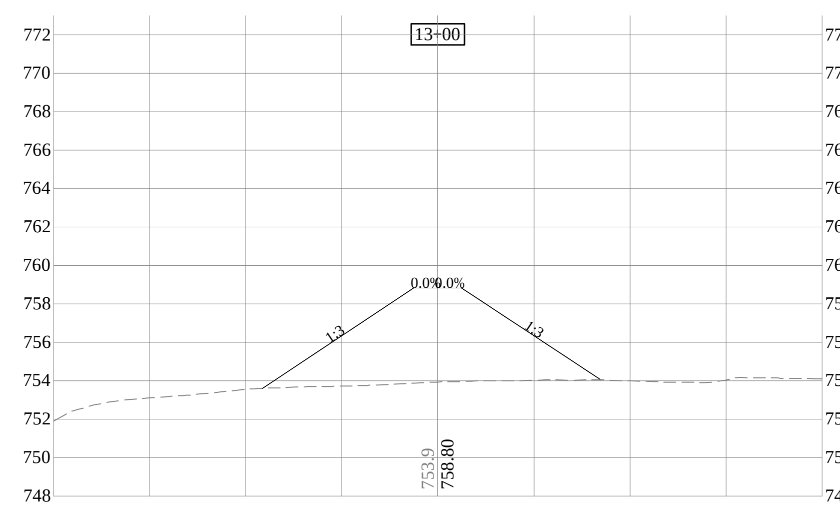


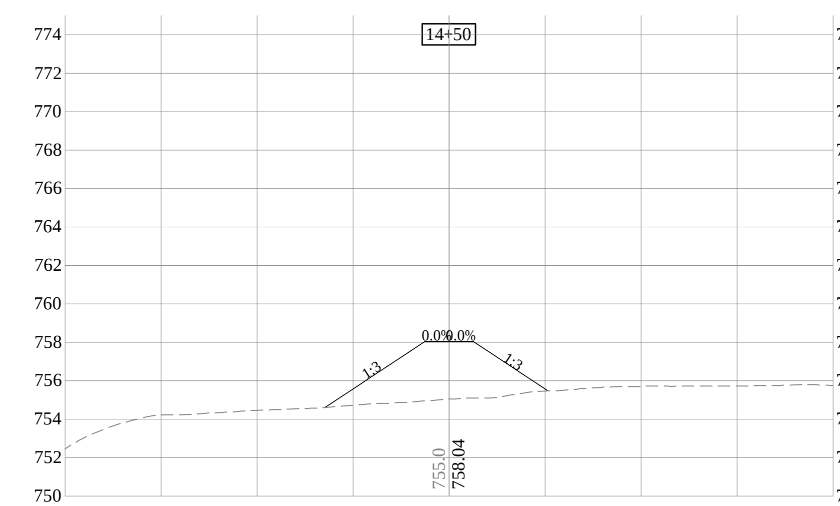












HORZ. SCALE 0 5 10 FEET

VERT. SCALE 0 5 10 FEET

BOLTON & MENK

CITY OF JORDAN

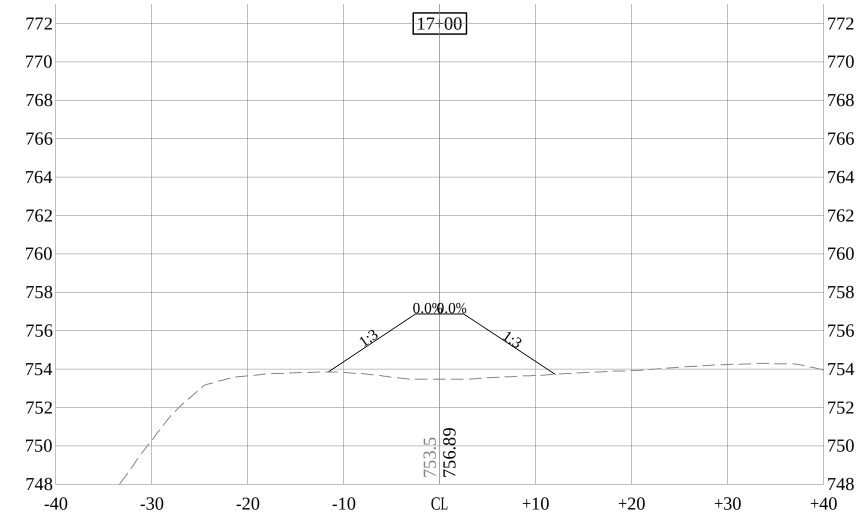
CITY OF JORDAN, MINNESOTA

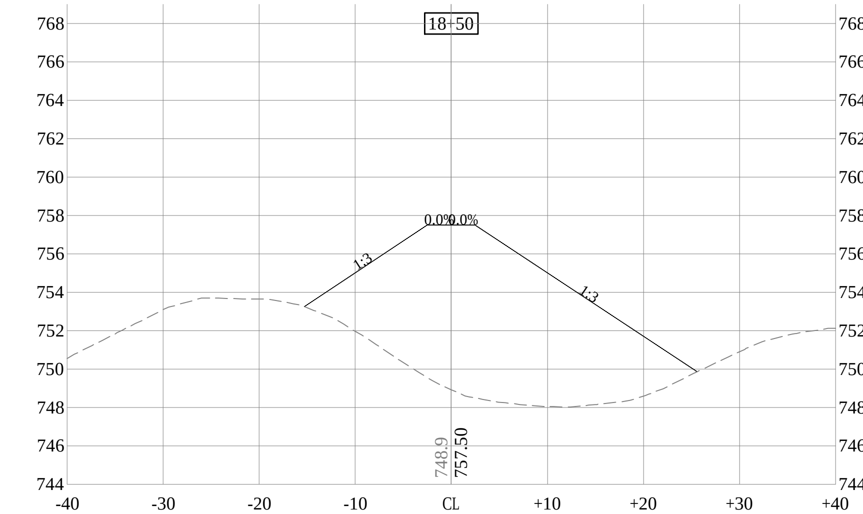
FLOODPLAIN MODELING

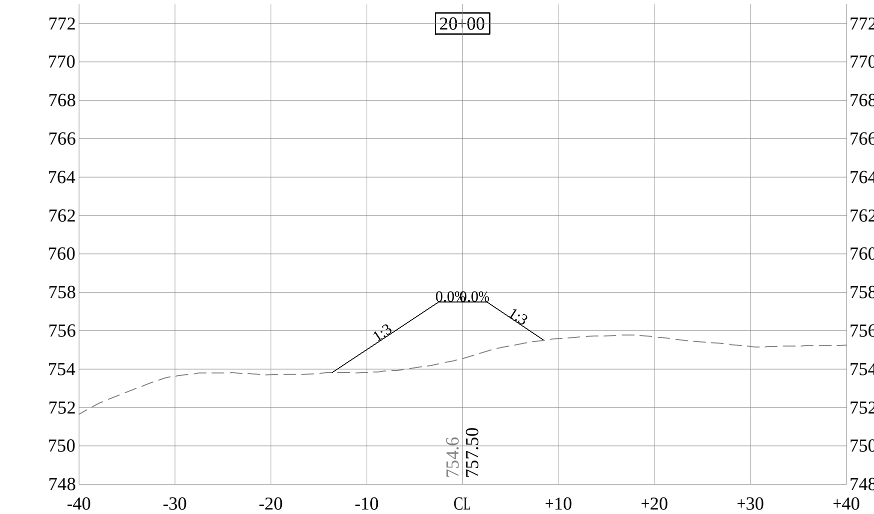
CROSS SECTIONS

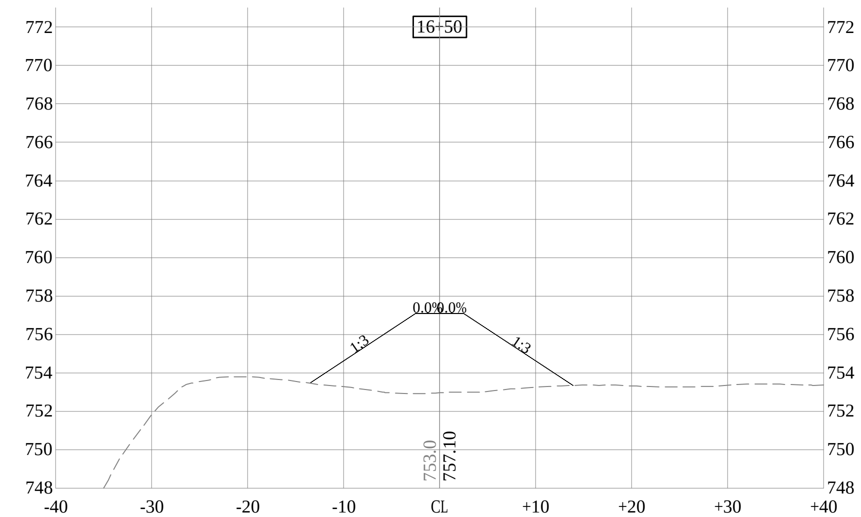
LEVEE

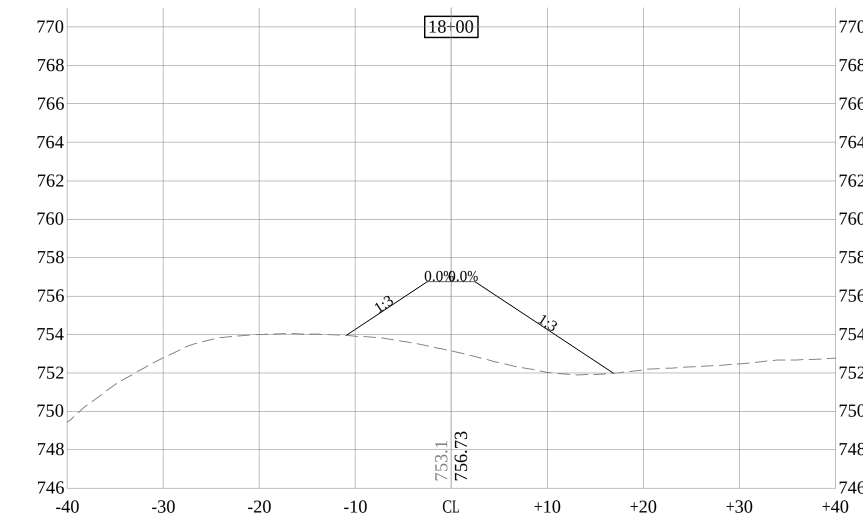
SHEET C9.03

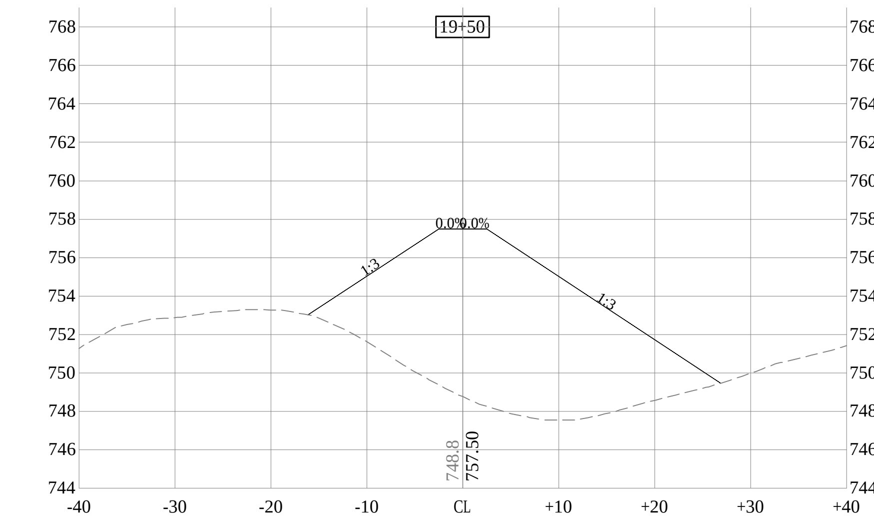


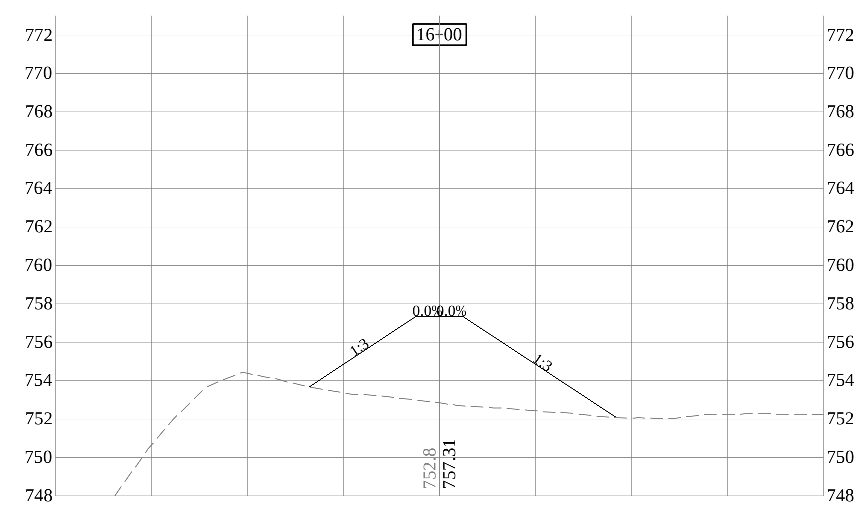


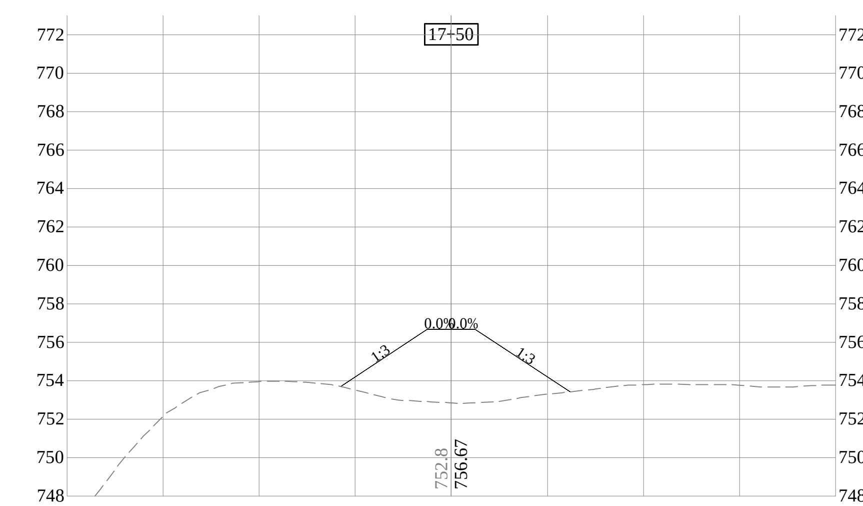


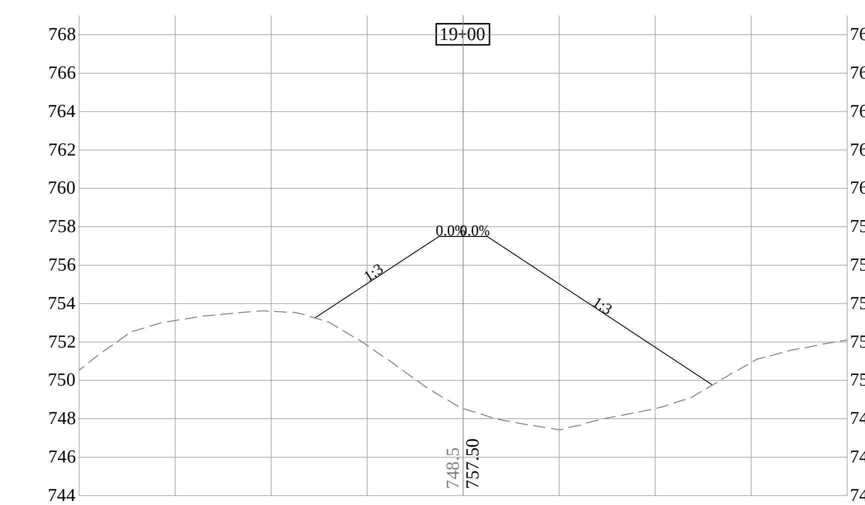












HORZ. SCALE 0 5 10 FEET

VERT. SCALE 0 5 10 FEET

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CITY OF JORDAN

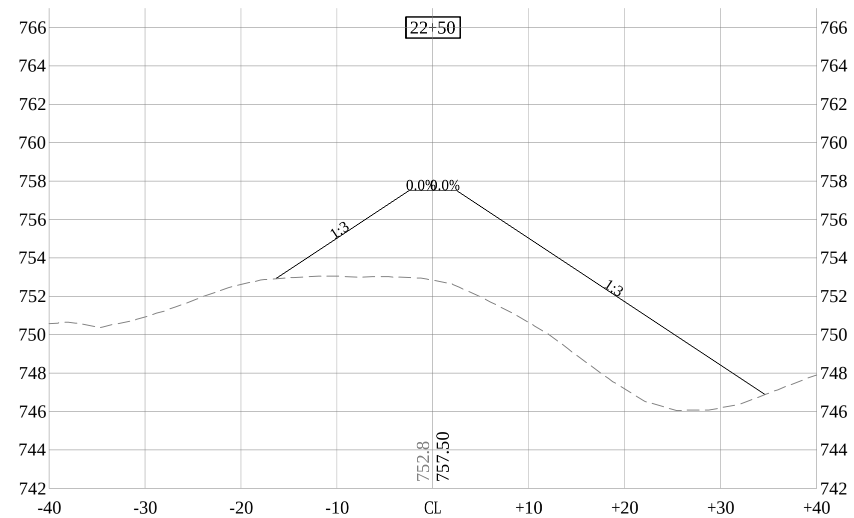
CITY OF JORDAN, MINNESOTA

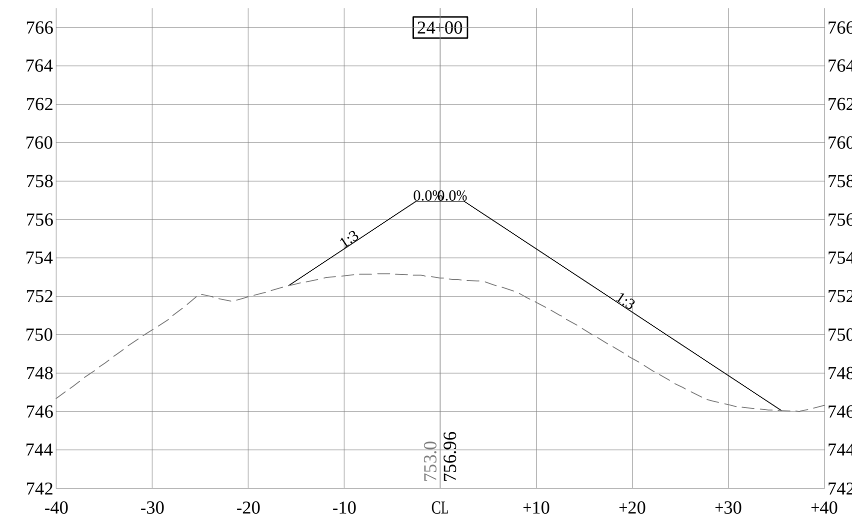
FLOODPLAIN MODELING

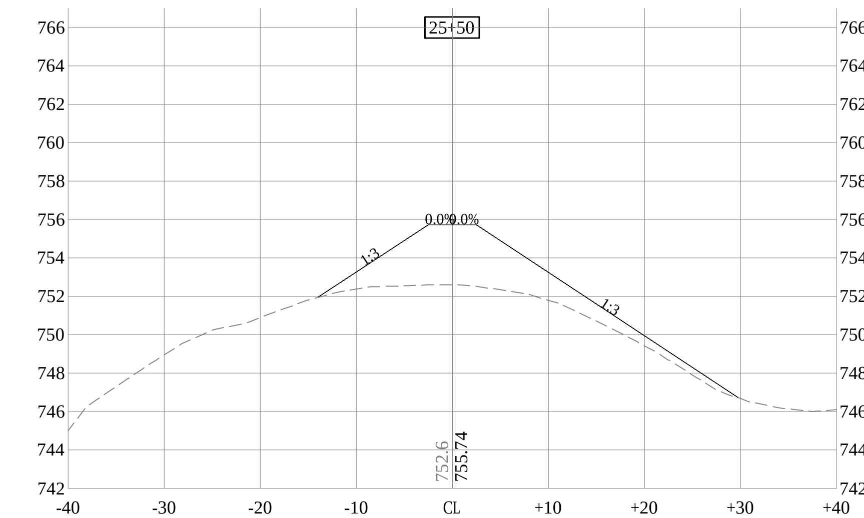
CROSS SECTIONS

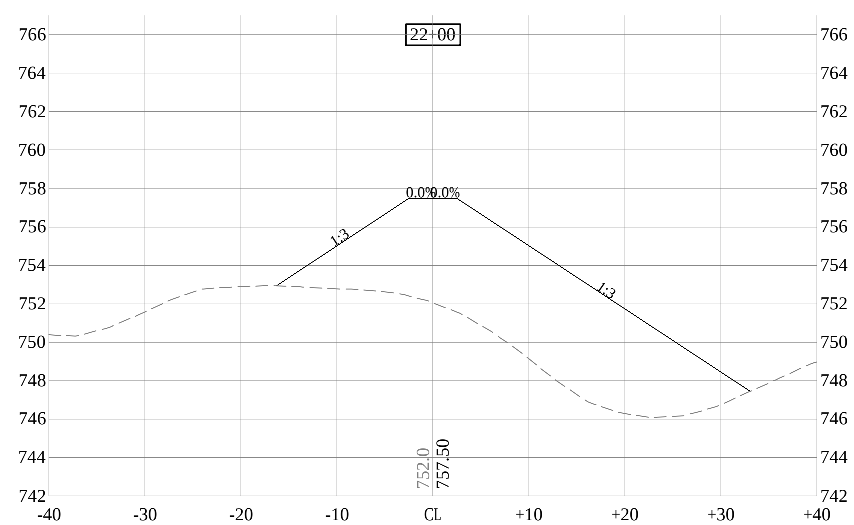
LEVEE

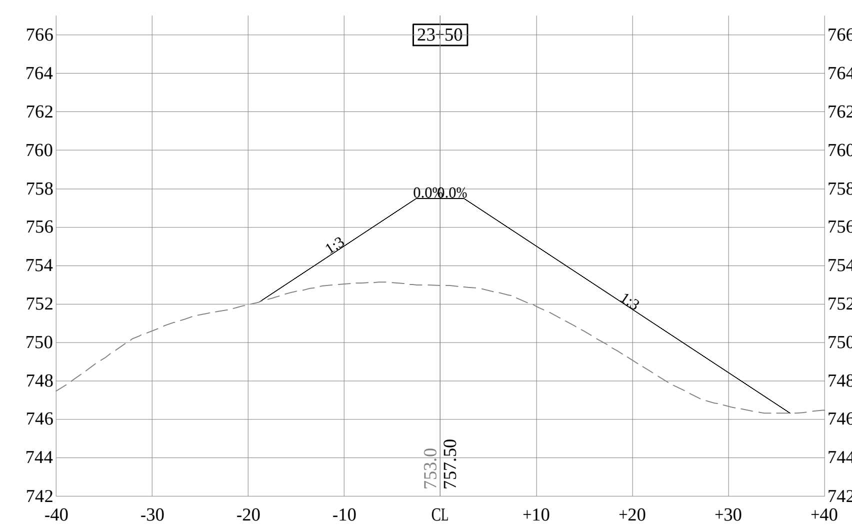
SHEET C9.04

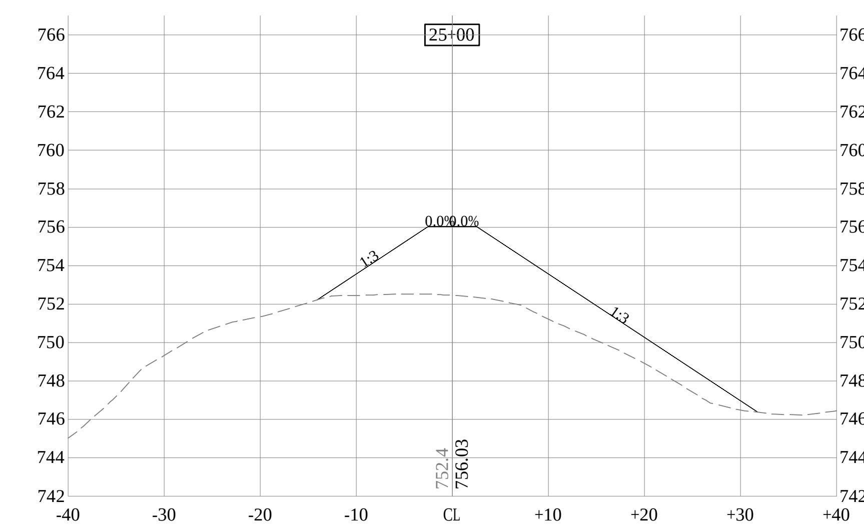


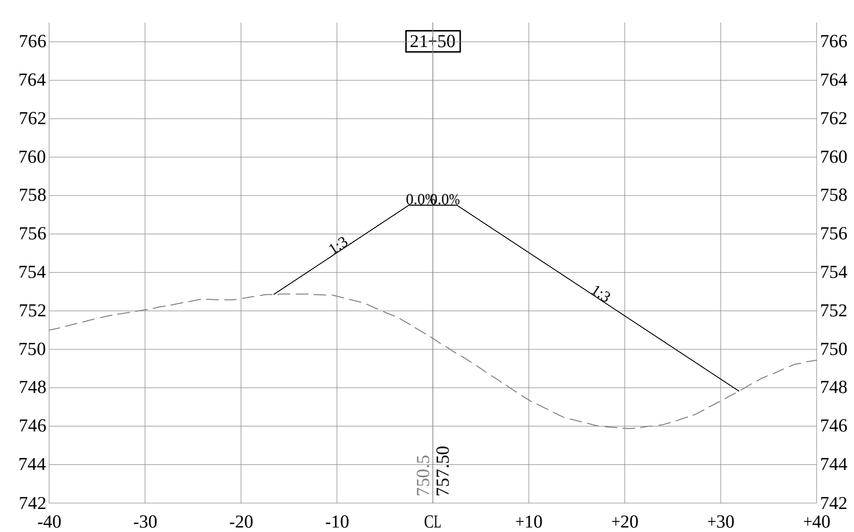


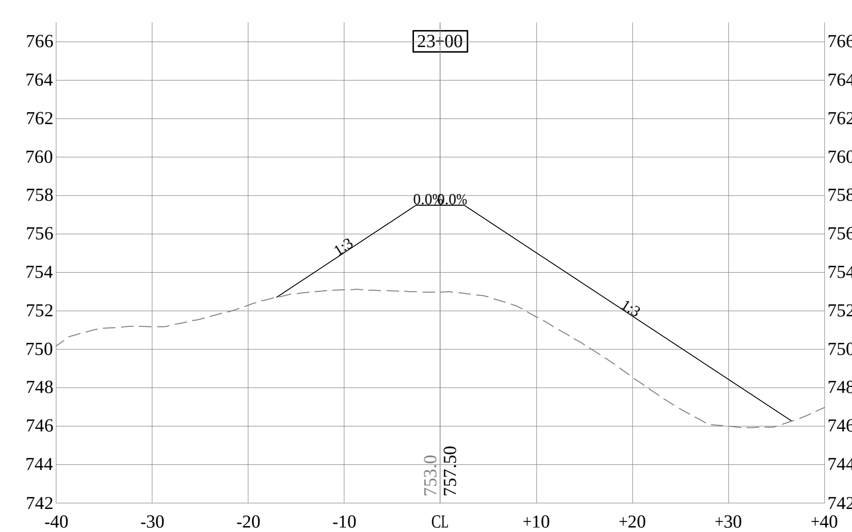


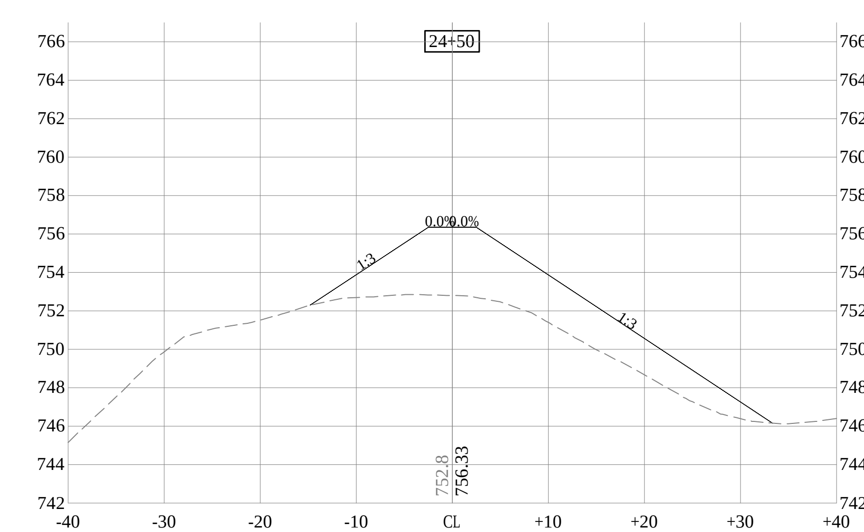












HORZ. 0 5 10 SCALE FEET

VERT. 0 5 10 SCALE FEET

BOLTON & MENK

CITY OF JORDAN

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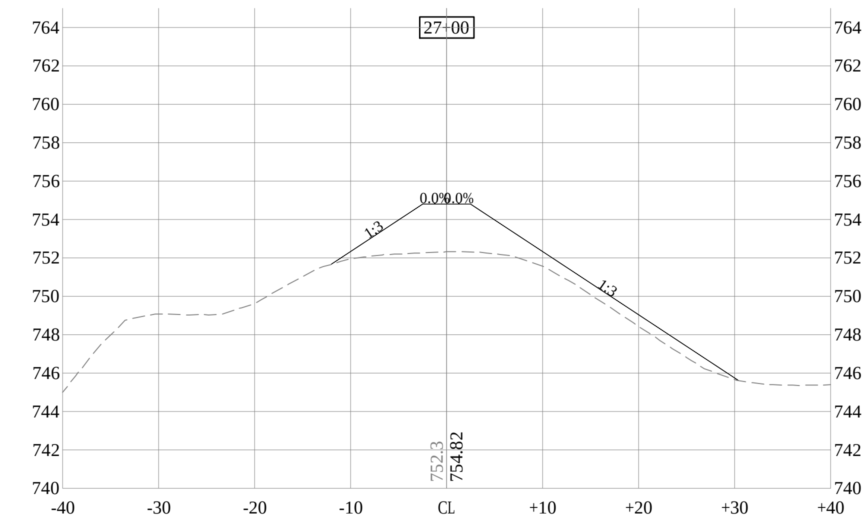
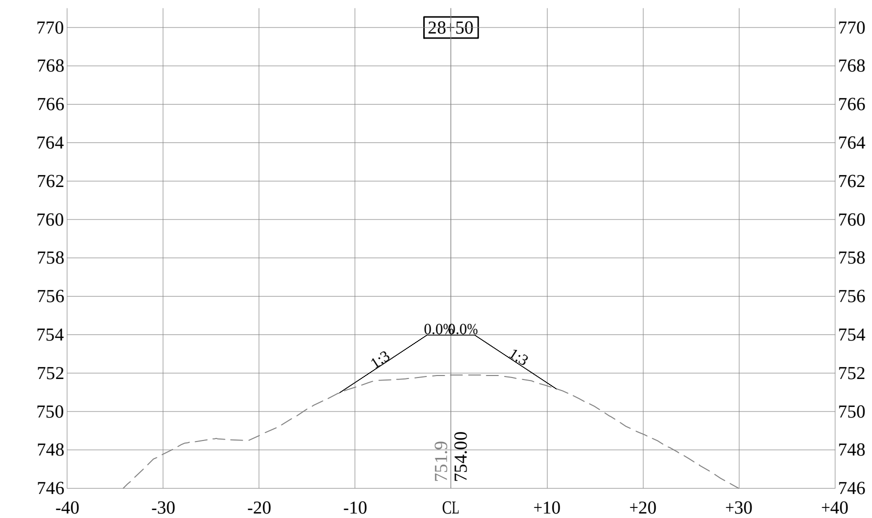
FLOODPLAIN MODELING

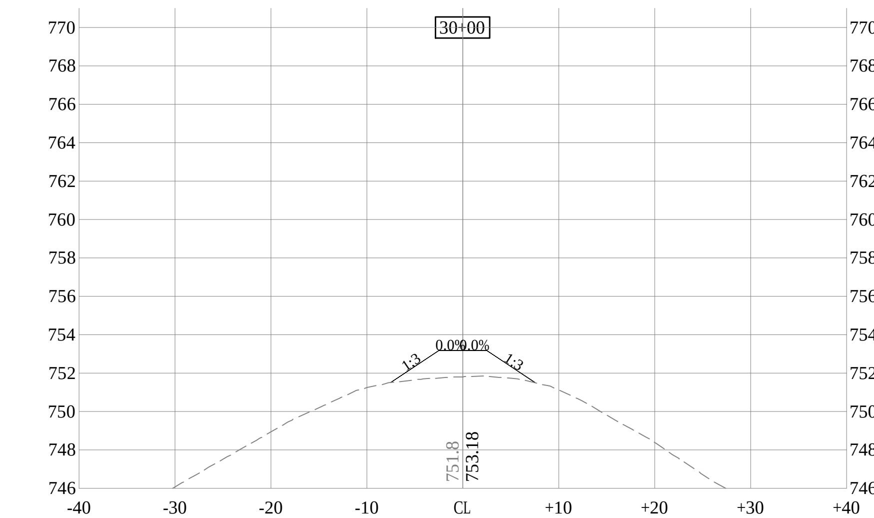
CROSS SECTIONS

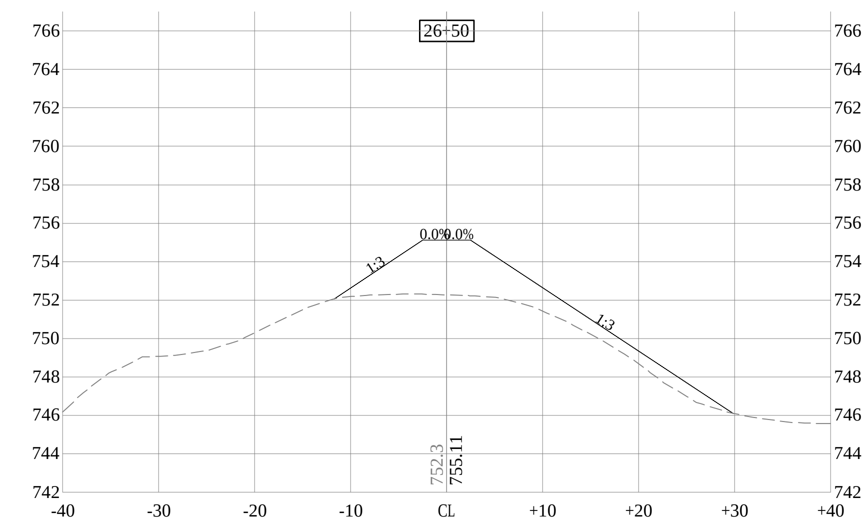
LEVEE

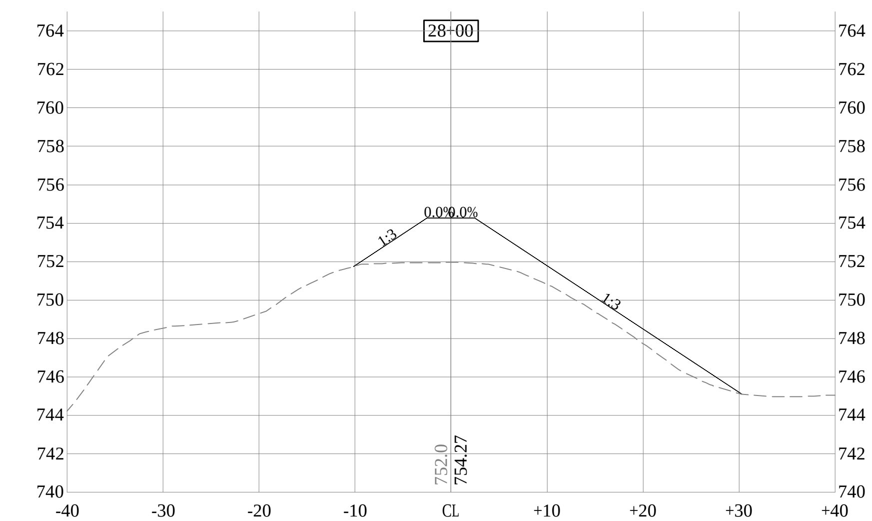
SHEET C9.05

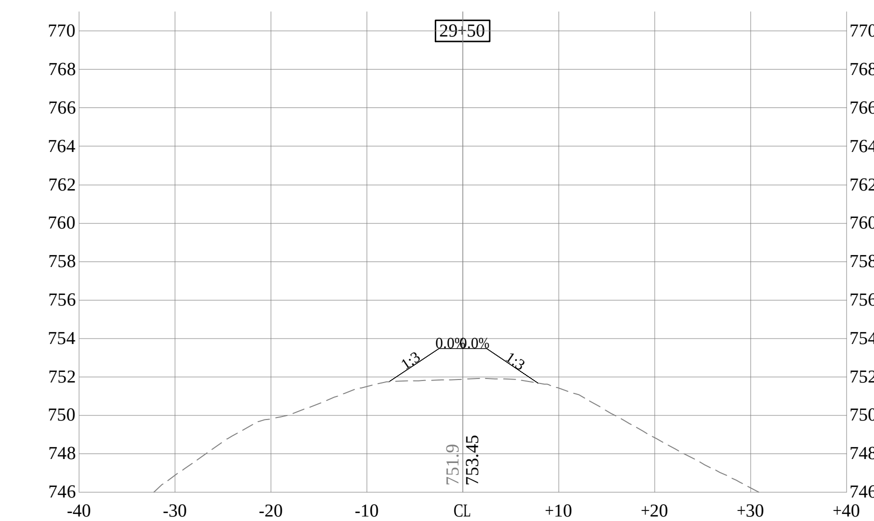


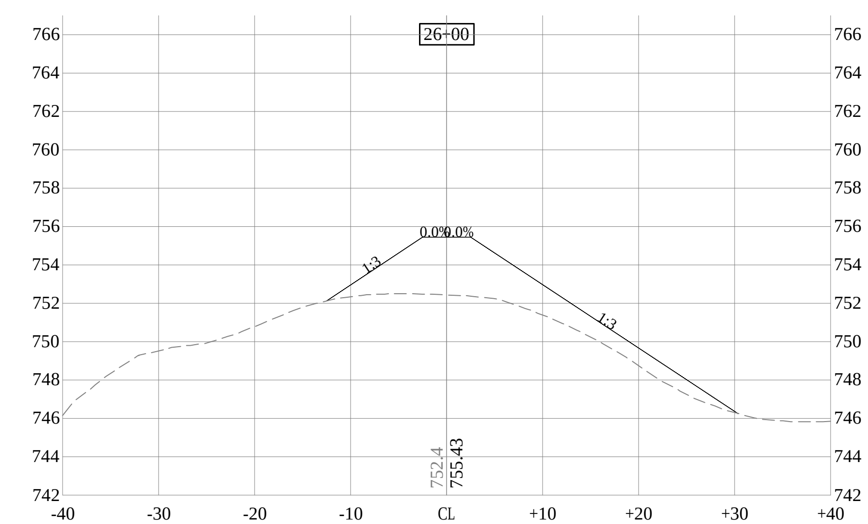


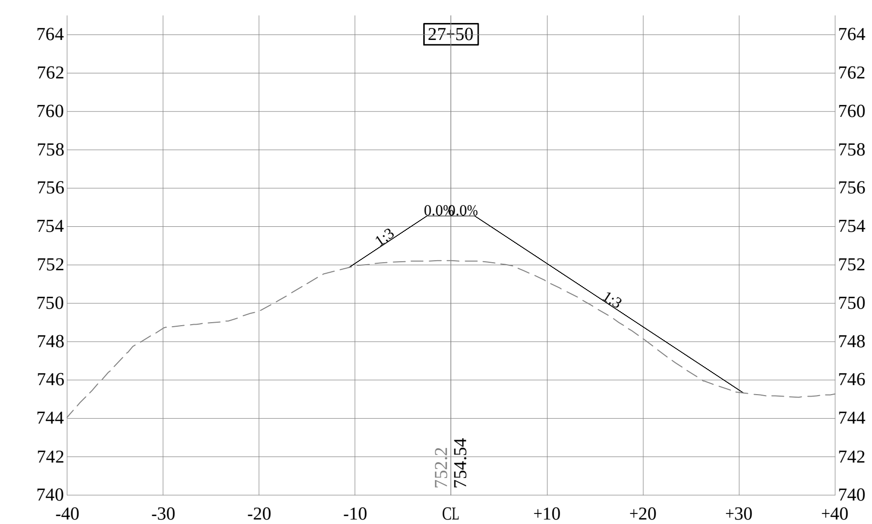


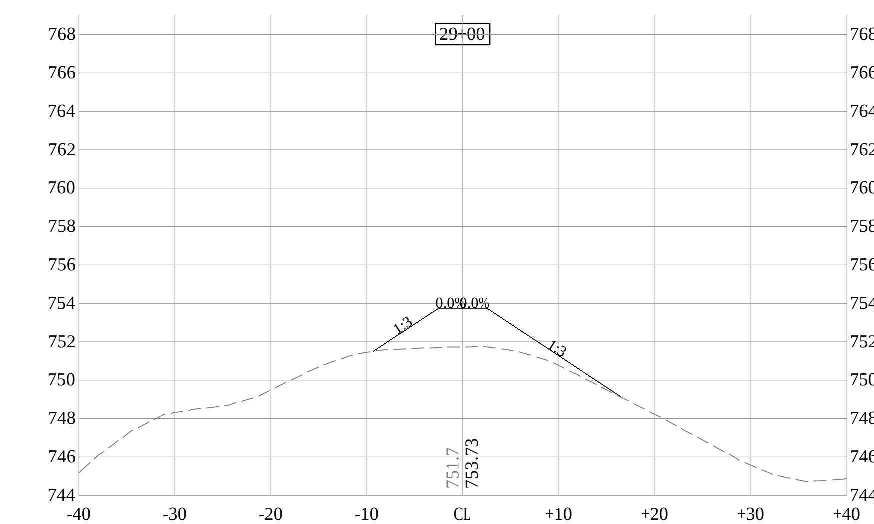












HORZ. 0 5 10 SCALE FEET

VERT. 0 5 10 SCALE FEET

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FLOODPLAIN MODELING

CROSS SECTIONS

LEVEE

SHEET

C9.06

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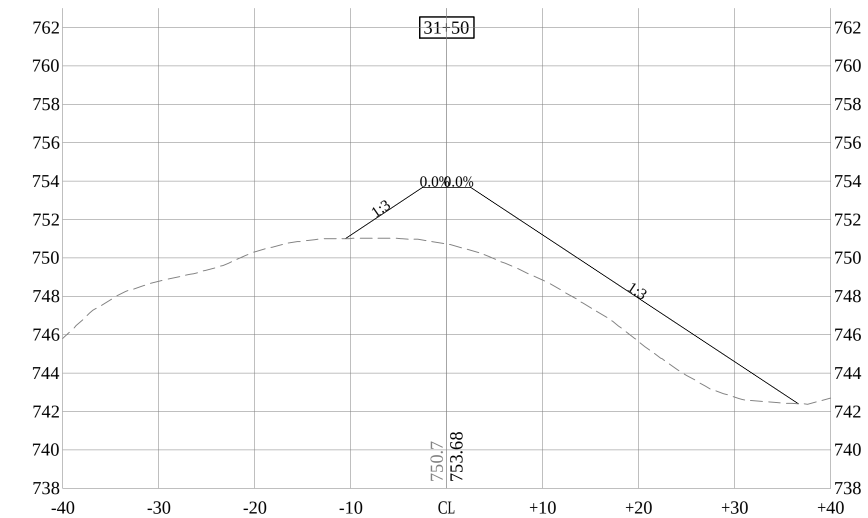

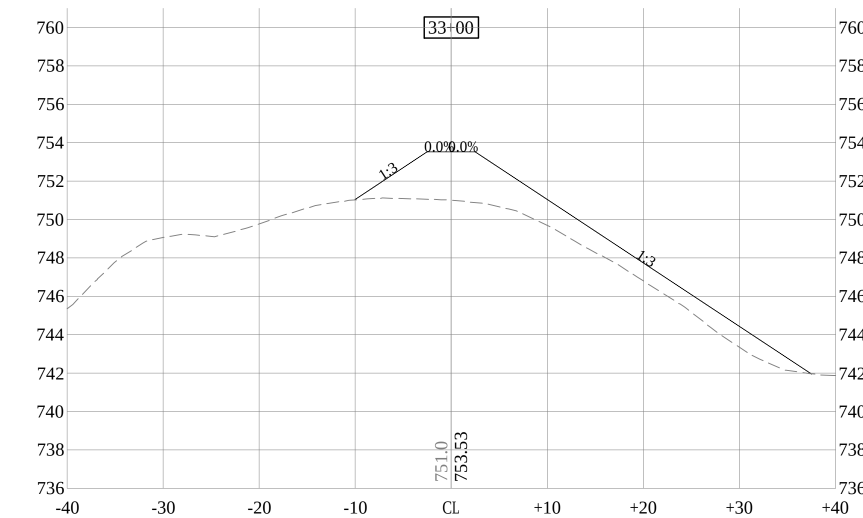

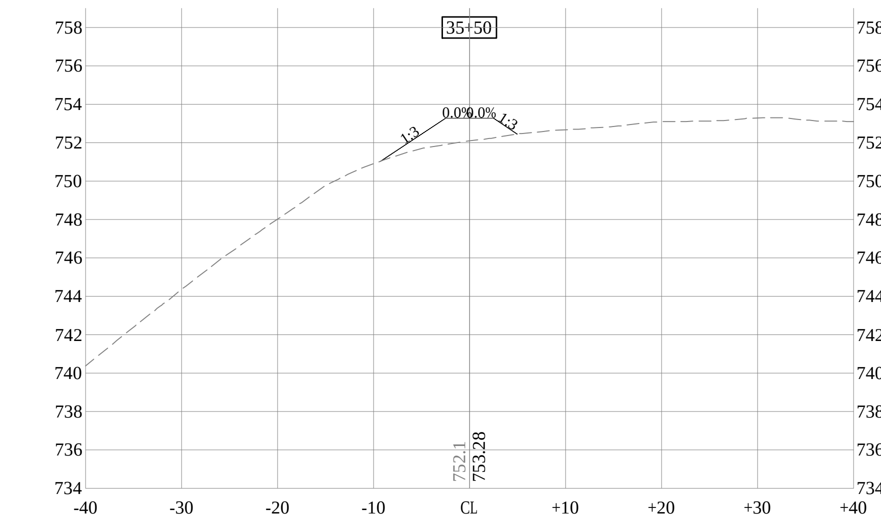

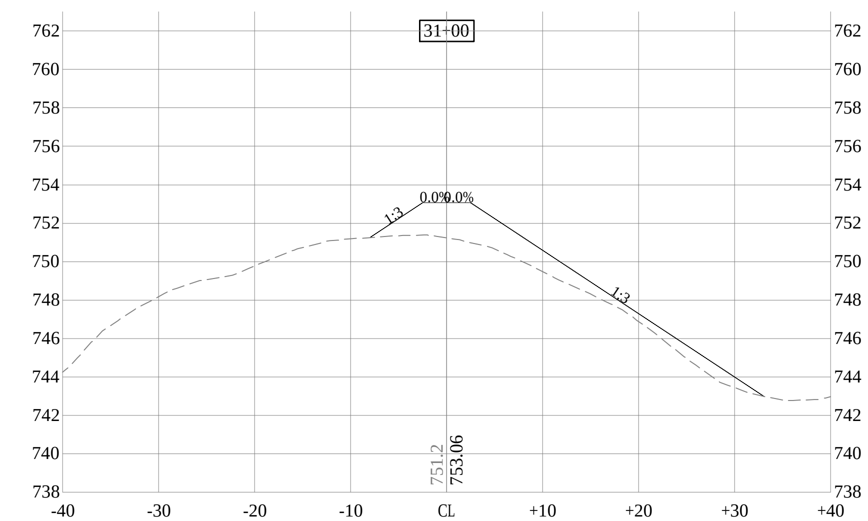

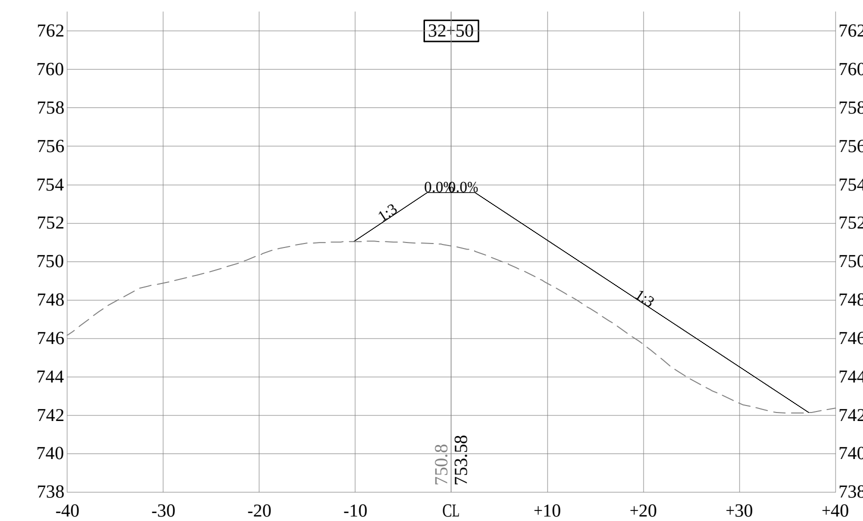

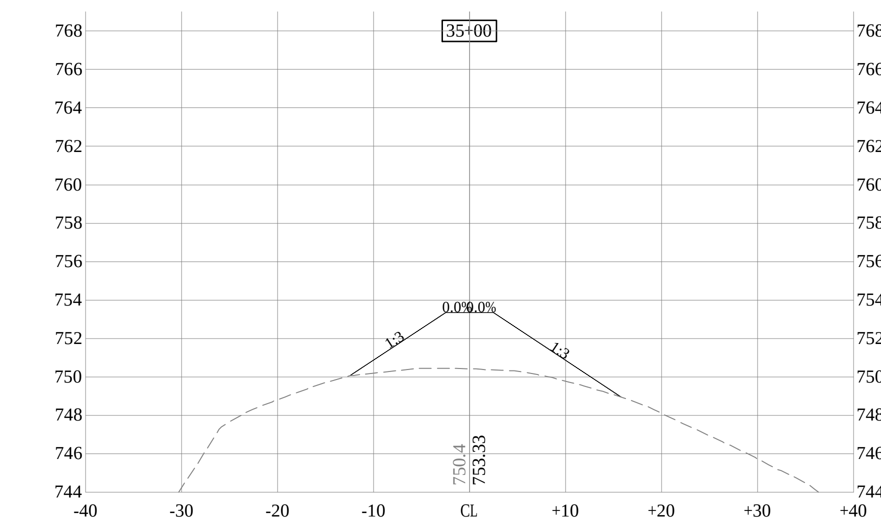

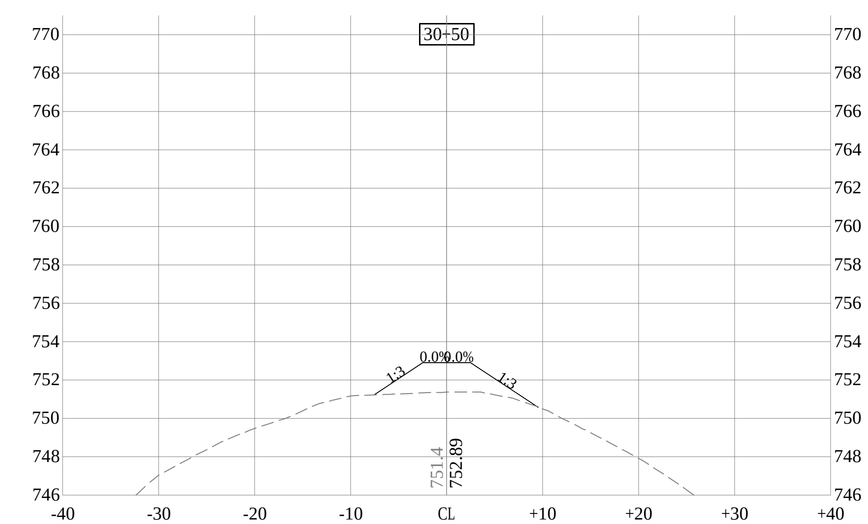

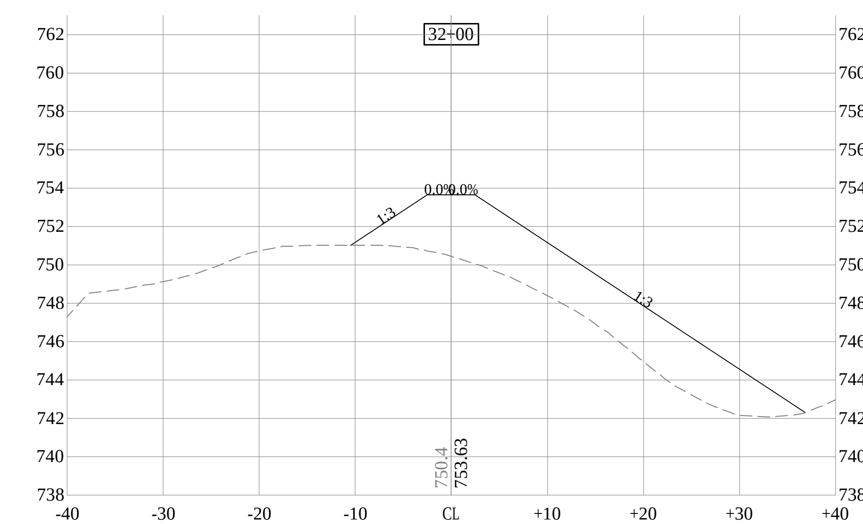

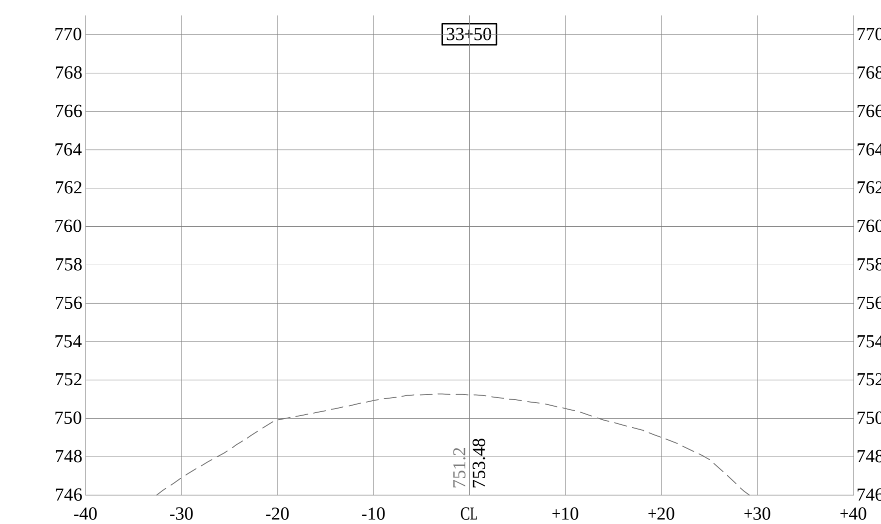

HORZ. SCALE 0 5 10 FEET

VERT. SCALE 0 5 10 FEET

BOLTON & MENK

CITY OF JORDAN

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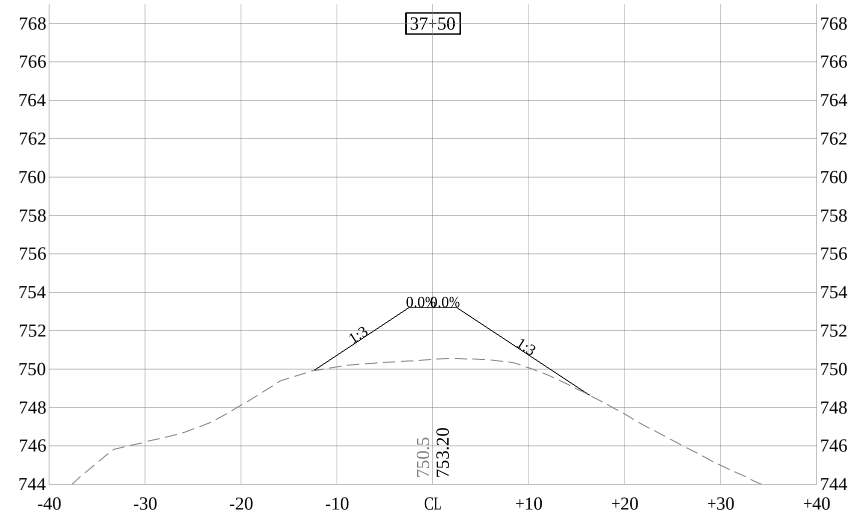
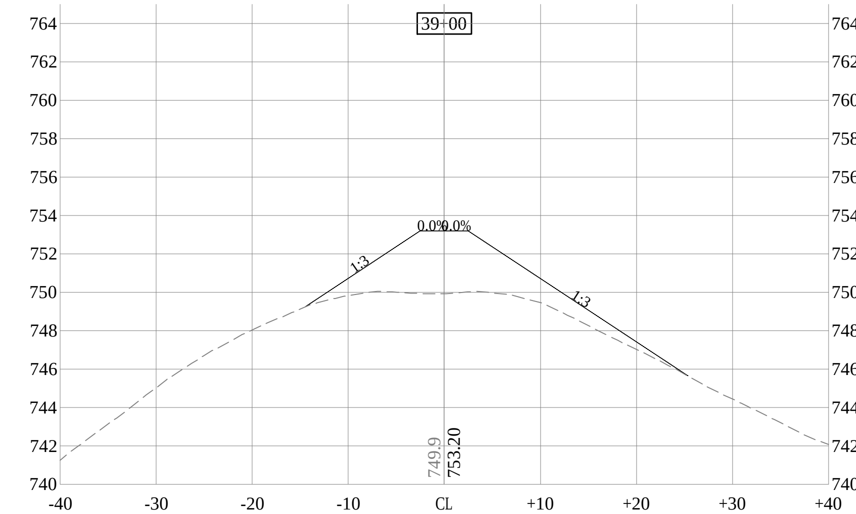
FLOODPLAIN MODELING

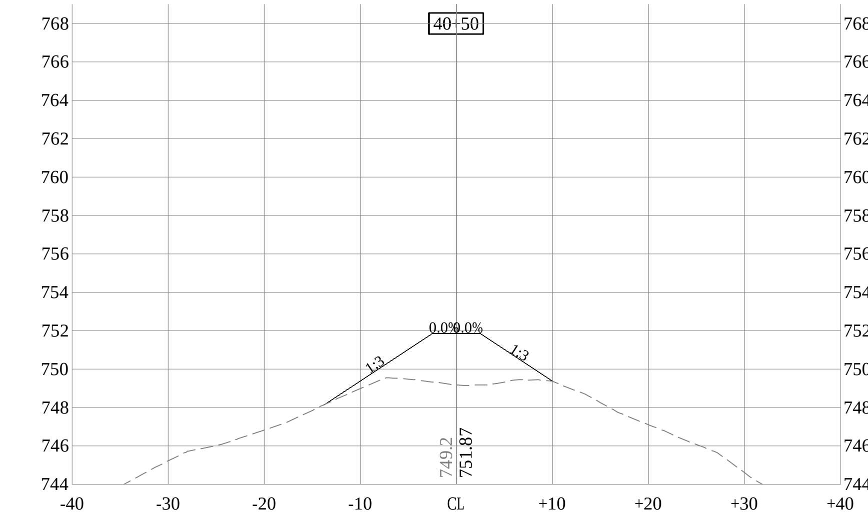
CROSS SECTIONS

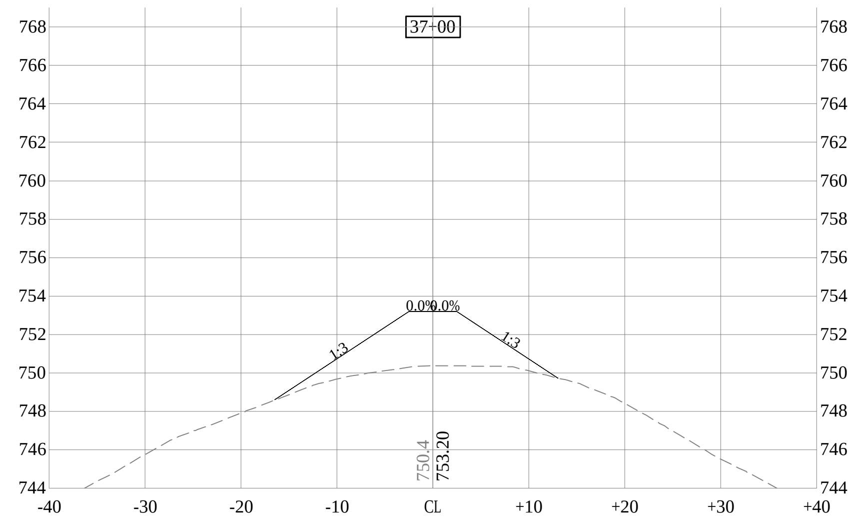
LEVEE

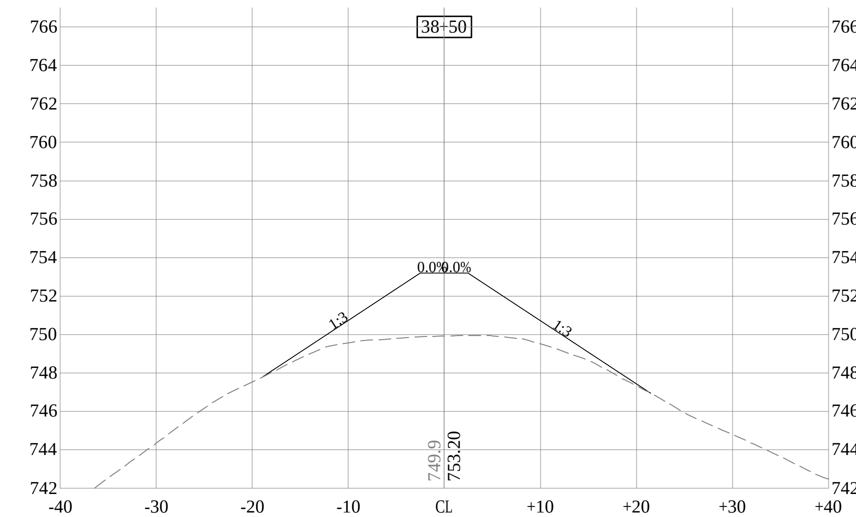
SHEET C9.07

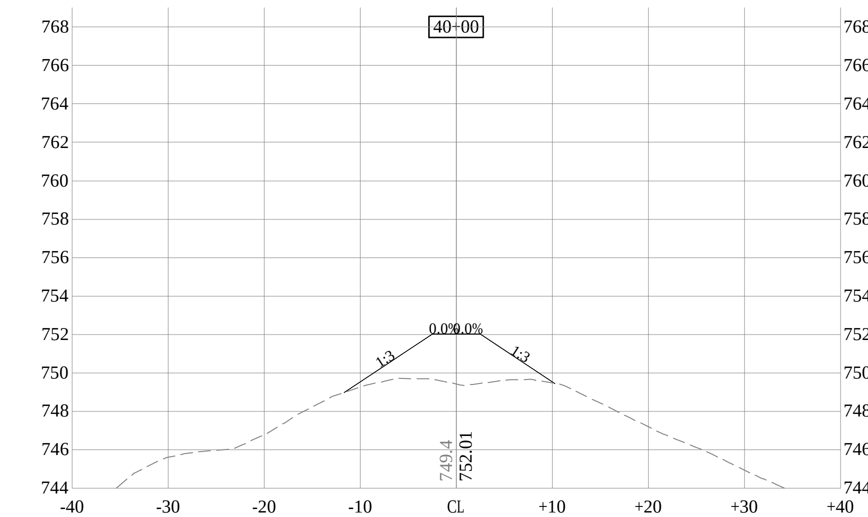


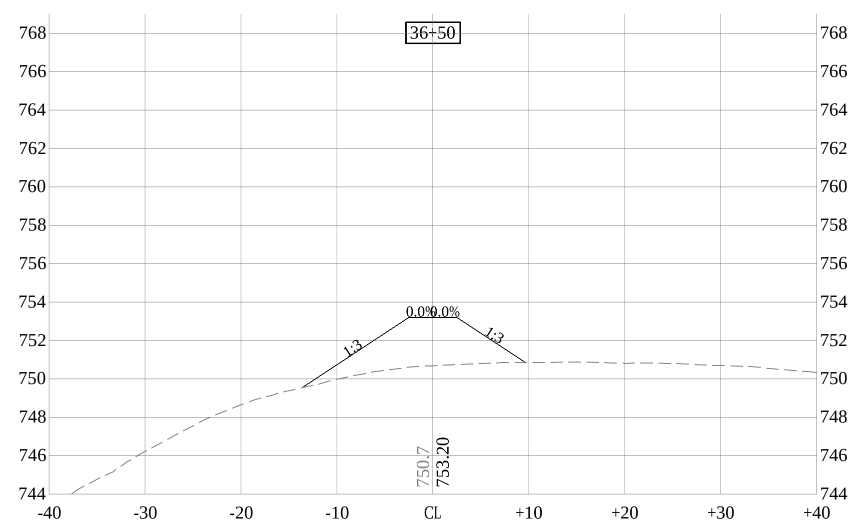


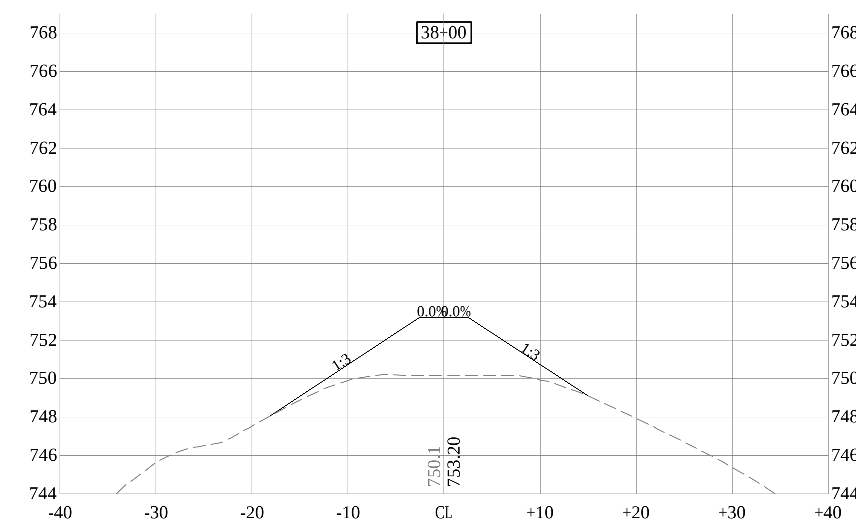


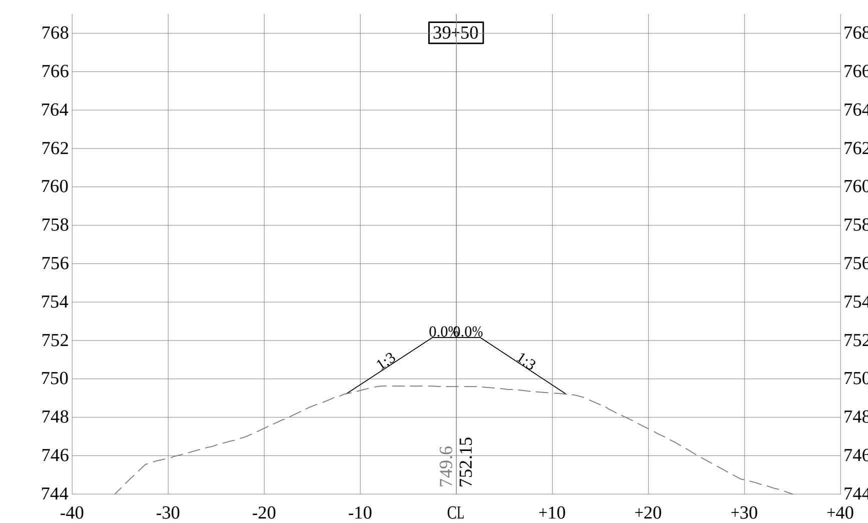












HORZ. 0 5 10 SCALE FEET

VERT. 0 5 10 SCALE FEET

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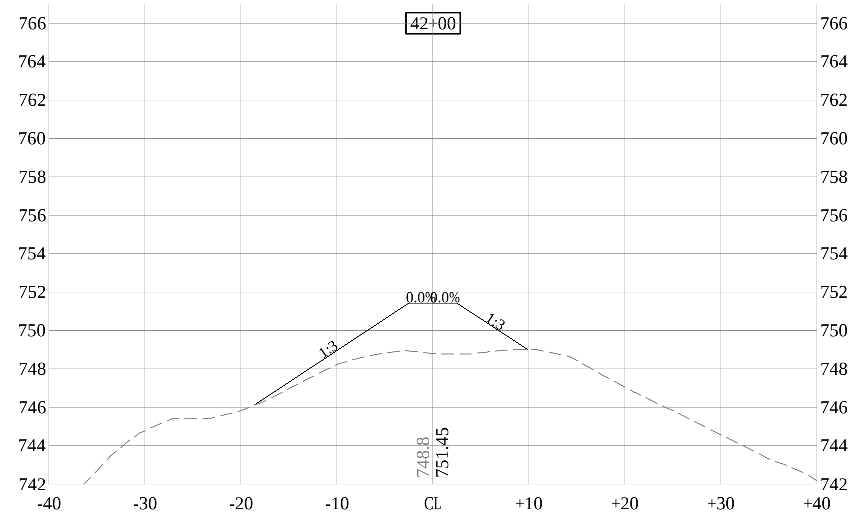
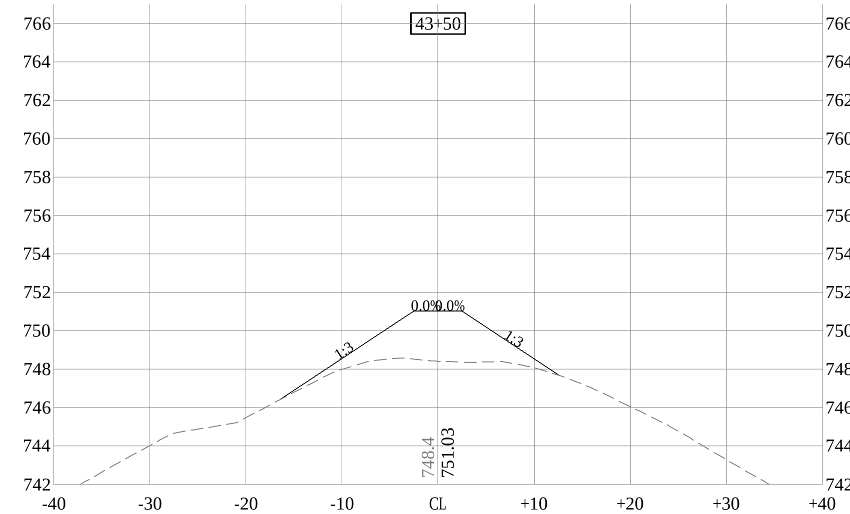
FLOODPLAIN MODELING

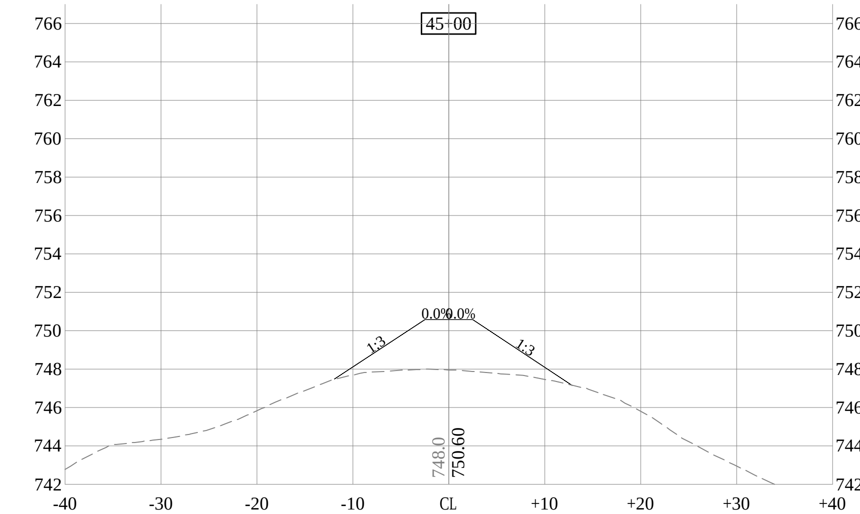
CROSS SECTIONS

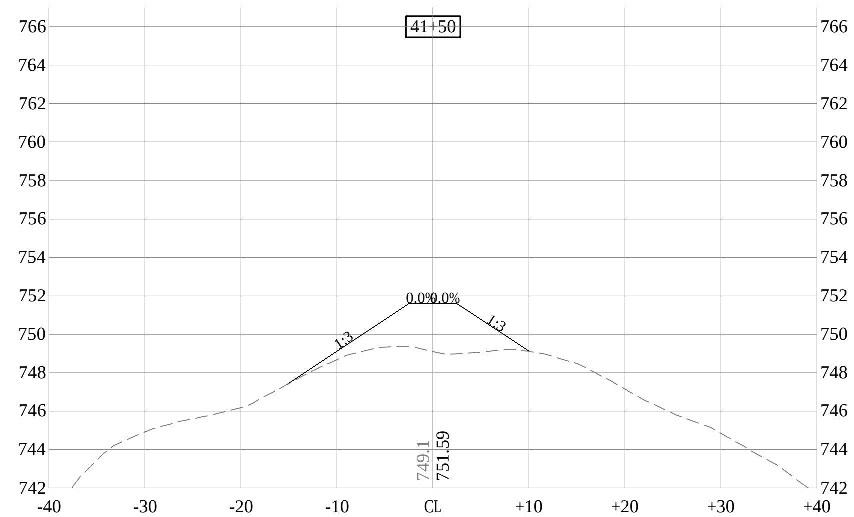
LEVEE

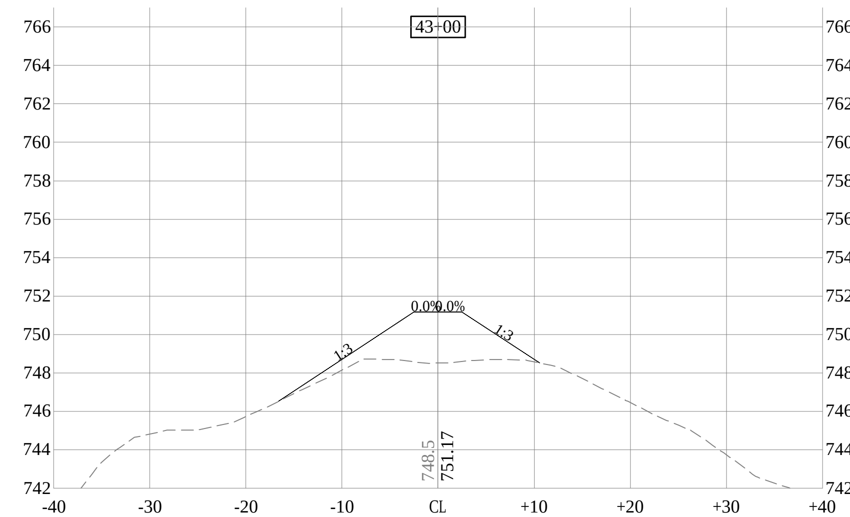
SHEET C9.08

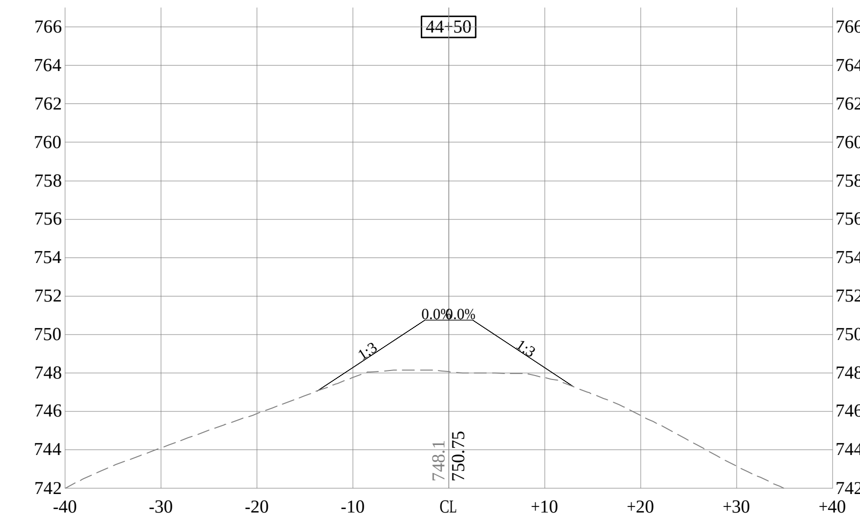


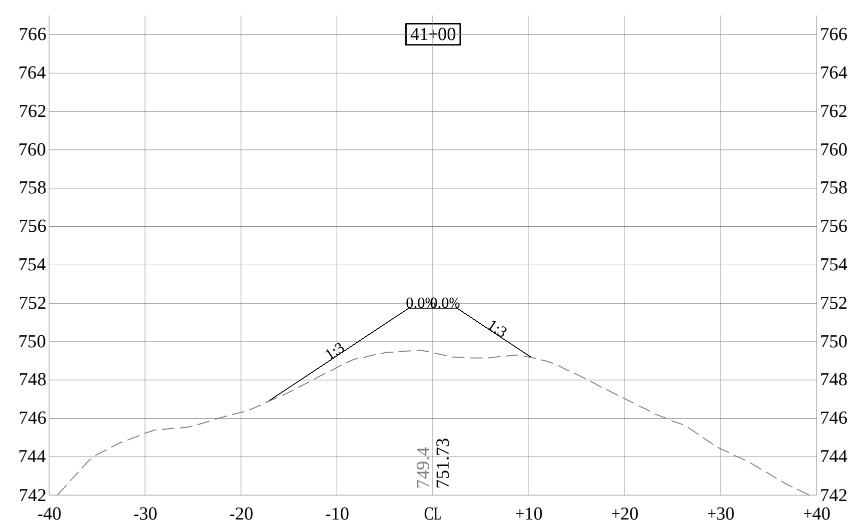


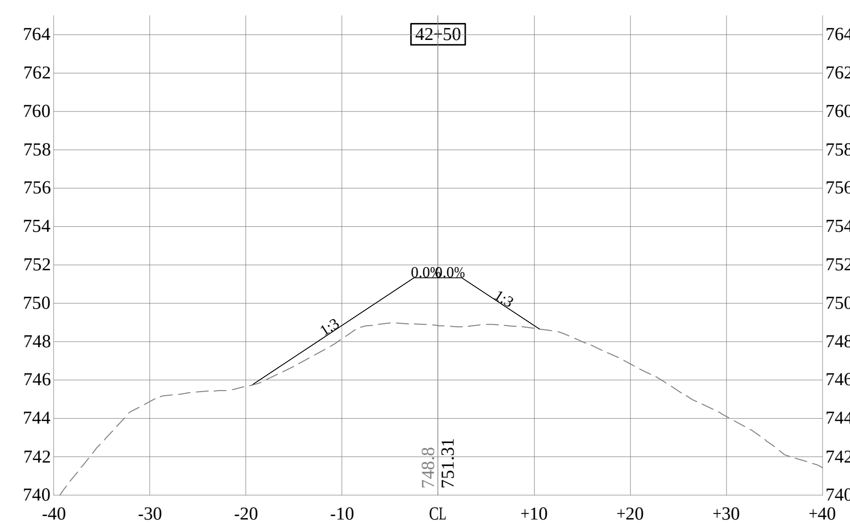


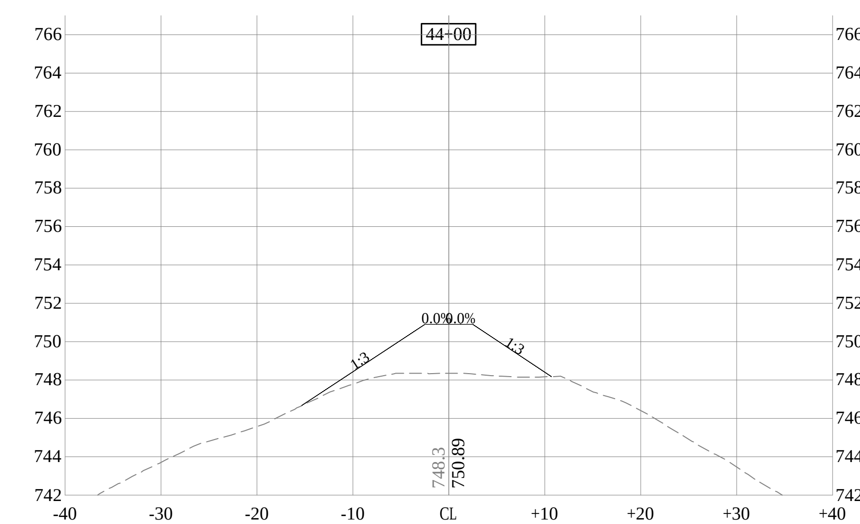












HORZ. SCALE 0 5 10 FEET

VERT. SCALE 0 5 10 FEET

BOLTON & MENK

CITY OF JORDAN

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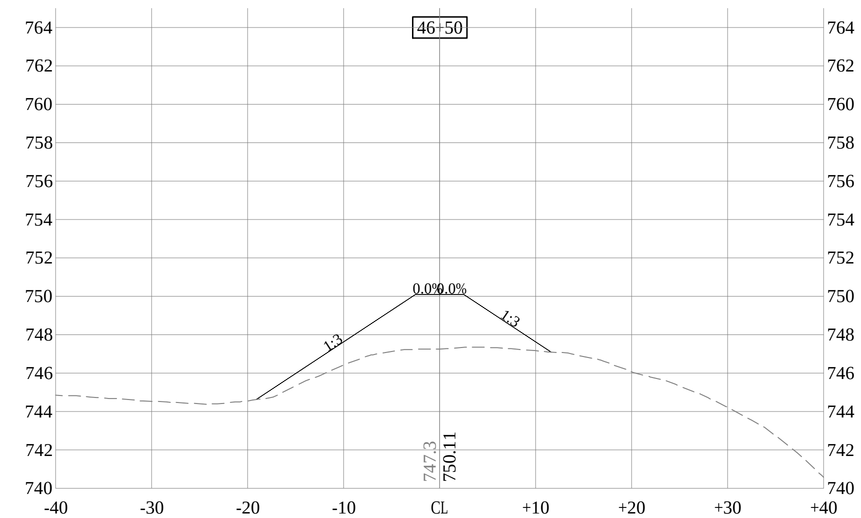
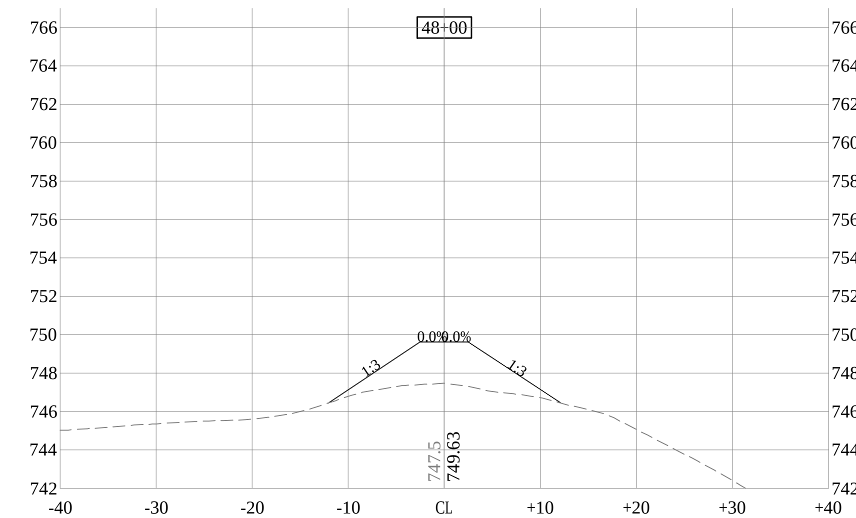
FLOODPLAIN MODELING

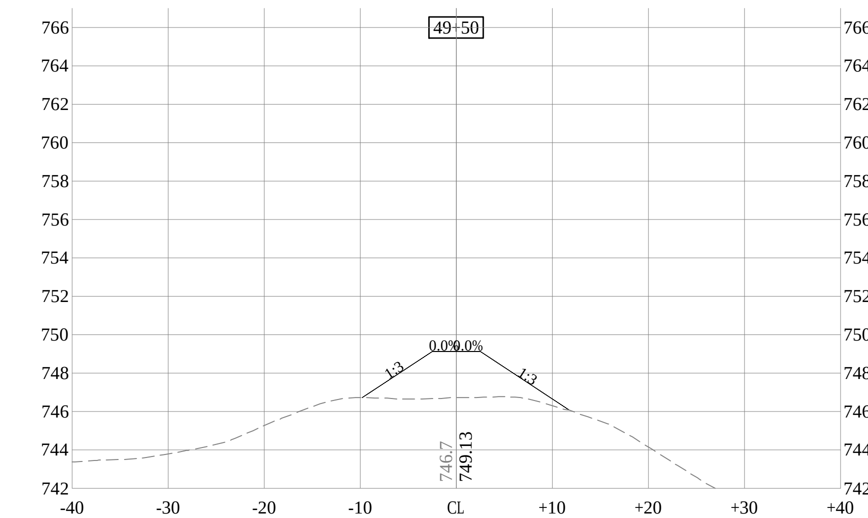
CROSS SECTIONS

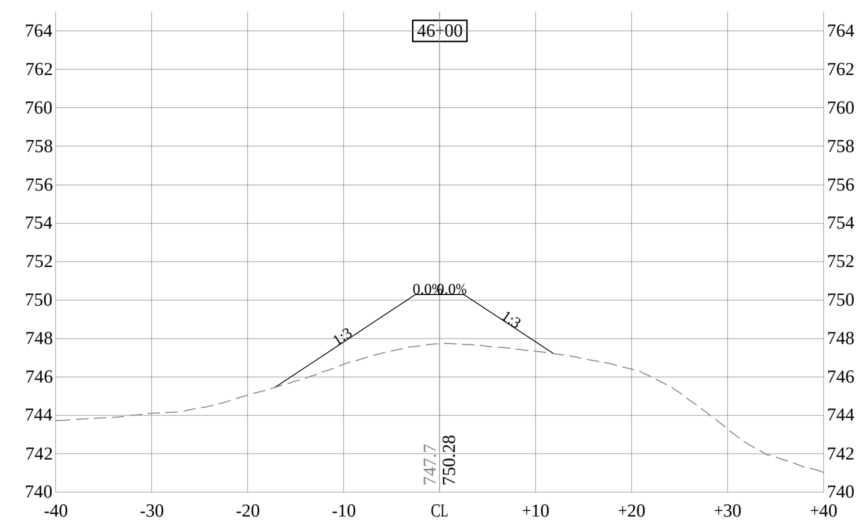
LEVEE

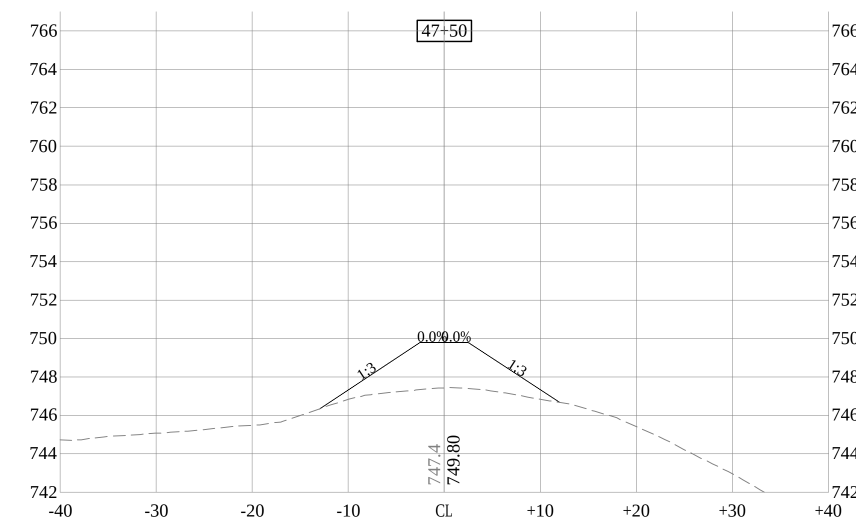
SHEET C9.09

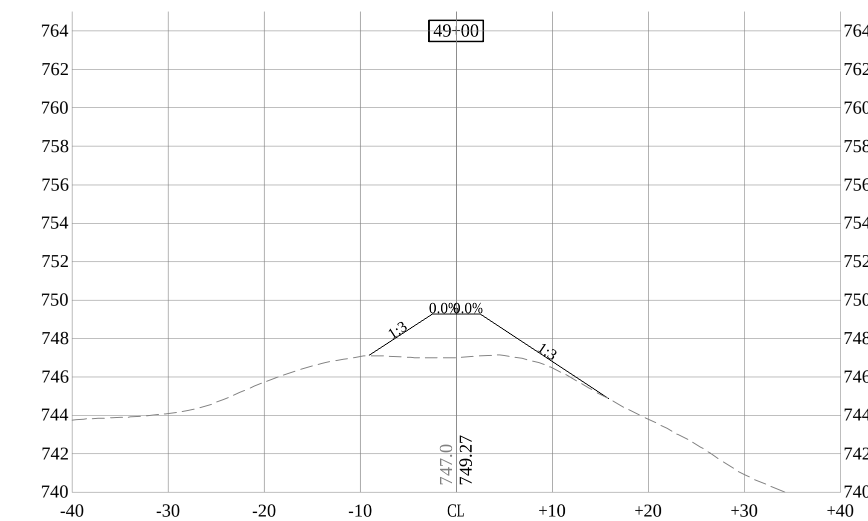


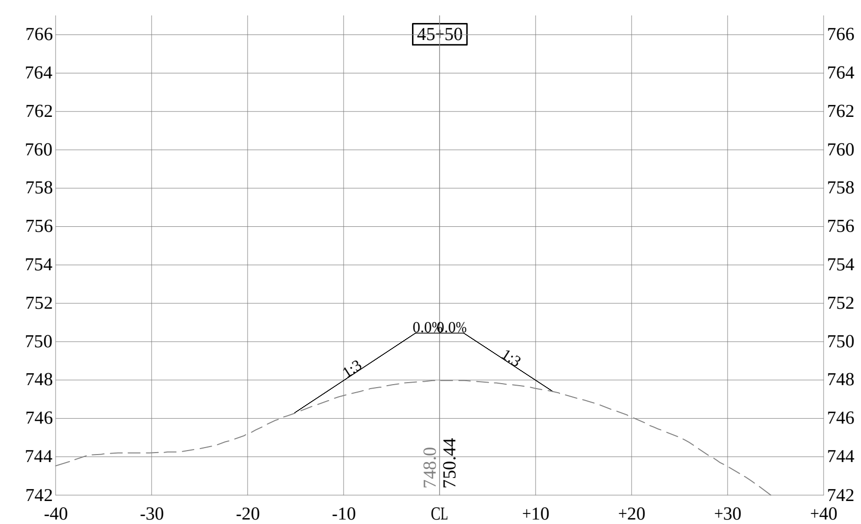


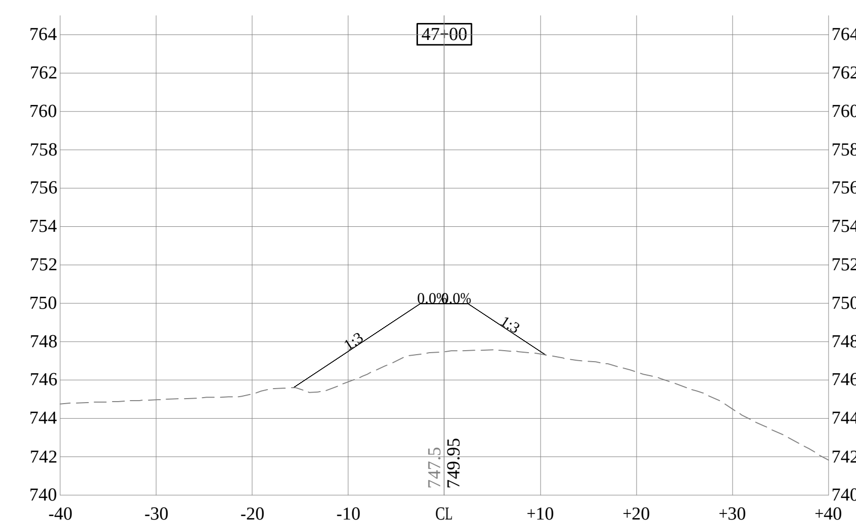


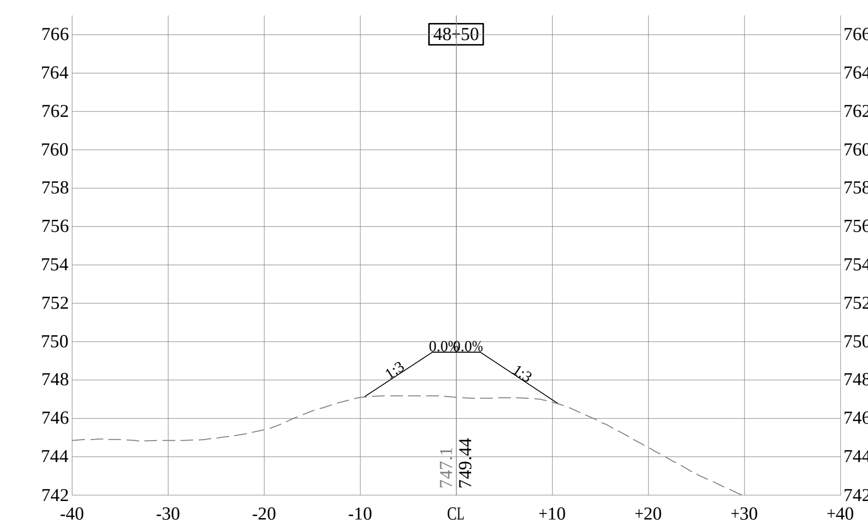












HORZ. 0 5 10 SCALE FEET

VERT. 0 5 10 SCALE FEET

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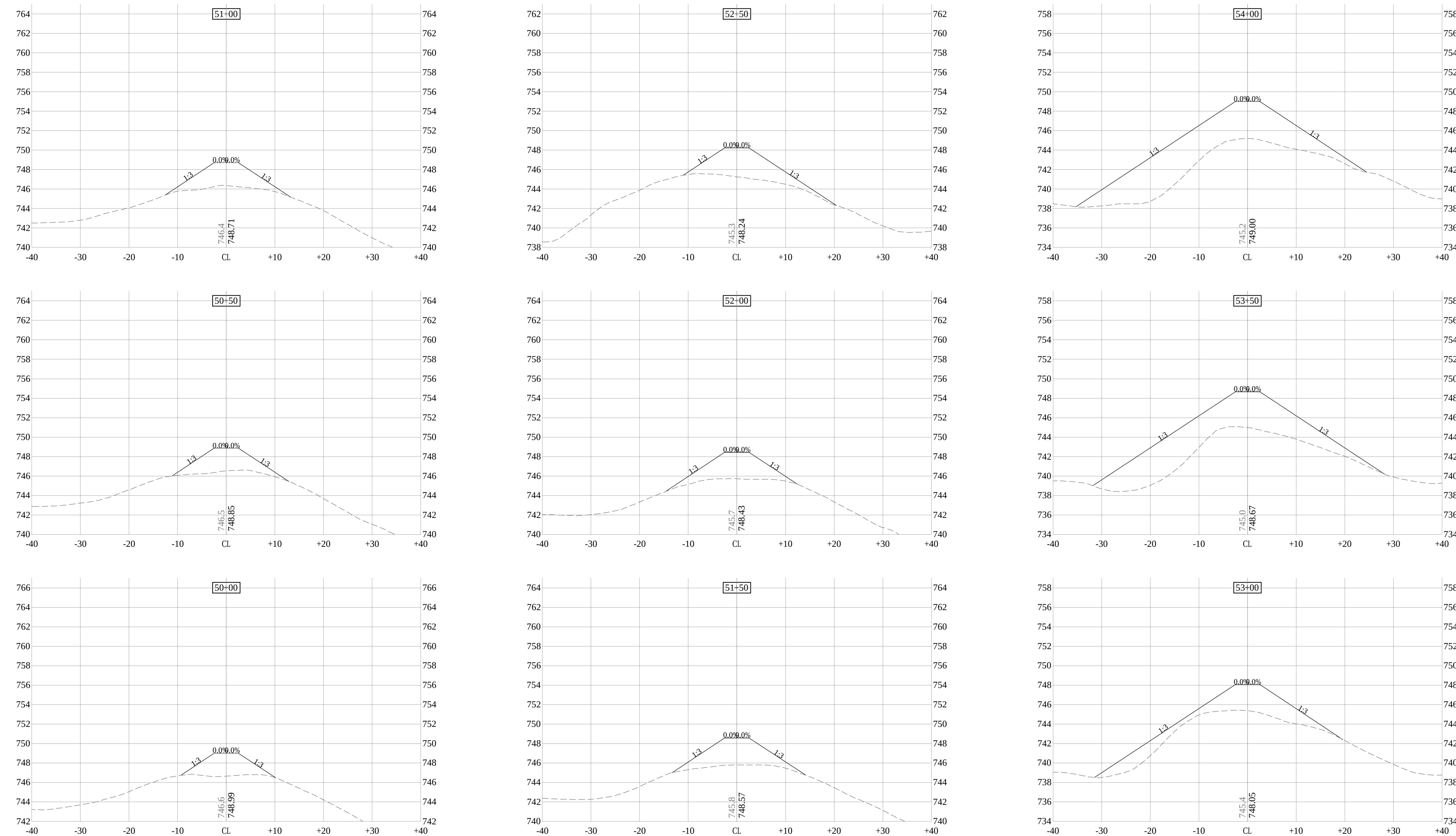
FLOODPLAIN MODELING

CROSS SECTIONS

LEVEE

SHEET

C9.10



HORZ. 0 5 10 SCALE FEET

VERT. 0 5 10 SCALE FEET

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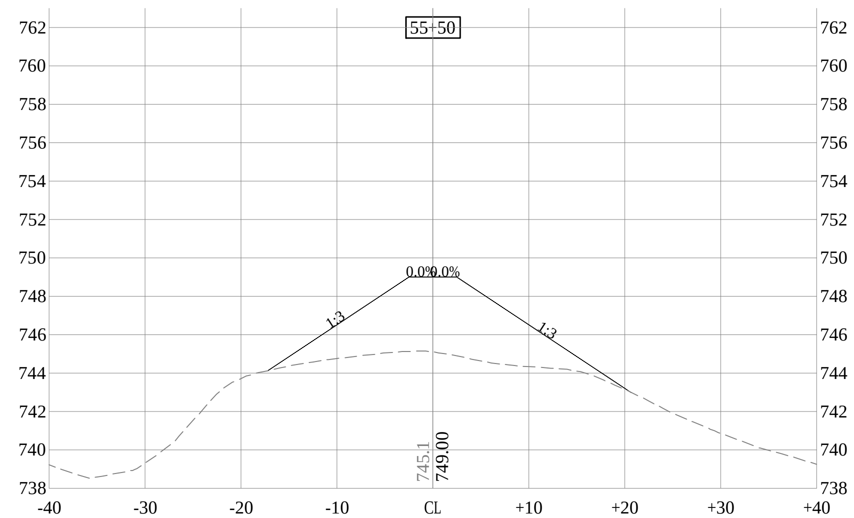
CITY OF JORDAN, MINNESOTA

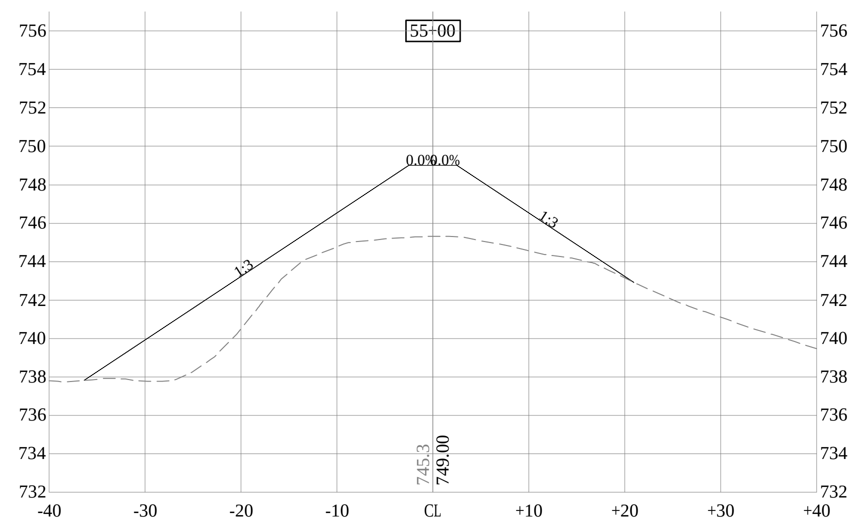
FLOODPLAIN MODELING

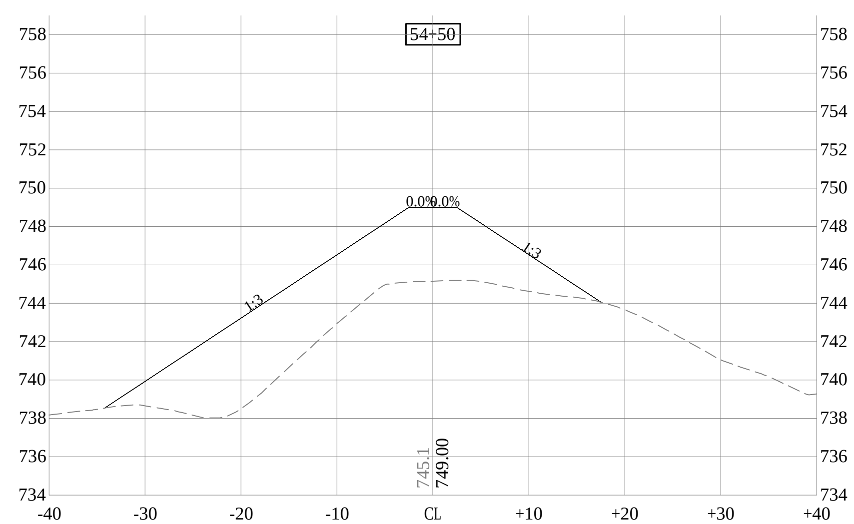
CROSS SECTIONS

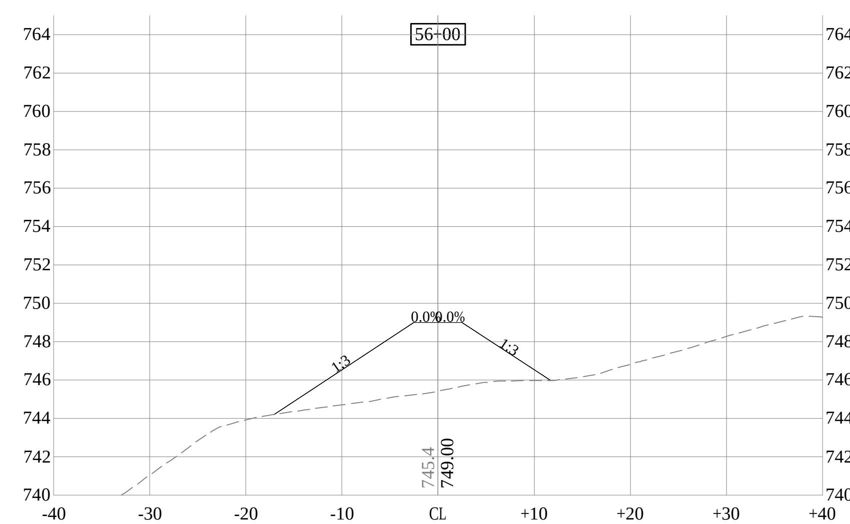
LEVEE

SHEET C9.11









HORZ. 0 5 10 SCALE FEET

VERT. 0 5 10 SCALE FEET

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CITY OF JORDAN

CITY OF JORDAN, MINNESOTA

FLOODPLAIN MODELING

CROSS SECTIONS

LEVEE

SHEET

C9.12

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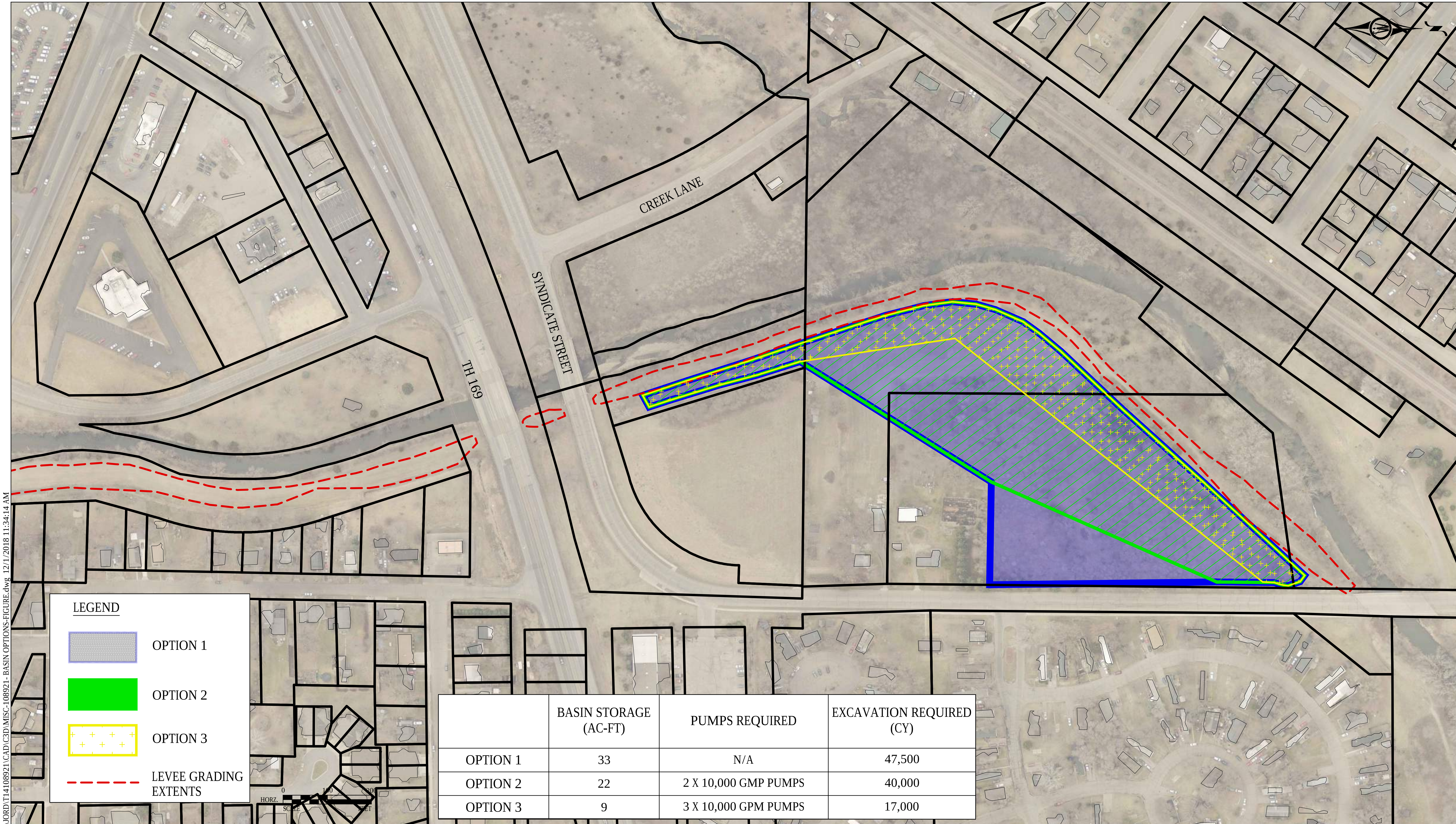
Appendix B: Basin Options



	BASIN STORAGE (AC-FT)	PUMPS REQUIRED	EXCAVATION REQUIRED (CY)
OPTION 1	33	N/A	47,500
OPTION 2	22	2 X 10,000 GMP PUMPS	40,000
OPTION 3	9	3 X 10,000 GPM PUMPS	17,000

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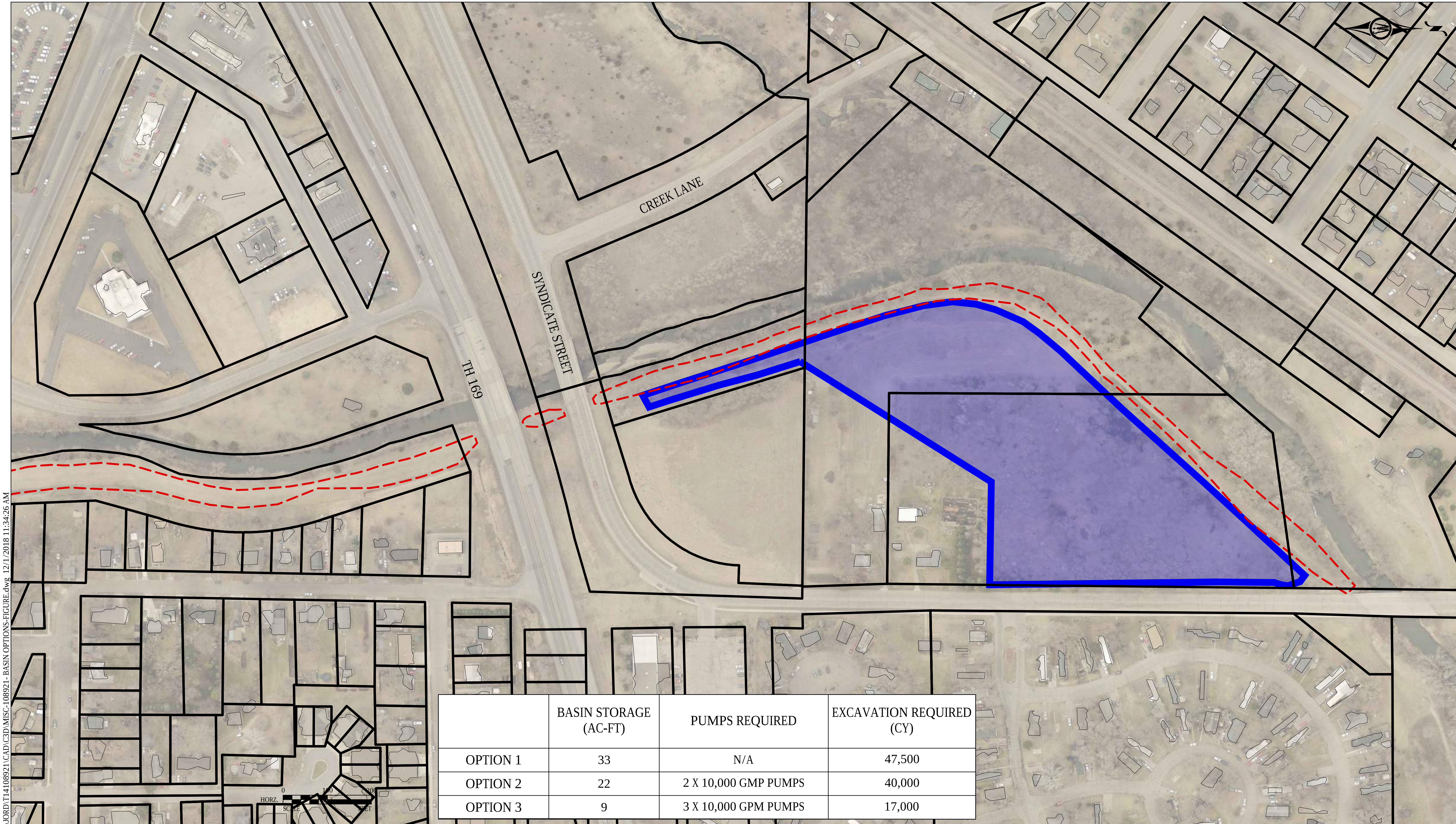

	BASIN STORAGE (AC-FT)	PUMPS REQUIRED	EXCAVATION REQUIRED (CY)
OPTION 1	33	N/A	47,500
OPTION 2	22	2 X 10,000 GMP PUMPS	40,000
OPTION 3	9	3 X 10,000 GPM PUMPS	17,000

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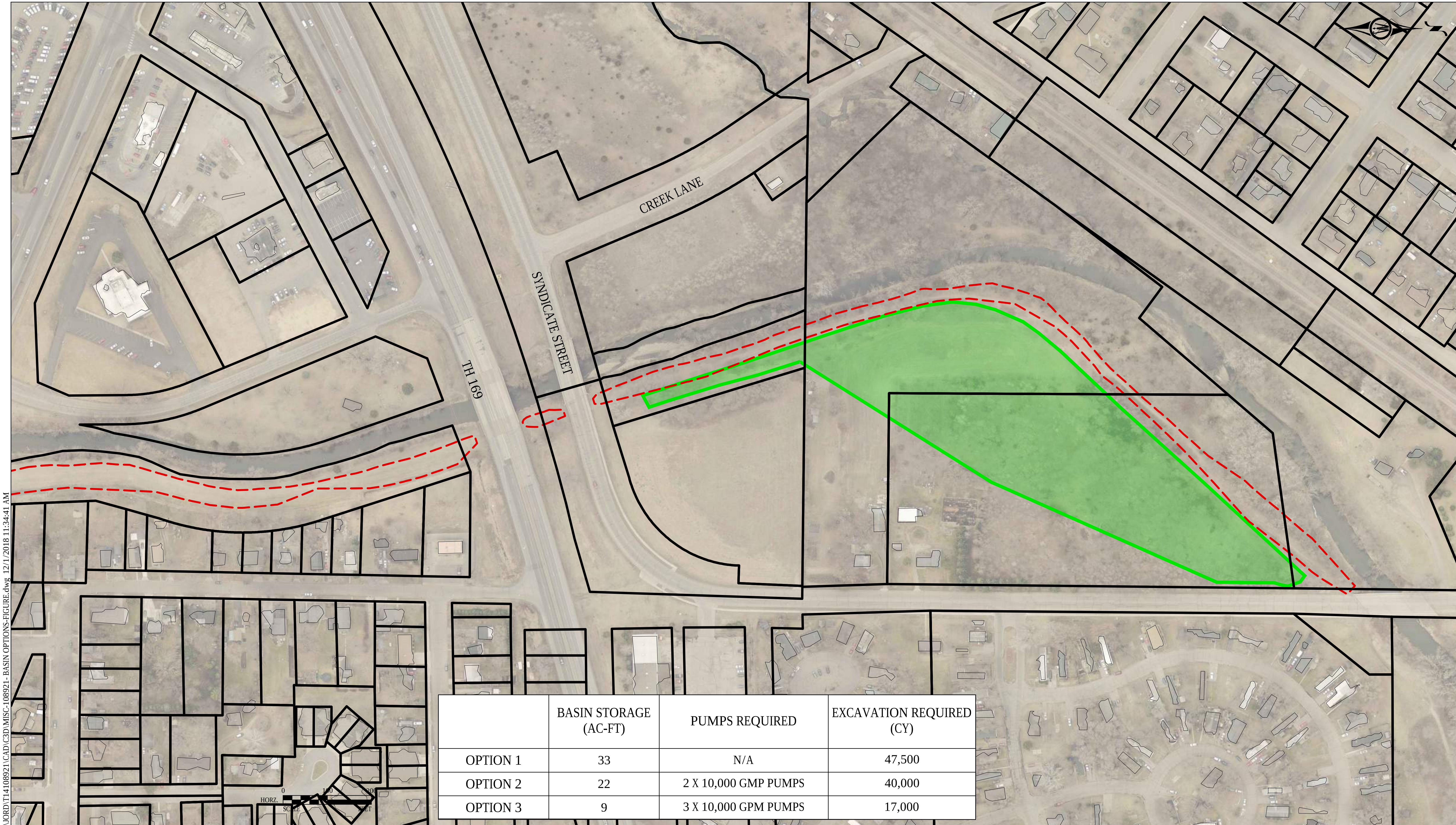
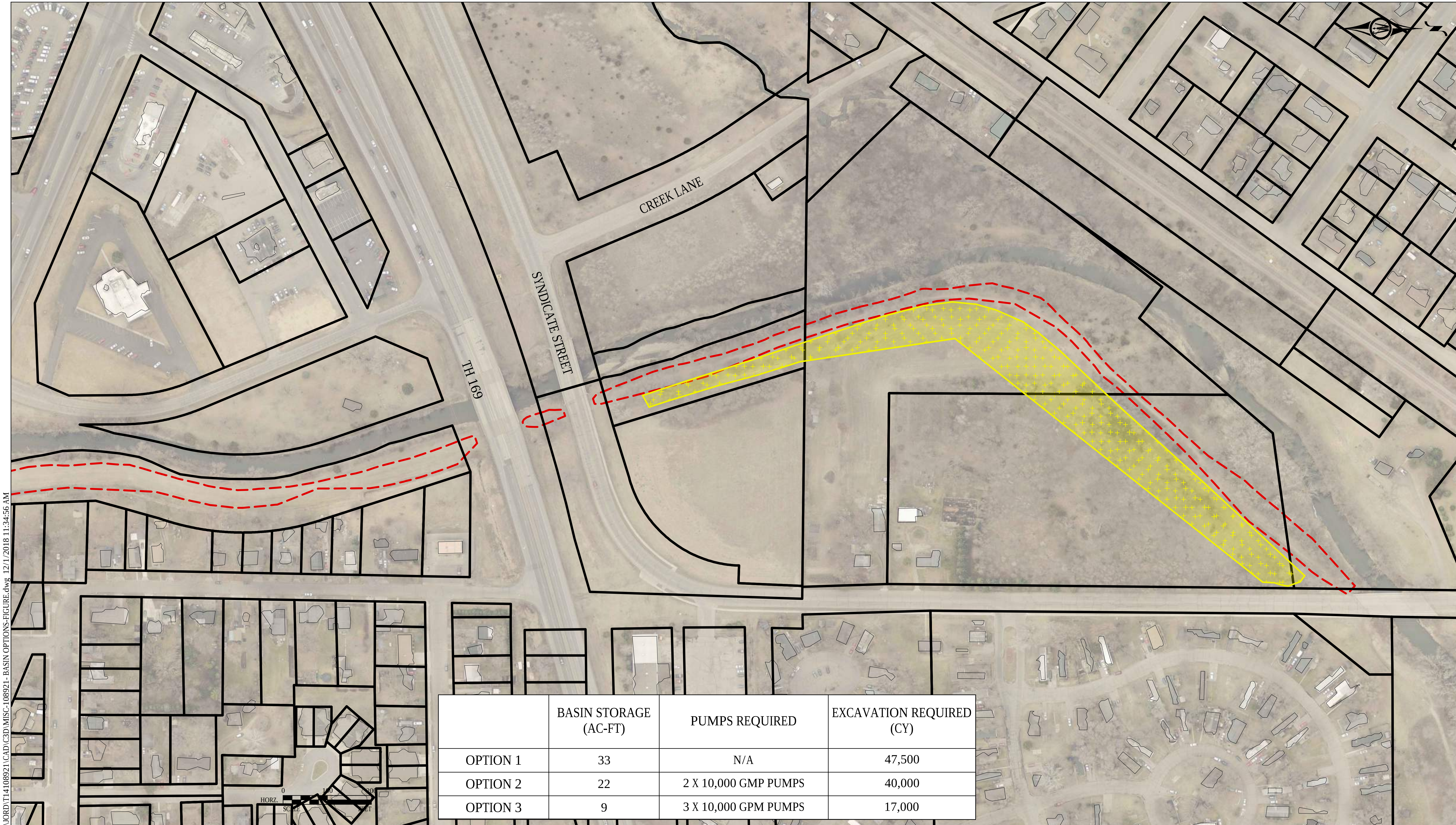


	BASIN STORAGE (AC-FT)	PUMPS REQUIRED	EXCAVATION REQUIRED (CY)
OPTION 1	33	N/A	47,500
OPTION 2	22	2 X 10,000 GMP PUMPS	40,000
OPTION 3	9	3 X 10,000 GPM PUMPS	17,000

BOLTON & MENK



	BASIN STORAGE (AC-FT)	PUMPS REQUIRED	EXCAVATION REQUIRED (CY)
OPTION 1	33	N/A	47,500
OPTION 2	22	2 X 10,000 GMP PUMPS	40,000
OPTION 3	9	3 X 10,000 GPM PUMPS	17,000

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Appendix C: Property Impacts

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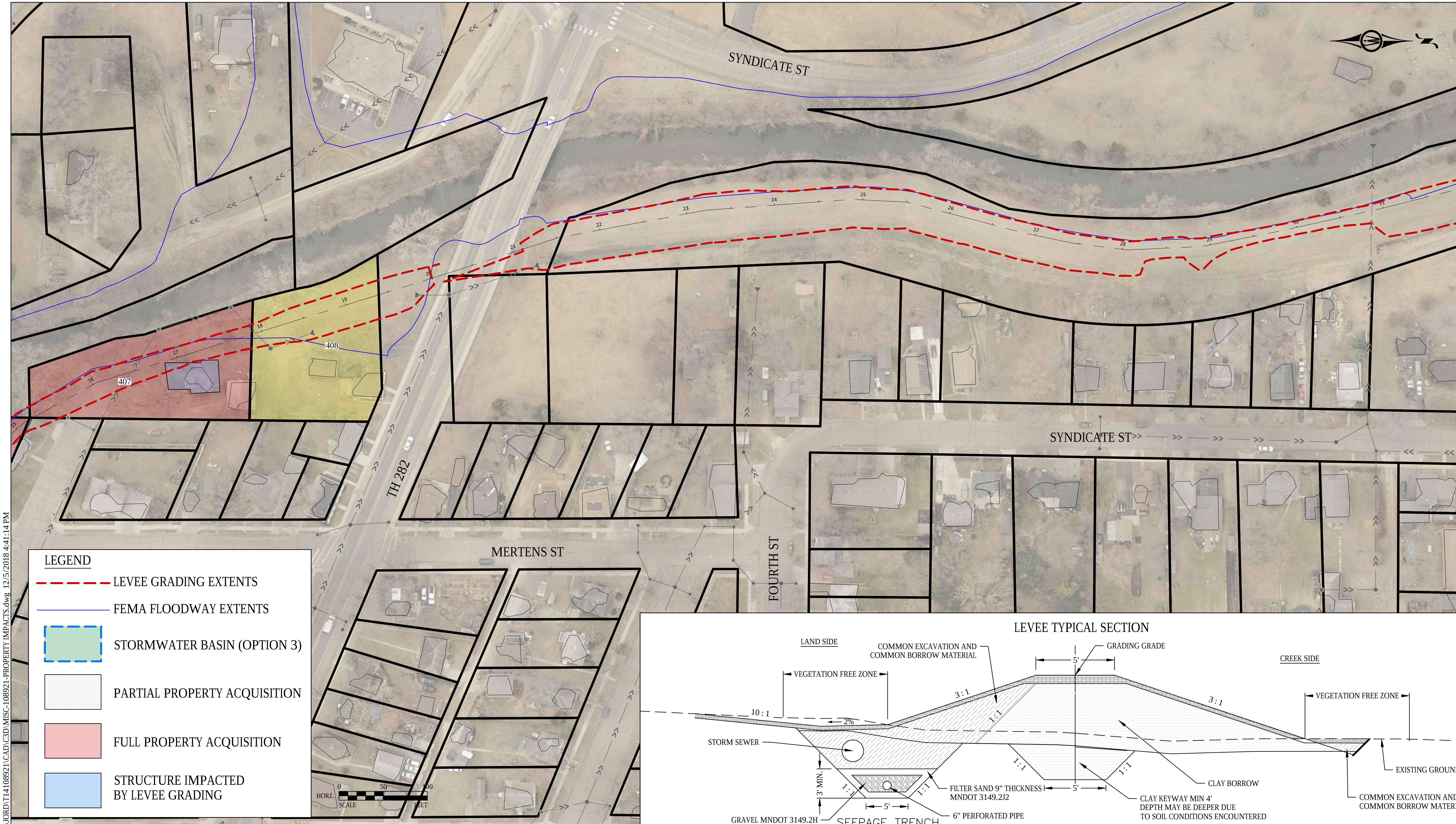
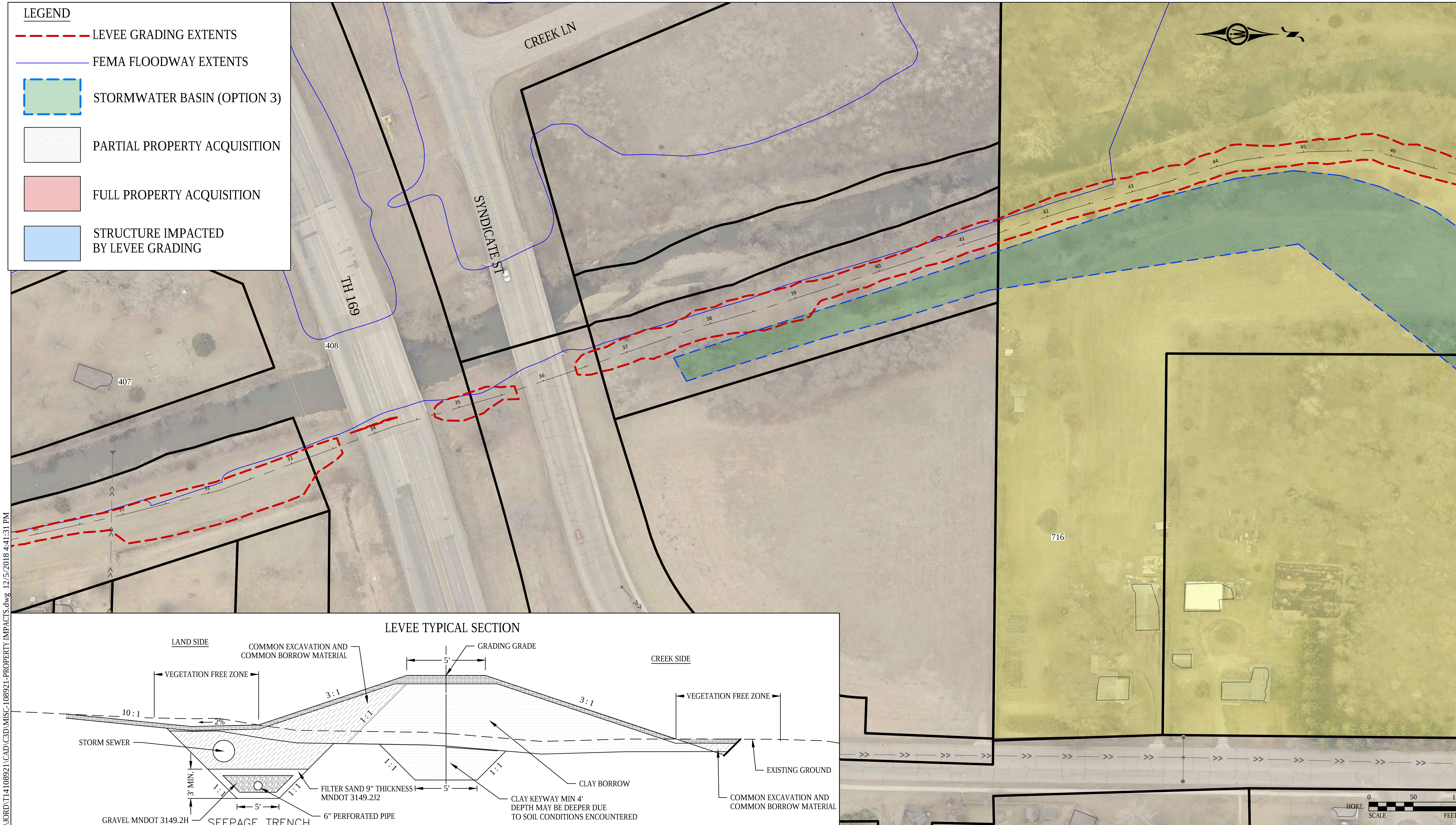

SYNDICATE ST
SYNDICATE ST
TH 282
MERTENS ST
FOURTH ST
407
408
LEGEND
LEVEE GRADING EXTENTS
FEMA FLOODWAY EXTENTS
STORMWATER BASIN (OPTION 3)
PARTIAL PROPERTY ACQUISITION
FULL PROPERTY ACQUISITION
STRUCTURE IMPACTED
BY LEVEE GRADING
HORZ.
SCALE
FEET
0
50
100
LEVEE TYPICAL SECTION
LAND SIDE
CREEK SIDE
COMMON EXCAVATION AND
COMMON BORROW MATERIAL
GRADING GRADE
5'
VEGETATION FREE ZONE
VEGETATION FREE ZONE
3 : 1
3 : 1
1 : 1
10 : 1
2%
STORM SEWER
3' MIN.
1 : 1
1 : 1
1 : 1
1 : 1
FILTER SAND 9" THICKNESS
MNDOT 3149.2J2
5'
5'
6" PERFORATED PIPE
GRAVEL MNDOT 3149.2H
SEEPAGE TRENCH
CLAY BORROW
CLAY KEYWAY MIN 4'
DEPTH MAY BE DEEPER DUE
TO SOIL CONDITIONS ENCOUNTERED
EXISTING GROUND
COMMON EXCAVATION AND
COMMON BORROW MATERIAL



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LEVEE PROPERTY IMPACTS

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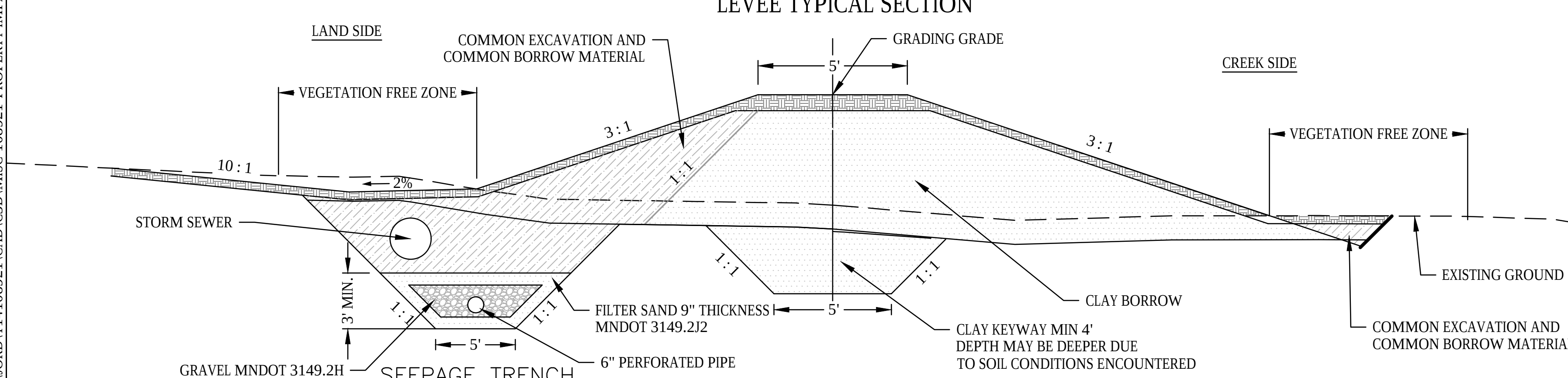
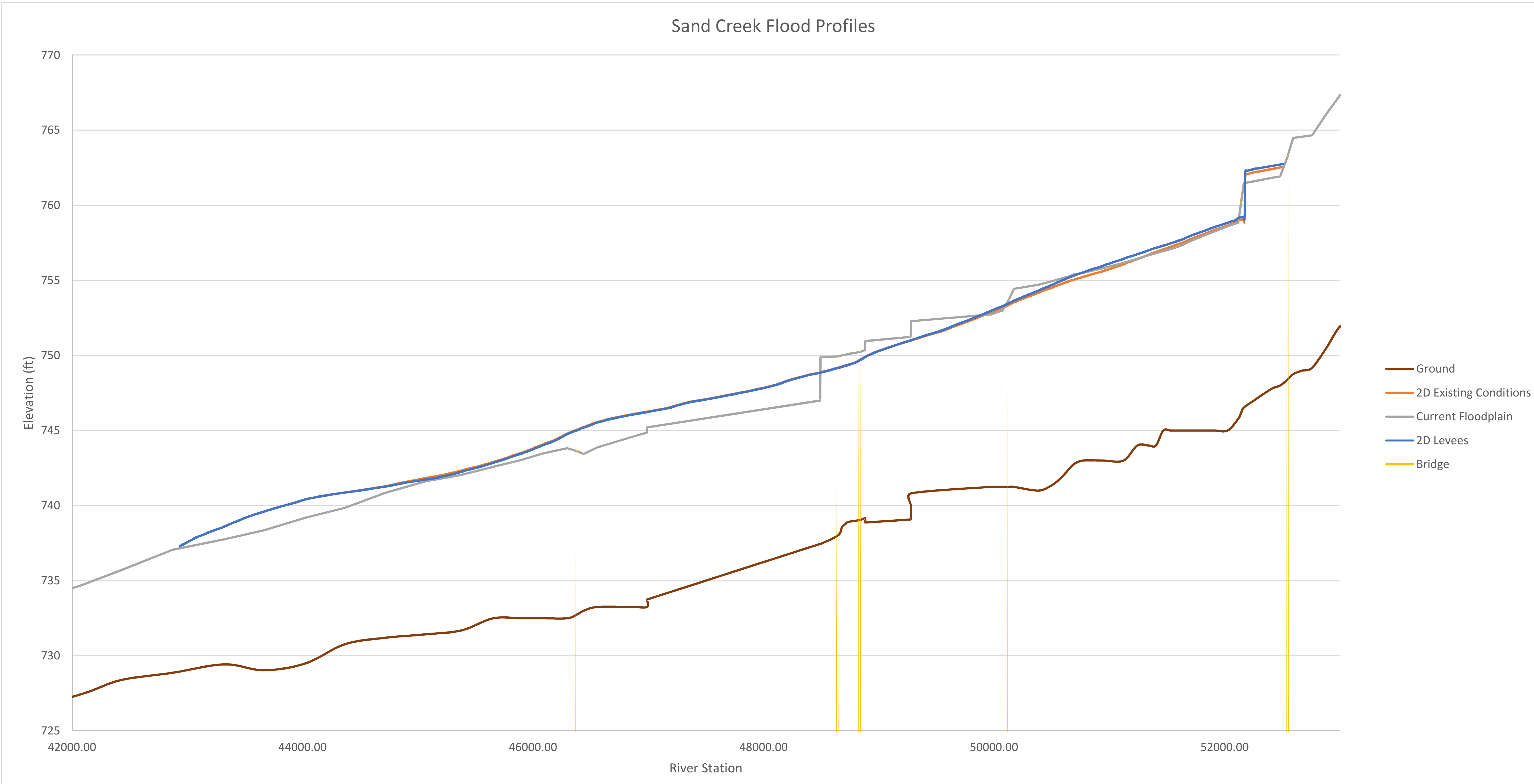
LEVEE TYPICAL SECTION



Appendix D: Flood Profile


Sand Creek Flood Profiles
Elevation (ft)
770
765
760
755
750
745
740
735
730
725
42000.00
44000.00
46000.00
48000.00
50000.00
52000.00
River Station
Ground
2D Existing Conditions
Current Floodplain
2D Levees
Bridge

Appendix E: Flood Map Comparisons

CITY OF JORDAN

Jordan Flood Protection Study

CITY OF JORDAN

Proposed Floodplain Comparison

January 2019

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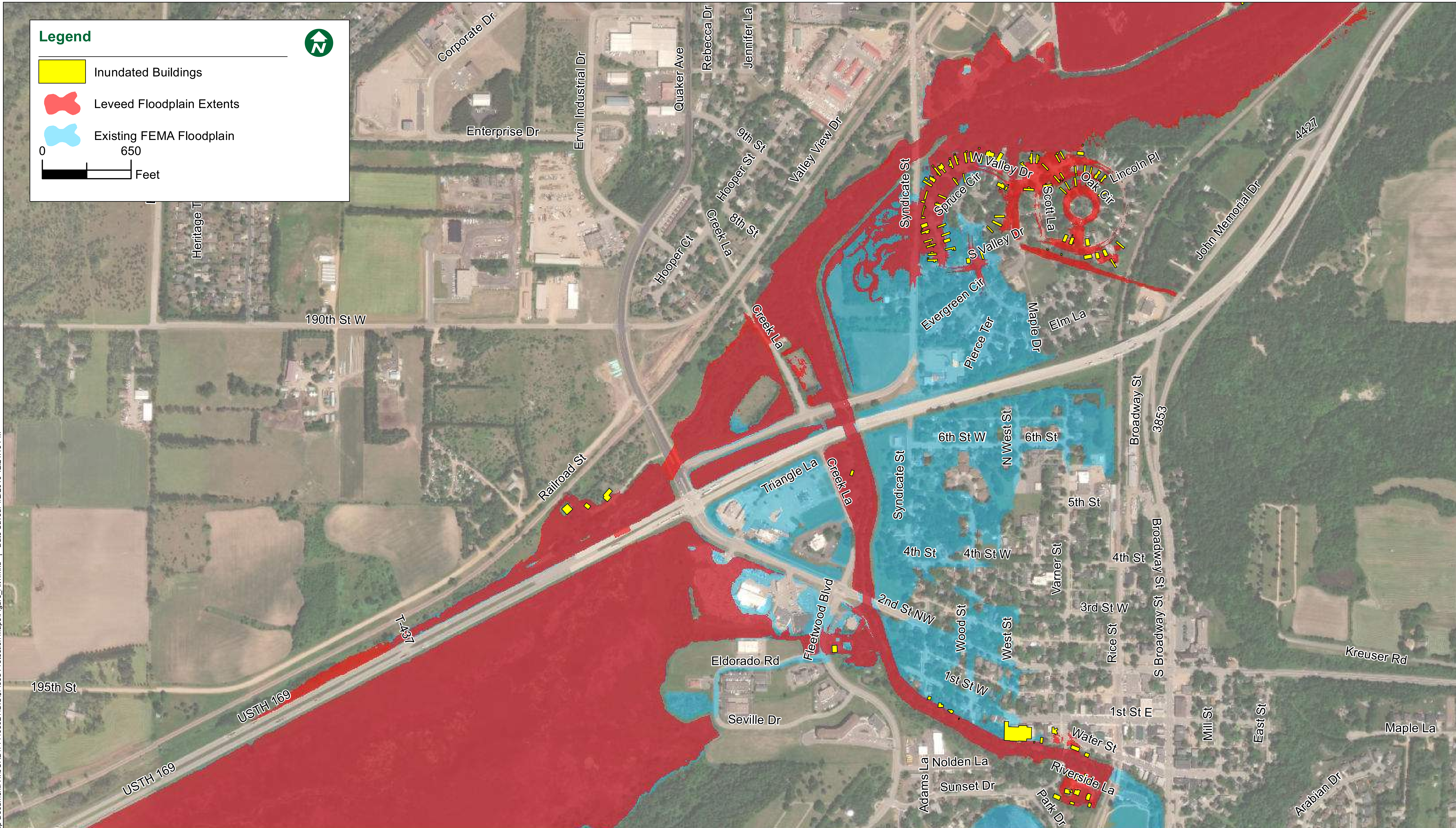

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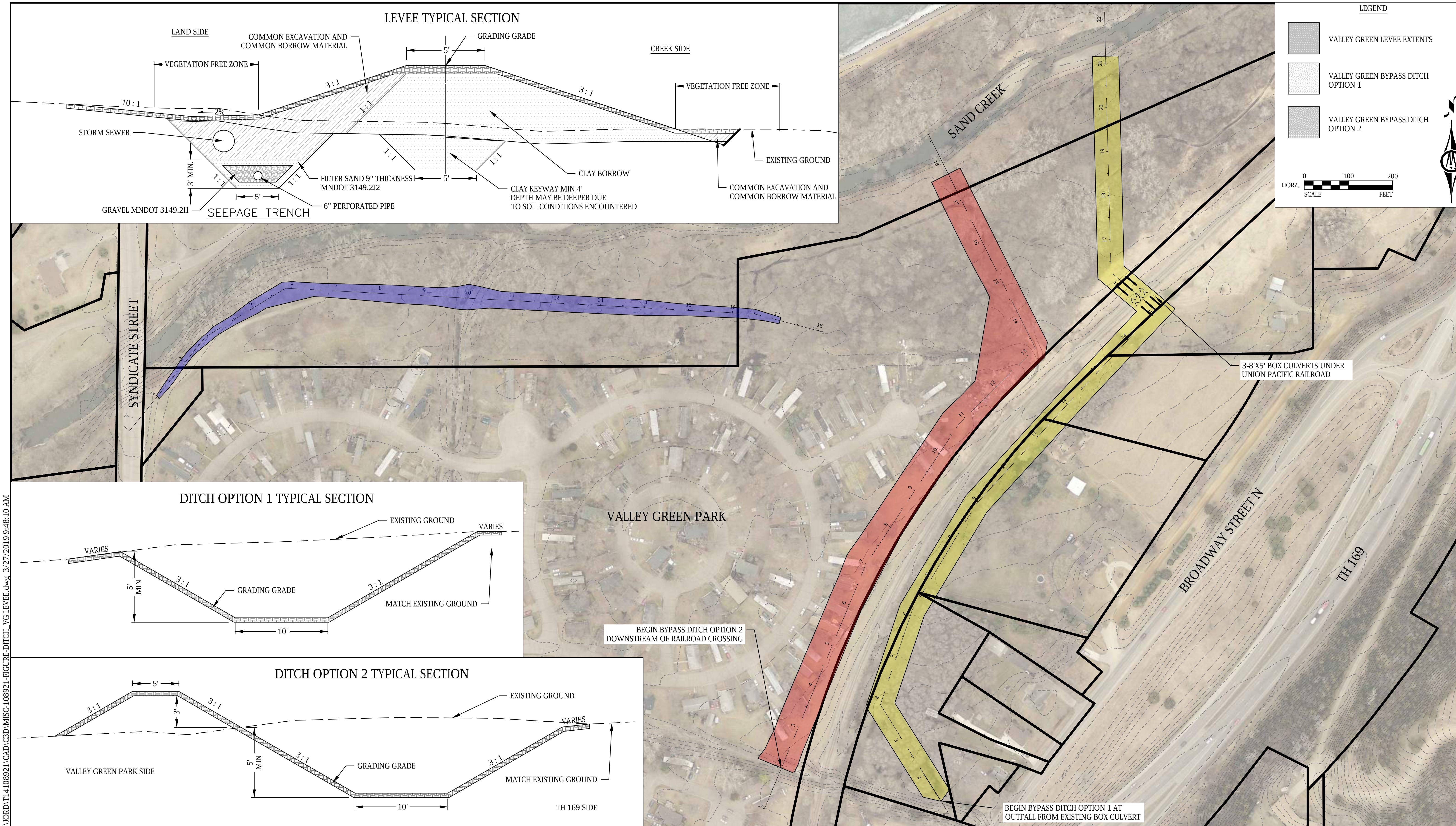
Appendix F: Valley Green Levee

VALLEY GREEN LEVEE AND DITCH

CITY OF JORDAN



Appendix G: Phase Diagram

CITY OF JORDAN

Flood Feasibility Study

City of Jordan, MN

Levee Phasing Map

April 2019

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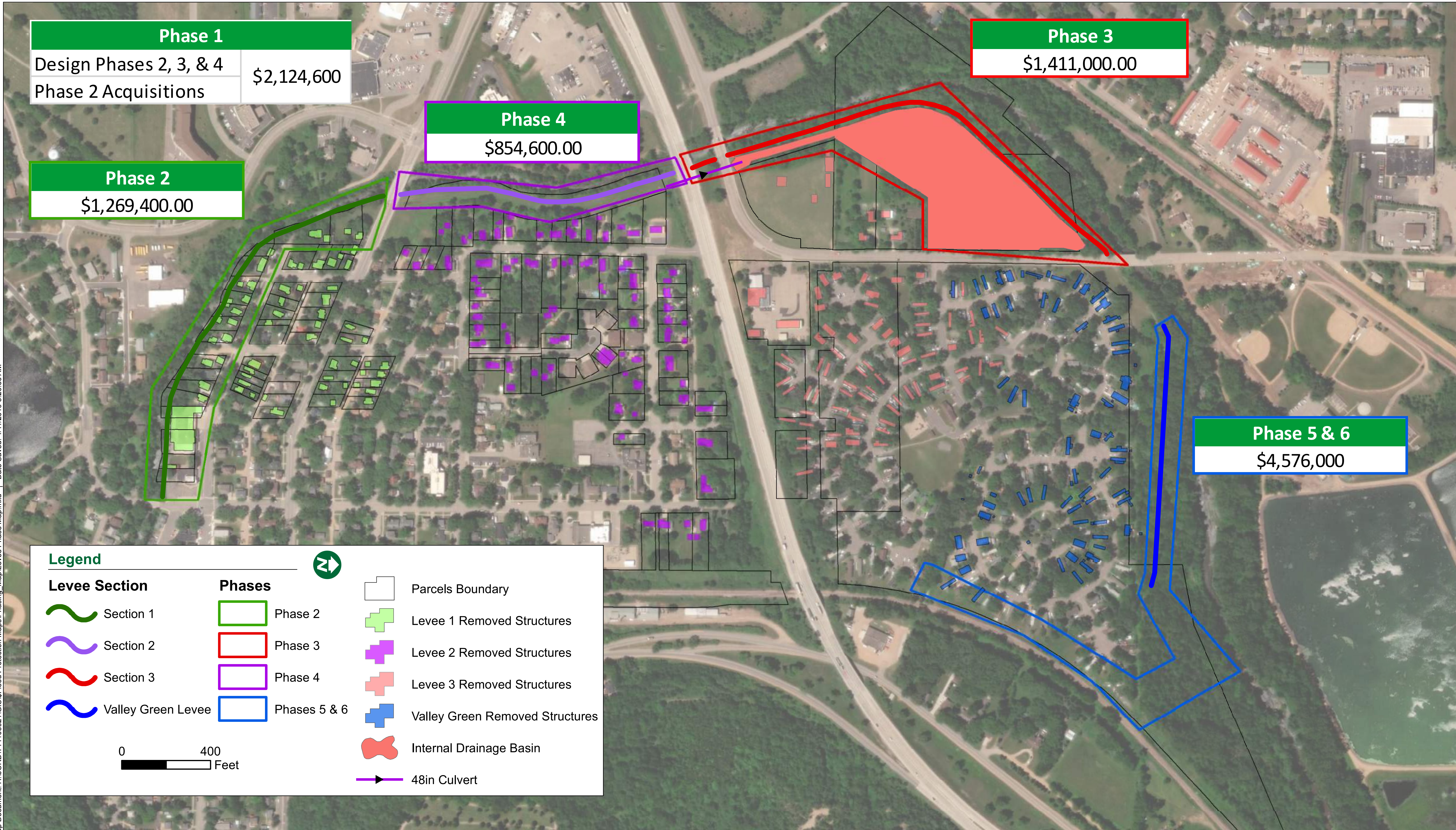

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