Erosion Stabilization Study

Study Area 3 Final Report

Prepared for the

City of Eden Prairie

October, 2008

Prepared by

SRF CONSULTING GROUP, INC.

SRF No. 0076205

TABLE OF CONTENTS

Page No.

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LIST OF TABLES **Page No.**

LIST OF FIGURES **Page No.**

Introduction

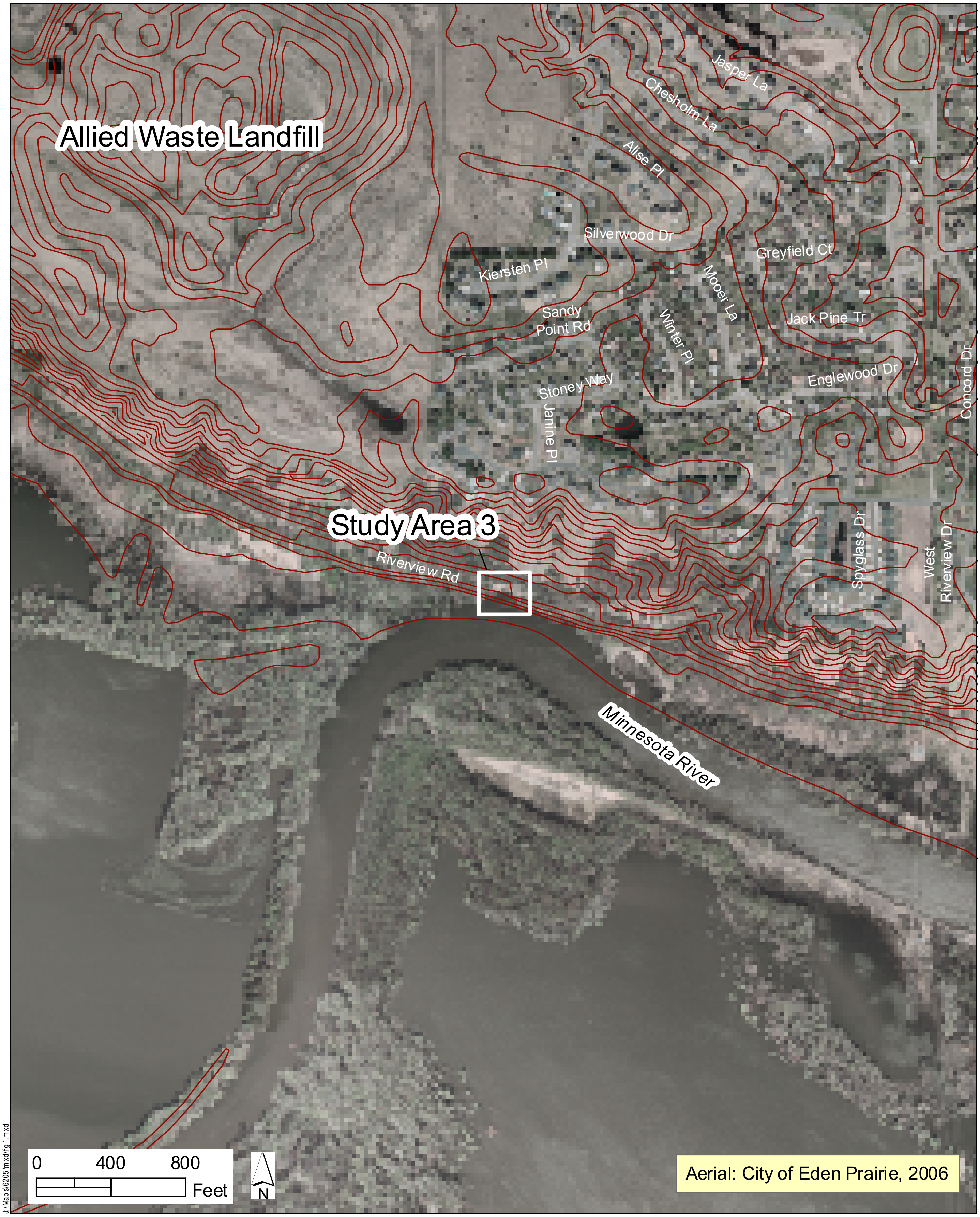
The City of Eden Prairie, in cooperation with the Lower Minnesota River Watershed District, commissioned SRF Consulting Group, Inc. to study various sites experiencing significant erosion within the Minnesota River Valley. The purpose of this study is to determine the root cause of the identified erosion problems and develop corrective measures that restore the identified sites and prevent future erosion problems. This report details the analysis of **Study Area 3**. Detailed discussions of the site background, site investigation, proposed alternatives and recommendations follow.

Background

Study Area 3 is located along the Minnesota River southeast of the Allied Waste Landfill and south of the intersection of the current Riverview Road and Janine Place (see Figure 1 for location map). Many years ago Riverview Road (unpaved) provided an important link to farms that were located along the top of a 40-ft high sandy bluff offering a picturesque view of the Minnesota River. As development occurred along the river bluffs and farms were converted to housing or returned to their natural state, use of Riverview Road slowed and eventually ceased. While the gravel road itself remained, a newer paved road located north approximately 700 feet, was named Riverview Road. Since the early 1980s, a one-mile portion of the old gravel road from Mooer Lane to the west became overgrown and eventually was closed to wheeled traffic by the City. Today, this portion of the road is used only as an unmaintained walking trail.

In the meantime, the Minnesota River in its natural cycle of flooding has shifted its meander to the north. Historical photos reveal that in the 1930's, Riverview Road was located approximately 200 feet from bluff's edge. As flooding and natural bluff erosion processes occurred, the sharp bend in the river moved north encroaching upon the bluff and, by the late 1990s, had meandered to within 100 feet of the road. By 1997, bluff erosion had accelerated and moved north another 100 feet, eventually causing the collapse of a significant section of the old gravel road into the river. The embankments of a stormwater treatment pond located just east of the bluff area were also eroded and breached, leaving the pond empty. Today, the bluff continues to erode and landslides periodically occur that threaten what remains of the road. Stabilization of the bluff is imperative in order to protect the road, walking trails, and surrounding forest.

A notable feature of the study area is the presence of flowing spring water at the base of the bluff. Spring water discharge functions to both carry soil toward the Minnesota River and to saturate the bluff toe. These dual conditions weaken the exposed face, which then is subject to collapsing when flooding occurs. Sandy soils, saturation due to the presence of groundwater, and frequent flooding are some of the causes that perpetuate the accelerated erosion at this location.



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Study Area 3 Location Map

Figure 1

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Site Investigation and Analysis

Historical Photo Analysis

While bluffs along the Minnesota River are in constant flux and geomorphic processes alter the river course over time, Study Area 3 is of particular interest because it appears to have undergone greater change than other portions of the bluff in the same area. Aerial photos taken between 1937 and 2006 provide a fascinating and revealing historic perspective. A number of observations based on qualitative analysis of the photos that appear in Appendix A can be made. First and foremost, Study Area 3 is located near the end of a very sharp 100 degree bend in the river that serves as the primary navigation channel. It can be surmised that relatively high river flow velocities, especially during flood events, do occur along the outside (northern) bank, precisely where the most severe landslides have occurred. In 1937, the northern river edge was located approximately 300 feet from Riverview Road, the river itself was about 200 feet wide and the southern bank was located approximately 500 feet from Riverview Road. In contrast, today the northern edge of the river is located approximately 100 feet from Riverview Road, the river is over 300 feet wide and the far bank is over 550 feet from the road. This historical northern migration is good evidence that erosive velocities occur along the outside bank of the river. Table 1 provides an analysis of distance from various points within the river to Riverview Road for the years in which aerial photos were obtained.

Table 1: Historical Photo Summary Analysis of Study Area 3

	Distance from Riverview Road to …		
Year	**Nearest bank water's edge (ft)**	**Furthest bank water's edge (ft)**	**Comments**
1937	300	500	
1940	300	500	
1947	300	500	River in flood stage.
1953	300	500	
1957	250	500	Well vegetated.
1964	240	500	Evidence of some vegetation removal and localized sloughing.
1969	240	550	
1979	200	550	
1984	100	550	River in flood stage. Evidence of significant vegetation removal.
1991	100	550	
1997	0	550	River in flood stage.
2000	120	450	River very low. Clear evidence of severe wasting in study area. 100-ft section of road has sloughed into valley.
2003	50	550	
2006	0	550	River in flood stage.

Historical photo analysis as summarized in Table 1 clearly show that the river has widened and migrated north towards Riverview Road. Whether by natural or human means, removal of vegetation after 1957 is also evident, leaving the slope exposed to erosive forces. Both the road and downstream pond have been compromised because of localized landslides that appear to have been exacerbated by removal of vegetation together with the effect of floods between the late 1950's and 2006. Of particular interest is the large amount of mass wasting along the bluff in the short 200-foot segment that comprises Study Area 3 and, to a lesser extent, as much as 600 feet downstream. Bluffs upstream and downstream of these areas do not exhibit as severe erosion as Study Area 3. The photos show that there may be some reverse vortex or higher velocity flow that occurs due to the combination of the sharp curve and a small spur of vegetation and soil that is present just upstream. As a result, a 150-foot long cut in the river bank formed over the years that has slowly worked its way towards Riverview Road.

Topographic Survey

A topographic survey of Study Area 3 was conducted in May, 2008 that encompassed the eroded embankment area. Survey data were utilized for slope stability analysis, design of proposed stabilization solutions, and for a proposed trail alignment.

Following the topographic survey, contours were created from the data and cross sections were cut at 25 foot intervals. Appendix B contains topographic, contour and cross-section information from the survey.

Analysis of the survey information and cross sections reveals that the most severely eroded area is limited to approximately 100 feet of roadway collapse where a bare, nearly vertical face is exposed. Figure 2a shows the most severe area of erosion. Below the vertical face, the slope gradually decreases to a more gentle grade before reaching water's edge (Figure 2b). Upstream and downstream from this area, the vertical face gradually transitions to approximately 1v:2h slope that is somewhat vegetated (Figure 2c). In addition, the survey data clearly delineates a 150-foot long cut in the river bank just below the most severe bluff landslide area.

As noted earlier, a series of springs emerge from the bluff between five and ten feet (vertical) above the water surface (as measured on May 16, 2008). Several cross sections within the most severely eroded area (station 11+25 through station 12+00 in Appendix B) show that sloughing above this elevation is somewhat more evident than in other sections.

Figure 2a

Figure 2b

Figure 2c

Soil and Slope Stability Analysis

Gale-Tec Engineering performed soil borings for Study Area 3 in May, 2008 at two locations near the eroded embankment. The complete soil investigation report including the boring logs can be found in Appendix C. A soil and slope stability analysis was also completed for the area using the cross section that best represents the most vertical (most unstable) face. The report makes the following summarized observations:

- Soils consist of 20 to 35 feet of loose to medium dense silty sands and 30 to 35 ft of medium dense silts. Below this is evidence of dense fine to medium sand. These soils have low in-situ stability factors as evidenced by the low N-values reported in the soil boring logs.
- Groundwater was encountered between 40 and 55 feet down in borehole B-1 and approximately 25 feet down in borehole B-2. This is consistent with the vertical elevation where springs have been observed emerging from the slope.
- The two major contributors or triggering factors to landslides are saturation of soils due to groundwater seepage together with the rise and fall of river levels, and loss of soil material at the slope toe. As material is removed from the toe due to river currents, saturated soils easily erode and slide downwards.
- Slope stability analysis suggests that the steepest slopes (greater than 1v:2h) are consistently on the verge of failure. A global stability factor of safety of just over 1.0 suggests that if disturbed by any of the triggering factors described above, a land slide will occur. Only surface vegetation, root systems, and the presence of residual moisture currently hold the soil in place.

River Flood Levels

An analysis of river flood levels was also completed in order to understand where velocity forces may arise and to what extent slope saturation may occur. Table 2 provides approximate river flood elevations computed from the Hennepin County Flood Insurance Study (FIS) – Bloomington Ferry Bridge cross section at river mile 16.9. Study Area 3 lies approximately 2.25 miles up river from the bridge at river mile 19.15. Since no FIS has been completed for the Minnesota River in the vicinity of Study Area 3, water surface slopes were extended from the Bloomington Ferry Bridge elevations to obtain approximate elevations at Study Area 3.

Table 2: Estimated Flood Elevations at Study Area 3

Flood Frequency	Bloomington Ferry Bridge Flood Elevation (ft)	Estimated Water Surface Slope (ft/mile)	Estimated Study Area 3 Flood Elevation (ft)
10-year	710.5	0.15	710.8
50-year	720.7	0.25	718.6
100-year	718.0	0.25	721.3
500-year	727.6	0.50	728.7
May 16, 2008	-	-	700.0

Eden Prairie is located near the confluence of the Minnesota and Mississippi rivers. The Minnesota River is over 350 miles long with a drainage area that includes much of southwest and west-central Minnesota. With only 19 miles remaining from Study Area 3 to its confluence with the Mississippi, it is not surprising that the river experiences significant flood stages. As Table 1 suggests, infrequent flood stages as high as 28 feet, and more often as high as 10 feet can occur near the site of Study Area 3. While this study did not quantify river hydraulics or velocity profiles, analysis of both historical photos and the FIS quickly reveals that erosive velocities are likely to occur along the outside river bank especially during flood stage.

Historical photos showing high water levels and the flooding stage analysis in Table 2 suggest that significant flood stages frequently occur. With flooding comes the inevitable bluff soil saturation. This, together with river bank erosion that arises from high velocities, leads one to conclude that this phenomenon must be a significant contributor to the general bluff erosion.

Cause Analysis

In summary, there are a number of factors that contribute to bluff instability. These include:

- Low internal soil strength properties;
- Removal of vegetation;
- Frequent river flooding;
- Soil saturation due to flooding and the presence of springs;
- High velocities along the outside bend of the river during flood stage; and
- Presence of steep slopes.

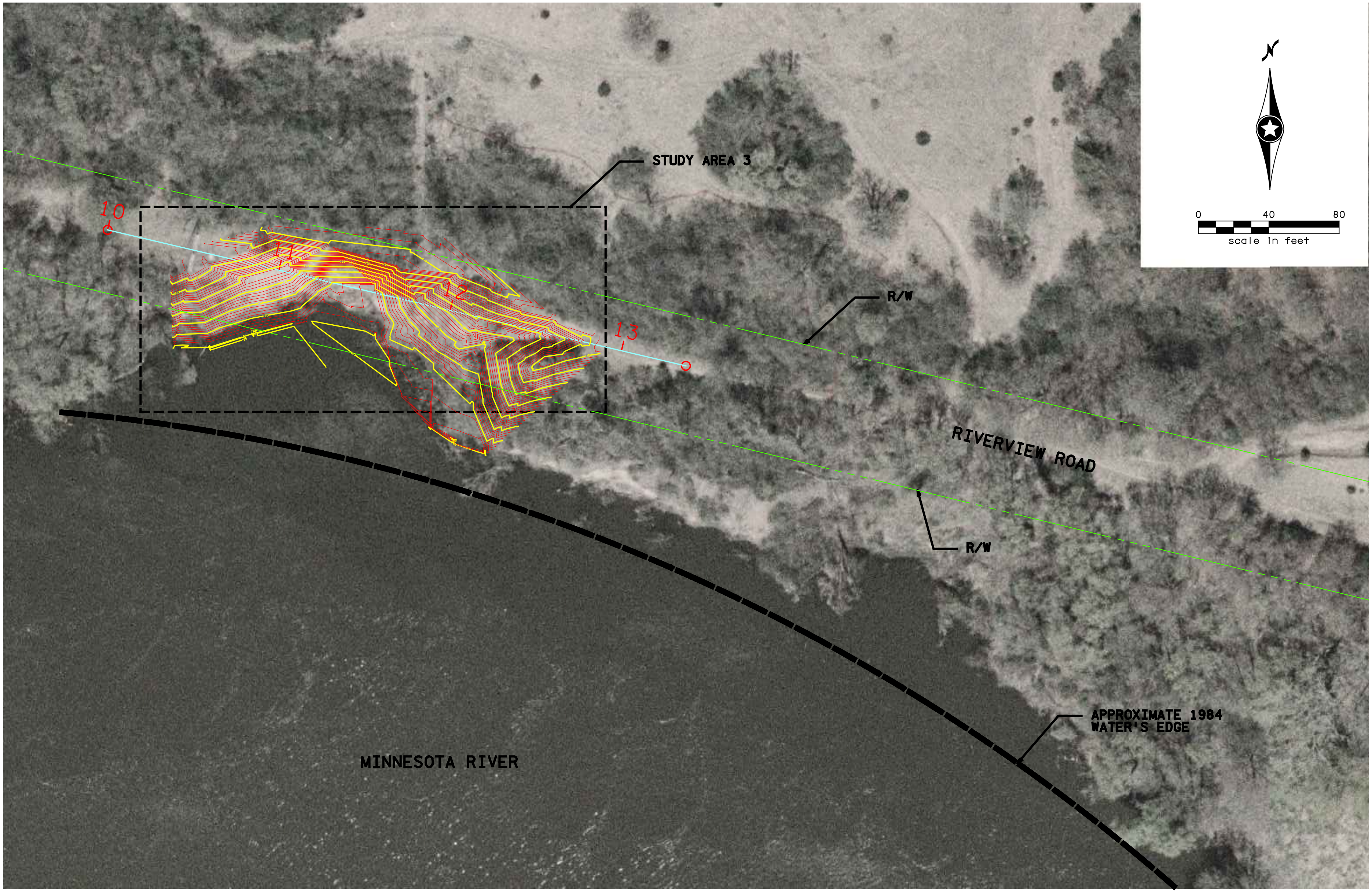
A more precise cause of erosion in this location is important to consider yet it is difficult to determine without more data collection and analysis. All bluffs along this reach of the river experience saturation during floods, but there is little evidence to suggest that Study Area 3 soils are significantly different (i.e. weaker) than other areas. Bluff slopes upstream and downstream are also similar. Bluff slope and soil type, then, may not be the major components acting to erode the area. What is perhaps unique to Study Area 3 is the presence of springs near the toe of the bluff and the 100 degree bend in the river. More than likely, it is a combination of localized erosive velocities as the river flows around the bend and the permanent soil saturation that occurs near the springs that has accelerated bluff erosion, which would otherwise occur more slowly from flooding saturation/desaturation, low in-situ soil shear strength, steep slopes, and the removal of vegetation.

Alternatives Investigation

Permanent stabilization of the slopes, according to the geotechnical analysis, should be designed such that the global stability factor of safety (FS) of 1.2 under short-term conditions and 1.3 under long-term conditions is attained. To achieve a stable slope, either the driving force (i.e. force of gravity acting against soil resistive forces) must be balanced or the soil properties must be altered to increase the resisting forces. Arresting and containing the destabilizing forces due to soil saturation – either those stemming from springs or from river flooding – must be at the core of any stabilization solution. Furthermore, the bluff toe must be stabilized – preferably with riprap – so that river velocity forces will not undermine the stabilized slopes. A flow medium underneath the riprap would also contain and properly channel spring outflow.

Toe Location

Since a localized cut in the river bank has formed and mass wasting has occurred over the years, it is important to consider where the toe of the stabilized embankment should be located. Ensuring a smooth curve through which the river travels is of greatest importance. Yet the final riverbank position would not necessarily have to be at its original location. Figure 3 shows where the 1984 water's edge may have been prior to the bluff failure. Before 1984, the roadway had not been compromised and the river bend was still somewhat smooth. After 1984, landslides accelerated and by 1991 the roadway had been compromised. It is reasonable, then, to assume that water's edge prior to 1984 represents a smooth, somewhat stable transition through the river bend. In order to accomplish this, the existing toe would need to be placed approximately 100 feet from the centerline of Riverview Road, thus pushing the toe out into the river over 50 feet. Unfortunately, a significant amount of imported soil and great expense would be necessary to backfill and return the 200 foot area that is most severely eroded to the 1984 condition. Filling the cut area to a lesser extent and armoring it – thereby providing a reasonable transition as the river bends through 100 degrees – is, however, quite possible. This would reduce or eliminate vortex currents that may have contributed to the original failure. Placing the proposed toe approximately 50 feet from the center of Riverview Road and armoring with riprap would provide a reasonably smooth and stable transition while limiting excessive importation of backfill.



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Study Area 3 Existing Conditions

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Figure 3

Job #
9/18/2008

Alternative Selection Criteria

Several criteria were used to select the alternatives that were analyzed in this report. They included:

- Constructability given steep slopes, high embankment, and close proximity to the river.
- Ability to contain and safely conduct groundwater seeps to the river.
- Ability to resist erosive river velocities and to remain stable during floods.
- Degree to which construction would extend beyond the northern Riverview Road right of way. While extending beyond the roadway right of way is not considered by the City to be an issue *per se*, topography continues to increase in elevation to the north, which could have significant implications on construction cost.
- Balance earthwork as closely as possible.
- Cost must be as low as possible while still providing a permanent solution.
- Long term maintenance must be minimal.
- Factor of safety must be 1.3 or greater for long term conditions.

Alternative Identification

A number of solutions for slope stabilization were considered based on the above criteria. Two general categories of solutions are: 1) Regrading to a more gentle slope in order to balance driving and resistive forces, and, 2) Increase resistive forces of the soil through the use of constructed, stabilized slopes.

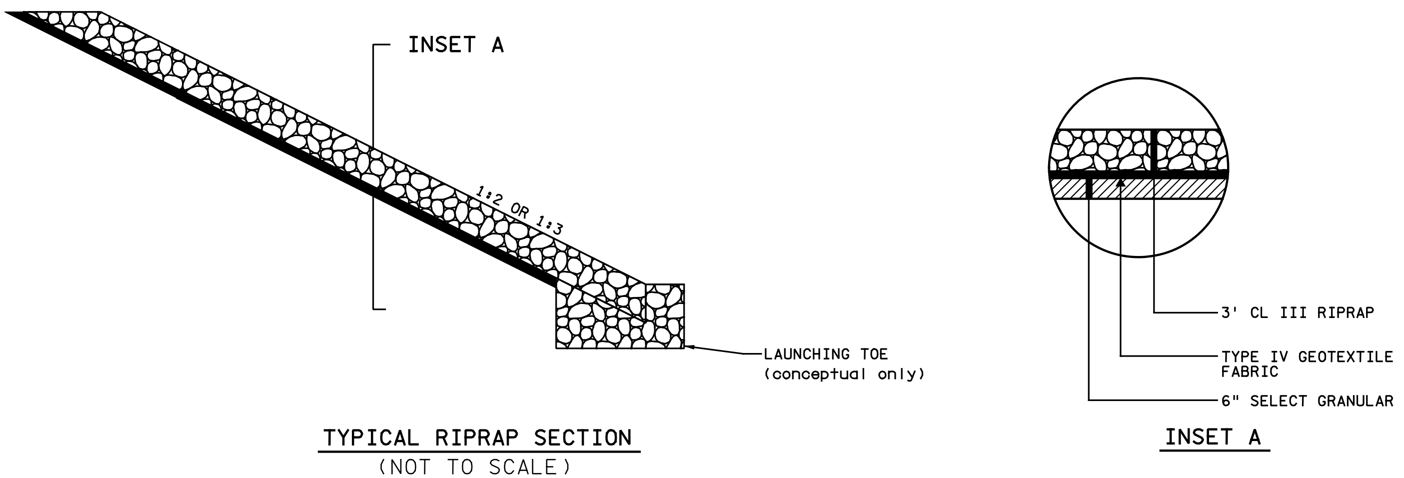
Regrading. Regrading would require construction of slopes that are 1v:3h or less. This option would not require stabilization other than temporary erosion control and establishment of good, permanent surface vegetation. While this option appears relatively straight forward, there are significant implications to constructing a slope that is much flatter than the surrounding bluff slopes. A 1v:3h design was considered and is analyzed as Alternative 1.

Structurally Stabilized Slope. Because of the relatively weak soils, construction of slopes greater than 1v:3h require the use of mechanically or structurally stabilized solutions. Consideration of retaining or typical mechanical stabilized earth (MSE) walls was quickly rejected because of expense, difficulty of construction on such steep, high embankments, and the need to remove and replace large quantities of in-situ soils with granular backfill. Soil nails and helical anchors were also considered but again rejected due to expense and difficulty of construction on steep, high embankments. A particular type of MSE application referred to as Reinforced Soil Slope (RSS) does, however, lend itself well to this situation. It is constructed utilizing a geogrid system together with granular backfill, and can easily be built under steep, high embankment conditions. Both 1v:2h and 1v:1h slopes were analyzed together with a 1v:2h riprap toe reinforcement. The 1v:2h construction proved to be difficult in terms of earthwork balance and upslope construction limit extents. A benched, 1v:1h system provided a more reasonable earthwork balance and did not extend far outside the existing roadway right of way. The benched, 1v:1h option was carried forward as Alternative 2.

Toe Stabilization. Toe protection beyond a typical vegetated system is also recommended in order to permanently stabilize this portion of the riverbank. The geotechnical report preliminarily identified a Class III riprap as adequate for this protection. Riprap class would need to be reassessed during preliminary design when river hydraulics are studied in more depth. Extension of the riprap toe upwards from the water surface to at least the elevation of spring emergence (approximately elevation 710.00 feet) is also recommended. It is more typical to extend this type of stabilization to the 100-year flood stage (elevation 721 feet) although extending the riprap to a lower elevation should be considered during preliminary design as a cost containment measure. Determination of this elevation would require coordination with state (MnDNR, Lower Minnesota River Watershed District) and federal (USACE) agencies. The riprap should be 3 feet thick with a six-inch granular filter and a Type IV geotextile. The granular filter is intended to provide a solid base upon which the riprap is placed and to serve as a controlled, stable conduit through which groundwater seep flow can travel. The toe of the riprap is designed as a “launching toe” and is recommended to extend down to scour depth. Since a river hydraulic analysis was not completed for this feasibility study, scour depth is unknown. Therefore, the riprap toe is shown in Appendixes D and E extending approximately 5 feet below the water surface level as surveyed on May 16, 2008. This places the bottom of the launching toe at elevation 695 feet. However, further investigation is necessary to determine a more precise toe depth and toe design in light of hydraulic factors and the presence of saturated soils. A typical riprap cross section is shown in Figure 4.

Both alternatives meet the long-term FS=1.3 criteria and both include a Class III riprap toe protection extending to the 100-year base flood elevation (approximately 21 vertical feet), with a granular seepage blanket installed to direct spring effluent safely towards the river.

Riverview Road is used as an unmaintained walking trail. Unfortunately, due to the collapse of a 200-foot section of the road, a new trail had to be blazed around the area by intrepid walkers. In the future, once stabilization is complete, a walking trail can be constructed around the area that suits more casual walkers and perhaps bikers as well. Figure 5 provides a concept of where the trail might be constructed to avoid the stabilized area and provide ample safety for trail users.



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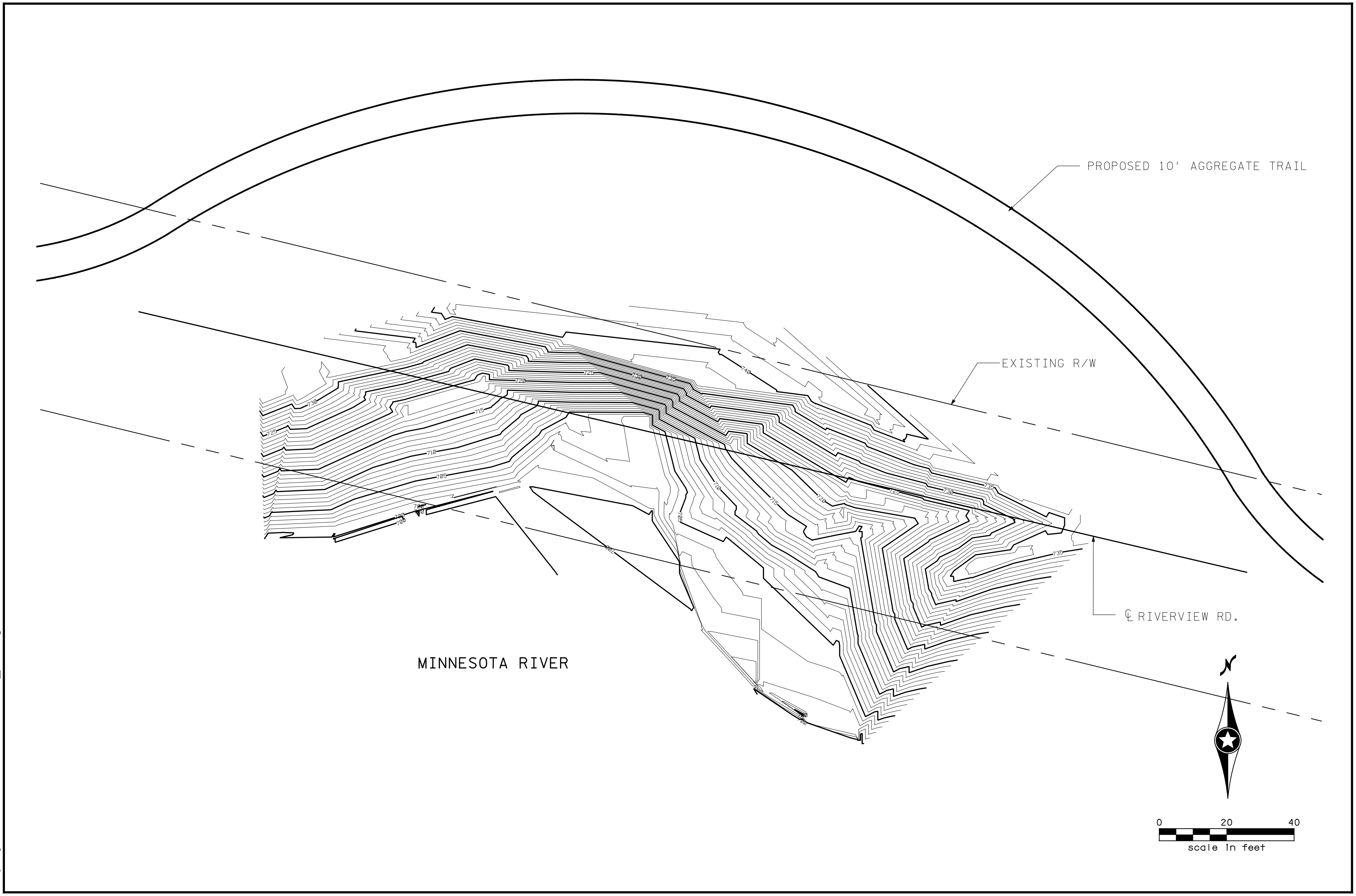
Study Area 3: Riprap Typical Section

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Figure 4

Job #6205
10/15/2008



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Study Area 3 Proposed Trail Alignment

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Eden Prairie, MN

Figure 5

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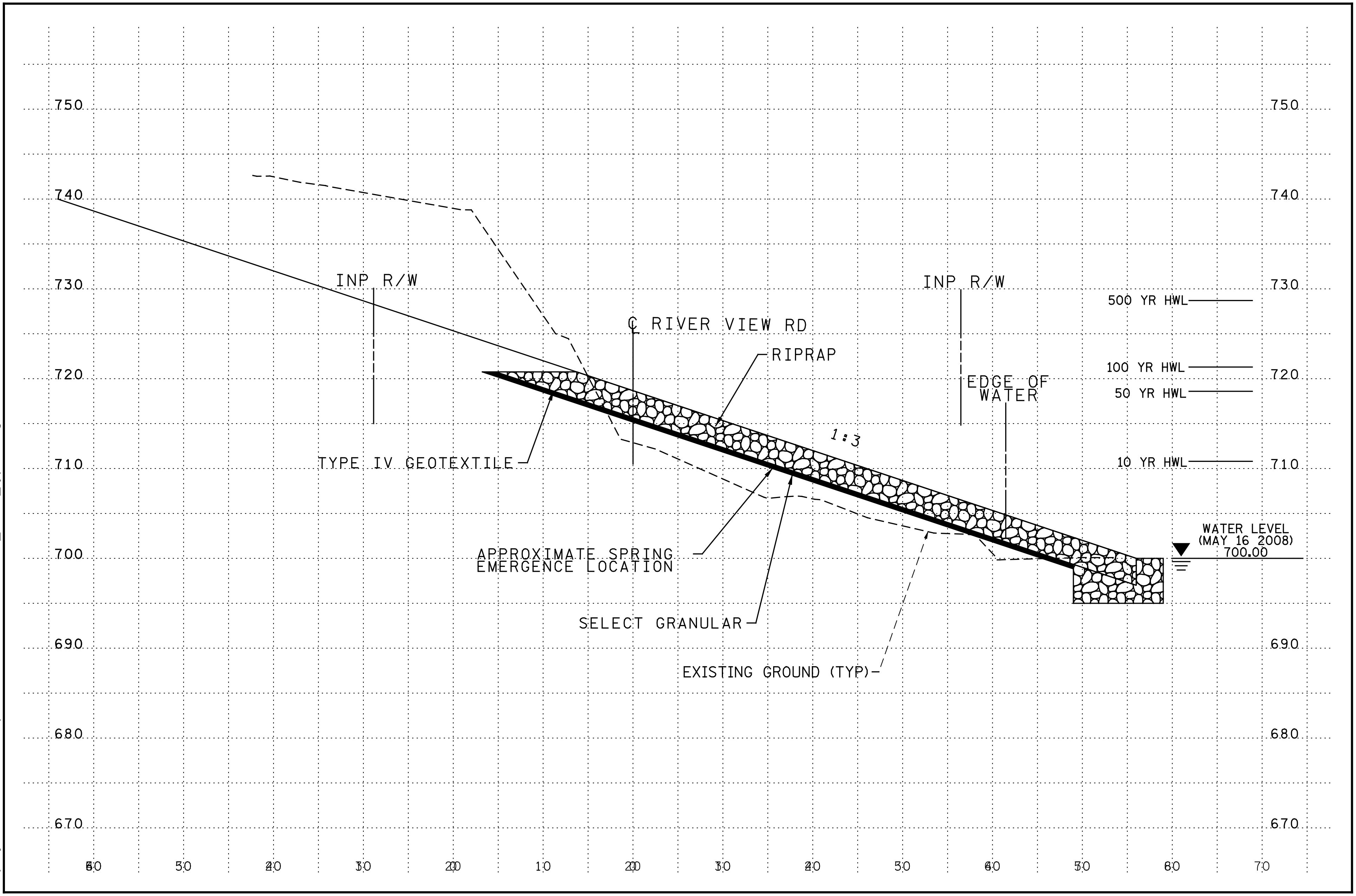
Alternative 1: Regrade slope to 1v:3h

By regrading the slope, driving forces are reduced and balanced with soil resistive forces. Appendix D includes a layout and set of cross sections that show the extents of this option. Figure 6 provides a typical section of Alternative 1.

Utilizing riprap up to the 100-year flood elevation provides a well stabilized toe. Slopes are easy to work on and construction is relatively straight forward with no special techniques required.

Construction limits extend over 40 ft north of existing right of way, however. This leads to extensive earthwork and wastage of soils with a net excavation (export) of over 6,000 cubic yards. Because this 200 foot section is at a 1v:3h slope while the existing bluffs upstream and downstream are at a 1v:2h, surface runoff would be directed towards the 1v:3h slope, causing significant flow and erosion to occur. In addition, a riprap volume of nearly 2,300 cubic yards is very high. Estimated cost of Alternative 1 is $433,615, which includes a 20 percent construction contingency and a 20 percent engineering design, permitting, and construction administration cost. The largest portion of the estimate is riprap (32 percent) and earthwork (23 percent) to flatten the existing slopes to 1v:3h.



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Study Area 3: 3:1 Regrading Typical Section

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Eden Prairie, MN

Figure 6

Job #6205
10/15/2008

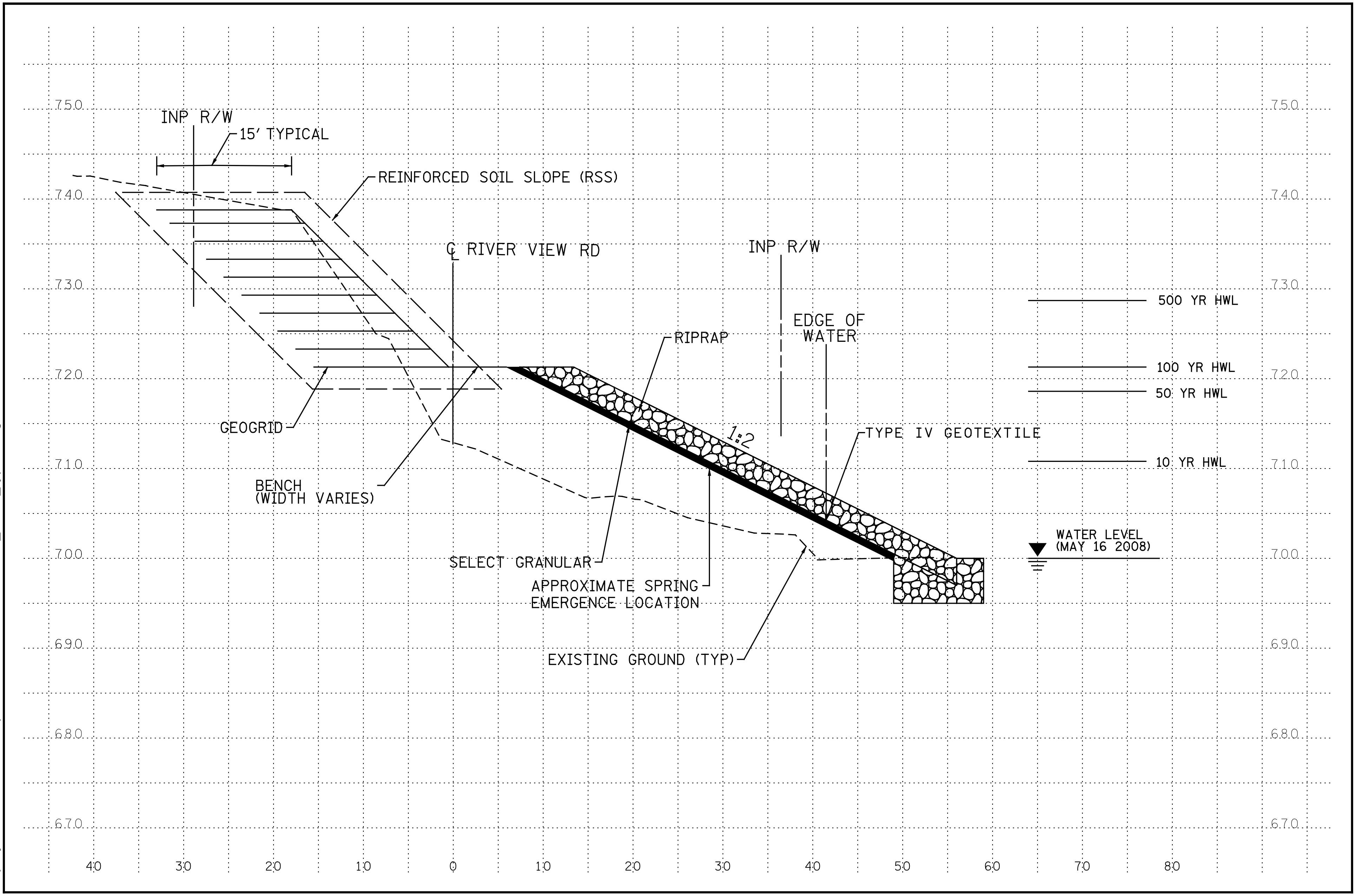
Table 3: Alternative 1 Estimate of Probable Construction Cost

ITEM NUMBER	ITEM DESCRIPTION	UNITS	QUANTITY	AVERAGE PRICE	COST
2021.501	MOBILIZATION (5%)	LS	1	$ 14,340.00	$ 14,340.00
2101.506	GRUBBING	ACRE	0.6	$ 2,100.00	$ 2,400.00
2101.511	CLEARING	ACRE	0.6	$ 2,400.00	$ 2,800.00
2105.501	COMMON EXCAVATON	CY	6650	$ 15.00	$ 99,750.00
2105.522	SELECT GRANULAR BORROW (CV)	CY	352	$ 17.50	$ 6,160.00
2105.525	TOPSOIL BORROW	CY	244	$ 21.00	$ 5,120.00
2105.601	DEWATERING	LS	1	$ 2,000.00	$ 2,000.00
2118.501	AGGREGATE TRAIL	LS	1	$ 19,980.00	$ 19,980.00
2511.501	RANDOM RIPRAP CL III	CY	2280	$ 60.00	$ 136,800.00
2573.502	SILT FENCE MACHING SLICED	LF	230	$ 2.00	$ 460.00
2573.505	FLOATATION SILT CURTAIN MOVING WATER	LF	230	$ 16.00	$ 3,680.00
2573.601	EROSION CONTROL SUPERVISOR	LS	1	$ 5,000.00	$ 5,000.00
2575.501	SEEDING	ACRE	0.3	$ 500.00	$ 500.00
2575.523	EROSION CONTROL BLANKET CAT 4 & 6	SY	1463	$ 1.40	$ 2,048.00
2575.608	SEED MIXTURE 325	LB	25	$ 3.30	$ 84.00
				Sub-total	**$ 301,122.00**
Contingency (20%)					$ 60,224.00
				ESTIMATED TOTAL CONSTRUCTION COST	**$ 361,346.00**
Engineering Design, Geotechnical Investigation, Bid Document, Permitting, Construction Administration (20%)					$ 72,269.00
				TOTAL ESTIMATED COST	**$ 433,615.00**

Alternative 2: RSS with 1v:1v slopes

This alternative envisions the construction of a 1v:2h riprap toe, a horizontal bench above the riprap, and then a 1v:1h RSS system that ties into the roadway. Appendix E includes a layout and set of cross sections that show the extents of this option and Figure 7 provides details of a typical section.

Utilizing riprap up to the 100-year flood elevation provides a well stabilized toe and the slope is easily constructed. A bench provides an area from which to construct the RSS. A 17-foot high (on average) 1v:1h RSS is easily constructed in lifts. Excavation limits extend north of the roadway right of way only a short distance, although the proposed trail would need to be set some distance away from such steep slopes. Until further investigations are completed during preliminary design, it is assumed that the RSS will require import of a modified granular material and that existing soils can not be used. As a result, there is a net export of approximately 500 cubic yards, which is much less than the 1v:3h option. Unlike Alternative 1 where earthwork cannot be balanced, Alternative 2 sections could possibly be shifted or slightly modified to more closely balance earthwork. Additional soils and geotechnical analysis may indicate that existing soils can be utilized as structural backfill for the RSS system instead of using an imported modified granular backfill, which would result in a significant decrease in construction costs. Surface runoff from above could easily be directed away from the area and the transition into the existing 1v:2h bluff is more natural. Riprap volume of about 1,600 cubic yards, while still considerable, is 30 percent less than Alternative 1. Estimated cost of this option is $413,938. The two highest cost items are riprap (24 percent) and the RSS system (20 percent). A 20 percent construction contingency is assumed, and the 25 percent design, permitting and CA cost includes additional geotechnical investigations and design of the RSS system.



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Study Area 3: 1:1 Reinforced Soil Slope with Bench Typical Section

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Figure 7

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10/15/2008

Table 4: Alternative 2 Estimate of Probable Construction Cost

ITEM NUMBER	ITEM DESCRIPTION	UNITS	QUANTITY	AVERAGE PRICE	COST
2021.501	MOBILIZATION (5%)	LS	1	$ 13,140.00	$ 13,140.00
2101.506	GRUBBING	ACRE	0.4	$ 2,100.00	$ 2,100.00
2101.511	CLEARING	ACRE	0.4	$ 2,400.00	$ 2,400.00
2105.501	COMMON EXCAVATION	CY	2465	$ 15.00	$ 36,975.00
2105.601	REINFORCED STABILIZED SOIL (RSS)	SF	4140	$ 20.00	$ 82,800.00
2105.522	SELECT GRANULAR BORROW (CV)	CY	215	$ 17.50	$ 3,763.00
2105.525	TOPSOIL BORROW	CY	133	$ 21.00	$ 2,796.00
2105.601	DEWATERING	LS	1	$ 2,000.00	$ 2,000.00
2118.501	AGGREGATE TRAIL	LS	1	$ 19,980.00	$ 19,980.00
2511.501	RANDOM RIPRAP CL III	CY	1655	$ 60.00	$ 99,300.00
2573.502	SILT FENCE MACHING SLICED	LF	230	$ 2.00	$ 460.00
2573.505	FLOATATION SILT CURTAIN MOVING WATER	LF	230	$ 16.00	$ 3,680.00
2573.601	EROSION CONTROL SUPERVISOR	LS	1	$ 5,000.00	$ 5,000.00
2575.501	SEEDING	ACRE	0.2	$ 400.00	$ 400.00
2575.523	EROSION CONTROL BLANKET CAT 4 & 6	SY	799	$ 1.40	$ 1,118.00
2575.608	SEED MIXTURE 325	LB	14	$ 3.30	$ 46.00
				Sub-total	**$ 275,958.00**
Contingency (20%)					$ 55,192.00
				ESTIMATED TOTAL CONSTRUCTION COST	**$ 331,150.00**
Engineering Design, Geotechnical Investigation, Bid Document, Permitting, Construction Administration (25%)					$ 82,788.00
				TOTAL ESTIMATED COST	**$ 413,938.00**

Jurisdictional and Regulatory Environment

Since work within the Minnesota River and below the Ordinary High Water (OHW) level for either alternative will be required, a number of jurisdictional and regulatory agencies will be involved in design review and permitting. These are identified and described in Table 5.

Table 5: Jurisdictional and Regulatory Agencies and Roles

Agency	Role
City of Eden Prairie	▪ Final alternative selection, preliminary design review, cost share, final design review and approval. ▪ Construction. ▪ Wetland impact determination and sequencing (if necessary) for WCA.
Lower Minnesota River Watershed District (LMRWD)	▪ Final alternative selection, preliminary design review, cost share, final plan review and acceptance.
MnDNR	▪ Design and plan review. ▪ Wetland impact review and jurisdictional determination (if necessary). ▪ Individual permit for work within a water of the state.
US Army Corps of Engineers (USACE)	▪ Design and plan review. ▪ Section 404 permit (if necessary). ▪ Work within navigable waters permit.
MPCA (NPDES Phase II or III)	▪ General Stormwater Permit for Construction Activity.

Conclusions and Recommendations

While it is difficult to state definitively that slope failure and landslides are caused by specific natural or human activities, Study Area 3 has experienced a number of erosive forces that have conspired to create significant and alarming damage to a 200-foot length of the natural bluff and Riverview Road overlooking the Minnesota River. Suffice to say, stabilization of this area is critical so that what remains of Riverview Road in this area is protected.

Several solutions were explored including retaining walls, regrading, and a combination of grading and stabilized soil systems. A number of criteria that must be met were identified, with the most important criteria being a long-term factor of safety of 1.3. In addition, a riprap toe protection is assumed to be necessary and smoothing the riverbank to blend into the existing riverbank is important to reduce erosive velocities. Of the several that were considered, two alternatives were selected for further analysis – regrading the area to a 1v:3 slope (Alternative 1) and utilizing a combination of regrading and reinforced soil slope (Alternative 2).

While Alternative 1 construction is somewhat less complex, the advantages are minimal and the disadvantages significant. Alternative 2 presents a number of advantages and meets the criteria more completely. Estimated construction and engineering costs for both alternatives were developed, with Alternative 2 coming in slightly lower than Alternative 1. Alternative 2 exhibits both technical and cost advantages and is, therefore, recommended.

Next Steps

With the recommendation of Alternative 2 comes the need for further work that should occur during the preliminary design stage.

Geotechnical

- Obtain several more soil borings.
- Install piezometers to more accurately determine level of groundwater and spring location.
- Perform additional sieve analysis of soils to estimate which onsite soil may be available as backfill for the RSS system.
- Perform direct sheer and Proctor dry density tests on the various soils found within the excavation area to determine suitability as structural fill within RSS system and underneath the riprap.
- Determine location of launching toe, conduct stability investigations, refine launching toe design.
- Prepare preliminary plans and specifications of the RSS system and riprap.

Water Resources/Survey/Landscape Architecture

- Conduct a river bottom survey to determine riprap extents and hydraulic cross sections.
- Conduct additional topographic survey of areas north of the immediate landslide area to better determine trail alignment and construction limits.
- Conduct a hydraulic study based on existing river models to determine river and riverbank velocities and potential scour depths.
- Refine the conceptual trail alignment based on geotechnical analysis and construction limits.
- Prepare preliminary construction plans for city and agency review.

Appendix A
Historical Photographs

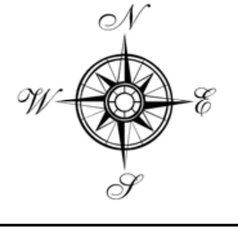
Riverview Road
Eden Prairie, Minnesota

2006

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')



HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

2003

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')

HIG
HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

2000

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')

HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1997

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')

HIG
HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1991

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')

N W E S

HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1984

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1”=500’)

HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

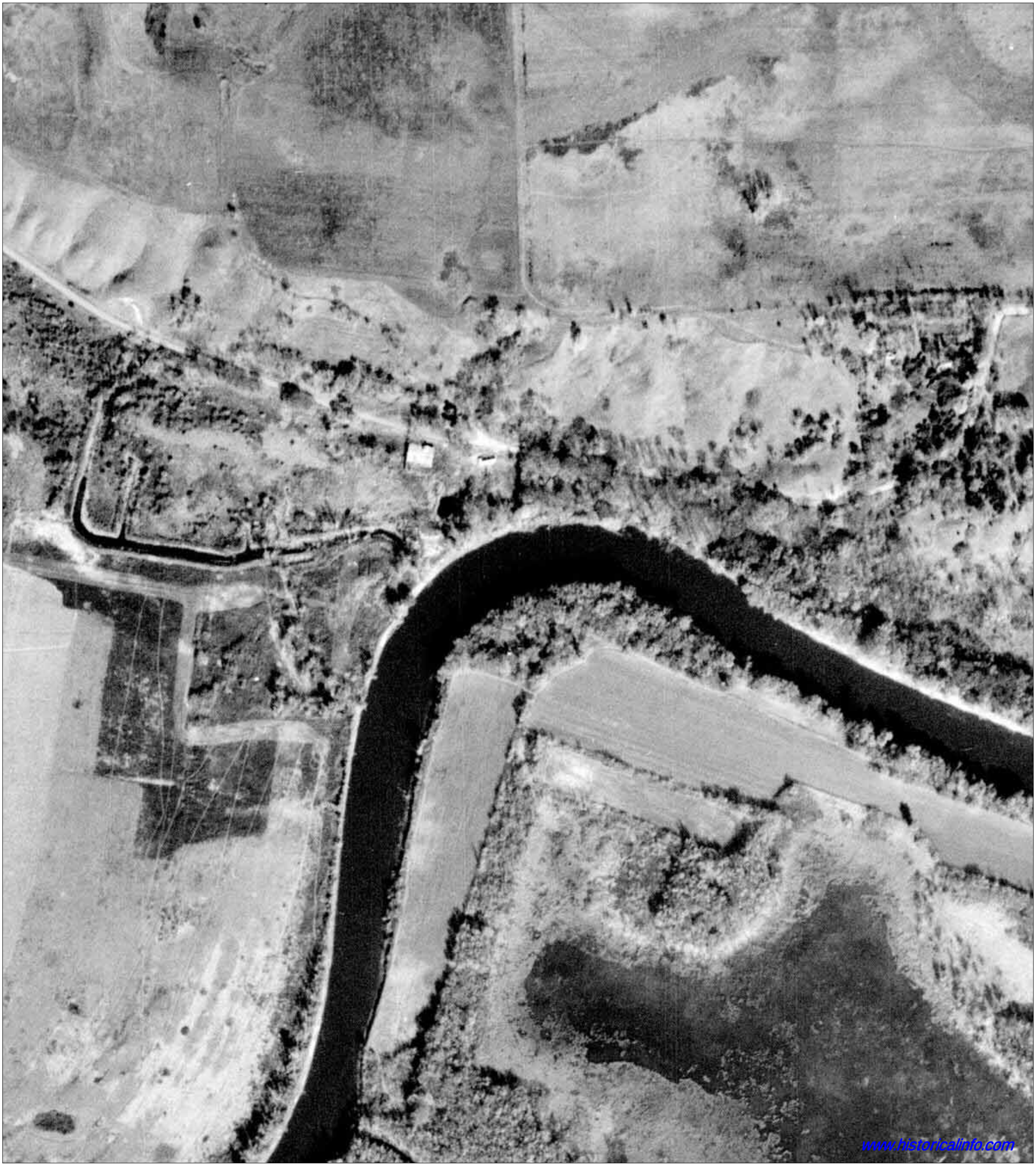
1979

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1”=500’)

N W E S



HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1969

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1”=500’)

N
W E
S

HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1964

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1”=500’)

N
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HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1957

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1”=500’)

N
W E
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HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1953

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')

N
W E
S

HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1947

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')

N W E S

Riverview Road
Eden Prairie, Minnesota

1940

HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')

N
W E
S

HIG
HISTORICAL INFORMATION GATHERERS, INC.

Riverview Road
Eden Prairie, Minnesota

1937

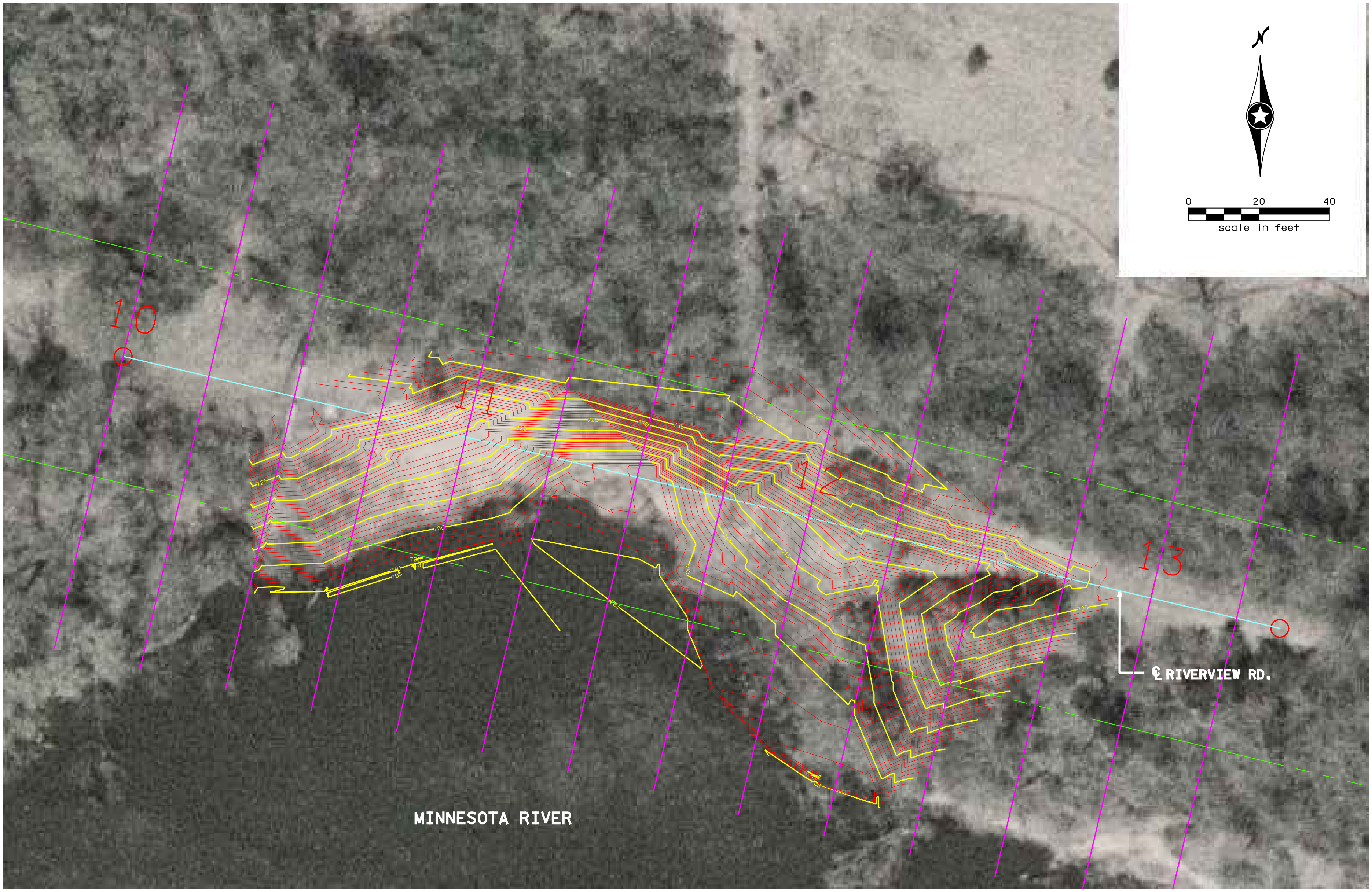
HIG Project Number: MAI-1217

Client Project Number: 6205-3280-24

Approximate Scale 1:6000 (1"=500')

N
W E
S

Appendix B
Existing Conditions Topography and Cross Sections



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SRF
Consulting Group, Inc.

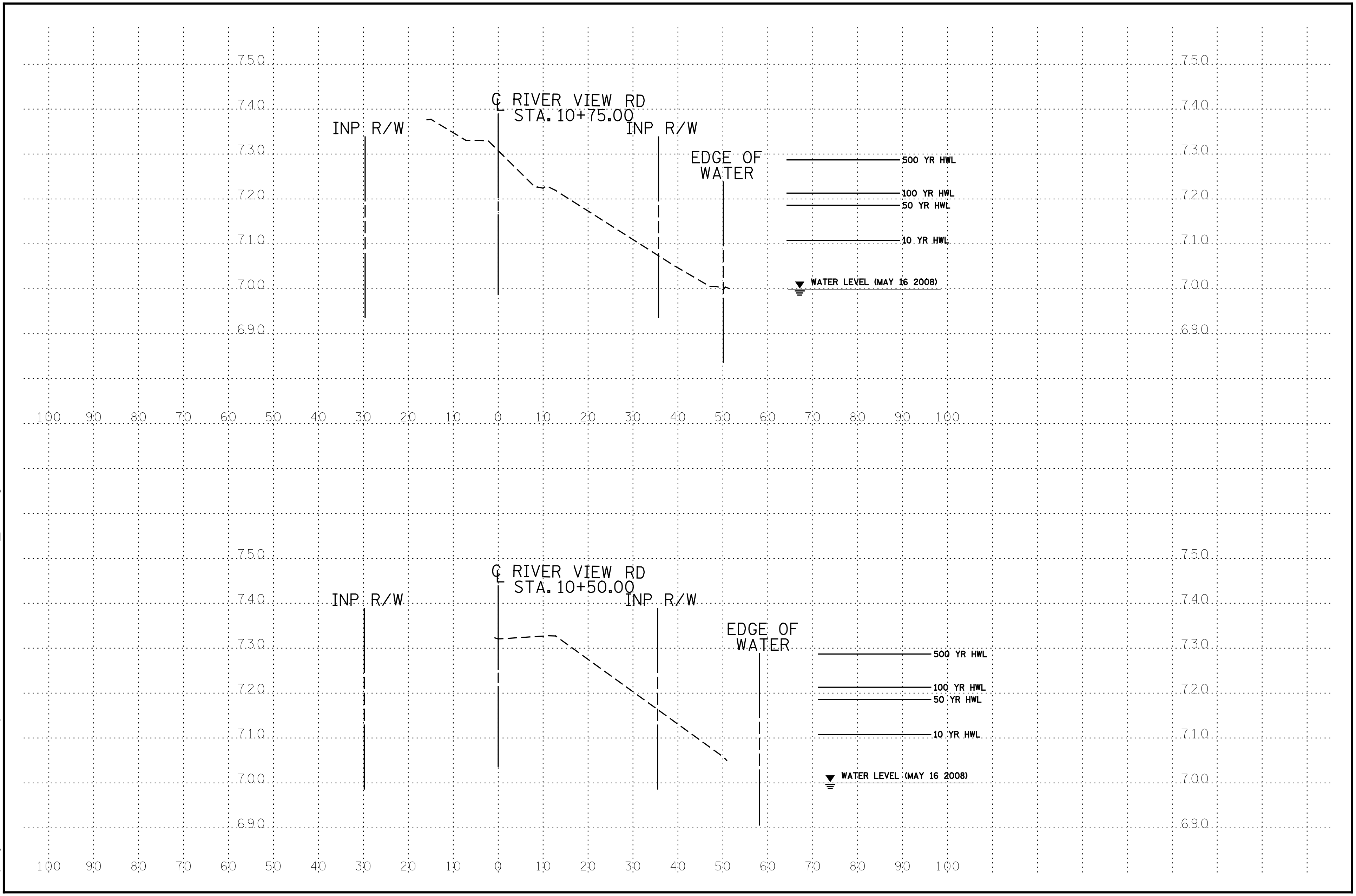
Appendix B: Study Area 3 Cross Section Layout (Existing Conditions)

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Figure B1

Job #
9/18/2008



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SRF Consulting Group, Inc.

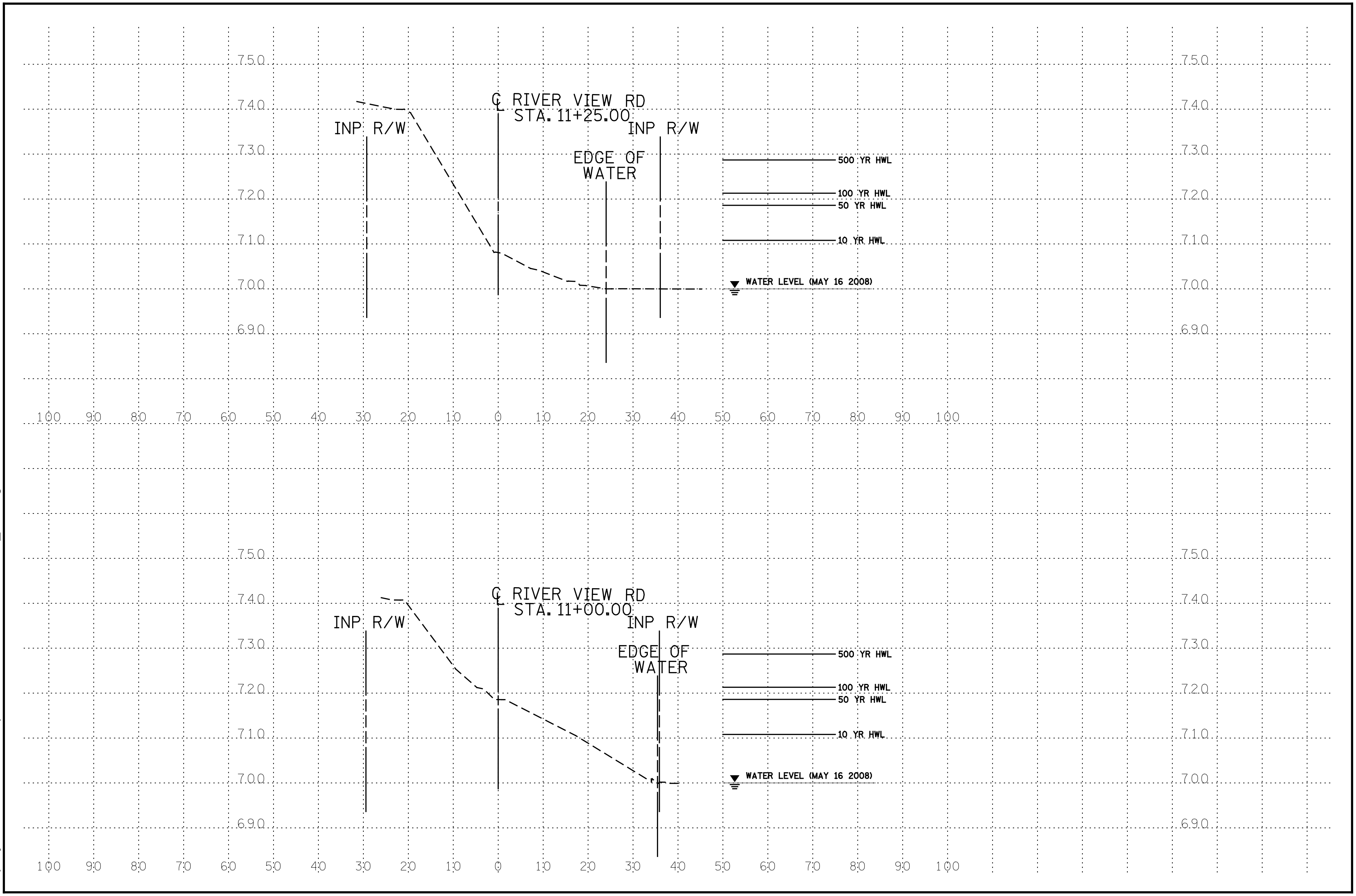
Appendix B - Existing Conditions

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Job #6205
9/18/2008

h:\projects\6205\WR\Graphics\Cross Sections\6205_ex2.dgn



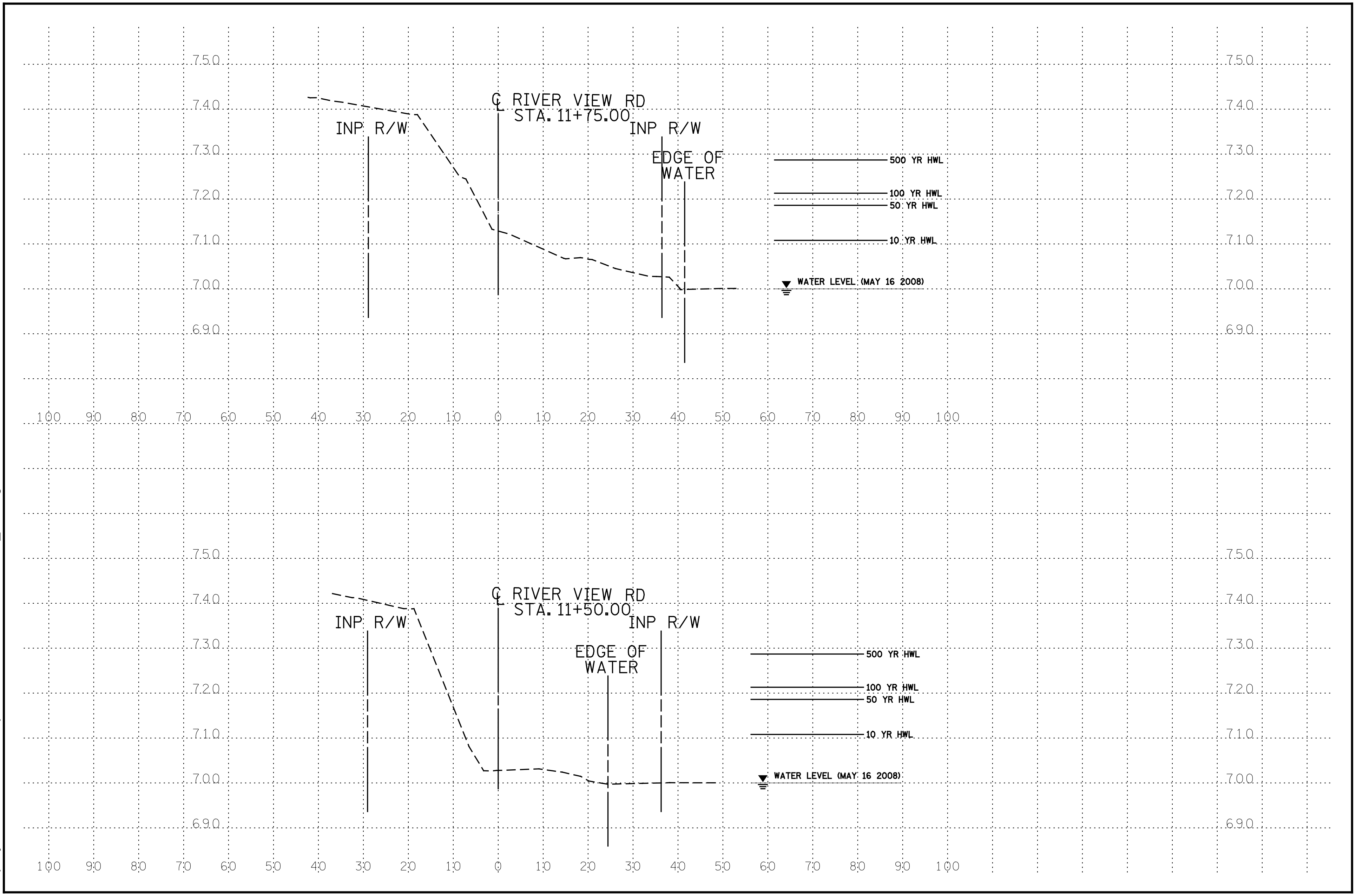
SRF Consulting Group, Inc.

Appendix B - Existing Conditions

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Job #6205
9/18/2008



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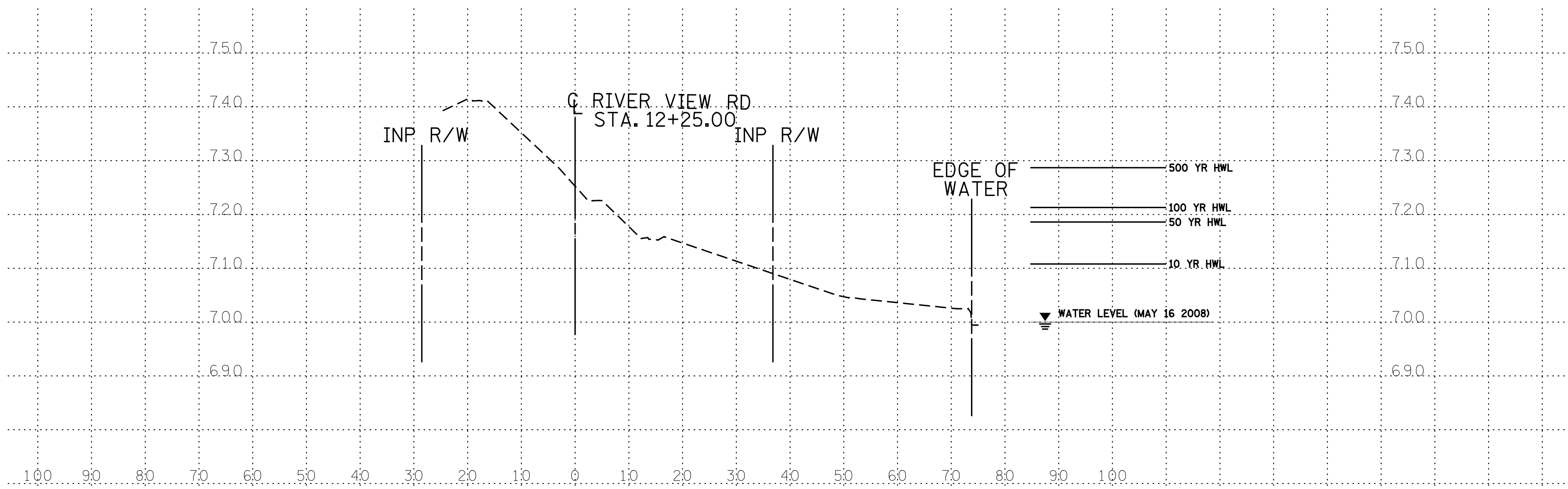
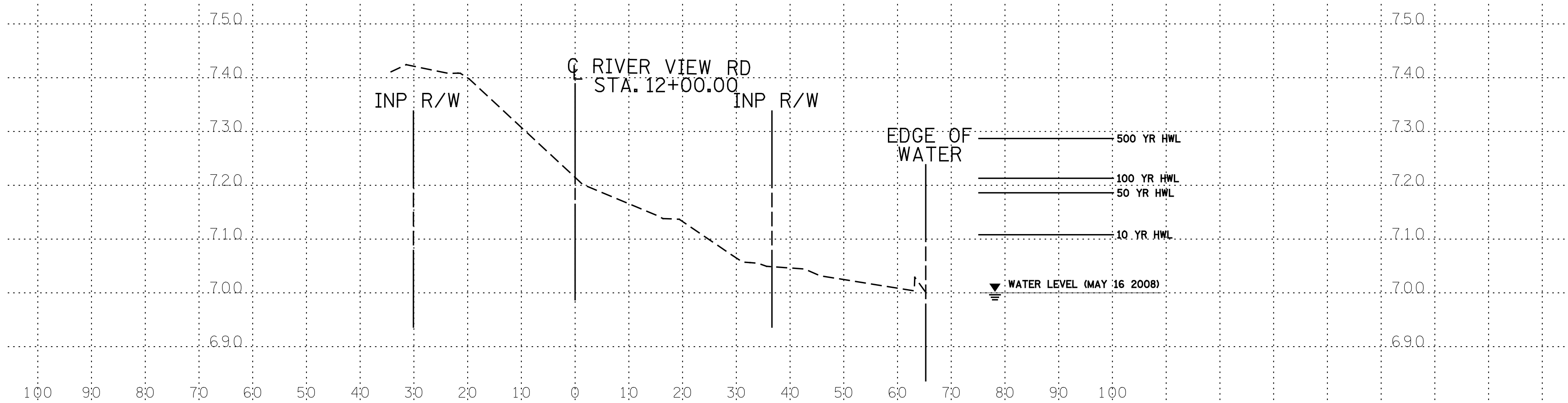
SRF
Consulting Group, Inc.

Appendix B - Existing Conditions

Eden Prairie Erosion Stabilization Study
Eden Prairie, MN

Job #6205
9/18/2008





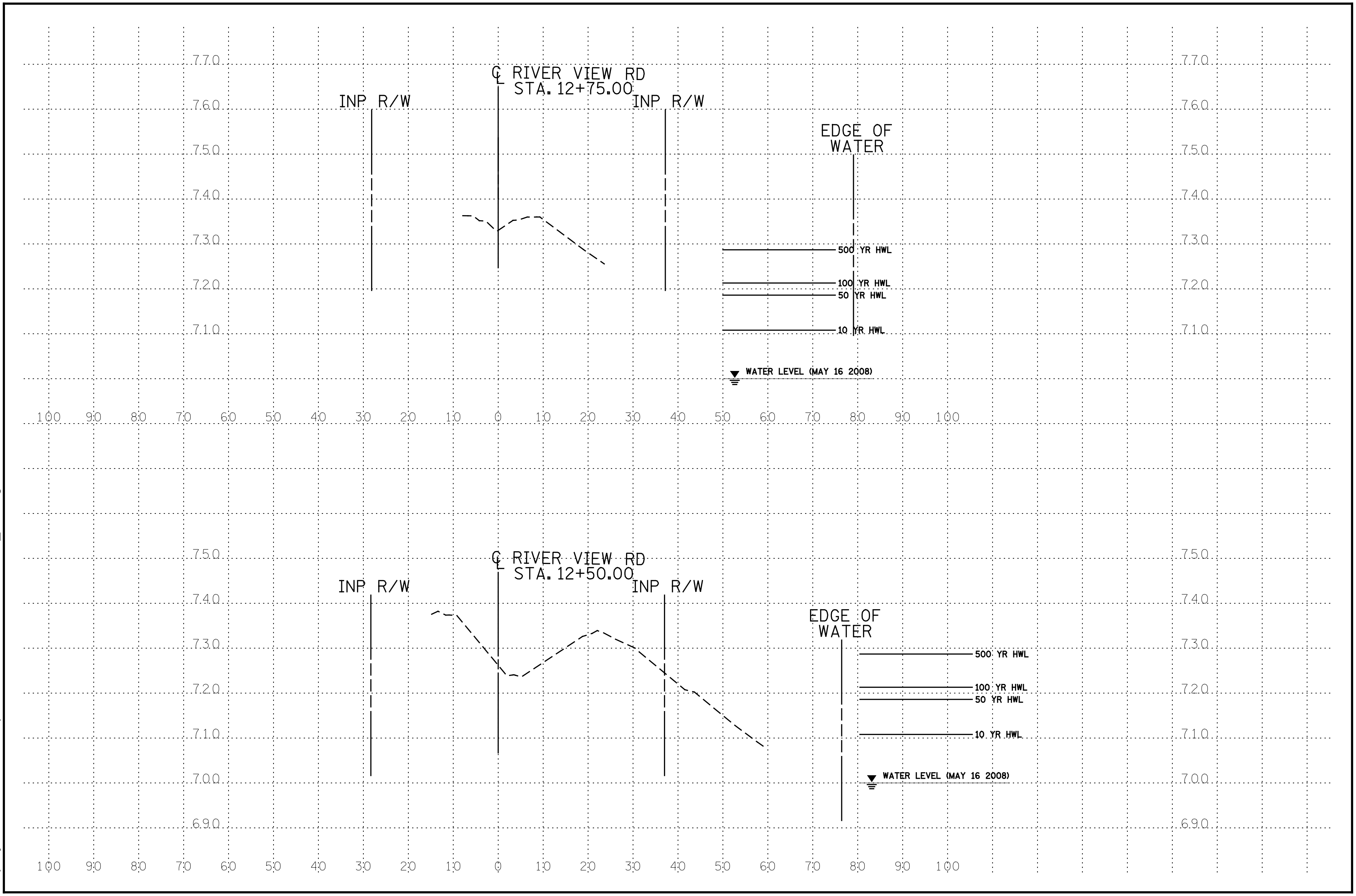
h:\projects\6205\WR\Graphics\Cross Sections\6205_ex4.dgn

SRF Consulting Group, Inc.

Appendix B - Existing Conditions

Eden Prairie Erosion Stabilization Study
Eden Prairie, MN

Job #6205
9/18/2008



h:\projects\6205\WR\Graphics\Cross Sections\6205_ex5.dgn

SRF
Consulting Group, Inc.

Appendix B - Existing Conditions

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Job #6205
9/18/2008

Appendix C
Geotechnical Report

GALE-TEC ENGINEERING, INC.

801 TWELVE OAKS CENTER DRIVE, SUITE 832
WAYZATA, MN 55391
TELEPHONE (952) 473-7193 FAX (952) 473-1492
www.gale-tec.com

June 6, 2008

Mr. Walter Eshenaur, P.E.
SRF Consulting Group, Inc.
One Carlson Parkway N, # 150
Minneapolis, MN 55447

GTE Project No. 95333

RE: Study Area 3 Report in Conjunction with the Lower Minnesota River Watershed District – Erosion Stabilization in Eden Prairie, MN

Dear Mr. Eshenaur:

We are pleased to provide this report to you for inclusion into the City of Eden Prairie and the Lower Minnesota River Watershed District erosion and slope stabilization feasibility study that you are preparing for Study Area 3.

We were requested to perform two (2) soil borings to 70 ft and prepare a report which discusses our assessment of the existing landslide and provides a discussion of potential options for remediation of the site. Materials provided to us by SRF and the City included

- Photographs of the landslide site
- Historical aerial photographs
- A topographic survey of the area

Our work was performed in substantial accordance with our May 31, 2007 Proposal and attached Terms for Geotechnical Engineering Services.

Background

The site for Area 3 is located along an unpaved section of Riverview Road in Eden Prairie where it abuts a meander in the Minnesota River to the south. The road is currently used as a walking trail. Currently, locked gates and concrete barriers restrict access to the area.

A series of slope failures and slumps over the years has created an ongoing landslide area at the site. Failure scarps from slides have progressed up the riverbank, across Riverview Road, and have deposited debris soil along portions of the lower slope.

Site Conditions

Our August 30, 2007 letter to you describes our observations during an August 29, 2007 visit to the site. Of note, visual observations identify 1) steep, exposed failure scarps along the upper slope portions and 2) seepage exiting the lower slope within the debris soils and flowing down to the river.

Soil Conditions

The project site is located within the Minnesota Valley Outwash geomorphic region. The region, which was formed by the Glacial River Warren as it drained Glacial Lake Agassiz, is characterized by undiffentiated sandy terraces along the river's course and interspersed areas of sand, silty sand and silt soils.

Two (2) soil borings were performed on May 5 and 6, 2008 at two locations as shown in Appendix No. 1. The boring locations were staked in the field by Gale-Tec Engineering, Inc. The borings were drilled outside the landslide area at the east and west ends of the project, along Riverview Road, each to a depth of approximately 70 ft. We could not obtain access within the landslide area. The final boring locations and elevations were surveyed by SRF.

Prior to drilling, Gopher State One Call was contacted to check for public underground utilities. The borings were drilled with a truck-mounted CME-75 drill rig and were advanced with hollow stem auger. Soil samples were collected at 5 ft. intervals using the split-spoon sampling procedure. In this method, the number of blows required to drive the split-spoon sampler into the ground in 6-inch increments is recorded; after a six inch set the number of blows required to drive the sample 1 ft into the soil is termed the N-Value. N-Values are shown on the boring logs. The sampling spoon is driven into the ground with a 140-pound hammer falling a distance of 30 inches. Soil samples were placed in glass jars and delivered to the laboratory for classification and further testing. The depth to groundwater was recorded while drilling. The borings were backfilled upon completion per Minnesota Department of Health requirements.

Laboratory tests were conducted on 6 selected soil samples. The tests were performed to determine the samples' fines content, or the percent of each sample (by weight) passing the U.S. No. 200 sieve. The test results were used to assist in the soil classification process.

In general, the soil borings indicate the slope soils to comprise of approximately 20 to 35 ft of loose to medium dense silty sands with a little to trace gravel overlying approximately 30 to 35 ft of medium dense to dense silts. Below the silt layer, boring B-2 identified dense fine to medium and medium coarse sands.

Groundwater was encountered in both of the borings during drilling operations. Groundwater was measured in the borehole in B-1 at a depth of approximately 40 ft while drilling and approximately 55 ft after collecting the last sample. Groundwater was measured in the borehole in B-2 at a depth of approximately 25 ft while drilling and could not be measured upon boring completion due to drilling fluid in the borehole.

Landslide Assessment

Landslide failure assessments employ a ratio, known as the factor of safety (FS), to help assess a slope's stability, or potential for failure. The FS can be described as the ratio of those forces resisting the slope's failure to forces driving the slope's failure; thus, a FS that is greater than 1.0 indicates that the resisting forces are greater than the driving forces.

The method of limit equilibrium is frequently used to analyze the stability of soil slopes. In this method, a FS equal to 1.0 is assumed to represent soil conditions at failure. In order to assess the limiting in-situ soil shear strength properties of the existing slope, the shear strengths of the slope soils that act to resist failure are adjusted in the limit equilibrium computer program in order to meet the FS = 1.0 limit equilibrium criteria. In this way, by employing limit equilibrium to the slope, the in-situ shear strengths of the slope soils and the groundwater conditions are estimated at the time of the landslide. Our slope stability and limit equilibrium analyses were performed using the commercially available computer program, GSlope, developed by Mitre Software.

For our analysis, we performed laboratory tests on collected soil samples in order to classify the soil and used those tests in conjunction with the boring logs and the survey drawings provided by SRF to develop the geometry and soil properties of the slope.

Analysis of the landslide was conducted assuming both a wedge-type translational failure at the slope surface and a deeper, circular failure surface. A topographic survey study conducted by SRF was used to develop the geometry of the existing slope.

The slope stability analysis indicates that the Riverview Road slope situation along the Minnesota River probably has a FS of just above 1.0, and is consistently on the verge of failure. Existing surface vegetation, root systems and residual moisture trapped in the soil can help hold the slope together in the short term. However, in such cases, water typically acts as the catalyst that "triggers" a landslide. It is our opinion that there are two components contributing to ongoing landslides at the site: 1) saturation of the slope soils due to both seepage and high river levels and 2) loss of soil material at the slope toe. Because of their silty nature, saturation of the slope soils can lead to a reduction in their shear strength. Currents from high river levels can scour silt-type soils, remove them from the toe, and carry them away downstream. Later, as river levels decrease, the increased weight of the saturated silty soils, combined with the loss of toe soil material, contribute to a landslide affecting a large portion of the slope. Repetition of this process over the years has likely led to the landslide failure scarp progressing across Riverview Road.

Recommendations – Slope Stability

The following recommendations are based on a review of the soil boring information, survey and site information made available, our analysis of the slope profile and on our experience with similar projects.

Slope Re-Grading – Since the forces causing landslide movements are essentially gravitational, or weight-driven, a simple approach to increasing stability would be to decrease the driving forces or lessen the weight of soil involved in a reconstructed slope. Techniques for this include flattened slopes and bench slopes. Lightweight fill replacement could also be an option; however, substantial excavation could be required and the material involved is typically costly. Flattened slopes and bench slopes entail changes to the geometry of the slope and their viability can be restricted depending on right-of-way boundaries, riverway channels, and other spatial concerns. Flattening of the slope should involve re-grading to a 3H:1V or shallower angle extending up from the slope toe. However, a flattened slope, while less expensive than other alternatives discussed below, does not alleviate the seepage conditions present in the slope. Groundwater could continue to seep out of the face of the slope and continue to soften soil material at the slope face and potentially contribute future slides. Slope face protection and toe armoring would be required if this option is chosen, as discussed in a subsequent section of the report.

Geogrid (RSS)

A second approach to landslide repair would be to increase the resisting forces. Although techniques can vary widely, the approach generally would function by either applying a large resisting force at the toe of a landslide such as a toe berm or buttress fill, or increasing the internal shear strength of the soils in the potential failure zone so that the slope remains stable.

Our preliminary analysis of potential repair schemes indicates that the stability of the slope is affected by the shear strength of the silty sand and silt layers. As such, one of the more effective and reliable local approaches to stabilizing slopes and repairing landslides is to increase the internal strength of soil with inclusions of geosynthetic tensile reinforcement; typically referred to as MSE for "mechanically stabilized earth." The technique is effective because the low shear strength soil and residual landslide debris materials are excavated, removed, and replaced with engineered structural fill incorporating strong reinforcing elements.

Other in-situ reinforcement that would provide tensile resisting forces would include soil nails or helical soil anchors. These techniques tend to be more costly than the geosynthetic reinforced soil approach.

The repair design should address both the short and the long-term stability of the slope. An FHWA RSS design guide outlines performance criteria for reinforced soil slopes. Specifically, it recommends that constructed soil slopes be designed for a global stability factor of safety (FS) of 1.2 under short-term conditions, and for a global stability FS of 1.3 under long-term conditions.

A particular type of MSE application called a reinforced soil slope, or RSS, could be used to repair the failed riverbank slope. An RSS consists of geogrid reinforcement layers placed in conjunction with a compacted granular backfill. The stability afforded by the strong frictional interaction between the geogrids and granular backfill and the high tensile strength of the geogrid allows for construction of slopes at angles that are not normally stable when only using soil (i.e. 1H:1V to near-vertical).

Our preliminary analysis indicates that the base of the recommended RSS should extend down to the riverbed elevation. Based on our observations, we estimate repair of approximately 150 to 200 ft in horizontal distance. This would entail excavating approximately 40 vertical feet of existing slope soils and replacing with compacted granular fill and inclusions of geogrid reinforcement.

Laboratory tests of on-site silty sand soils found within the upper 40 ft of the slope indicate fines content of 8% (fines content defined as material passing the U.S. No. 200 sieve). Direct shear tests should be conducted on this material to determine its internal friction angle when compacted and if it could be suitable for re-use as structural fill.

Erosion and Scour Protection – Regardless of whether the slope is re-graded or reconstructed with geogrid, any landslide repair scheme should address both 1) the seepage along the slope face and 2) further loss of slope toe material due to river scour. We recommend placing a riprap cover on the slope face that extends from the top of the silt layer (approximate elevation 710 ft) down to scour depth. The riprap could be a crushed, quarry-run Mn/DOT 3601 Class III material. The riprap cover should have a minimum thickness of 3 ft and should be underlain with 6-inch granular filter and Mn/DOT 3733 Type IV geotextile.

The face of the slope above the riprap should be dressed, seeded and fertilized with new topsoil and an erosion control blanket similar to Mn/DOT 3885 Category 3 (if graded to 3H:1V) or Category 4 (if graded to 2H:1V or steeper). Depending on whether the slope is reconstructed or just re-graded, a geosynthetic product such as a geocell could also be used in conjunction with new topsoil to help provide confinement and moisture retention for seed germination.

Drainage – An important aspect that needs to be taken into consideration with regard to the repair is the collection and drainage of runoff. Deep erosion gullies from runoff were observed along Riverview Road to the east of the landslide site. Runoff discharge resulting from high precipitation events should be directed away the site. Since water typically acts as the trigger in many landslides, instituting recommended drainage measures can help reduce the potential for future failures.

Other Considerations – The recommendations of this report are based, in part, on the results of two soil borings drilled at the top of the slope along Riverview Road. These soil borings represent subsurface conditions at only two discreet points located at each end of the project site. Prior to undertaking the design and construction of the actual repair, we recommend performing test pits within the failed area to verify soil conditions.

The flow of seepage water through the slope can have an impact on the potential of future landslides. We also recommend that piezometers be installed at selected locations on-site, such as at the top of the slope and on the slope face, to further study seepage flow patterns.

If you have any questions concerning our comments for your feasibility report, please do not hesitate to contact us.

Respectfully,

GALE-TEC ENGINEERING, INC.

Brent A. Theroux, P.E.
Project Engineer

Stephan M. Gale, P.E.
Principal Engineer

Enclosures

I hereby certify that this report was prepared by me or under my direct supervision and that I am a registered professional engineer under Minnesota Statute, Sections 326.02 to 326.15.

Brent A. Theroux

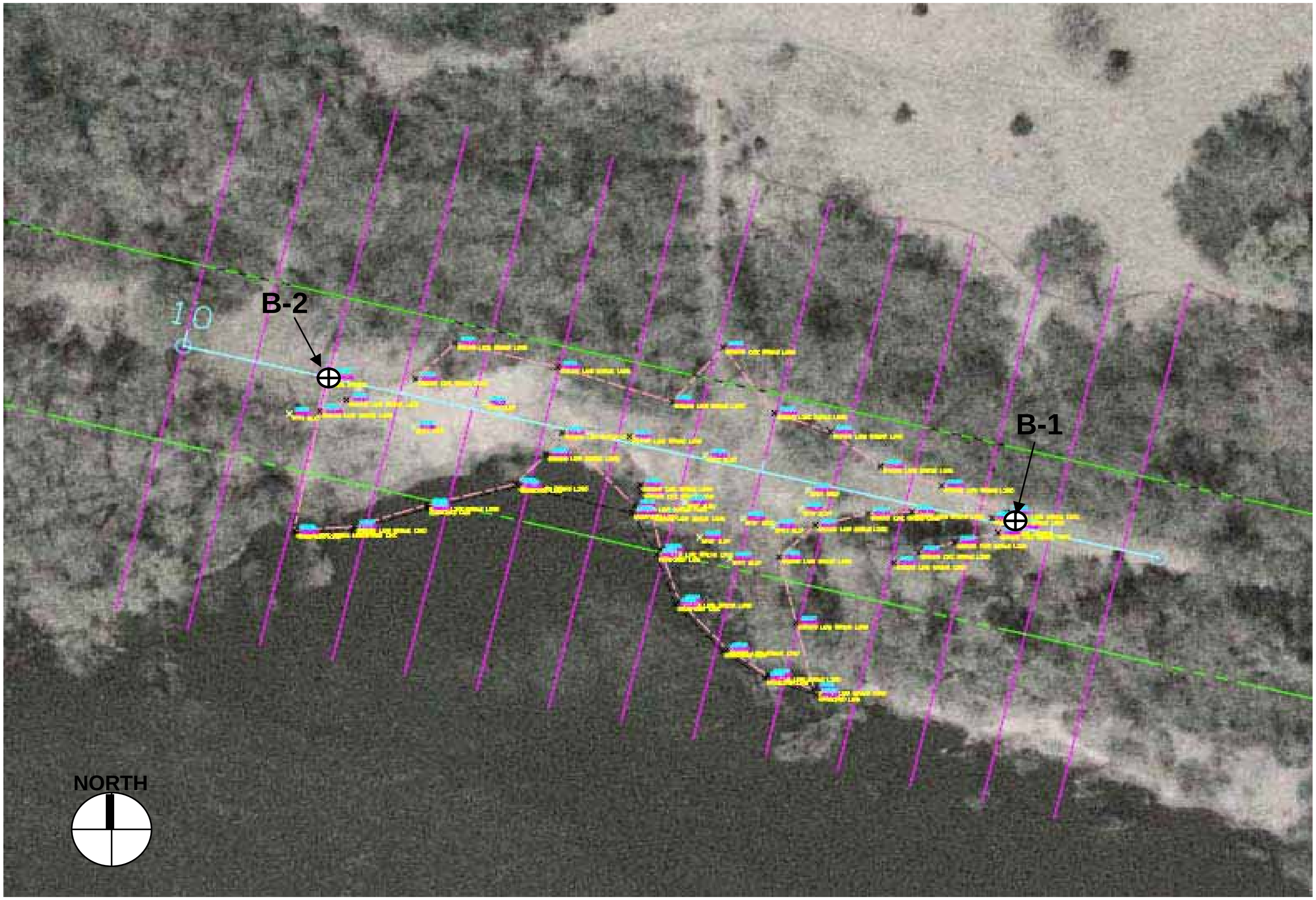
Date: 6-6-08 Reg. No. 44276

BAT/blm
REPORT/ SRF Consulting Group, Inc., Study Area 3 Report

APPENDIX

1. STUDY AREA 3 PLAN & SOIL BORING LOCATION DIAGRAM
2. SOIL BORING LOGS
3. GENERAL NOTES
4. CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES
5. SLOPE STABILITY CALCULATION

GTE Gale-Tec Engineering,Inc	PROJECT Eden Prairie Erosion Stabilization Study Area 3		SHEET NO. 1
	SUBJECT Soil Boring Location Diagram (taken from original provided SRF)		
	DATE June, 2008	BY BAT	GTE PROJECT NO. 95333



BORING NO. ST-1

PROJECT: Lower Minnesota River Watershed - Erosion Stabilization

CLIENT: SRF Consulting Group, Inc./City of Eden Prairie

LOCATION: Eden Prairie, Minnesota

ARCHITECT - ENGINEER: SRF Consulting Group, Inc.

DEPTH IN FEET	SAMPLE NO.	SAMPLE TYPE	SOIL DESCRIPTION (SURFACE ELEVATION: 736.18 ft)	N-VALUE IN BLOWS/FT.	% REC.	LABORATORY TESTS W (%)	LABORATORY TESTS P200 (%)
	1	AUG	Fine Sand, dark brown to brown, moist, loose, trace gravel, trace grass and roots at 1 ft (SP)				
5	2	SS		8	78		
10	3	SS		8	67		
15	4	SS		8	78		
20	5	SS		9	78		
			Silty Sand with a little Gravel, brown, moist, medium dense (SP-SM)				
25	6	SS		12	78	8	8.0

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ the transition may be gradual.

WATER LEVEL OBSERVATIONS	
WL	40 ft, WD
WL	55 ft, AB
CAVE IN DEPTH	

GTE
GALE-TEC ENGINEERING, INC.

BORING STARTED 5-5-08	
BORING COMPLETED 5-5-08	
RIG CME 75	FOREMAN BR
DRAWN BAT	JOB# 95333

EDEN PRAIRIE LANDSLIDE EDENPRAIRIE_3.GPJ UNITWT.GDT 5/23/08

BORING NO. ST-1

PROJECT: Lower Minnesota River Watershed - Erosion Stabilization

CLIENT: SRF Consulting Group, Inc./City of Eden Prairie

LOCATION: Eden Prairie, Minnesota

ARCHITECT - ENGINEER: SRF Consulting Group, Inc.

DEPTH IN FEET	SAMPLE NO.	SAMPLE TYPE	SOIL DESCRIPTION	N-VALUE IN BLOWS/FT.	% REC.	LABORATORY TESTS W (%)	LABORATORY TESTS P200 (%)
			Silty Sand with a little Gravel, brown, moist, medium dense (SP-SM)				
30	7	SS	Fine Sand, brown, moist, medium dense, trace gravel (SP)	14	78		
35	8	SS		19	78		
40	9	SS	Silt, brown, saturated, medium dense to dense (ML)	23	78	25	66.7
45	10	SS		37	78		
50	11	SS	Silty Sand, brown, wet, dense (SM)	37	78		

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ the transition may be gradual.

WATER LEVEL OBSERVATIONS	
WL	40 ft, WD
WL	55 ft, AB
CAVE IN DEPTH	

GTE
GALE-TEC ENGINEERING, INC.

BORING STARTED 5-5-08	
BORING COMPLETED 5-5-08	
RIG CME 75	FOREMAN BR
DRAWN BAT	JOB# 95333

BORING NO. ST-1

PROJECT:	CLIENT:
Lower Minnesota River Watershed - Erosion Stabilization	SRF Consulting Group, Inc./City of Eden Prairie
LOCATION:	**ARCHITECT - ENGINEER:**
Eden Prairie, Minnesota	SRF Consulting Group, Inc.

DEPTH IN FEET	SAMPLE NO.	SAMPLE TYPE	SOIL DESCRIPTION	N-VALUE IN BLOWS/FT.	% REC.	LABORATORY TESTS W (%)	LABORATORY TESTS P200 (%)
			Silty Sand, brown, wet, dense (SM)				
55	12	SS		41	78		
			Silt, brown, saturated, dense (ML)				
60	13	SS		42	89	25	59.0
65	14	SS		58	83		
			Silt, gray, wet, very dense (ML)				
70	15	SS		56	83		
			End of Boring - 70.5 ft Boring advanced full depth with hollow stem auger and backfilled with bentonite grout upon completion.				

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ the transition may be gradual.

WATER LEVEL OBSERVATIONS	
WL	40 ft, WD
WL	55 ft, AB
CAVE IN DEPTH	

GTE
GALE-TEC ENGINEERING, INC.

BORING STARTED 5-5-08	
BORING COMPLETED 5-5-08	
RIG CME 75	FOREMAN BR
DRAWN BAT	JOB# 95333

EDEN PRAIRIE LANDSLIDE EDENPRAIRIE_3.GPJ UNITWT.GDT 5/23/08

BORING NO. ST-2

PROJECT: Lower Minnesota River Watershed - Erosion Stabilization

CLIENT: SRF Consulting Group, Inc./City of Eden Prairie

LOCATION: Eden Prairie, Minnesota

ARCHITECT - ENGINEER: SRF Consulting Group, Inc.

DEPTH IN FEET	SAMPLE NO.	SAMPLE TYPE	SOIL DESCRIPTION (SURFACE ELEVATION: 732.06 ft)	N-VALUE IN BLOWS/FT.	% REC.	LABORATORY TESTS W (%)	LABORATORY TESTS P200 (%)
	16	AUG	Silty Sand, dark brown, moist, trace grass and roots (SM) (Topsoil)				
5	17	SS	Silty Sand with a little Gravel, brown, moist, loose (SM)	4	72		
10	18	SS	Silty Sand, brown, moist, loose, trace gravel (SP-SM)	5	72		
15	19	SS	Silty Sand, brown, moist, loose, trace gravel (SM)	6	67		
20	20	SS	Fine Sand, brown, moist, medium dense (SP)	11	78		
25	21	SS	Silt, brown, saturated, loose to medium dense (ML)	10	78	27	96.3

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ the transition may be gradual.

WATER LEVEL OBSERVATIONS	
WL	25 ft, WD
WL	
CAVE IN DEPTH	

GTE
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BORING STARTED 5-6-08	
BORING COMPLETED 5-6-08	
RIG CME 75	FOREMAN BR
DRAWN BAT	JOB# 95333

BORING NO. ST-2

PROJECT:	CLIENT:
Lower Minnesota River Watershed - Erosion Stabilization	SRF Consulting Group, Inc./City of Eden Prairie
LOCATION:	ARCHITECT - ENGINEER:
Eden Prairie, Minnesota	SRF Consulting Group, Inc.

DEPTH IN FEET	SAMPLE NO.	SAMPLE TYPE	SOIL DESCRIPTION	N-VALUE IN BLOWS/FT.	% REC.	LABORATORY TESTS W (%)	LABORATORY TESTS P200 (%)
30	22	SS	Silt, brown, saturated, loose to medium dense (ML)	17	89		
35	23	SS		13	78		
40	24	SS		15	78		
45	25	SS	Silty Sand, brown gray, moist, dense to medium dense, trace black silty sand and roots at 50 ft (SM)	35	83	20	42.8
50	26	SS		15	72		

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ the transition may be gradual.

WATER LEVEL OBSERVATIONS		BORING STARTED 5-6-08	
WL	25 ft, WD	BORING COMPLETED 5-6-08	
WL		RIG CME 75	FOREMAN BR
CAVE IN DEPTH		DRAWN BAT	JOB# 95333

GTE
GALE-TEC ENGINEERING, INC.

BORING NO. ST-2

PROJECT:	CLIENT:
Lower Minnesota River Watershed - Erosion Stabilization	SRF Consulting Group, Inc./City of Eden Prairie
LOCATION:	ARCHITECT - ENGINEER:
Eden Prairie, Minnesota	SRF Consulting Group, Inc.

DEPTH IN FEET	SAMPLE NO.	SAMPLE TYPE	SOIL DESCRIPTION	N-VALUE IN BLOWS/FT.	% REC.	LABORATORY TESTS W (%)	LABORATORY TESTS P200 (%)
			Silty Sand, brown gray, moist, dense to medium dense, trace black silty sand and roots at 50 ft (SM)				
55	27	SS		23	78		
60	28	SS	Fine to Medium Sand, brown gray, wet, medium dense to dense, trace gravel and silt (SP-SM)	34	78	23	5.7
65	29	SS		35			
			Medium to Coarse Sand, brown gray, wet, dense, trace gravel (SP)				
70	30	SS		26	67		
			End of Boring - 70.5 ft				
			Boring advanced full depth with hollow stem auger and backfilled with bentonite grout upon completion. Bentonite drilling fluid added at 52 ft due to onset of blown-in at bottom of auger.				

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ the transition may be gradual.

WATER LEVEL OBSERVATIONS			
WL	25 ft, WD	BORING STARTED 5-6-08	
WL		BORING COMPLETED 5-6-08	
		RIG CME 75	FOREMAN BR
CAVE IN DEPTH		DRAWN BAT	JOB# 95333

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GENERAL NOTES

DRILLING & SAMPLING SYMBOLS:

SL : SS with Liner
SS : Split Spoon – 1 3/8" I.D., 2" O.D. unless Otherwise noted
ST : Shelby Tube – 2" O.D., unless otherwise noted
PA : Power Auger
DB : Diamond Bit – NX: BX: AX
AS : Auger Sample
JS : Jar Sample
VS : Vane Shear
OS : Osterberg Sampler – 3" Shelby Tube
HS : Hollow Stem Auger
WS : Wash Sample
FT : Fish Trail
RB : Rock Bit
BS : Bulk Sample
PM : Pressuremeter test – in situ

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split spoon, except where noted.

WATER LEVEL MEASUREMENT SYMBOLS:

WL : Water Level
WCI : Wet Cave In
DCI : Dry Cave In
WS : While Sampling
WD : While Drilling
BCR : Before Casing Removal
ACR : After Casing Removal
AB: : After Boring

Water levels indicated on the boring logs are the levels measured in the boring at the times indicated. In pervious soils, the indicated elevations are considered reliable ground water levels. In impervious soils, the accurate determination of ground water elevations is not possible in even several days observation, and additional evidence of ground water elevations must be sought.

GRADATION DESCRIPTION & TERMINOLOGY

Coarse Grained or Granular Soils have more than 50% of their dry weight retained on a #200 sieve; they are described as: boulders, cobbles, gravel or sand. Fine Grained Soils have less than 50% of their dry weight retained on a #200 sieve; they are described as: clays or clayey silts if they are cohesive, and silts if they are non-cohesive. In addition to gradation, granular soils are defined on the basis of their relative in-place density and fine-grained soils on the basis of their strength or consistency, and their plasticity.

Major Component of Sample	Size Range	Descriptive Term(s) (Of Components Also Present in Sample)	Percent of Dry Weight
Boulders	Over 8 in. (200mm)	Trace	1-9
Cobbles	8 in. to 3 in. (200mm to 75mm)	Little	10-19
Gravel	3 in. to #4 sieve (75mm to 2mm)	Some	20-34
Sand	#4 to #200 sieve (2 mm to 0.074mm)	And	35-50
Silt	Passing #200 sieve (0.074mm to 0.005mm)		
Clay	Smaller than 0.005mm		

CONSISTENCY OF COHESIVE SOILS:

Unconfined Comp. Strength, Qu, tsf	Consistency
<0.25	Very Soft
0.25-0.49	Soft
0.50-0.99	Medium (Firm)
1.00-1.99	Stiff
2.00-3.99	Very Stiff
4.00-8.00	Hard
>8.00	Very Hard

RELATIVE DENSITY OF GRANULAR SOILS:

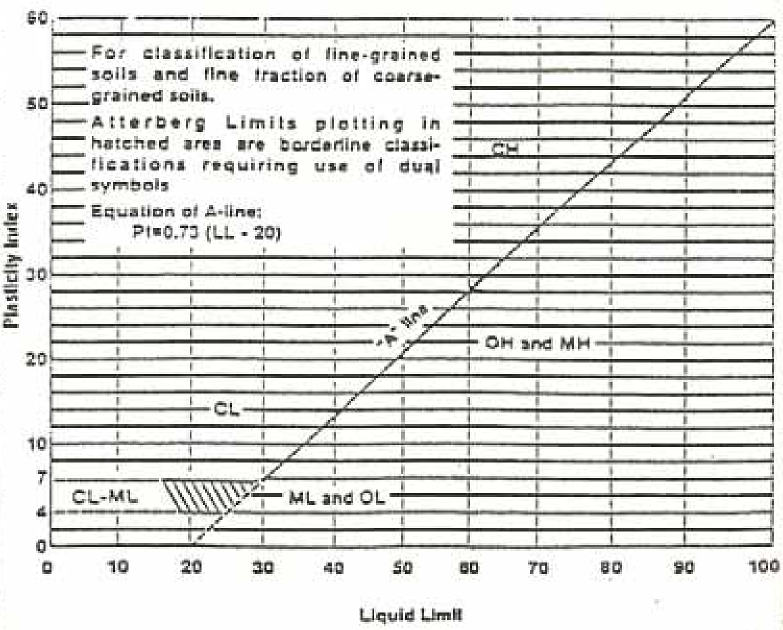
N-Blows/ft.	Relative Density
0-3	Very Loose
4-9	Loose
10-29	Medium Dense
30-49	Dense
50-80	Very Dense
80+	Extremely Dense

GALE-TEC ENGINEERING, INC.

CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

(ASTM: D 2487 and 2488)

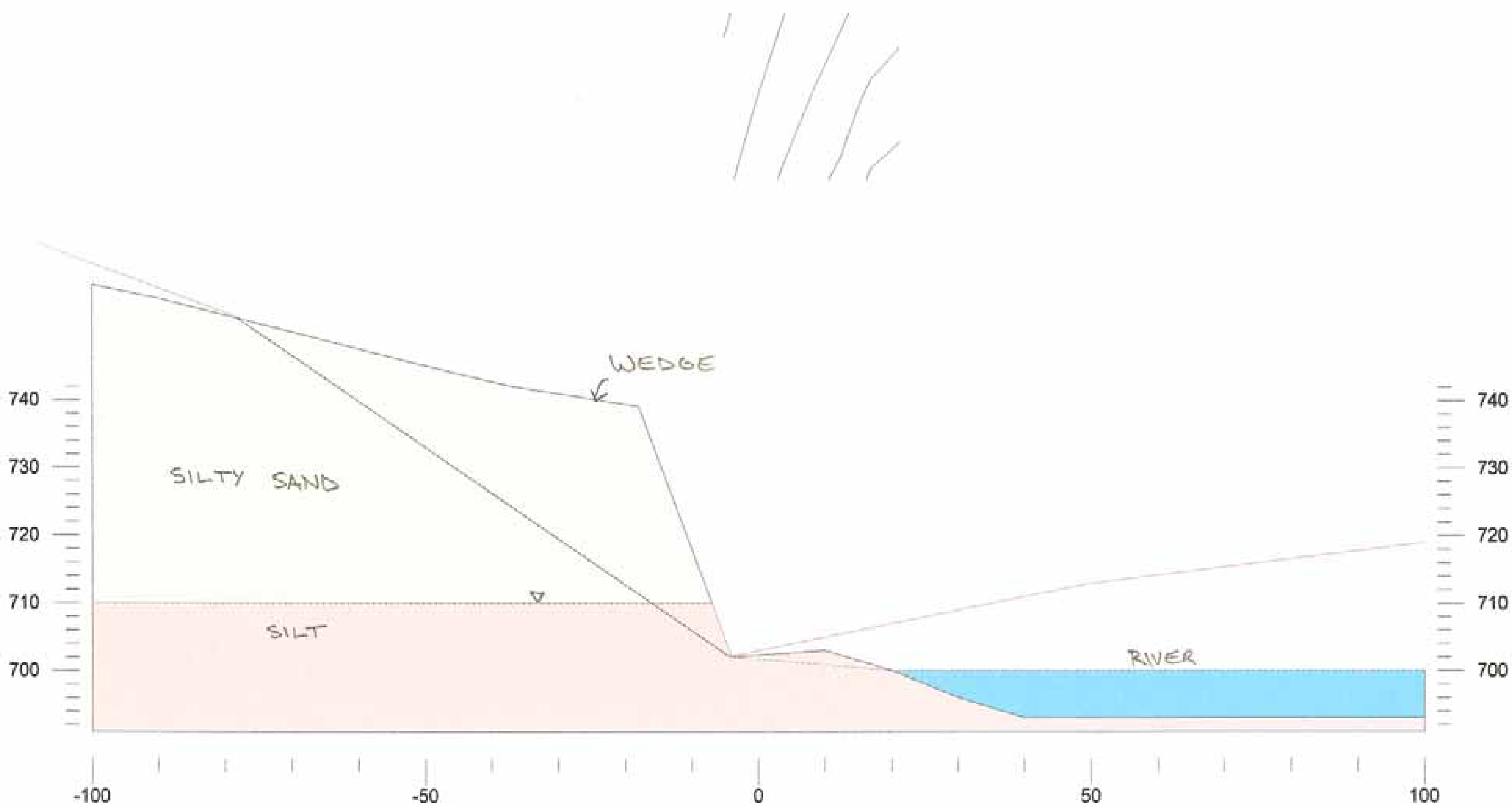
Major divisions			Group symbols		Typical names	Laboratory classification criteria		
Coarse-grained soils (More than half of material is *larger* than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW		Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5 per cent .... GW, GP, SW, SP; More than 12 per cent .... GM, GC, SM, SC; 5 to 12 per cent .... *Borderline* cases requiring dual symbols	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP		Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM	d	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols
				u				
			GC		Clayey gravels, gravel-sand-clay mixtures		Atterberg limits below "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP		Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	d	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Limits plotting in hatched zone with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols.
				u				
			SC		Clayey sands, sand-clay mixtures		Atterberg limits below "A" line or P.I. greater than 7	
Fine-grained soils (More than half of material is *smaller* than No. 200 sieve)	Silts and clays (Liquid limit less than 50)		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity			
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL		Organic silts and organic silty clays of low plasticity			
	Silts and clays (Liquid limit greater than 50)		MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH		Inorganic clays of high plasticity, fat clays			
			OH		Organic clays of medium to high plasticity, organic silts			
Highly organic soils			Pt		Peat and other highly organic soil			



Plasticity Chart

	Gamma pcf	C psf	Phi deg	Piezo Surf.	Ru
River	62.4	0	0	1	0
Silty Sand	120	50	34	1	0
Silt	120	50	28	1	0

Eden Prairie Stabilization - Area 3
Gale-Tec Engineering, Inc.
June, 2008
Station 11+50, Wedge Failure
Assumed Conditions for Limit Equilibrium (FS=1.0)



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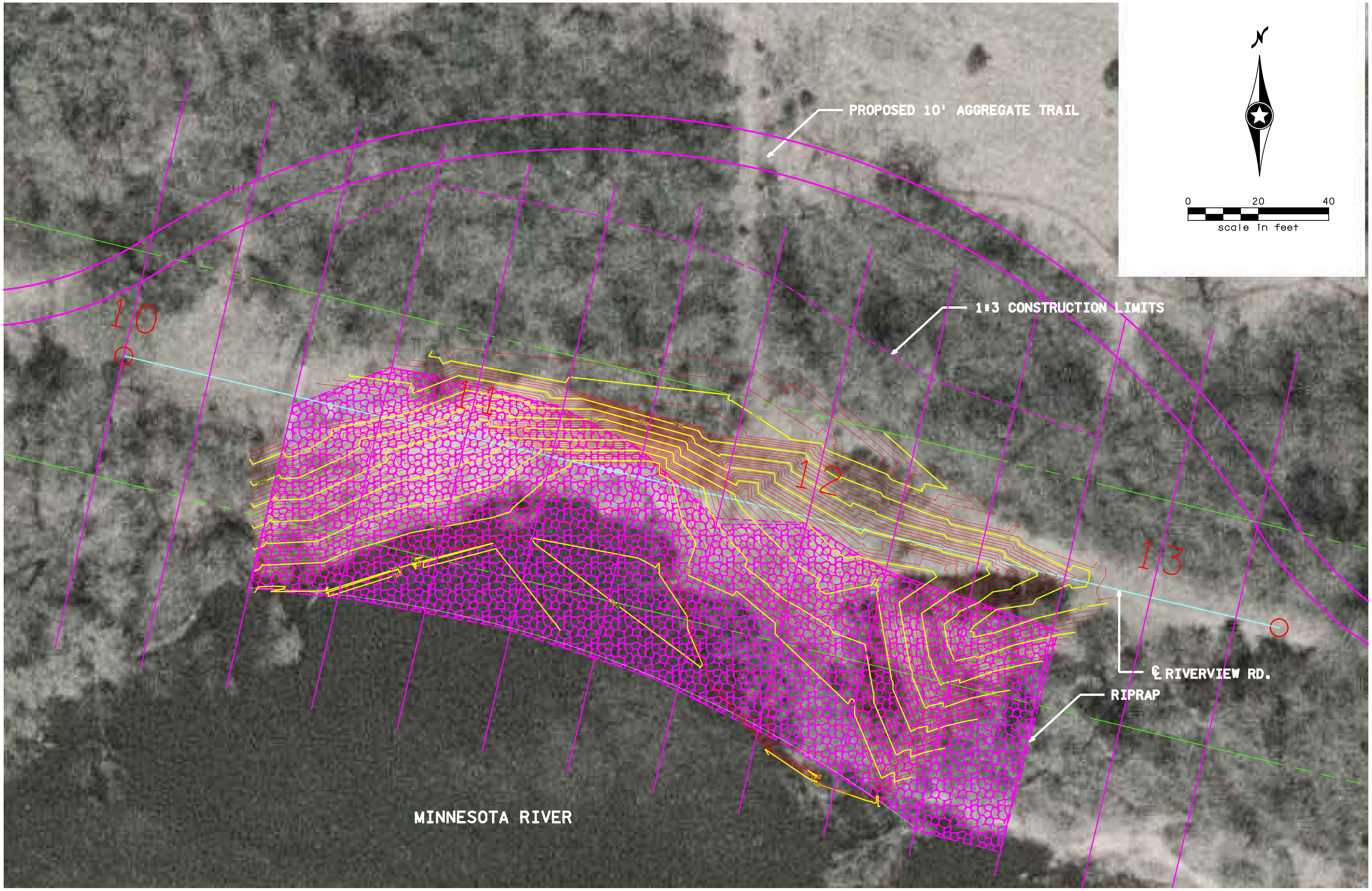
Appendix D
Alternative 1: Layout and Cross Sections



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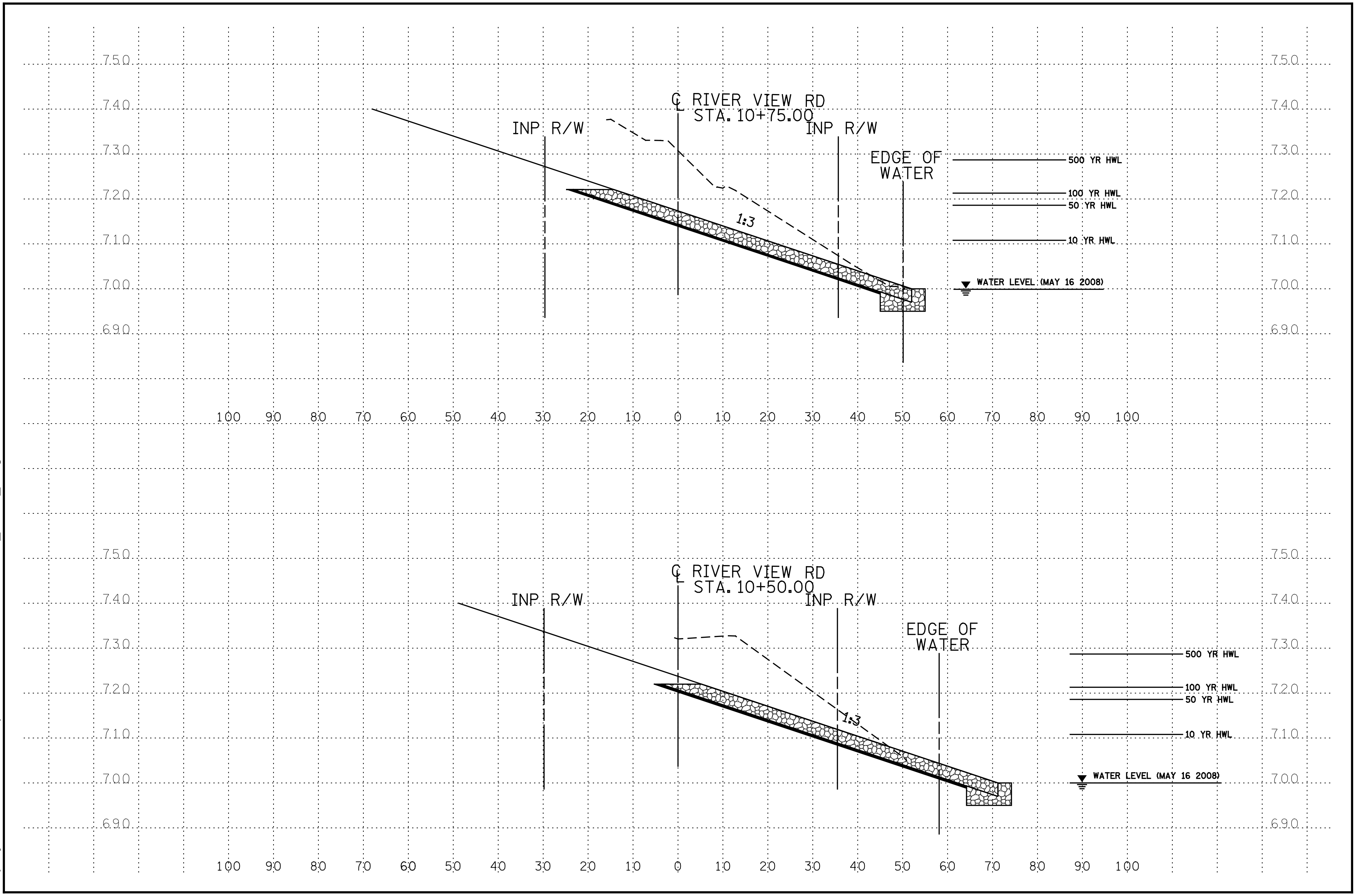
SRF Consulting Group, Inc.

Appendix D: Study Area 3 Cross Section Layout (1:3 Slope)

Eden Prairie Erosion Stabilization Study
Eden Prairie, MN

Figure D1

Job #
9/18/2008



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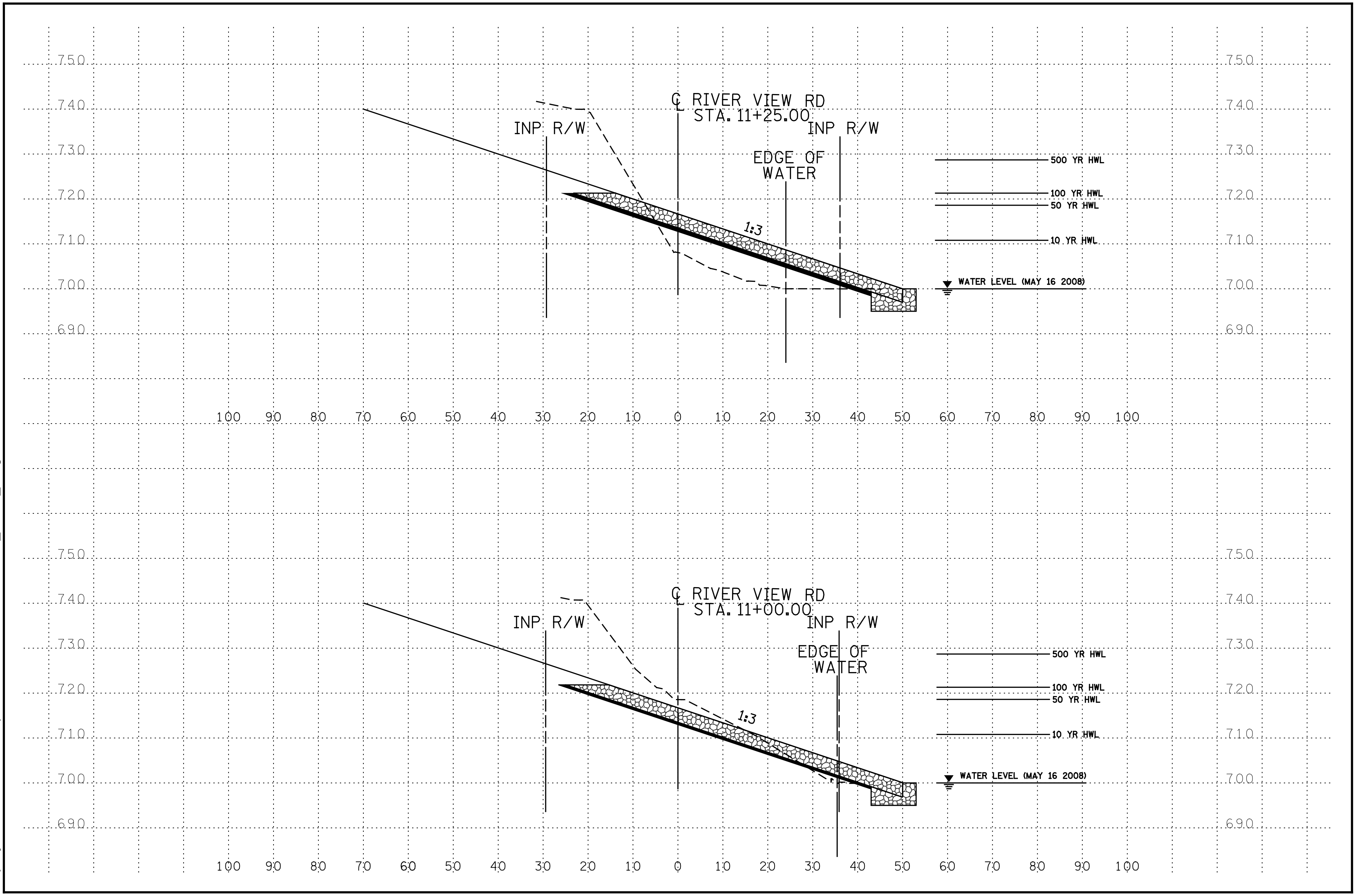
SRF
Consulting Group, Inc.

Appendix D - 1:3 Soil Slope

Eden Prairie Erosion Stabilization Study
Eden Prairie, MN

Job #6205
9/18/2008



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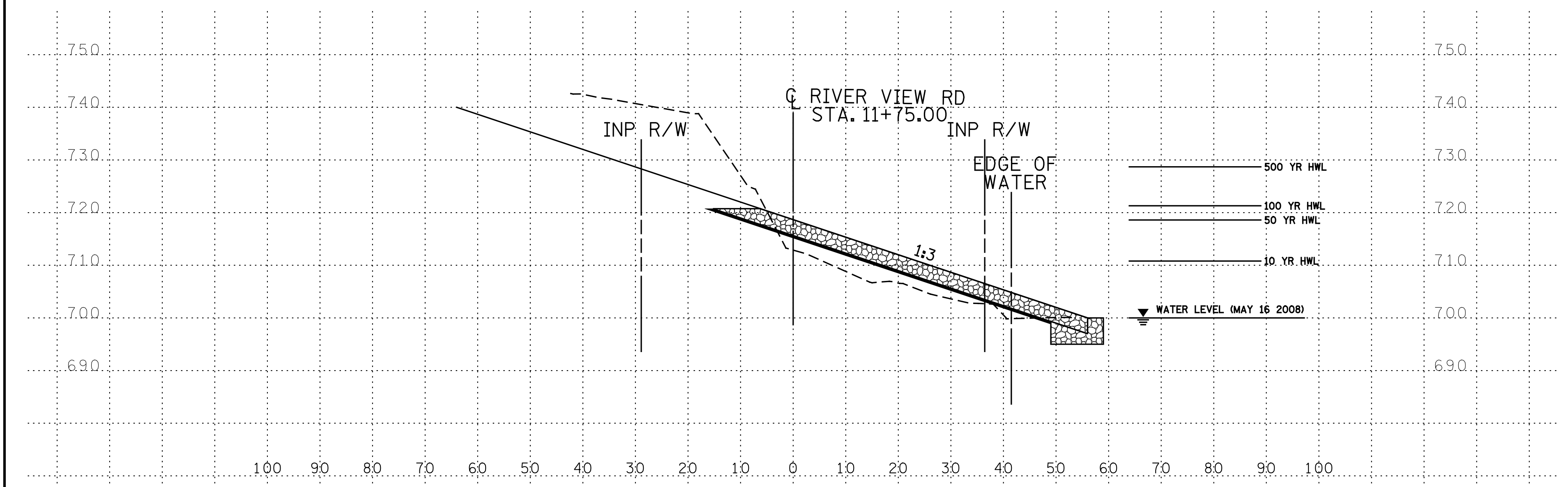
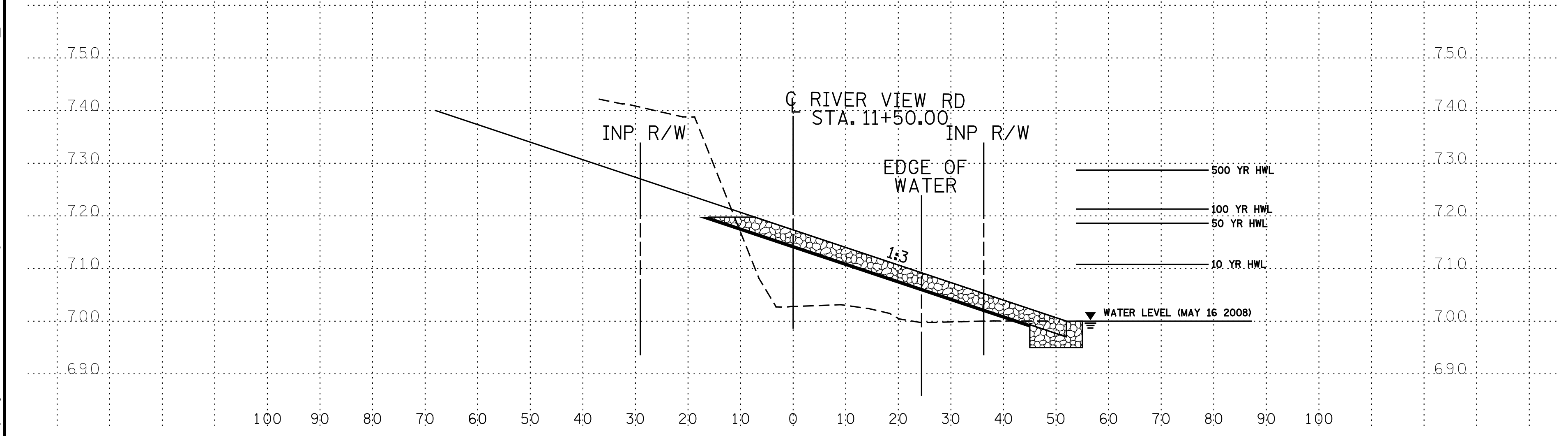
SRF Consulting Group, Inc.

Job #6205
9/18/2008

Appendix D - 1:3 Soil Slope

Eden Prairie Erosion Stabilization Study
Eden Prairie, MN





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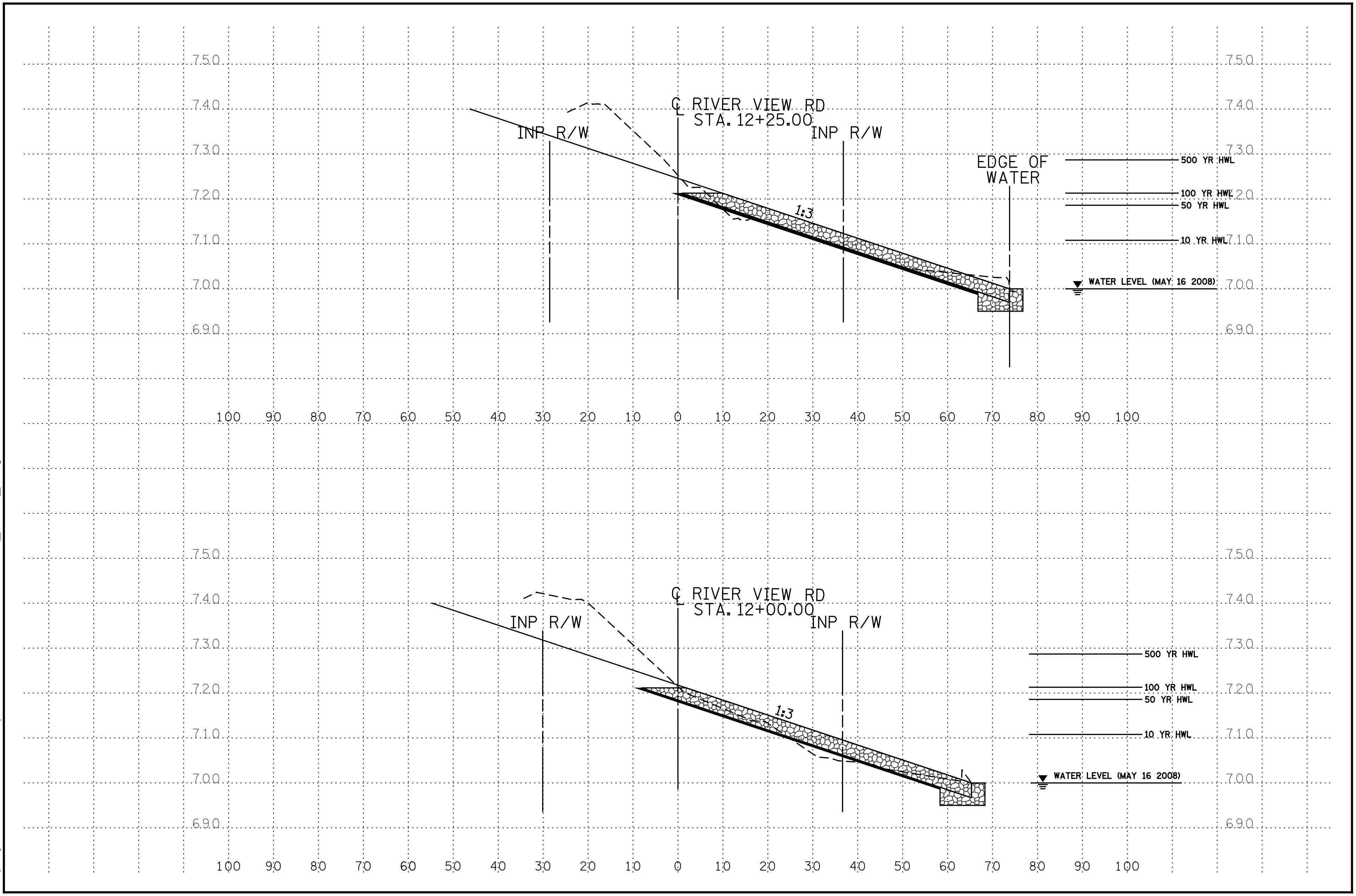
SRF Consulting Group, Inc.

Appendix D - 1:3 Soil Slope

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Job #6205
9/18/2008



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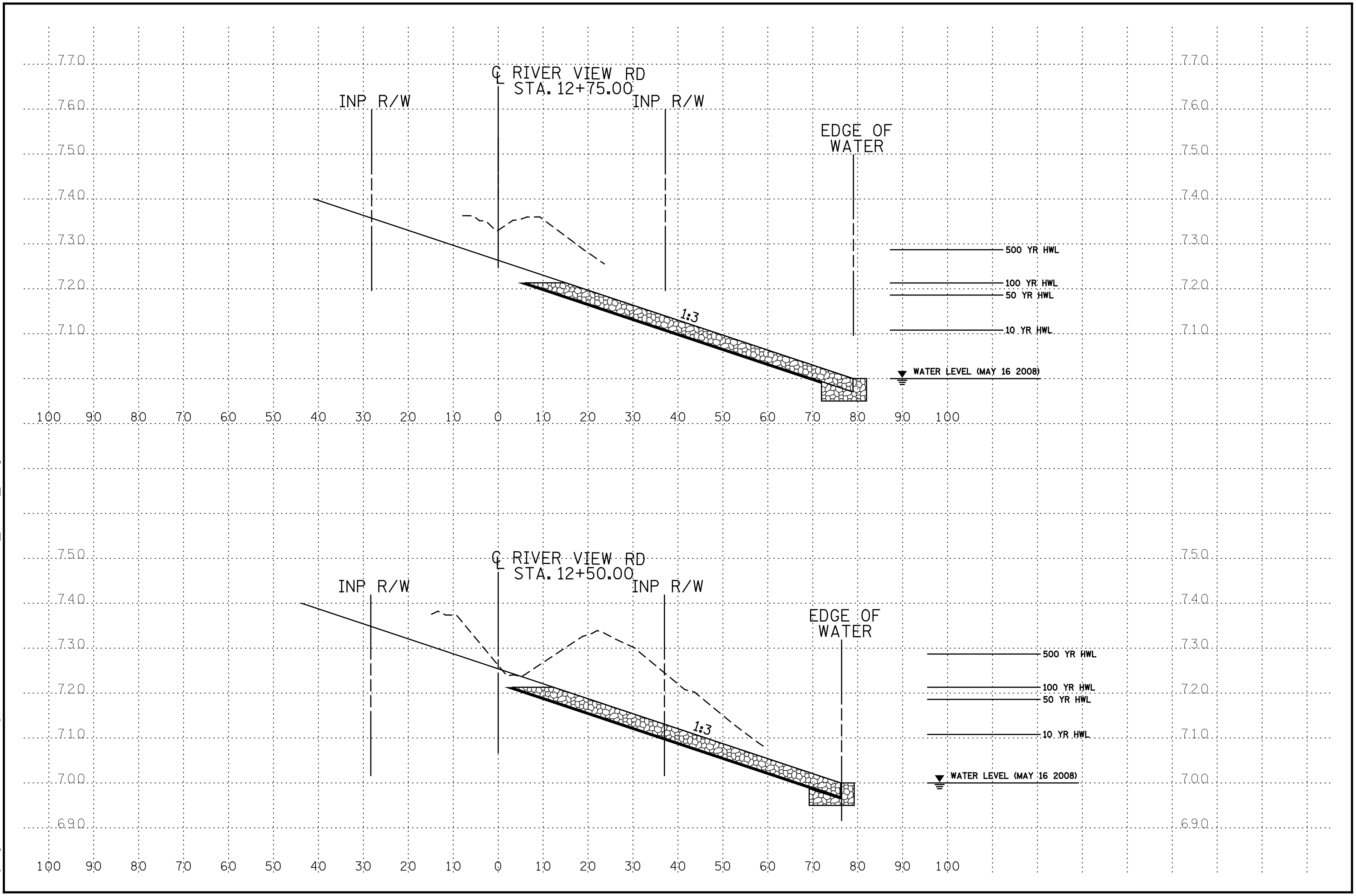
Appendix D - 1:3 Soil Slope

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Job #6205
9/18/2008



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Job #6205
9/18/2008

Appendix D - 1:3 Soil Slope

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Appendix E
Alternative 2: Layout and Cross Sections

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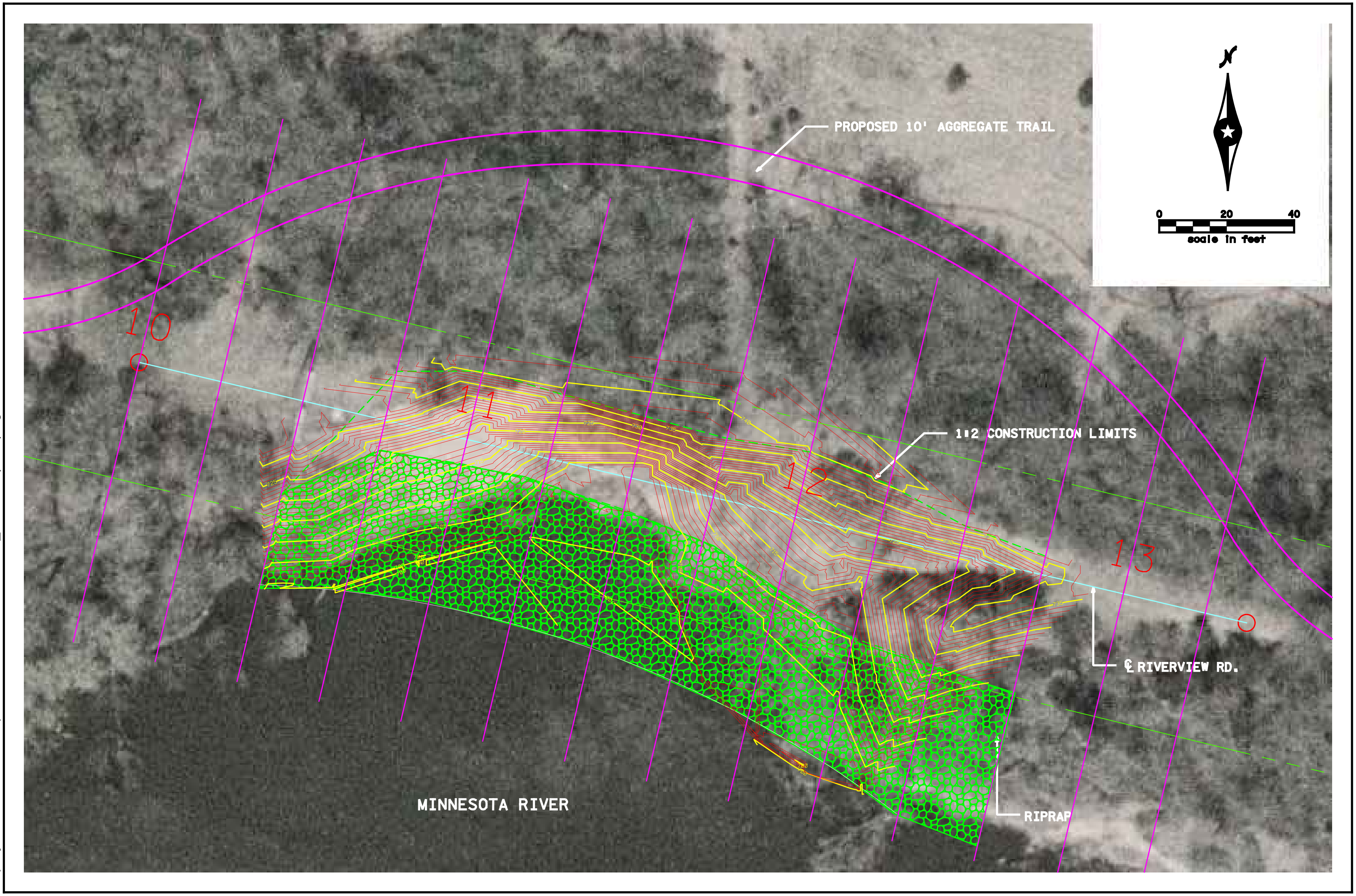


SRF Consulting Group, Inc.

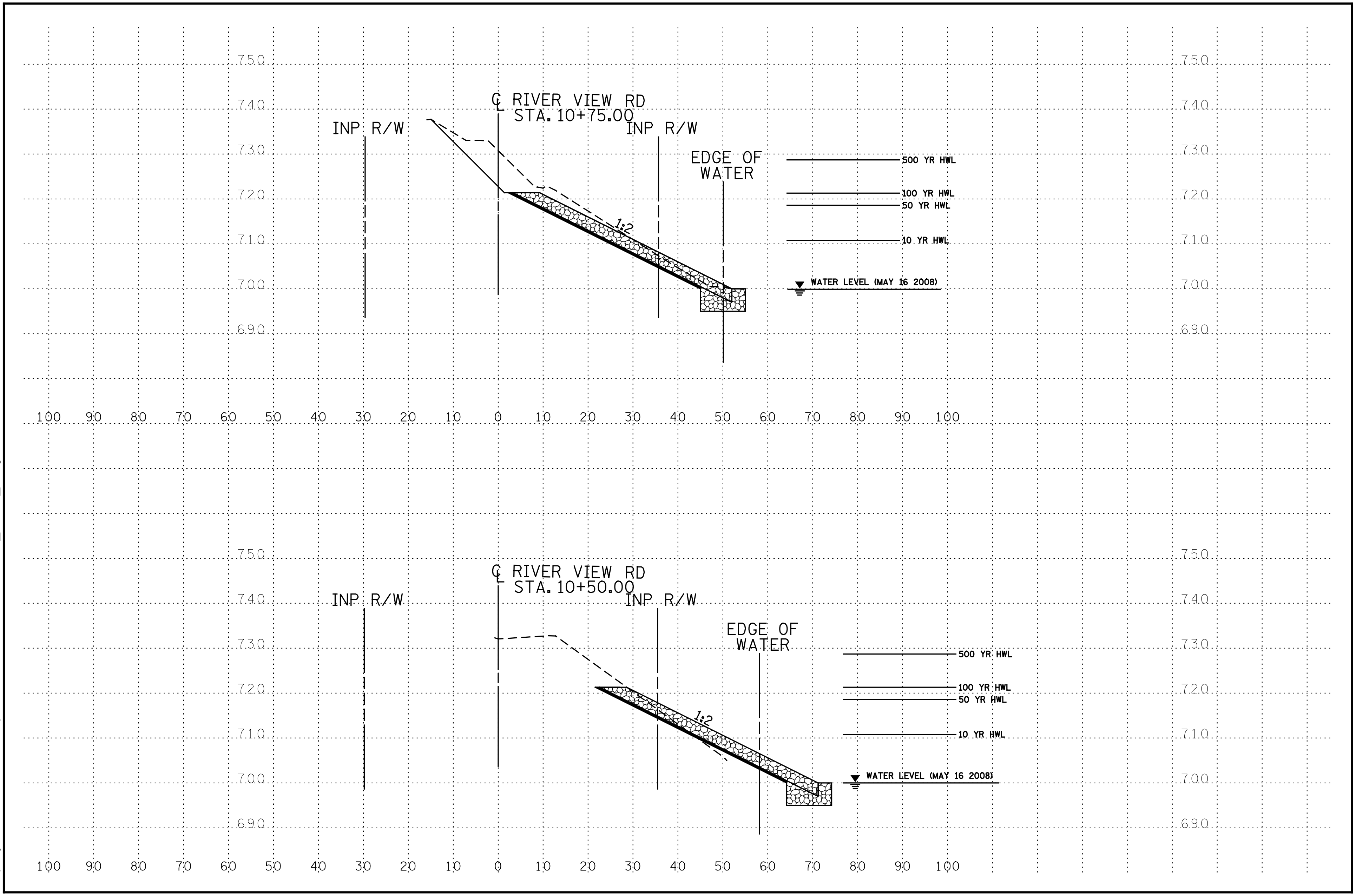
Appendix E: Study Area 3 Cross Section Layout (1:1 RSS)

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Figure E1

Job #
9/18/2008



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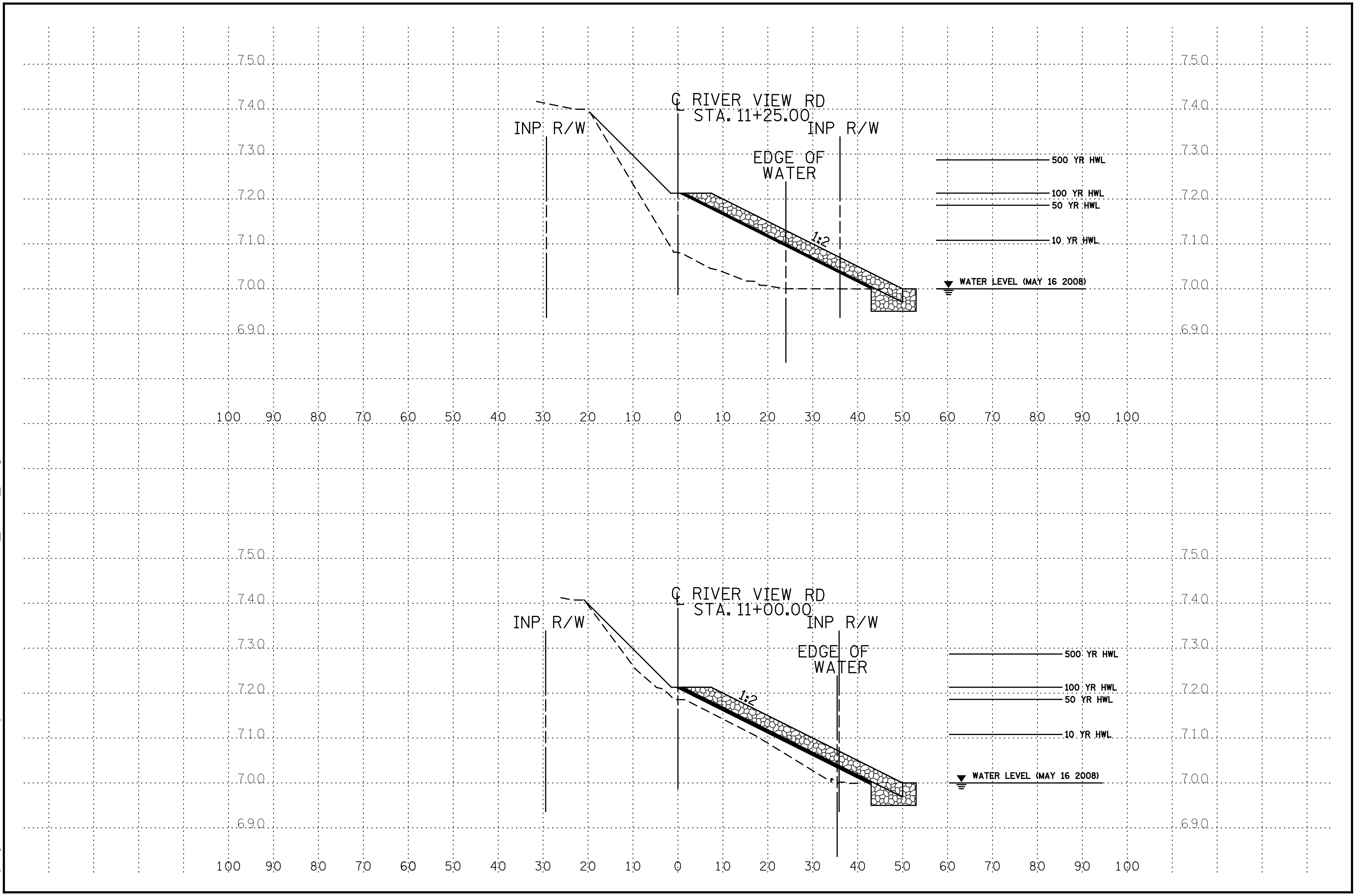
SRF Consulting Group, Inc.

Appendix E - 1:1 Geogrid Reinforced Soil Slope with Bench

Eden Prairie Erosion Stabilization Study
Eden Prairie, MN

Job #6205
9/18/2008



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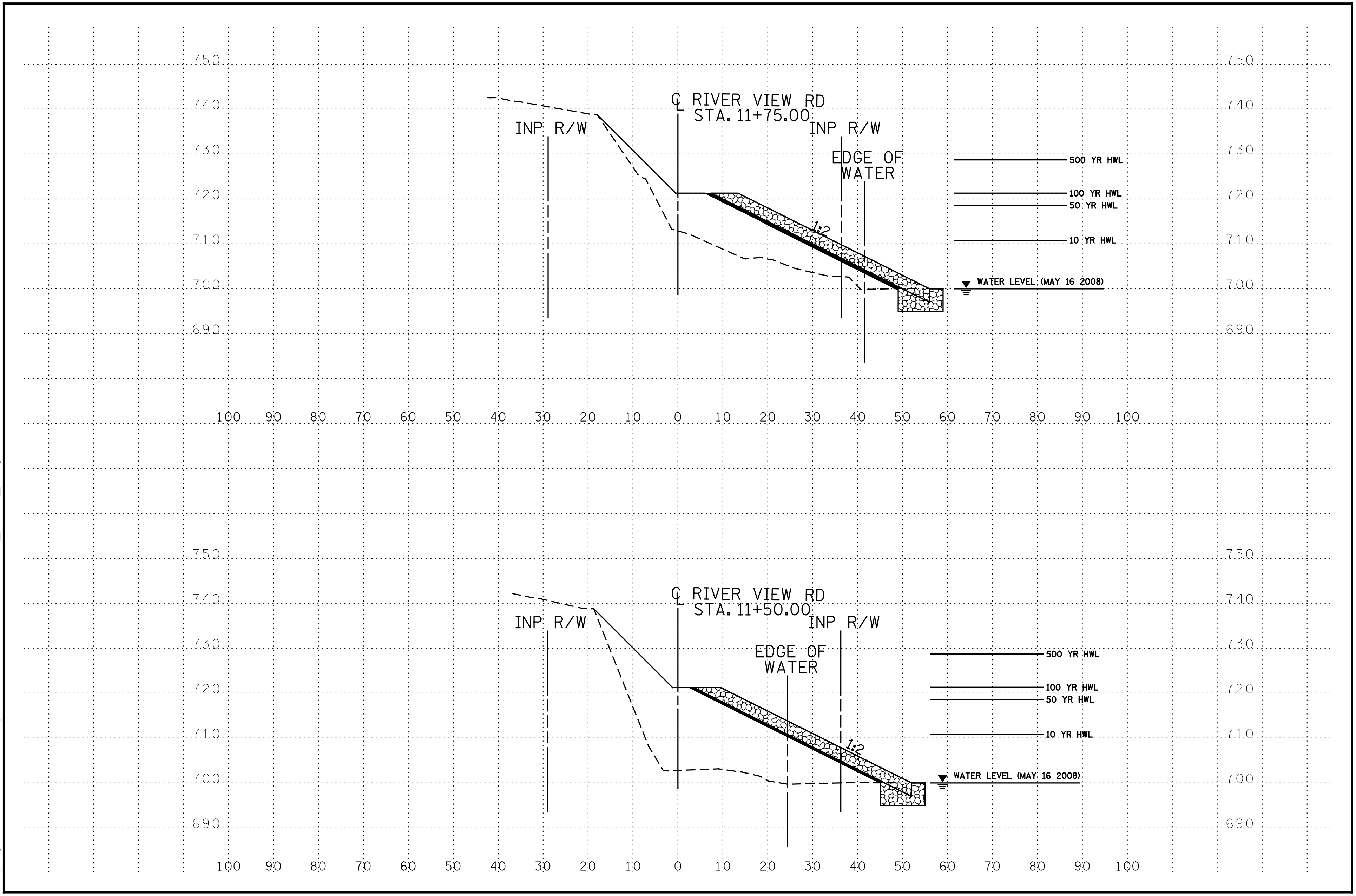
SRF Consulting Group, Inc.

Appendix E - 1:1 Geogrid Reinforced Soil Slope with Bench

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Job #6205
9/18/2008



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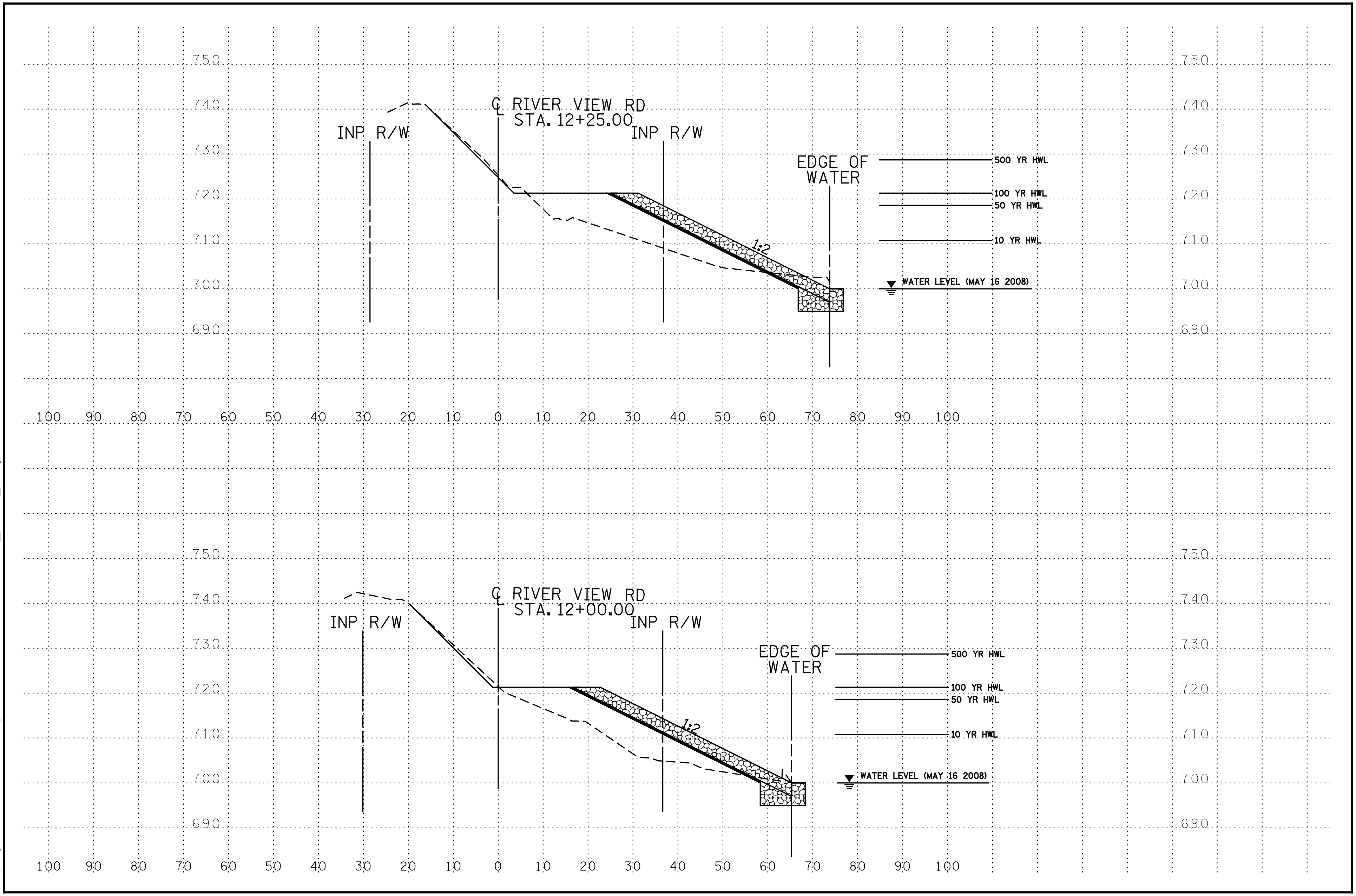
SRF Consulting Group, Inc.

Appendix E - 1:1 Geogrid Reinforced Soil Slope with Bench

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Job #6205
9/18/2008



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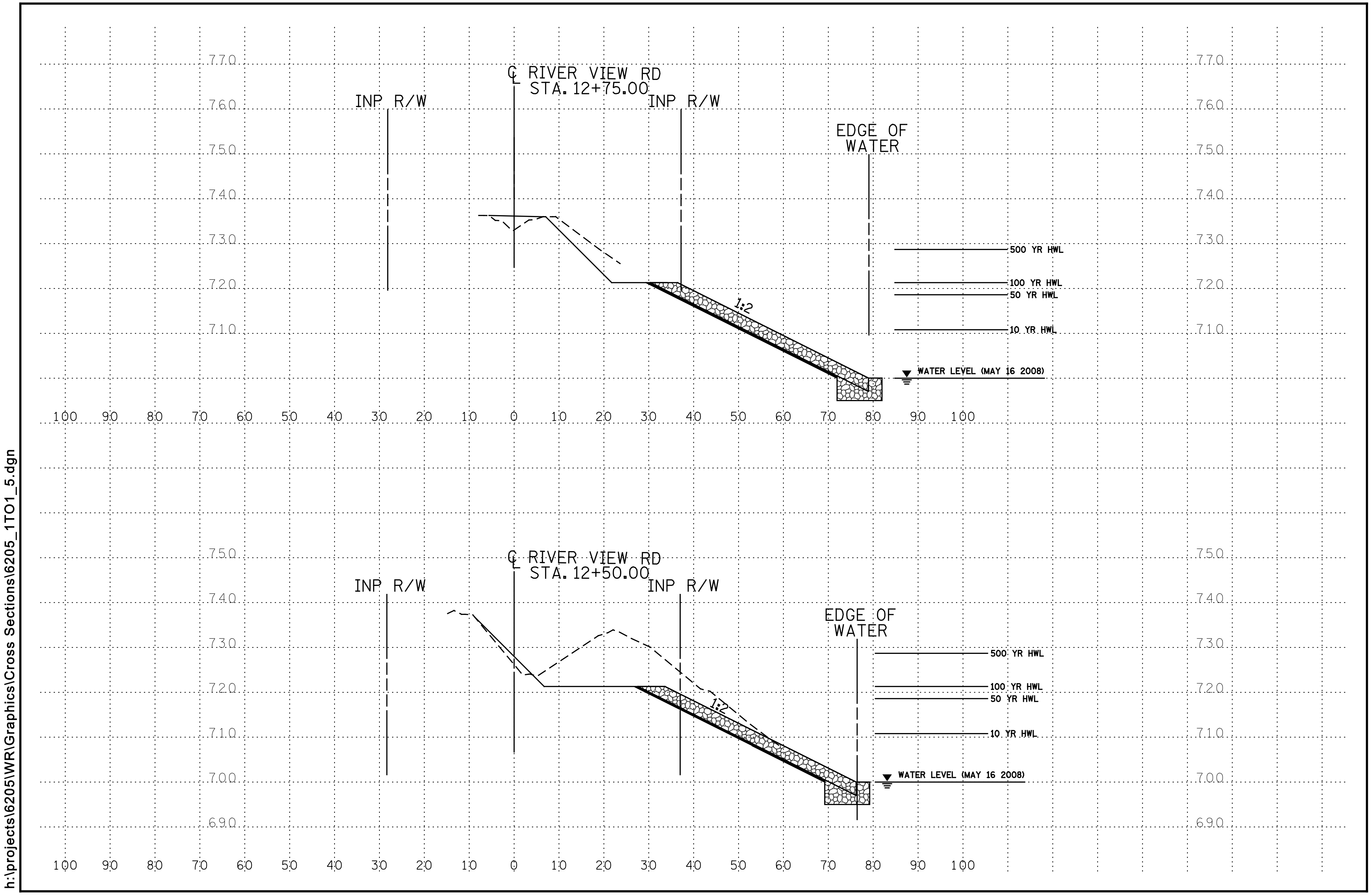
SRF
Consulting Group, Inc.

Appendix E - 1:1 Geogrid Reinforced Soil Slope with Bench

Eden Prairie Erosion Stabilization Study
Eden Prairie, MN

Job #6205
9/18/2008



SRF Consulting Group, Inc.

Appendix E - 1:1 Geogrid Reinforced Soil Slope with Bench

Eden Prairie Erosion Stabilization Study

Eden Prairie, MN

Job #6205
9/18/2008