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March 7, 2024

Arcadis
8133 Warden Ave, Unit 300
Markham, Ontario
L6G 1B3

Attn: Hedieh Hashtroudi, P.Eng., M.A.Sc., M.Eng.
Project Lead

Re: Fluvial Geomorphology Assessment at subject reach of Cooksville Creek
Detailed Design and Schedule 'B' Class EA Services for the 525-mm Sanitary Sewer - Kirwin Avenue (Cooksville Creek) Project 23-2129
City of Mississauga, Region of Peel
GEO Morphix Ltd. Project No. PN23123

Introduction

The Region of Peel is investigating sanitary sewer alignment alternatives to divert existing sewer flows to new larger sewers in order to accommodate growth along the Hurontario Street corridor. It is understood that the preferred alternative includes diversion of flows from the existing 300 mm diameter sewer into a proposed 525 mm sewer that will follow Kirwin Avenue and cross beneath Cooksville Creek west of the roadway. GEO Morphix Ltd. (GEO Morphix) was retained by Arcadis to verify that the riverine erosion hazard at the proposed watercourse crossing is sufficiently mitigated in the design.

The following activities were completed as part of this study:

- A review of available background materials, including proposed sewer design drawings, existing Credit Valley Conservation-generated HEC-RAS hydraulic modelling results for Cooksville Creek, and geomorphic mapping related to channel form and function
- A review of watershed characteristics that directly influence the local geomorphology at the subject crossing location at Cooksville Creek
- Geomorphic assessment and survey results for the subject crossing location at Cooksville Creek that include key watercourse characteristics (e.g., bankfull parameters and channel boundary material erodibility)
- Characterization of the erosion risk to the proposed sewer at the subject crossing based on field observations and the review and interpretation of in-house hydraulic modelling results
- General phasing, erosion, and sediment control plan recommendations for the proposed works
- Guidance related to the monitoring and mitigation for potential in-stream frac out events
- Design implementation and post-construction monitoring recommendations

This technical letter outlines the results of the fluvial geomorphological assessment at the subject watercourse crossing and includes design recommendations to support implementation of the new works.

Existing Channel Conditions

The watershed and associated channel of Cooksville Creek have been heavily modified to accommodate urban development. For example, the channel and valley were historically straightened and armoured, which has contributed to significant changes in the watercourse flow regime and channel function. General changes include an increased magnitude and frequency of peak flows at the channel following runoff/rainfall events, reduced sediment input and replenishment of bed materials, and increased stream gradient and power. These factors generally promote channel instability. Although, bed and bank armouring will help counteract potential adjustment at a local scale.

Field observations at Cooksville Creek were collected on January 12, 2024. To provide context, a photographic record is provided in **Appendix A** and field notes are included in **Appendix B**. A description of the observed channel conditions is provided below.

The proposed sewer crossing location is situated approximately 12 m west of the Kirwin Avenue bridge that extends over Cooksville Creek. At the proposed crossing location, Cooksville Creek flows in southwesterly direction through a wooded park. A paved trail follows the left (east) bank of the watercourse. According to historical aerial imagery, the section of channel west of Kirwin Avenue was realigned/armoured by 2015. Armouring at the channel bed included incorporation of series of steps and pools, mimicking a cascade. Steps consisted of armourstone-based weirs spaced at approximately 30 m intervals. Pools were lined with a gradation of angular stone. Channel banks were also stabilized with angular stone and vegetation (i.e., shrubs). The channel armouring extended from Kirwin Avenue to Dundas Street East and was in good condition at the time of the field visit. For example, there was limited evidence of displaced materials and the armourstone weirs and adjacent stone revetments were physically intact. In addition, the channel banks were vegetated with a high density of shrubs and small trees. Average channel width and maximum depth, as surveyed during the field assessment using Real-Time Kinematic (RTK) instrumentation, were 11.5 and 1.2 m. Valley width and depth, as measured from the top of bank adjacent to the park trail was approximately 26.5 m and 3.3 m. Local channel gradient was surveyed at 0.79%. Channel bed elevation near the proposed sewer crossing location was surveyed at approximately 108.86 m. Armourstone blocks varied in size but assessed dimensions corresponded approximately to a 1.5 tonne stone. Bed materials ranged in size from small gravels to 0.8 m diameter riprap. A modified Wolman pebble count revealed a D50 of 0.18 m and D84 of 0.45 m. Bank materials generally ranged from 0.3 m to 0.7 m diameter riprap.

The channel of Cooksville Creek upstream of Kirwin Avenue was also recently reinforced. Aerial imagery suggests that the work was completed around 2018. The bed was stabilized with armourstone weirs and riprap. Channel banks were also protected with a riprap-based revetment. However, at the time of the field visit, these erosion mitigation treatments were not performing as effectively as those installed downstream of Kirwin Avenue, near the subject sewer crossing location. For example, undercutting was observed along the channel bank, and, in conjunction with this, a portion of the supporting riprap had detached from the bank and become displaced in-channel. In addition, till exposure was documented along the bed of pools, which suggests that the channel had incised into the previously buried materials and that further downcutting is possible.

Assessment of Existing Channel Stability

Generally, a geomorphic assessment for a given channel includes evaluation through application of the Rapid Geomorphic Assessment (RGA; OME, 2003; VANR, 2007) and the Rapid Stream Assessment Technique (RSAT; Galli, 1996). The results of the RGA provide a general evaluation of channel sensitivity based on the presence or absence of common adjustment indicators (specific to the processes of aggradation, degradation, channel widening, and planimetric [planform] adjustment). The RSAT is used to evaluate stream health and the ecological functioning of the watercourse. However, both rapid assessment techniques are intended for alluvial systems with naturally meandering planimetric forms and that have not undergone significant alteration. Field observations revealed that Cooksville Creek has undergone extensive modifications in recent years (realignment and armouring). As such, the rapid assessment techniques were not deemed to be directly applicable for the study area. Instead, the geomorphic conditions and associated channel stability at the subject reach were broadly assessed based on general observations and inferences and with consideration of RGA and RSAT evaluation criteria.

The results of the field study at the subject stretch of channel (i.e., the area west of Kirwin Avenue) demonstrated generally stable conditions. For instance, there was limited evidence of the adjustment indicators described in the RGA. The channel was reinforced with armourstone weirs, which were intact at the time of inspection and serve to reduce the potential for bed degradation. Upstream of each weir, the degradational tendency of the bed in an alluvial stream is inherently mitigated, although this effect decreases progressively farther upstream as the tailwater effect of the weir is reduced. Channel widening and/or planimetric adjustment was inhibited by the noted riprap revetments, which were also in good condition. All channel materials were angular in shape, which provide enhanced resistivity to displacement over more rounded materials. In addition, a high density of shrubs were present along the channel and are understood to provide additional bank stability through deep rooting and enhanced boundary roughness (e.g., reduced flow velocity).

Assessment of Potential Erosion Risk

Hydraulic modelling results for Cooksville Creek, as provided by CVC (via Arcadis), were reviewed to help inform channel susceptibility to erosion at the proposed sewer crossing location. According to the model, in-channel velocities and shear stress ranged from 2.32 m/s and 32 N/m^2, during the 2-year return period flood event, to 4.10 m/s and 80 N/m^2, during the 100-year event. These velocities were compared to the permissible flow velocities associated with the observed in-channel materials. Permissible flow velocities were estimated from two methodologies:

1) Isbash (1936) Method

The Isbash method was developed based on an investigation of the stability of rock dumped into flowing rivers for dam construction. The study focused on the sizing required for individual stones located on the downstream dam slope to resist displacement due to overtopping flow and percolation through the embankment. The model estimates the median stone size (D_{50}; m) under high turbulence flow conditions:

$$D = \frac{V^2}{2gK^2(s_r - 1)}$$ **Equation 1**

Where V is the mean flow velocity (m/s), g is acceleration due to gravity (m/s^2), K the dimensionless Isbash coefficient equivalent (0.86 for high turbulent and/or supercritical flow), and s_r is the specific gravity of rock (approximately equivalent to 2.6).

2) Fischenich (2001) Method

Fischenich (2001) summarizes reported permissible flow velocities and critical shear for a range of materials, including angular stone and heavy armouring. In this case, the reported permissible diameter for riprap is reviewed and compared as a check to the other methods.

The results from the two methods are summarized in **Table 1**.

Table 1: Hydraulic sizing of permissible in-channel materials

Model	Design Velocity† (m/s)	Design Shear† (N/m^2)	Recommended D_{50} (m)	D_{50} with 1.2x Safety Factor (m)
Isbash (1936)	4.10	80	0.72	0.86
Fischenich (2001)			0.61 (riprap or hard surfacing††)	0.73††

† Highest reported in-channel velocity and shear up to the modelled 100-year return period flow event
†† Hard surfacing options include armourstone, gabion basket, or concrete-based armouring

Of note, the permissible material sizes were equipped with a safety factor for added resistance to erosion and displacement. This considers observed upstream channel trends of instability and potential future impacts to flow magnitude related to climate change.

Overall, the results of the analysis demonstrate that large angular boulders and/or armourstone are required at the crossing location to withstand the potential for erosive flows and prevent the channel from scouring towards the proposed sewer crossing. A gradation of materials is recommended, however, to help fill the interstitial space between the boulders and prevent subsurface piping.

Sewer Cover Depth Recommendations

The existing channel materials, when combined with the added stability and grade control provided by the armourstone weirs, were likely designed to address the current vertical riverine erosion hazard. A review of permissible in-channel materials in **Table 1** supports this theory. As such, further reinforcement of the channel is not practical to support the sewer placement at this time, given that the existing armour materials are intact and functioning as intended. Instead, a geomorphic monitoring program is recommended at the crossing location to provide a basis to assess channel change, and, if required, implement mitigation measures and corrective actions. Considering the recent channel realignment work upstream (2018) and downstream of the proposed crossing (2015), such a program was likely already undertaken and has potentially concluded. Continued monitoring will help to verify long-term stability/integrity of the channel and sewer, given that erosion issues would be identified and promptly addressed, should they arise.

Long-term monitoring at the subject crossing is a vital component of managing the potential risk of the riverine erosion hazard. This considers that Cooksville Creek is a known dynamic and erosion-prone stream due to hydrological and sedimentological disturbances from extensive, historical modification of the watershed (Tinkler and Parrish, 1998). The erosive nature of Cooksville Creek is demonstrated by the observed adjustment processes at the newly restored upstream channel segment, coupled with instances of failed or ineffective treatment measures at this same section of channel. Moreover, erosive forces are likely further enhanced at the site, given that the sewer is located downstream of a bridge. Scour potential at the subject crossing would be heightened due to the constriction of upstream flows (at the bridge crossing), and, in turn, the opportunity for increased flow velocity and shear stress (in the areas immediately downstream). Monitoring guidelines are set out below for consideration.

In general, infrastructure associated with new sewer crossings should be positioned below the anticipated extent of scour and encased in concrete for added protection. In this case, scour potential is mitigated by the existing channel armouring (e.g., armourstone and riprap), which was designed to, and should theoretically, withstand channel adjustment over a long-term period. An alternative solution would therefore be to install the sewer below the existing bed substrate design elevation with an added factor of safety (i.e., one bankfull depth). This would leave ample space to restore and protect the bed in the event of future channel maintenance. Placement elevation may be determined from an as-built survey of the constructed armouring elements. If this information is not available, the depth of treatment may be approximated based on industry accepted thickness requirements. For example, bed substrate thickness should be at minimum two-times (2x) the diameter of the largest clasts (i.e., 0.8 m x 2 = 1.6 m). A factor of safety equivalent to the average bankfull depth (i.e., roughly equivalent to 0.9 m) is applied for a total estimated placement depth of 2.5 m, as measured from the top (obvert) of the sewer/encasement. Note, this approach relies on the expectation of continued stability of the existing armouring treatment, as supported by the results of a robust monitoring program to identify, and address in a timely manner, erosion issues as they occur.

Without an assurance of continued channel bed stability through monitoring and/or due to a limited bed substrate thickness, sewer placement recommendations become increasingly stringent. For example, following Credit Valley Conservation (CVC) scour guidelines (CVC, 2019), the sewer would be placed 5 m or more below the average channel bed elevation to account for local scour, natural scour, and a factor of safety.

Bank Restoration Recommendations

It is understood that the sewer crossing is proposed to be constructed using trenchless methodologies, thereby avoiding disturbance to the existing channel bed. However, the work will require a degree of "open-cut" along the channel bank to facilitate the installation. As such, the work area along the bank should be isolated from the channel with erosion and sediment control measures, with a plan to re-instate/restore affected areas of channel bank to pre-construction condition. This includes restoration of the existing vegetated riprap revetment, which consists of a gradation of angular stone up to 0.9 m diameter. Restoration details are set out in the accompanying design drawings in **Appendix C** and should be reviewed in tandem with this report.

For immediate erosion protection, mechanical stabilization in the form of a biodegradable erosion control blanket with a tight weave (e.g., S150BN or equivalent) should be used. The blanket should be installed in a horizontal manner across the slope of the bank, parallel to the direction of flow. As the blanket will biodegrade over time, it will serve as a short-term stabilization measure. For longer-term stability, implementation of a planting plan is recommended. This includes prescription of a riparian seed mix, which consists of deep rooting native grasses and other herbaceous species to be distributed and raked into the area of the channel banks. A high density of dead staking is recommended to secure the erosion control blanket in-place. Surfaces consisting of manicured lawn should be restored with sod, as appropriate. Finally, trees affected by the cut should be identified and compensated for as determined by the project arborist/ecologist.

Construction inspections of the identified erosion protection measures should be performed by a geomorphologist or fluvial specialist, as this type of work differs considerably from engineering projects. An experienced inspector will be able to provide a timely and appropriate response to issues that may arise and will confirm that construction proceeds in accordance with the approved design and contract.

Contingency Plan for Potential Frac-Out Events During Installation

Trenchless drilling activities (e.g., horizontal directional drilling or other) at watercourse crossings could result in accidental releases of drilling mud or cementitious grout components to the surface water environment (adjacent to or in a watercourse), recognizing that drilling mud releases to a watercourse can have adverse impacts on water quality and aquatic organisms. In the event of channel bed fracture during directional drilling, stream related frac-out mitigation plan considerations are outlined in **Appendix C** to help reduce impacts to the surface environment due to the potential release of drilling fluids. The frac-out mitigation plan includes a drawing of stream related restoration and work area isolation. The following general recommendations are also provided to supplement the overall drilling frac-out plan and response and corrective actions protocols when dealing specifically with in-stream conditions:

- Maintain visual observation of channel conditions coupled with in-construction water quality monitoring to identify instances of elevated turbidity
- Immediately stop all works in the vicinity of the fracture
- Notify the Spills Action Centre of the Ministry of the Environment and Climate Change
- Immediately isolate the frac-out location as necessary using 1 m pea-gravel cofferdams
- Pump the water and excess drilling mud from the isolated area for treatment and discharge as appropriate back to the channel
- Clean up excess drilling mud in the water and restore the affected section of the channel to the original condition to the extent possible with the addition of hydraulically sized stones along the channel bed

Post-Construction Monitoring

A post-monitoring program is recommended to assess the performance of the implemented works and confirm stability of the existing channel bed armouring at the proposed sewer crossing. Monitoring observations can also be used to determine the need for remedial measures. Based on our experience with similar projects, post-monitoring work is often undertaken by the municipality as part of their stream valley infrastructure monitoring program. As such, we provide the following general suggestions to be considered as part of this type of program:

- Post-construction monitoring should be undertaken by a certified geomorphologist or fluvial specialist with direction from the project geomorphologist and/or designer
- The post-monitoring program should adhere to the recommendations set out in the "SMART" monitoring protocol (River Restoration Centre, 2011) and the TRCA Protocol for Monitoring of New Sites, as possible
- General observations of the disturbance area/bank restoration area should be documented after construction and after the first large flooding event to identify any potential areas of erosion concern

  - The channel is deemed stable based on the absence of knickpoints, rills, gullies or other erosional damage to the riparian zone and banks following channel inspections
  - Areas subject to erosion will be repaired in the year during which issues were noted
- Collection of a photographic record to visually assess site conditions at years 1, 3, and 5 post-construction
- Complete an "as-built" survey of the channel planform, longitudinal profile and cross sections just after construction to assess conformance with the design and to obtain reference data for the following monitoring years
  - Differences in the final build from the plan will be approved by the City or corrected as required
- Installation of monumented cross sections to be resurveyed once per year of monitoring (years 1, 3, and 5)
- Bed material characterization using the Wolman (1954) pebble count technique once per year of monitoring (years 1, 3, and 5)
- Installation of erosion pins at monumented cross sections after construction to monitor knickpoint and/or channel migration
- A general vegetation survey during each year of monitoring to assess in-channel vegetation establishment
  - More than 20% of vegetation planting loss will warrant planting replacement to at least 95% of the planned coverage
- Re-survey of the longitudinal profile and cross sections, as well as monitoring of erosion pins at monumented cross sections at years 1, 3, and 5
- Annual reporting with a final report at the end of the monitoring period

Summary

The key findings and recommendations from the fluvial geomorphic assessment for the subject channel reach at Cooksville Creek include the following:

- Field observations at the subject channel location, coupled with a review of the CVC-generated hydraulic results relative to the erosion threshold methods from Isbash (1936) and Fischenich (2001), demonstrated generally stable conditions at the channel under a wide range of flow conditions (up to and including the 100-year event), recognizing that recently installed (circa 2015) armouring works at the channel have remained intact and are functioning as intended to minimize the potential for channel degradation and widening.
- As a preliminary recommendation, the obvert of the proposed sewer pipe should be placed at an elevation of at least 2.5 m the existing channel bed elevation.
- Notwithstanding the above, a geomorphic monitoring program is recommended at the crossing location (following the installation of the new sewer) to provide a basis to assess channel change over time, and, if required, implement mitigation measures and corrective actions, recognizing that the broader channel at Cooksville Creek is known to support active erosion and adjustment processes.
- The implementation of a contingency plan will be required during construction to address the potential for drilling-related frac-out events (as outlined in **Appendix C**).
- The implementation of ESC measures will be required in the vicinity of the planned open-cut portion of the works, with a plan for the contractor to complete bank restoration measures following the works, as well as follow-up monitoring to confirm stabilization.

We trust this letter meets your current requirements. Should you have any questions, please contact the undersigned.

Respectfully submitted,

Paul Villard, Ph.D., P.Geo., CAN-CISEC, EP, CERP
Director, Principal Geomorphologist

Bryce Molder, M.Sc., P.Geo., CAN-CISEC
Geomorphologist, Project Manager

References

Fischenich, C. 2001. Stability Thresholds for Stream Restoration Materials. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Isbash, S.V. 1936. Construction of dams by depositing rock in running water. Transactions, Second Congress on Large Dams. Washington, D.C.

Ministry of the Environment (MOE). 2003. Ontario Ministry of the Environment. Stormwater Management Guidelines.

Tinkler, K.J., and Parrish, J., 1998, Recent adjustments to the long profile of Cooksville Creek, an urbanized bedrock channel in Mississauga, Ontario. American Geophysical Union, Geophysical Monograph 107, p. 167–188.

Vermont Agency of Natural Resources (VANR). 2007. Step 7: Rapid Geomorphic Assessment (RGA). Phase 2: Stream Geomorphic Assessment.

Appendix A: Photographic Record

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Photo	
Photo 1	 Upstream of Kirwin Drive and the subject sewer crossing location, Cooksville Creek was armoured with riprap and armourstone grade controls. The arrow denotes flow direction.
Photo 2	 Sections of the treatment were in poor condition. For example, riprap had become detached and displaced in-channel. Till exposure was also documented along the channel bed.

Photo 3	 The channel was historically reinforced with riprap within and downstream of the Kirwin Drive stream crossing.
Photo 4	 The riprap treatment extended downstream of Kirwin Drive. The treatment was in moderately stable condition. There was limited evidence of scouring and channel banks were well vegetated. The approximate proposed sewer crossing is delineated in red.

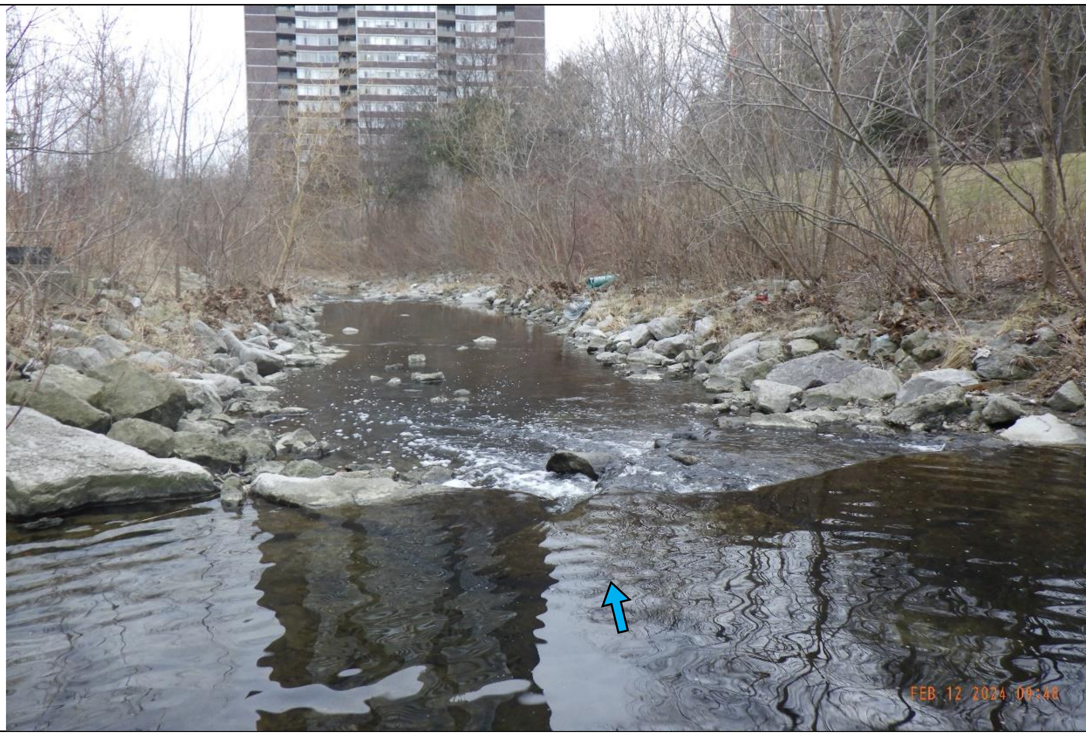
Photo 5	 The channel was realigned/armoured by 2015 downstream of the proposed sewer crossing to Dundas Street. An armourstone weir located 18 m downstream would provide upstream grade control to the new sewer.
Photo 6	 Channel banks were vegetated and protected with riprap. The treatment was in good condition at the time of assessment.

Photo	
Photo 7	 Overview of sewer crossing location. The anticipated area of disturbance is roughly outlined in red.
Photo 8	 Projected area of disturbance along north (right) bank. Affected riprap revetment to be restored with vegetated riprap treatment. Affected small shrubs to be restored with live stakes. Affected sections of manicured lawn sections to be restored with sod. Trees to be compensated for as determined by ecologist/arborist.

Appendix B: Field Notes

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Reach Characteristics

Project Number: PN23123

Date:	Feb 12, 2024	**Field Staff:**	BM SC	**Watershed/Subwatershed:**	Cooksville Ck
Time:	8:00am	**Stream:**	Cooksville Ck	**UTM (Upstream):**	611 805.97 4826719.6
Weather:	-2°C overcast	**Reach:**	CC1	**UTM (Downstream):**	611 787.29 4826696.6

Land Use (Table 1): 5 | **Valley Type** (Table 2): 3 | **Channel Type** (Table 3): 1 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Evidence of Groundwater ~~X~~ Location: NA Photo: NA

Riparian Vegetation

- **Dominant Type** (Table 6): 2
- **Encroachment** (Table 7): 1
- **Coverage:** ☐ None ☐ Fragmented ☑ Continuous
- **Channel Widths:** ☑ 1 - 4 ☐ 4 - 10 ☐ > 10
- **Age (yrs):** ☑ Immature (<5) ☑ Established (5-30) ☐ Mature (>30)

Aquatic & Instream Vegetation

- **Type** (Table 8): 6
- **Reach Coverage %:** 50
- **Woody Debris:** ☐ In Cutbank ☐ In Channel ☑ Not Present
- **WD Density:** ☑ Low ☐ Mod ☐ High
- **WDJ/50m:** 0

Water Quality

- **Odour** (Table 16): 1
- **Turbidity** (Table 17): 2

Channel Characteristics

- **Sinuosity Type** (Table 9): 1
- **Gradient** (Table 11): 2
- **Entrenchment** (Table 13): 2
- **Down's Model** (Table 15): S*
- **Sed Sorting** (Table 20): VP
- **Transport Mode** (Table 21): 1
- **Geomorphic Units** (Table 22): 2
- Weir **Riffle-Pool Spacing (m):** 25
- **Sinuosity Degree** (Table 10): 2
- **# of Channels** (Table 12): 1
- **Bank Failure** (Table 14): 1
- **Bankfull Indicators** (Table 18): 4/1 (constructed)
- **Sediment Transport Observed?** ☐ Yes ☐ No ☑ Not Visible
- **% of Bed Active:** NA
- **Mass Movement** (Table 23): None
- **% Riffles:** (Weir) 30
- **% Pools:** 70
- **Bank Angle:** ☐ 0 – 30 ☑ 30 – 60 ☐ 60 – 90 ☐ Undercut
- **Bank Erosion:** ☑ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

(Table 19)	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Bank	☐	☑	☑	☑	☑	☐	☐
Weir ~~Riffle~~	☐	☐	☐	☐	☑ AR	☐	☐
Pool	☐	☑	☑	☑	☑	☐	☐
~~Bed~~ (if no riffle-pool morphology)	☐	☐	☐	☐	☐	☐	☐

	BKF1		Valley
Bankfull Width (m)	11.5		26.5
Bankfull Depth (m)	1.2		3.3
Undercuts (m)	0		/
Pool Depth (m)	1.4		/
~~Riffle Length~~ **(m)**	NA		/

Wetted Width (m)	7.25		/
Wetted Depth (m)	0.18		/
Velocity (m/s)	0.2	/	
Velocity Estimate Method	Est	/	
Meander Amplitude (m)	NA	/	

Notes: Armourstone cascade - Constructed in 2015 based on aerial imagery. Ties into older armouring (riprap) at the sewer crossing location and Kirwin Bridge. Treatments are in moderate to good condition. US treatments (E of bridge) in poor condition.

Photos: As taken

Version #4
Last edited: 04/04/2023

Senior staff sign-off (if required): / Checked by: PV Completed by: BM

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General Site Characteristics

Project Number: PN23123

Date:	Feb 12, 2024	**Stream:**	Cooksville Ck
Time:	8:00am	**Reach:**	CC1
Weather:	-2°C Overcast	**Location:**	Kirwin Ave
Field Staff:	BM SC	**Watershed/Subwatershed:**	Cooksville Ck

Features		Monitoring	
(symbol)	Reach break	(symbol)	Long-profile
(symbol)	Station location	(symbol)	Monumented XS
(symbol)	Cross-section	(symbol)	Monumented photo
(symbol)	Flow direction	(symbol)	Monumented photo direction
(symbol)	Riffle	(symbol)	Sediment sampling
(symbol)	Pool	(symbol)	Erosion pins
(symbol)	Sediment bar	(symbol)	Scour chains
(symbol)	Eroded bank/slope	**Additional Symbols**	
(symbol)	Undercut bank		
(symbol)	Bank stabilization		
(symbol)	Leaning tree		
(symbol)	Fence		
(symbol)	Culvert/outfall		
(symbol)	Swamp/wetland		
(symbol)	Grasses		
(symbol)	Tree		
(symbol)	Instream log/tree		
(symbol)	Woody debris		
(symbol)	Beaver dam		
(symbol)	Vegetated island		

Flow Type

H1	Standing water	**H1A**	Back water
H2	Scarcely perceptible flow		
H3	Smooth surface flow		
H4	Upwelling		
H5	Rippled		
H6	Unbroken standing wave		
H7	Broken standing wave		
H8	Chute		
H9	Free fall	**H9A**	Dissipates below free fall

Substrate

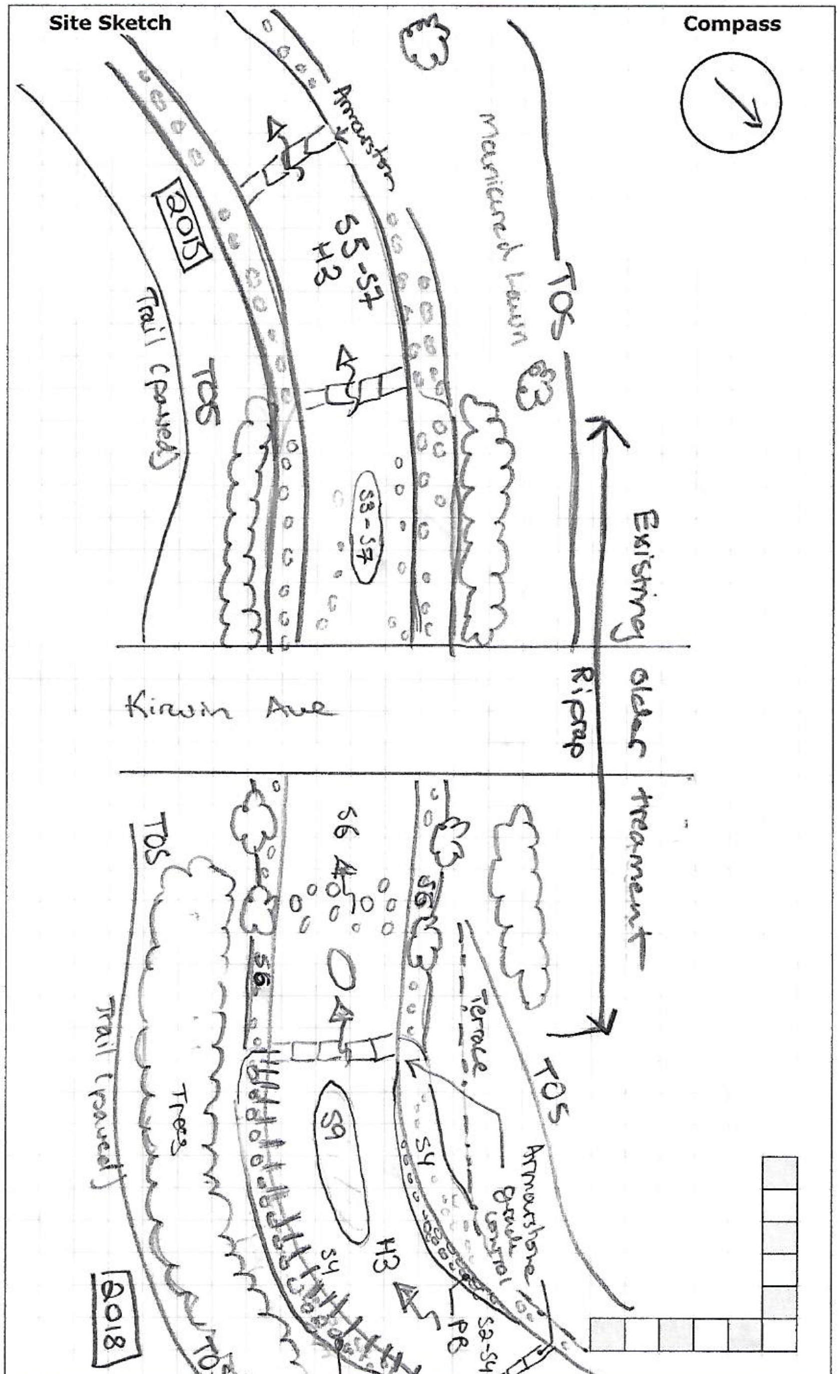
S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble	S10	Armourstone

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch

Compass



Photos:

Notes:

2018 US treatment in poor condition. Scouring observed. Transitions to older riprap based treatment (moderate condition) then to 2015 cascade. (good)

Version #4
Last edited: 21/02/2023

Senior staff sign-off (if required): / Checked by: PV Completed by: BM

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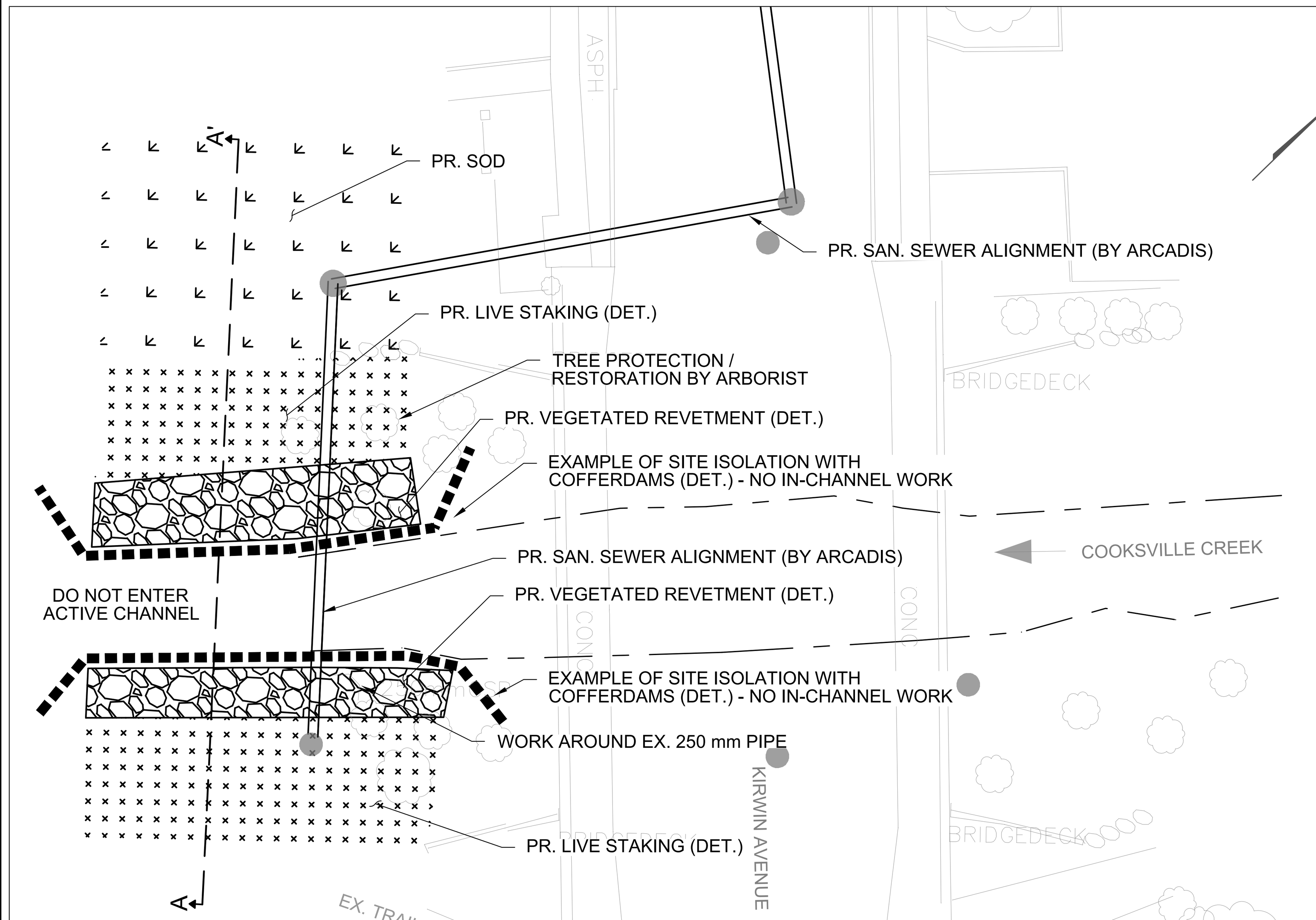
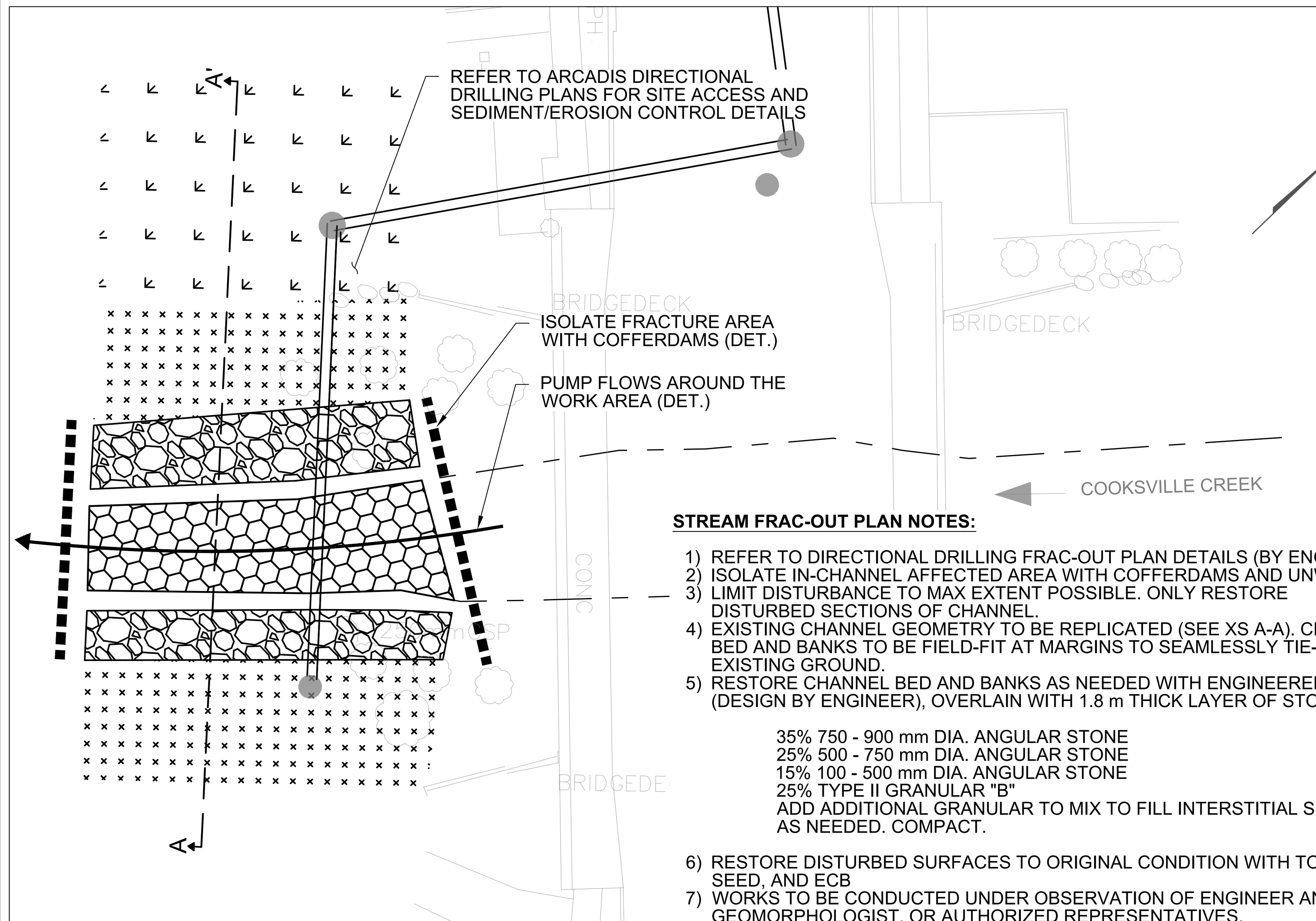
Appendix C: Bank Restoration Drawings



NOTE:
- RESTORATION EXTENTS TO BE DETERMINED/ REFINED BASED ON AREA OF DISTURBANCE AND TO MATCH EX. ADJACENT GROUND
- DISTURBANCE LIMITED TO OVERBANK AREA, NO IN-CHANNEL WORK ANTICIPATED. FULL CHANNEL SHOWN IN CASE OF FRAC OUT.

BANK RESTORATION PLAN
1:250



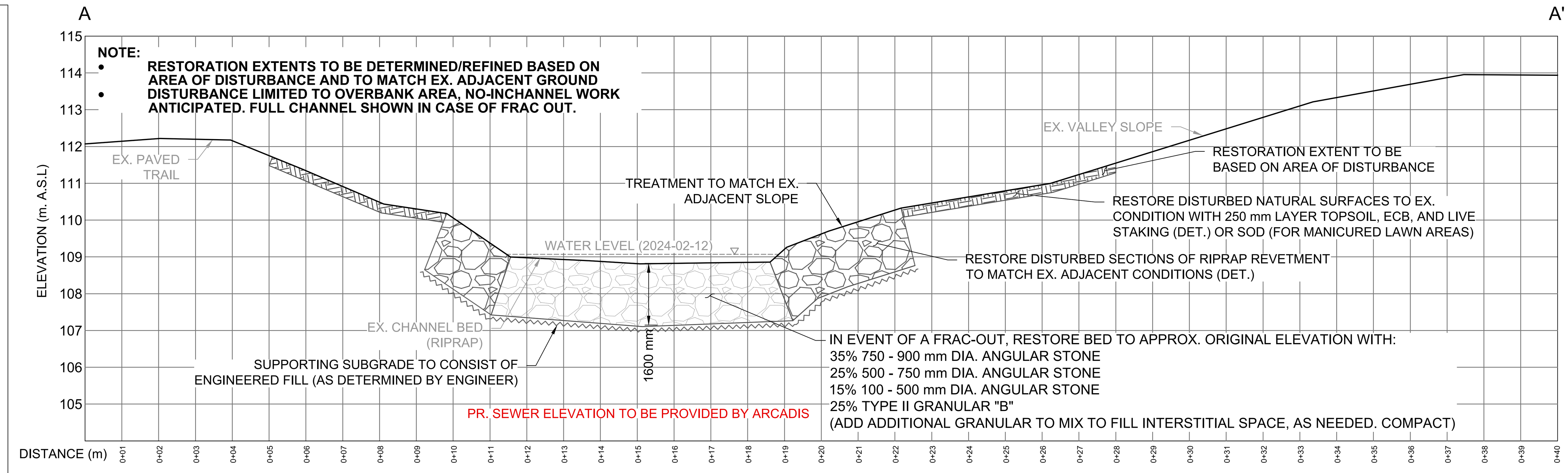
STREAM FRAC-OUT PLAN NOTES:

1) REFER TO DIRECTIONAL DRILLING FRAC-OUT PLAN DETAILS (BY ENGINEER)
2) ISOLATE IN-CHANNEL AFFECTED AREA WITH COFFERDAMS AND UNWATER
3) LIMIT DISTURBANCE TO MAX EXTENT POSSIBLE. ONLY RESTORE DISTURBED SECTIONS OF CHANNEL.
4) EXISTING CHANNEL GEOMETRY TO BE REPLICATED (SEE XS A-A). CHANNEL BED AND BANKS TO BE FIELD-FIT AT MARGINS TO SEAMLESSLY TIE-IN TO EXISTING GROUND.
5) RESTORE CHANNEL BED AND BANKS AS NEEDED WITH ENGINEERED FILL (DESIGN BY ENGINEER), OVERLAIN WITH 1.8 m THICK LAYER OF STONE MIX:

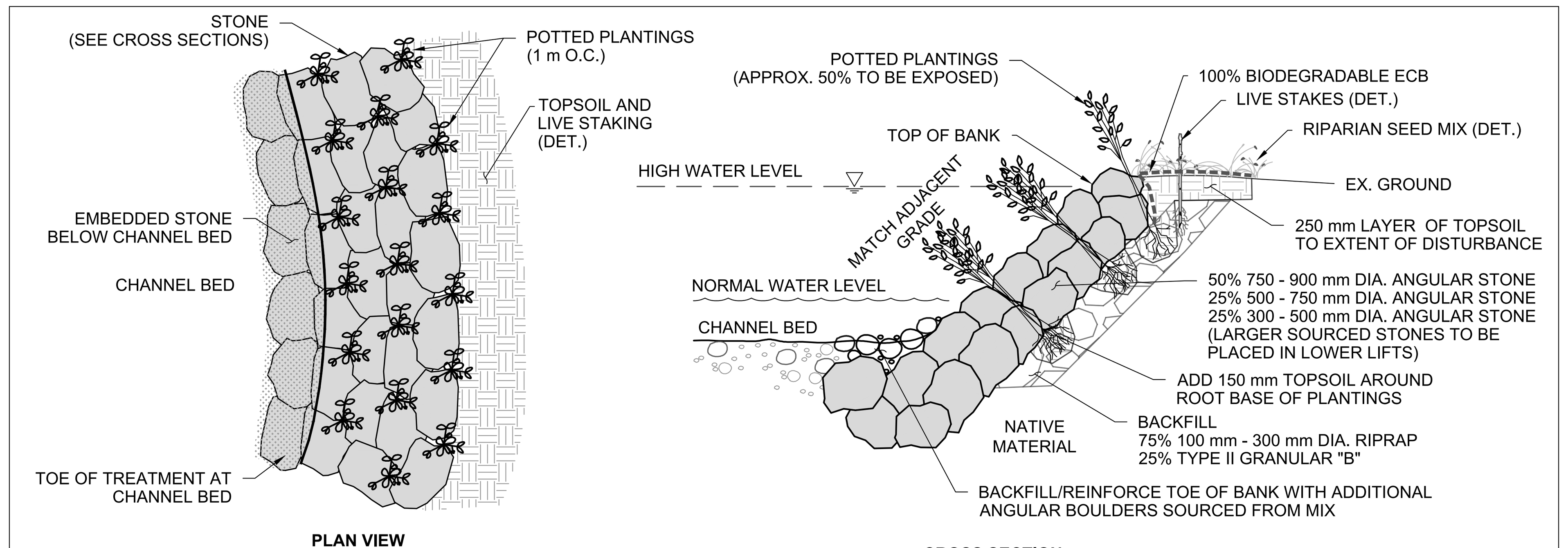
   35% 750 - 900 mm DIA. ANGULAR STONE
   25% 500 - 750 mm DIA. ANGULAR STONE
   15% 100 - 500 mm DIA. ANGULAR STONE
   25% TYPE II GRANULAR "B"
   ADD ADDITIONAL GRANULAR TO MIX TO FILL INTERSTITIAL SPACE, AS NEEDED. COMPACT.

6) RESTORE DISTURBED SURFACES TO ORIGINAL CONDITION WITH TOPSOIL, SEED, AND ECB
7) WORKS TO BE CONDUCTED UNDER OBSERVATION OF ENGINEER AND GEOMORPHOLOGIST, OR AUTHORIZED REPRESENTATIVES.
8) AVOID DISTURBANCE TO EXISTING TREES TO MAXIMUM EXTENT POSSIBLE. TREES IMPACTED BY WORKS TO BE ASSESSED BY AN ENVIRONMENTAL INSPECTOR OR ARBORIST AND COMPENSATED FOR IN ACCORDANCE WITH CVC'S COMPENSATION PROTOCOL.

FRAC-OUT PLAN
1:250



XS A-A'
SCALE = 1:100



SEQUENCE OF CONSTRUCTION

LOWER LIFTS OF STONE:
1. EMBED LOWEST LIFTS OF STONE, BACKFILLING AS NEEDED WITH PROPOSED RIPRAP / GRANULAR MIX. COMPACT.

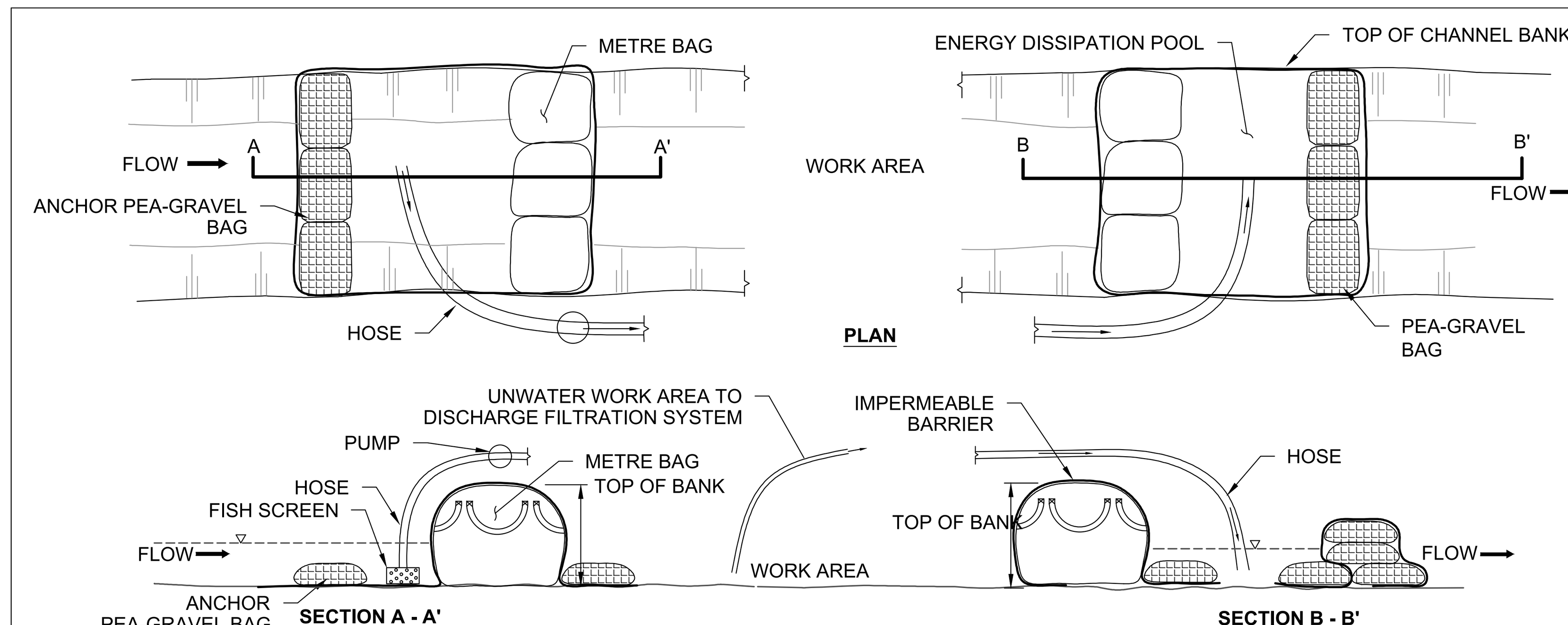
MIDDLE TO UPPER LIFTS:
2. INSTALL SINGLE LIFT OF STONE, BACKFILLING AS NEEDED WITH PROPOSED RIPRAP / GRANULAR MIX. COMPACT.
3. INSTALL CONTINUOUS ROW OF LIVE PLANTINGS OVERTOP NEWLY PLACED STONE LIFT AND ADD 150 mm LAYER OF TOPSOIL AROUND BASE OF PLANTINGS.
4. REPEAT STEPS 2-3 FOR ADDITIONAL LIFTS TO TOP OF BANK.

PLANTINGS SPECIFICATIONS

COMMON NAME	SCIENTIFIC NAME	QTY	CONDITION
RED OSIER DOGWOOD	*Cornus sericea*	15	1 m, POTTED PLANTINGS
BEBB'S WILLOW	*Salix bebbiana*	15	1 m, POTTED PLANTINGS
PUSSY WILLOW	*Salix discolor*	15	1 m, POTTED PLANTINGS
SANDBAR WILLOW	*Salix exigua*	15	1 m, POTTED PLANTINGS
SHINING WILLOW	*Salix lucida*	15	1 m, POTTED PLANTINGS

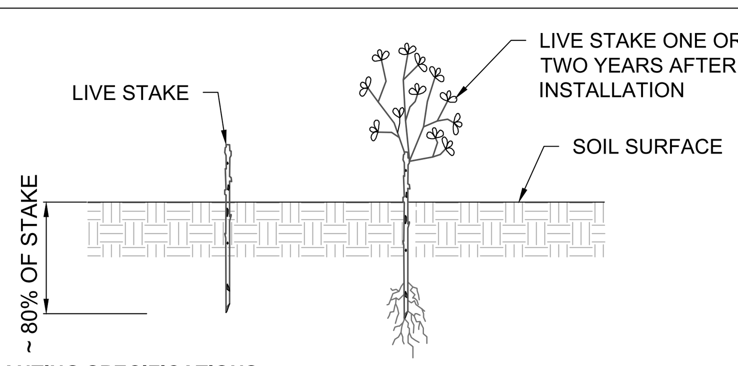
NOTE: POTTED PLANTINGS TO BE REPLACED WITH LIVE CUTTINGS PLANTINGS IF PLANTING TO OCCUR DURING THE DORMANT PERIOD (FALL / WINTER). INSTALL 1 m O/C.

VEGETATED REVETMENT TREATMENT
N.T.S.



NOTES
1. PUMPING RATE MUST MATCH WORKING FLOW CONDITIONS.
2. BAGS TO BE FILLED WITH PEA-GRAVEL.
3. BAGS TO BE INSTALLED TO MATCH EXISTING TOP OF BANK.
4. IMPERMEABLE BARRIER (PLASTIC SHEET) TO COVER THE BAGS TO LIMIT SEEPAGE INTO WORK AREA.
5. BACKUP PUMP AND HOSE SHALL BE KEPT ONSITE TO ADDRESS FAILURES AND HIGH FLOW CONDITIONS.
6. PEA-GRAVEL WITHIN BAGS TO BE DISPOSED OF OFFSITE ONCE CONSTRUCTION IS COMPLETE.

PEA-GRAVEL BAG COFFERDAM AND BYPASS PUMPING
N.T.S.



PLANTING SPECIFICATIONS

COMMON NAME	SCIENTIFIC NAME	QTY	CONDITION
BEBB'S WILLOW	*Salix bebbiana*	130	1 m, LIVE STAKE
PUSSY WILLOW	*Salix discolor*	130	1 m, LIVE STAKE
SANDBAR WILLOW	*Salix exigua*	130	1 m, LIVE STAKE
UPSLOPE PLANTINGS (E.G., ABOVE EL. 110.50 m):			
STAGHORN SUMAC	*Rhus typhina*	200	1 m, LIVE STAKE

NOTES
1. QUANTITY TO BE REFINED BASED ON AREA OF DISTURBANCE TO BE RESTORED
2. LIVE SHOULD BE FROM AT MINIMUM 2-YEAR OLD STOCK.
3. LIVE STAKES ARE TO BE INSTALLED AT A DENSITY OF 3 STAKES PER SQUARE METRE.
4. LIVE STAKES SHOULD BE PRE-SOAKED (SUBMERGED IN WATER) FOR AT LEAST 24 HOURS AFTER HARVESTING AND IMMEDIATELY BEFORE INSTALLATION.
5. LIVE STAKES SHOULD NOT BE STORED FOR A PERIOD LONGER THAN 2 DAYS, UNLESS THEY ARE BEING SOAKED.
6. THE CONTRACTOR SHALL PROTECT PLANT MATERIALS FROM DRYING FROM THE TIME OF HARVEST UNTIL INSTALLED.
7. LIVE STAKES ARE TO BE A MINIMUM OF 25 mm IN DIAMETER AND CUT TO A LENGTH OF 1000 mm.
8. CUT ANGLE AT THE BOTTOM OF THE STAKE AND FLAT ON THE TOP.
9. TRIM ALL SIDE BRANCHES WHILE TAKING CARE NOT TO DAMAGE THE BARK.
10. INSTALL STAKES WITH BUDS POINTING UPWARDS AND THICKER STEM IN THE BED.
11. LIVE STAKES SHOULD BE INSTALLED USING A LARGE RUBBER MALLET.
12. 80% OF THE STAKE IS TO BE BELOW SURFACE.
13. TAMP THE LIVE STAKE INTO THE GROUND AT RIGHT ANGLE TO THE SURFACE.
14. IN COMPACT SOIL A PILOT HOLE SHOULD BE USED TO LIMIT DAMAGE TO THE STAKES.
15. IF USING A PILOT HOLE REPACK SOIL AROUND THE LIVE STAKE.
16. LIVE STAKES SHOULD STAND FIRM FROM THE SOIL FOLLOWING INSTALLATION.
17. ALL STAKES NOT PLANTED TO THE SPECIFICATIONS ABOVE WILL BE REPLACED AT THE CONTRACTOR'S EXPENSE.
18. ALTERNATIVE NATIVE SPECIES MAY BE USED IF APPROVED IN ADVANCE BY THE CONSERVATION AUTHORITY.

LIVE STAKE
N.T.S.

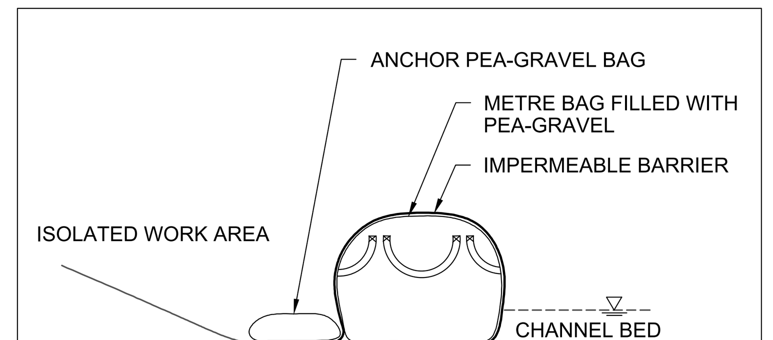
SITE STABILIZATION NOTES

RESTORE/STABILIZE ALL DISTURBED SOILS WITH 150 mm LAYER OF TOPSOIL, RIPARIAN SEED MIX, AND S150BN EROSION CONTROL BLANKET (OR APPROVED EQUIVALENT TIGHT WEAVE BIODEGRADABLE EROSION CONTROL BLANKET).

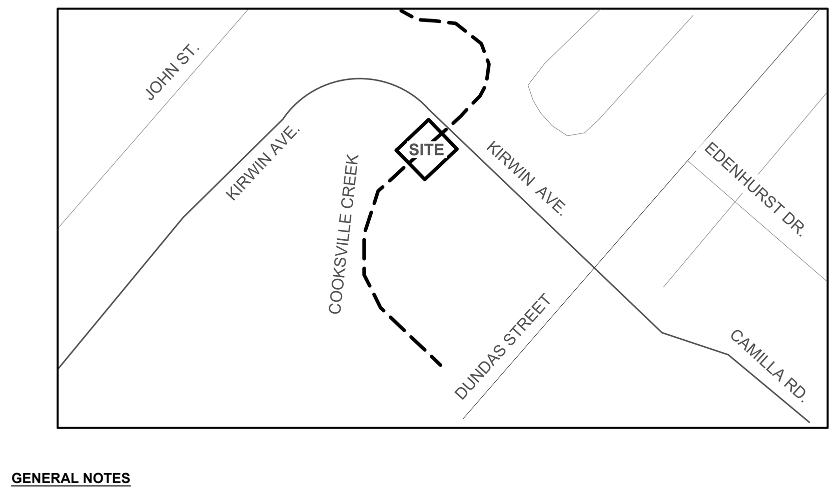
RIPARIAN SEED MIX SPECIES INCLUDED APPROXIMATE VOLUME BY TOTAL WEIGHT:

COMMON NAME	SCIENTIFIC NAME	% OF MIX
FOWL MANNA GRASS	Glyceria striata	2
FOWL BLUEGRASS	Poa palustris	30
FOX SEDGE	Carex vulpinoidea	30
PATH RUSH	Juncus tenuis	8
VIRGINIA WILD RYE	Elymus virginicus	30

NOTES
1. APPLY SEED MIX AT A RATE OF 25 kg PER HECTARE.
2. SEEDING SHALL OVERLAP ADJACENT GROUND COVER BY 300 mm.
3. APPLY COMMON OAT (*Avena sativa*) NURSE CROP AT A RATE OF 22 kg PER HECTARE.
4. WATER SOIL AFTER SEED APPLICATION.



METRE BAG COFFERDAM
N.T.S.



GENERAL NOTES

1. THE ACCOMPANYING TECHNICAL LETTER PREPARED BY GEO MORPHIX LTD. (2024) PROVIDES ADDITIONAL DESIGN DETAILS AND DIRECTION FOR IMPLEMENTATION AND IS TO BE REVIEWED IN CONJUNCTION WITH THIS DRAWING SET.
2. ALL CONTRACT DRAWINGS, SPECIFICATIONS AND APPLICABLE PERMITS MUST BE KEPT ON SITE DURING CONSTRUCTION FOR REFERENCE.
3. THE CONTRACTOR MUST NOTIFY THE DESIGNER AND CONTRACT ADMINISTRATOR OF THE INTENT TO COMMENCE WORK AT LEAST 48 HOURS IN ADVANCE.
4. THE CONTRACTOR IS RESPONSIBLE FOR ALL UTILITY LOCATES.
5. LAYOUT MUST BE REVIEWED AND APPROVED BY THE DESIGNER / DESIGNER REPRESENTATIVE, DESIGNATED ENGINEER, AND THE CONTRACT ADMINISTRATOR.
6. CONSTRUCTION OBSERVATION IS TO BE PERFORMED BY A CERTIFIED FLUVIAL GEOMORPHOLOGIST OR EXPERIENCED ENVIRONMENTAL INSPECTOR UNDER DIRECTION FROM THE DESIGNER.
7. ON-SITE SUPPORT FROM PROJECT ENGINEER (E.G., GEOTECHNICAL, HYDROGEOLOGICAL, AND/OR WATER RESOURCES ENGINEER) REQUIRED TO ASSESS AND ENSURE FAVOURABLE SURFICIAL AND SUBSURFACE CONDITIONS TO SUPPORT CHANNEL REALIGNMENT CONSTRUCTION.
8. BE ADVISED THAT THE LOCAL REGULATORY BODY MAY, AT ANY TIME, WITHDRAW THIS PERMISSION, IF, IN THE OPINION OF THE AUTHORITY, THE CONDITIONS OF THE PERMIT ARE NOT BEING COMPLIED WITH. THIS APPROVAL DOES NOT EXEMPT THE PROPERTY OWNER/APPLICANT/AGENT FROM THE PROVISIONS OF ANY OTHER FEDERAL, PROVINCIAL OR MUNICIPAL STATUTES, REGULATIONS OR BY-LAWS, OR ANY RIGHTS UNDER COMMON LAW.

TIMING OF WORKS

1. WORKS SHALL BE COMPLETED DURING THE DESIGNATED IN-WATER WORKS WINDOW SET OUT BY MNRF/DFO.
2. TREE CLEARING IS TO BE COMPLETED OUTSIDE THE BIRD NESTING SEASON (APRIL 1ST TO AUGUST 1ST) TO COMPLY WITH THE FEDERAL MIGRATORY BIRDS CONVENTION ACT. ANY TREES THAT REQUIRE REMOVAL OUTSIDE OF THIS TIMING WINDOW MUST FIRST BE INSPECTED BY A QUALIFIED BIOLOGIST TO DETERMINE THE PRESENCE OF NESTING BIRDS.
3. THE WEATHER FORECAST SHOULD BE CONTINUALLY MONITORED TO ENSURE THAT WORKS ARE UNDERTAKEN ONLY DURING FAVOURABLE WEATHER CONDITIONS.
4. COMPLETE THE WORKS WITH MINIMAL AVOIDABLE INTERRUPTIONS ONCE THEY COMMENCE.

SITE AND MATERIAL MANAGEMENT

1. ALL CONSTRUCTION EQUIPMENT AND MATERIALS (IMPORTED OR EXCAVATED) MUST BE STORED AT LEAST 30 m AWAY FROM ANY WATERBODY IN A STABLE AREA ABOVE THE ACTIVE FLOODPLAIN, OR IN A DESIGNATED STAGING/STORAGE AREA.
2. IN THE EVENT OF AN UNEXPECTED STORM, ALL UNFIXED ITEMS THAT HAVE THE POTENTIAL TO CAUSE A SPILL OR AN OBSTRUCTION TO FLOW MUST BE MOVED A STABLE AREA ABOVE ACTIVE FLOODPLAIN.
3. STOCKPILES MUST BE LOCATED OUTSIDE THE ISOLATED WORK AREAS.
4. STABILIZE, TEMPORARILY OR PERMANENTLY, ANY DISTURBED AREAS AS WORK PROGRESSES, OR SOON AS CONDITIONS ALLOW.
5. MINIMIZE THE AREA OF DISTURBANCE TO THE EXTENT POSSIBLE. ALL DISTURBED GROUND LEFT INACTIVE FOR MORE THAN 30 DAYS SHALL BE STABILIZED USING APPROPRIATE EROSION CONTROL MEASURES AND AN APPROPRIATE SEED MIX AS NOTED WITHIN THE FINAL APPROVED RESTORATION PLAN.
6. ALL VEGETATION, ADJACENT TO THE WORK AREA, MUST BE PROTECTED AND DELINEATED WITH CONSTRUCTION FENCING OR TREE PROTECTION BARRIERS.
7. ALL GRADES IN THE AREA REGULATED BY THE CONSERVATION AUTHORITY MUST BE MAINTAINED OR MATCHED, UNLESS OTHERWISE AUTHORIZED IN THE APPLICABLE PERMIT.
8. AN AFTER-HOURS CONTACT NUMBER IS TO BE VISIBLY POSTED ONSITE FOR EMERGENCIES. ALL THE PLANS SHOULD HAVE NAME AND CONTACT INFO OF THE PERSON RESPONSIBLE FOR ESC MEASURES.

EROSION AND SEDIMENT CONTROL

1. ALL TEMPORARY EROSION AND SEDIMENT CONTROL MEASURES MUST BE INSTALLED PRIOR TO START OF WORKS.
2. FOLLOWING INSTALLATION OF THE PROPOSED ESC MEASURES, A QUALIFIED AGENT OF THE PROPONENT (E.G. CAN-CISEC CERTIFIED MONITOR) WILL CONDUCT REGULAR SITE VISITS TO MONITOR ALL WORKS, PARTICULARLY THE CONDITION OF THE ESC MEASURES, DEWATERING, AND IN- OR NEAR-WATER WORKS. SHOULD CONCERNS ARISE; THE ENVIRONMENTAL MONITOR WILL CONTACT THE PROPONENT, THE CONSERVATION AUTHORITY, AND ANY OTHER APPROPRIATE PARTIES.
3. EROSION AND SEDIMENT CONTROLS MUST BE MAINTAINED DURING CONSTRUCTION, AND ANY REQUIRED REPAIRS OR REPLACEMENTS MUST BE COMPLETED WITHIN 24 HOURS AFTER THEY HAVE BEEN IDENTIFIED DURING THE MONITORING.
4. EROSION AND SEDIMENT CONTROLS MAY REQUIRE PERIODIC ADJUSTMENTS TO REFLECT CHANGING SITE CONDITIONS. THE CONTRACTOR WILL BE RESPONSIBLE FOR THESE ADJUSTMENTS TO ENSURE PROPER FUNCTION.
5. ANY CHANGES TO THE EROSION AND SEDIMENT CONTROL PLAN BEYOND MINOR ADJUSTMENTS MUST BE APPROVED BY THE CONTRACT ADMINISTRATOR.
6. ADDITIONAL EROSION AND SEDIMENT CONTROL SUPPLIES MUST BE KEPT ON SITE IN ORDER TO FACILITATE IMMEDIATE REPAIRS AND/OR UPGRADES AS NEEDED.
7. ALL TEMPORARY SEDIMENT CONTROLS MUST BE REMOVED AFTER THE CONTRACT ADMINISTRATOR DEEMS THE SITE TO BE STABLE.
8. THE PROJECT PROPONENT OR THEIR REPRESENTATIVE IS ULTIMATELY RESPONSIBLE FOR CONTROLLING SEDIMENT AND EROSION WITHIN THE CONSTRUCTION SITE FOR THE TOTAL PERIOD OF THE CONSTRUCTION.
9. IF EXCESSIVE SILTATION RESULTS FROM THE CONSTRUCTION ACTIVITIES, THE ONSITE SUPERVISOR/INSPECTOR AND/OR THE LOCAL REGULATORY BODY RESERVE THE RIGHT TO REQUEST ADDITIONAL ESC MEASURES WHICH WOULD BE INSTALLED PRIOR TO FURTHER CONSTRUCTION ACTIVITIES.

DELETERIOUS SUBSTANCE CONTROL/SPILL MANAGEMENT

1. PREVENT THE RELEASE OF SEDIMENT, SEDIMENT-LADEN WATER, RAW CONCRETE, CONCRETE LEACHATE OR ANY OTHER DELETERIOUS SUBSTANCES INTO ANY WATERBODY, RAVINE OR STORM SEWER SYSTEM.
2. ENSURE EQUIPMENT AND MACHINERY ARE IN GOOD OPERATING CONDITION (POWER WASHED), FREE OF LEAKS, EXCESS OIL, AND GREASE.
3. NO EQUIPMENT REFUELLING OR SERVICING SHOULD BE UNDERTAKEN WITHIN 30 m OF ANY WATERCOURSE OR SURFACE WATER DRAINAGE.
4. A SPILL CONTAINMENT KIT MUST BE READILY ACCESSIBLE ON SITE IN THE EVENT OF A RELEASE OF A DELETERIOUS SUBSTANCE TO THE ENVIRONMENT. ONSITE STAFF MUST BE TRAINED IN ITS USE.
5. THE CONTRACT ADMINISTRATOR MUST BE NOTIFIED IMMEDIATELY IN THE EVENT OF A SPILL OF DELETERIOUS SUBSTANCE. ANY SEDIMENT SPILL FROM THE SITE SHOULD BE REPORTED TO MINISTRY OF ENVIRONMENT (SPILL ACTION CENTER) AT 1-800-268-6060.

WORK AREA ISOLATION

1. ALL WORK IN ISOLATED WORK AREAS MUST BE COMPLETED IN THE DRY. AN ADEQUATE NUMBER OF PUMPS MUST BE USED FOR UNWATERING.
2. CROSSING AN ACTIVE WATERCOURSE OR WETLAND BY EQUIPMENT, VEHICLES, PERSONNEL, ETC. IS NOT PERMITTED UNLESS APPROVED BY THE CONSERVATION AUTHORITY. ALL ACCESS TO WORK SITES SHALL BE FROM EITHER SIDES OF THE WATERCOURSE OR WETLAND.
3. THE UNWATERING DISCHARGE LOCATION MUST BE LOCATED AT LEAST 30 M FROM ANY WATERCOURSE OR WETLAND IN AN AREA WITH DENSE VEGETATIVE GROUNDCOVER, AND WHERE THE DISCHARGE CAN RETURN TO THE WATERBODY DOWNSTREAM OF THE WORK AREA OVER THE GROUNDCOVER.
4. FISH MUST BE REMOVED FROM THE WORK AREA ONCE ISOLATED. FISH SALVAGE MUST BE COMPLETED BY A QUALIFIED TECHNICIAN WITH A LICENSE FROM THE ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY.

SUPPORTING BASE FILES

1. TOPOGRAPHIC SURVEY AND HYDRAULIC MODELLING COMPLETED AND PROVIDED BY ARCADIS

#	DATE	BY	REVISIONS
1.	2024-02-29	BM	DESIGN SUBMISSION #1 (TO CLIENT)

DESIGNED BY: P.V.	CHECKED BY: P.V.
DRAWN BY: B.M.	DATE: FEBRUARY 29, 2024

DRAFT FOR INTERNAL REVIEW

NOT FOR CONSTRUCTION

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REGION OF PEEL
SANITARY SEWER DETAILED DESIGN
KIRWIN AVENUE (PROJECT 23-2129)

COOKSVILLE CREEK
BANK RESTORATION DESIGN
PLAN AND DETAILS

PROJECT No.: 23123	DRAWING No.: GEO-1
SCALE: AS NOTED	SHEET 1 OF 1