Interim Turning Basin Expansion

Presented to:

NC State Ports Authority

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1. Introduction

The North Carolina State Ports Authority (NCSPA) is currently conducting a feasibility study of potential navigation improvements at the Port of Wilmington with the objective to enable the Assistant Secretary of the Army (Civil Works) to make appropriate recommendations to the Congress regarding authorization of a Federal navigation project for the Port of Wilmington. During the course of this study, a 12,400 TEU Container Ship was selected as the design vessel with the characteristics shown in Table 1-1.

Table 1-1: Design Vessel Characteristics

Name	Year Built	Beam (ft)	LOA (ft)	Design Draft (ft)	TEU	DWT
MSC Lauren	2011	159	1200	51	12,400	139,324

However, the process of completing the study and associated environmental documentation, and obtaining federal authorization and funding will likely take several years and the NCSPA desires to review options to serve the design vessel in the interim. In order to do so, it has been determined that the turning basin, currently 1400' in diameter should be enlarged to allow such a vessel to safely turn and berth at the Port of Wilmington.

The purpose of this conceptual study was to develop several alternative turning basin configurations with their associated costs and potential impacts for consideration as an interim project to allow the design vessel to berth at the Port of Wilmington.

2. Geotechnical Analysis

CATLIN Engineers & Scientists (CATLIN) conducted a geotechnical analysis along the Cape Fear River to determine the following:

- The soil properties in the area of the proposed retaining walls;
- The minimum stable slope of the soil to be maintained for dredging;
- If the channel could be widened without affecting the existing structures.

No subsurface investigations were performed during the geotechnical analysis. CATLIN utilized existing subsurface data for the analysis; specifically, the borings advanced for the most recent Turning Basin widening on the east side of the Cape Fear River and some 1982 borings advanced on the land just north of the project area. No soil borings were found for the west side of the river for the Turning Basin Widening area. Therefore, the soil properties in this area were determined based on previous experience.

CATLIN estimated the soil types and strength properties to be used for the design of a concept level toe wall (for Alternatives A & B discussed in Chapters 3 and 4) based on the available borings. The soil properties for these walls are shown in Tables 2-1, 2-2 and 2-3. The slope stability analysis was performed on the east side of the river using approximated soil strengths based on information obtained from the previous turning basin widening. The tank structures on the property east of the turning basin are reported to be supported on piles and would not affect the slope stability. The results of the analysis show that a slope of 2.75V:1H or flatter would be stable. It is recommended that a slope of 3H:1V be used on the east side of the turning basin and that the berm around the tanks be relocated to a minimum of 10 feet away from the top of the cut crest.

A slope stability analysis was performed on the west side of the river using approximated soil strengths based on previous experience on that side of the river and an assumed dike elevation of 50 feet. CATLIN compared the Factor of Safety results for the existing conditions and a possible future channel widening to determine the stability at Eagle Island. This analysis between Station 2255+00 and Station 2272+00 (see Chapter 3 and Appendices for figures showing stationing) revealed that a cut would negatively affect the stability of the future dike raise on Eagle Island. Another analysis was performed below Station 2254+00 and above Station 2273+00 and it was determined that the proposed channel widenings in these areas would not affect the slope stability. Based on these analyses, CATLIN recommends that no channel widening that requires cutting of the existing slope without the construction of a toe wall on the west side be performed in the area between Station 2255+00 and Station 2272+00. Widening the river as proposed below Station 2254+00 and above Station 2273+00 is acceptable.

Table 2-1: Toe Wall Design Parameters – Eagle Island Side (Alt. A)

Retaining Wall Design Parameters - Boring General - Eagle Island Side				
	Elevation (feet MLLW)			
	5 to -6	-6 to -40(-26)	-40 (-26) to -50	-50 to
Soil Type	Silt & Clay	Organic Silt	Sand	MARL
Blow Count (N)	Varies	0	up to 30	NA
Total Unit Weight, Υ_t (psf)	105	90	120	135
Cohesion, C (psf)	600	350	0	0
Angle of Internal Friction, ϕ (degrees)	0	0	32	45
Coefficient of Active Earth Pressure, k_a	1.0	1.0	0.3	0.2
Coefficient of At-Rest Pressure, k_o	1.0	1.0	0.5	0.3
Coefficient of Passive Earth Pressure, k_p	1.0	1.0	3.3	5.8
Coefficient of Sliding Friction (sand to steel)	NA	NA	0.3	0.4
Adhesion C_A (psf)	550	350	NA	NA
Soil Strain (e50)	0.02	0.02	NA	NA
Modulus (k)	35	30	60	125

NOTE: Water level is approximately elev. 3'

Table 2-2: Toe Wall Design Parameters – East Side (Alt B)

Retaining Wall Design Parameters - Boring TB-2 - Port Side				
	Elevation (feet MLLW)			
	-3.9 to -36.9	-36.9 to -45.9	-45.9 to -50.4	Approx -52
Soil Type	Organic Clay	Sand	Sand with Silt	MARL
Blow Count (N)	WOH	9, 7	31	
Total Unit Weight, Υ_t (psf)	90	120	120	135
Cohesion, C (psf)	200	0	0	0
Angle of Internal Friction, ϕ (degrees)	0	30	40	45
Coefficient of Active Earth Pressure, k_a	1.0	0.3	0.2	0.2
Coefficient of At-Rest Pressure, k_o	1.0	0.5	0.4	0.3
Coefficient of Passive Earth Pressure, k_p	1.0	3.0	4.6	5.8
Coefficient of Sliding Friction (sand to steel)	NA	0.3	0.25	0.4
Adhesion C_A (psf)	200	NA	NA	NA
Soil Strain (e50)	0.02	NA	NA	NA
Modulus (k)	30	20	90	125

Table 2-3: Toe Wall Design Parameters – East Side (Alt. B)

Retaining Wall Design Parameters - Boring B-4 With MARL Adjusted - ALT Port Side					
	Elevation (feet MLLW)				
	4.0 to -10.5	-10.5 to -14.0	-14.0 to -33.0	-33.0 to -41.5	-45.0 to Depth
Soil Type	Sand Fill	Sand Fill	Organic Silt	Sand	MARL
Blow Count (N)	2, 1, 4, 1	40	0, 0, 1, 3	5, 2	56/6"
Total Unit Weight, Υ_t (psf)	120	125	90	120	135
Cohesion, C (psf)	0	0	250	0	0
Angle of Internal Friction, ϕ (degrees)	28	40	0	30	45
Coefficient of Active Earth Pressure, k_a	0.4	0.2	1.0	0.3	0.2
Coefficient of At-Rest Pressure, k_o	0.5	0.4	1.0	0.5	0.3
Coefficient of Passive Earth Pressure, k_p	2.8	4.6	1.0	3.0	5.8
Coefficient of Sliding Friction (sand to steel)	0.3	0.3	NA	0.3	0.4
Adhesion C_A (psf)	NA	NA	250	NA	NA
Soil Strain (e50)	NA	NA	0.02	NA	NA
Modulus (k)	20	125	30	20	125

NOTE: Water level is approximately elev. 1.9'

3. Alternative Turning Basin Configurations

Five turning basin configurations were developed for consideration. They range from ones likely to be selected as the preferred layout for the feasibility study of potential navigation improvements which can accommodate the design vessel under the desired operating conditions (Alternatives A & B) to minimal "interim" configurations that may be acceptable under favorable environmental operating conditions (Alternatives C, D & E).

3.1. Alternative A - 1500' Turning Basin Centered with Toe Walls

Alternative A (see Figure 3-1 and Appendix A) is basically an enlargement of the existing turning basin to 1500' in width and a 1000' channel elongation along the river with toe walls 1751' and 1438' in length along the west and east side, respectively. The toe walls are discussed in detail in Chapter 4. The 1500' dimension provides a ratio of 1.25 times the length of the design vessel which is a typical minimum for general operating conditions. This dimension was confirmed with the Wilmington Pilots as being acceptable. Additionally, vessel maneuvering simulations performed for the feasibility study confirmed that this layout is acceptable under the design operating conditions (15 Knot winds, Spring currents). Figure 3-2 shows the envelope of vessel swept paths for the inbound port navigation simulations. The density of vessel traffic for the five inbound simulations is shown in Figure 3-3, illustrating the variability of channel use between transits.

The 1000' dimension along the length of the river provides adequate "drift" distance for the vessel due to current forces while it is being turned. This configuration also includes a widening taper on the southwest side of the turning basin, thereby allowing safe passage of the vessel past any moored vessels at Berths 1, 2 and 3 while the rotation of the vessel is being completed before it begins to move back downriver to be berthed. It should be noted that vessels were assumed docked at Berths 3, 5 and 9 for these simulations; hence the bias to the west of the channel for the transit into and from the turning basin confirming the need for this widening taper. The Berth 1 mooring dolphin may remain for this alternative, but the existing "Chevron" pier will need to be removed.

Since this configuration is acceptable for the design vessel under the proposed operating conditions, it can be considered as an "ultimate" layout which would only require deepening in the future to the channel depth selected in the feasibility study. Thus, while the NCSPA would incur the costs of enlarging the turning basin in plan and constructing the walls up front, these costs would not have to be borne by the proposed navigation improvement project nor be included in its cost / benefit analyses other than the additional costs to deepen the basin to match the selected channel depth.

3.2. Alternative B - 1524' Turning Basin Shifted Eastward with One Toe Wall

Alternative B (see Figure 3-4 and Appendix B) is similar to Alternative A but shifts the turning basin to the east so that a toe wall is not required on the west side and there is no impact to the existing slope along Eagle Island. It still provides a turning basin 1500' in width with a 1000' elongation along the river. However since initially this basin will only be dredged to -42' MLLW, the initial turning basin is actually 1524' wide, thereby providing 1500' if the west slope is carried down to an ultimate deepening of as much as -50' MLLW. A 1612' long toe wall is required on the east side, and this shift may potentially impact the Kinder Morgan facility; thus more detailed analyses are required to confirm that no adjustments to the existing containment berm are necessary.

While this alternative was not directly evaluated in the desktop navigation simulations, the alternative is feasible based on Figure 3-5 which shows that the envelope of vessel swept paths for the inbound port navigation simulations fits within the Alternative B geometry. This configuration also includes a widening taper on the southwest side of the turning basin thereby allowing safe passage of the vessel past any moored vessels at Berths 1, 2 and 3 while the rotation of the vessel is being completed before it begins to move back downriver to be berthed. It should be noted that vessels were assumed docked at Berths 3, 5 and 9 for these simulations; hence the bias to the west of the channel for the transit into and from the turning basin confirming the need for this widening taper. The Berth 1 mooring dolphin may remain for this alternative, but the existing "Chevron" pier will need to be removed.

As with Alternative A, since this configuration is acceptable for the design vessel under the proposed operating conditions, it can be considered as an "ultimate" layout which would only require deepening in the future to the channel depth selected in the feasibility study. Thus, while the NCSPA would incur the costs of enlarging the turning basin in plan and constructing the wall up front, these costs would not have to be borne by the proposed navigation improvement project nor included in its cost / benefit analyses other than the additional costs to deepen the basin to match the selected channel depth.

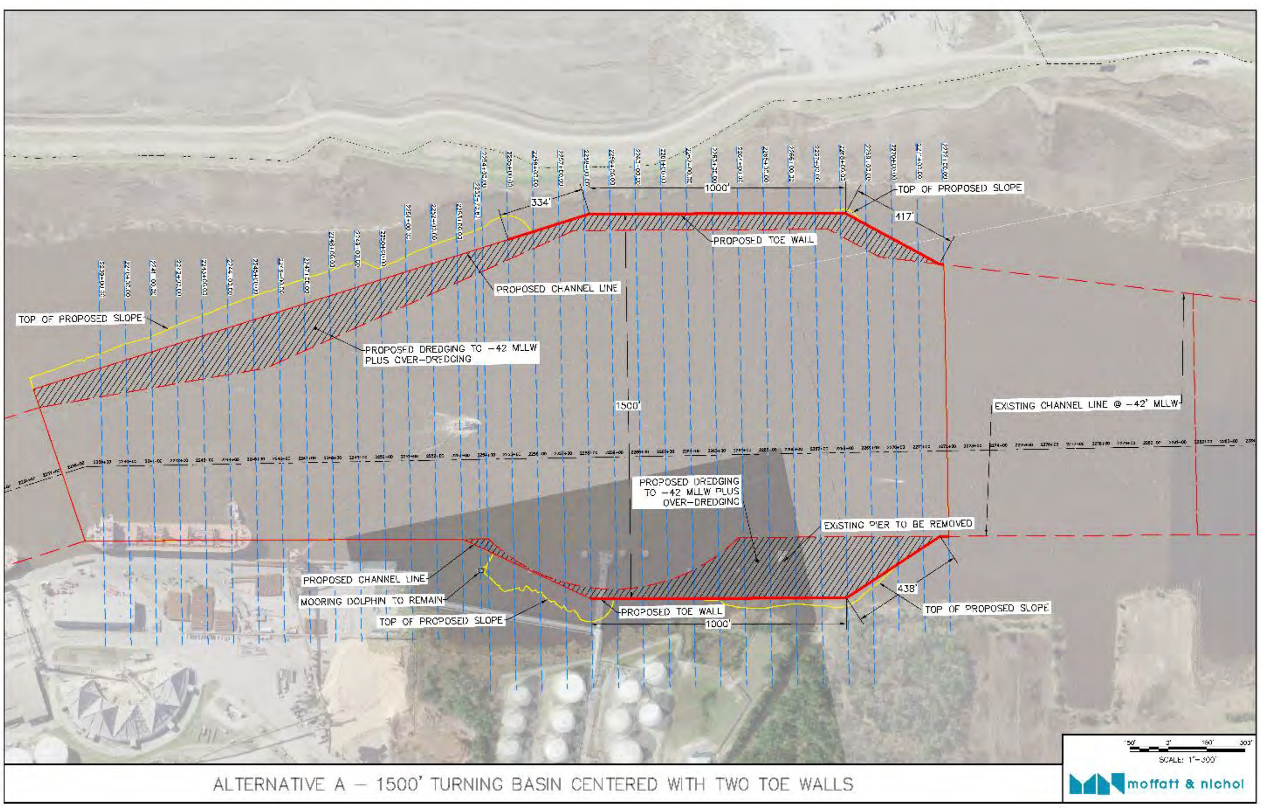


Figure 3-1: Alternative A

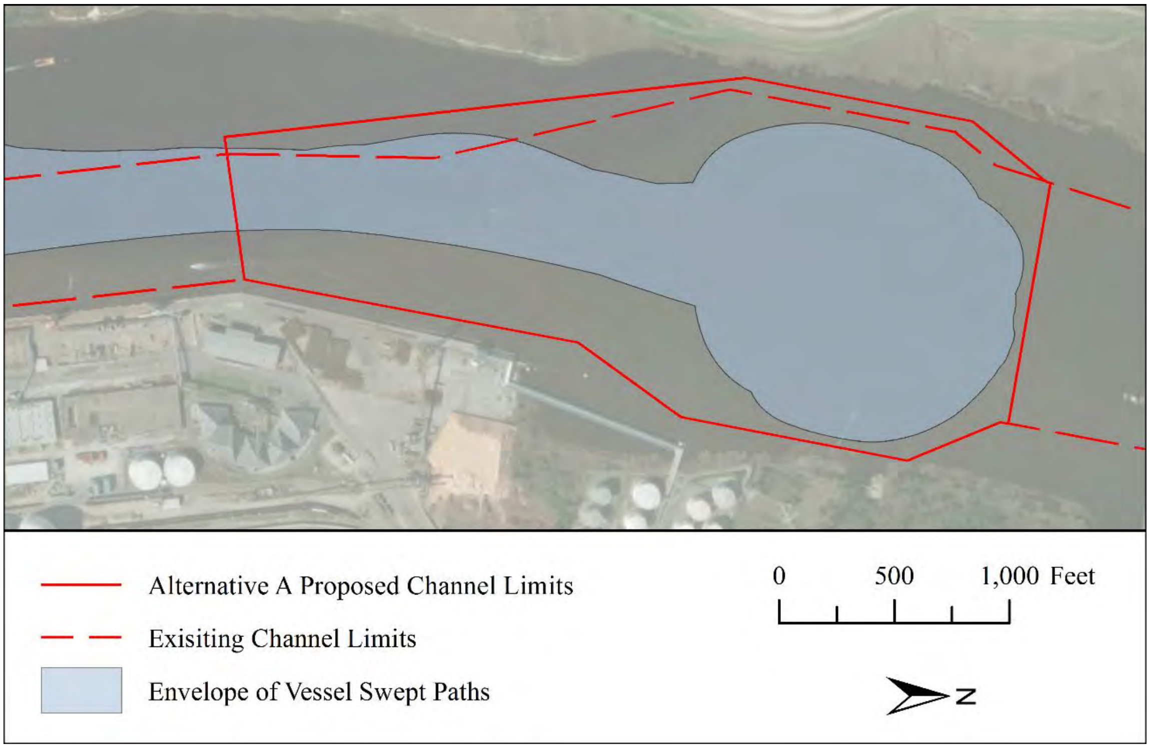


Figure 3-2: Alternative A - Composite of Vessel Swept Paths

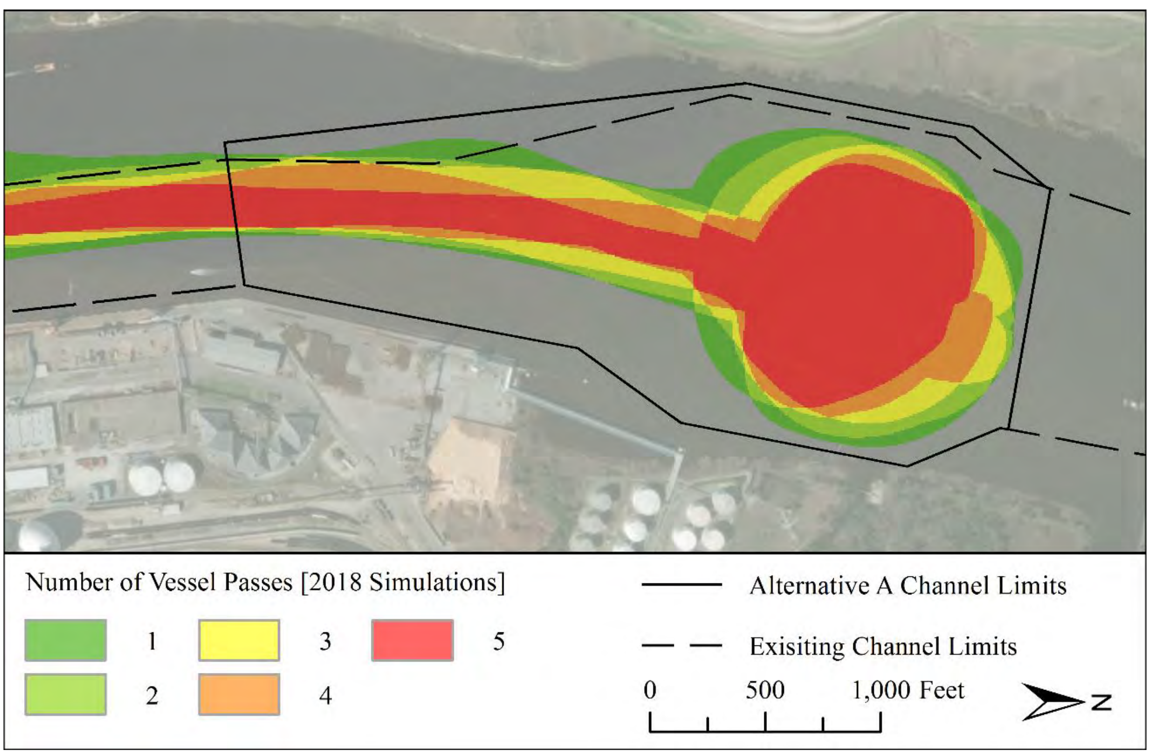


Figure 3-3: Density Map of Inbound Navigation Port Simulations for Alternative A

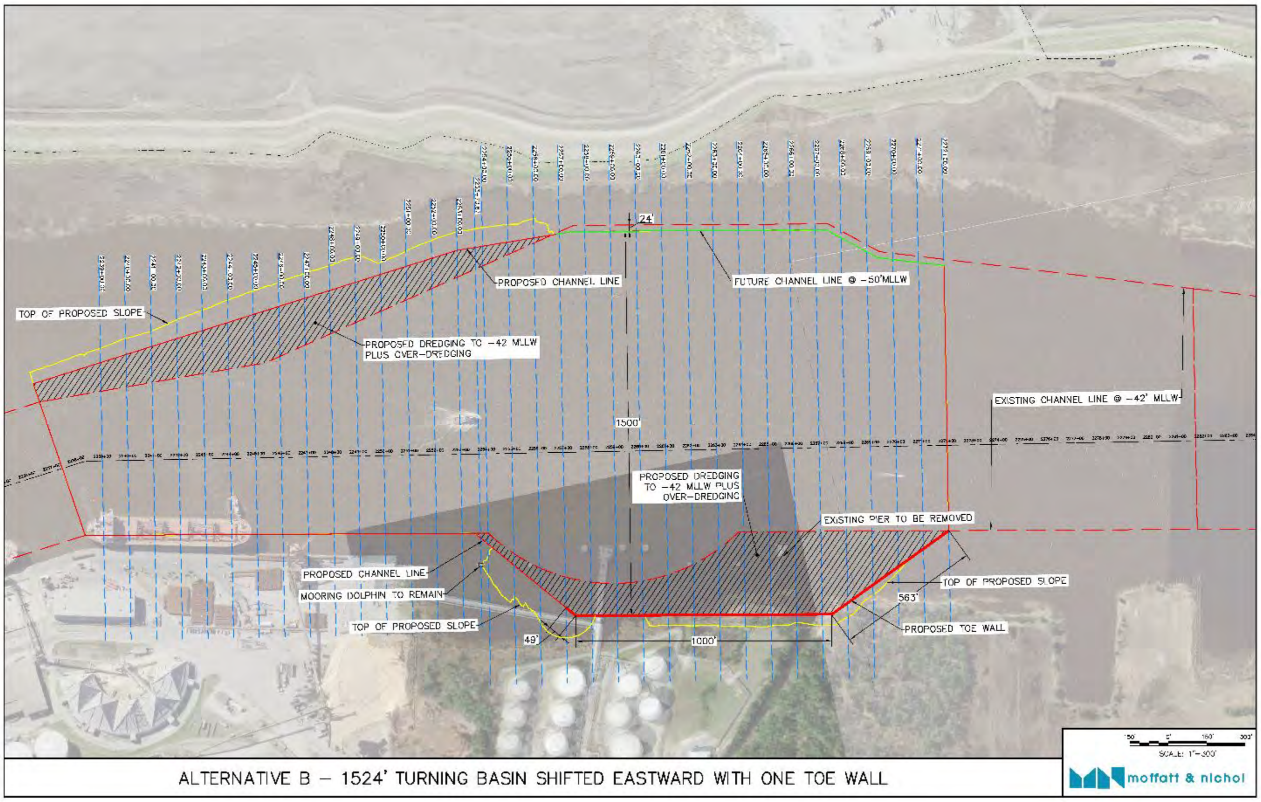


Figure 3-4: Alternative B

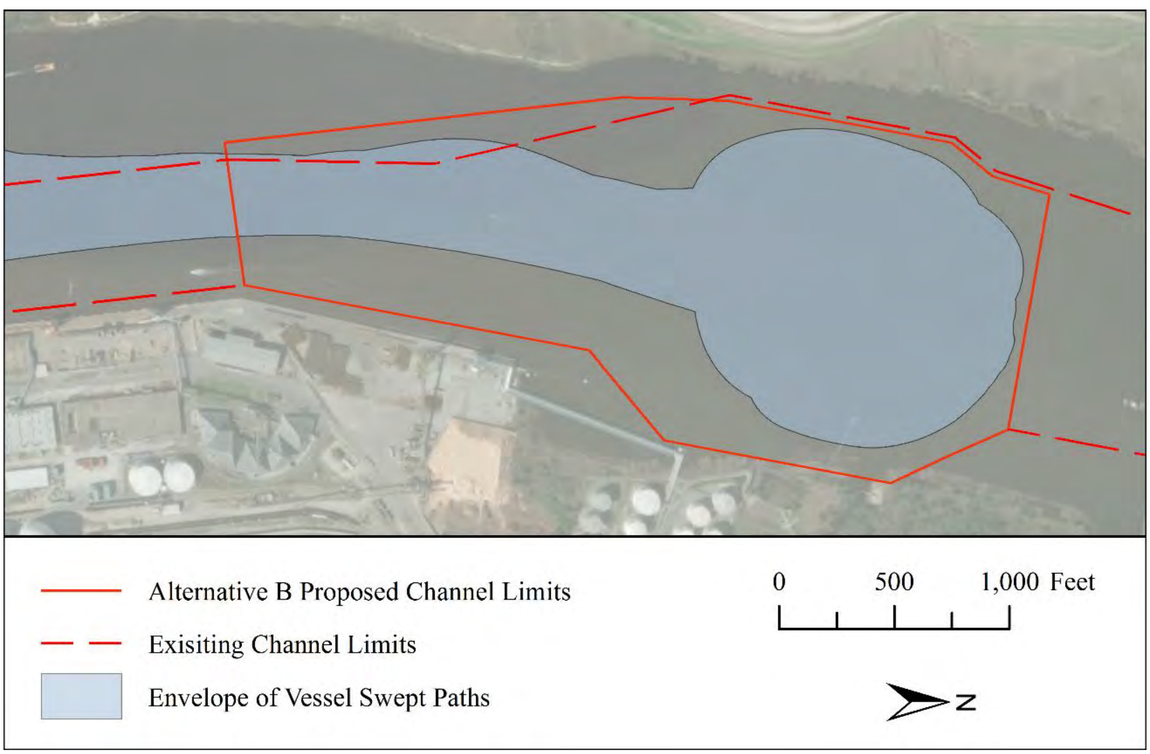


Figure 3-5: Alternative B - Composite of Vessel Swept Paths

3.3. Alternative C - 1450’ Turning Basin (Shortened) with No Walls

Alternative C (see Figure 3-6 and Appendix C) was developed as an “interim” solution to allow for the arrival of the design vessel under favorable wind and current conditions. It is offset to the east to eliminate any impacts to Eagle Island and the necessity for a toe wall, but reduces the turning basin width to 1450’ which is only 20% greater than the length of the design vessel. This allows for the elimination of a toe wall on the east side which instead has a 3:1 dredged slope. The slope, though, does impact the existing containment berm at the Kinder Morgan facility, and thus the berm will need to be moved shoreward at least 10’ from the top of the dredged slope to remain stable. The length of the basin is also reduced to 500’ in an attempt to minimize costs. The Berth 1 mooring dolphin may remain for this alternative, but the existing “Chevron” pier will need to be removed.

This alternative was not directly evaluated in the desktop navigation simulations. However, Figure 3-7 shows the feasibility of this alternative. This figure shows the envelope of vessel swept paths for the inbound port navigation simulations. The envelope of the swept paths was shifted to illustrate that the turn could be completed in the Alternative C geometry while maintaining the same variability between transits as observed in the real-time simulation effort.

This configuration also includes a widening taper on the southwest side of the turning basin thereby allowing safe passage of the vessel past any moored vessels at Berths 1, 2 and 3 while the rotation of the vessel is being completed before it begins to move back downriver to be berthed. It should be noted that vessels were assumed docked at Berths 3, 5 and 9 for these simulations; hence the bias to the west of the channel for the transit into and from the turning basin confirming the need for this widening taper. The need for this widener on an interim basis may be eliminated if vessels are not docked at Berths 1, 2 or 3 during the transit of the design vessel, but this should be confirmed in discussions with the docking pilots.

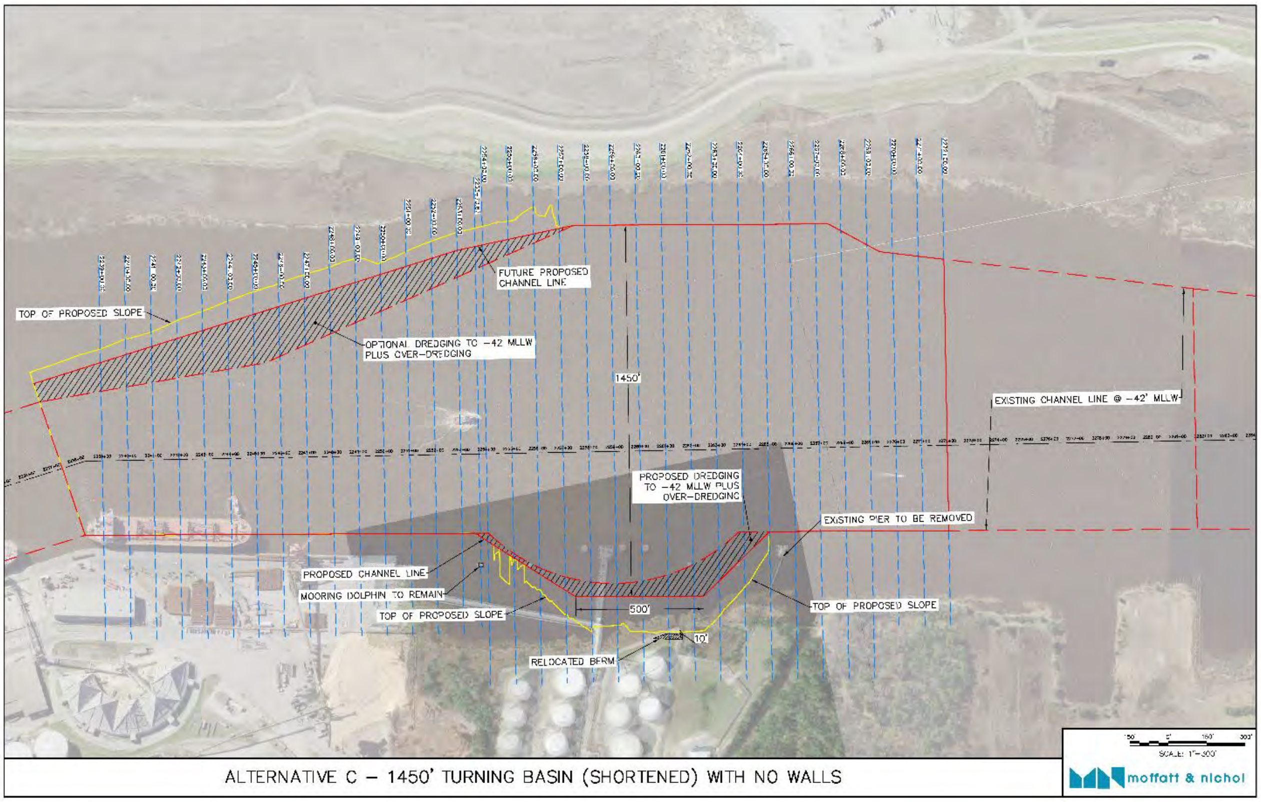


Figure 3-6: Alternative C

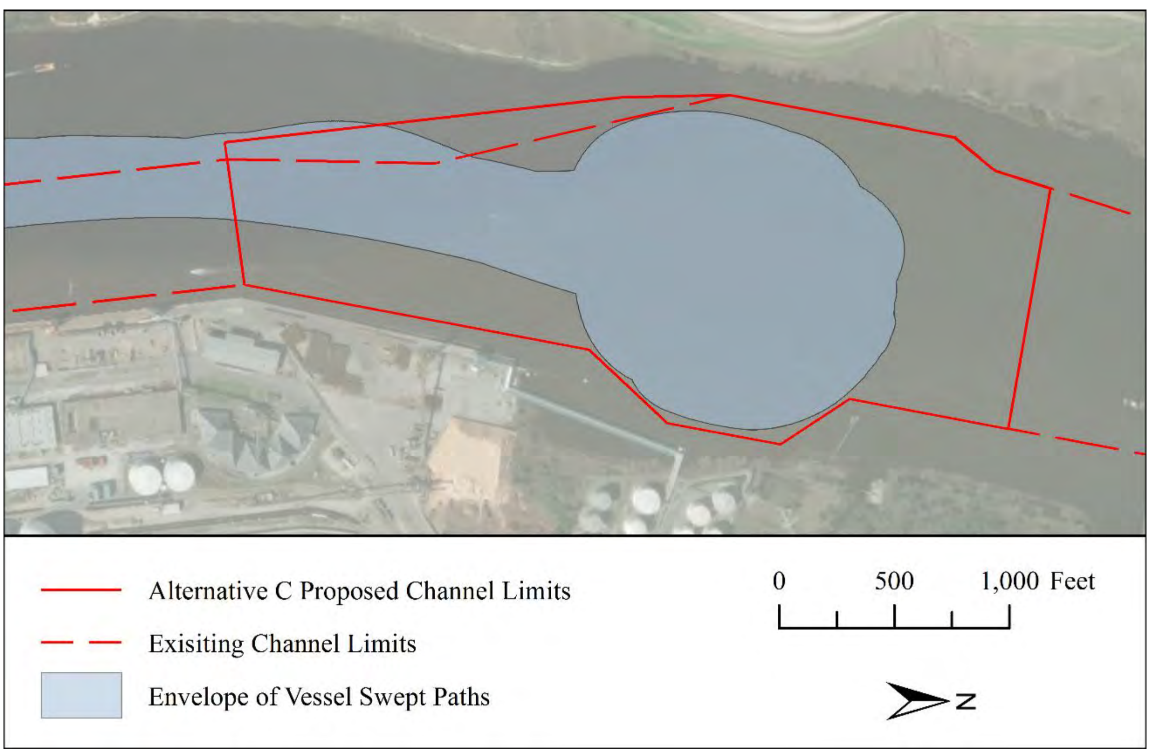


Figure 3-7: Alternative C - Composite of Vessel Swept Paths

3.4. Alternative D - 1524’ Turning Basin (Shortened) Shifted Eastward with One Toe Wall

Alternative D (see Figure 3-8 and Appendix D) is based on Alternative B but reduces the length of the turning basin on the eastern side to only 500’. Thus, significant sections of the toe wall and dredged area that ultimately would have to be constructed in Alternative B are proposed not to be built at this time for this “interim” configuration in order to reduce initial costs. Being an “interim” solution, it will allow for the arrival of the design vessel under favorable wind and current conditions.

Alternative D was not directly evaluated in the desktop navigation simulations. However, the feasibility of this alternative is shown in Figure 3-9. This figure shows the envelope of vessel swept paths for the inbound port navigation simulations. The envelope of the swept paths was shifted from the real-time simulation tracks to illustrate how the use of the turning basin during simulations could fit within the Alternative D geometry. This configuration also includes a widening taper on the southwest side of the turning basin thereby allowing safe passage of the vessel past any moored vessels at Berths 1, 2 and 3 while the rotation of the vessel is being completed before it begins to move back downriver to be berthed. It should be noted that vessels were assumed docked at Berths 3, 5 and 9 for these simulations; hence the bias to the west of the channel for the transit into and from the turning basin confirming the need for this widening taper. Similar to Alternative C, the need for this widener on an interim basis may be eliminated if vessels are not docked at Berths 1, 2 or 3 during the transit of the design vessel, but this should be confirmed in discussions with the docking pilots.

The Berth 1 mooring dolphin may remain for this alternative, but the existing “Chevron” pier will need to be removed. As with Alternative B, this shift may potentially impact the Kinder Morgan facility, and thus more detailed analyses are required to confirm that no adjustments to the existing containment berm are necessary.

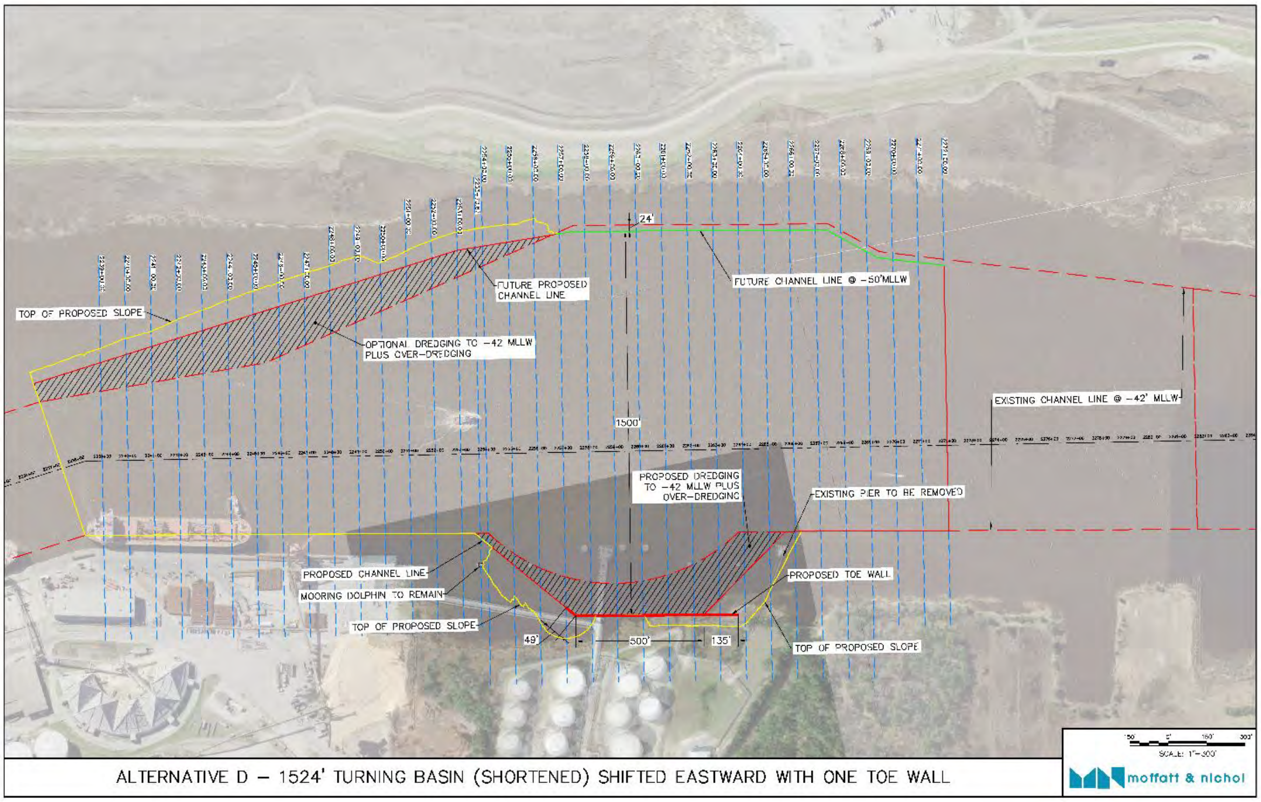


Figure 3-8: Alternative D

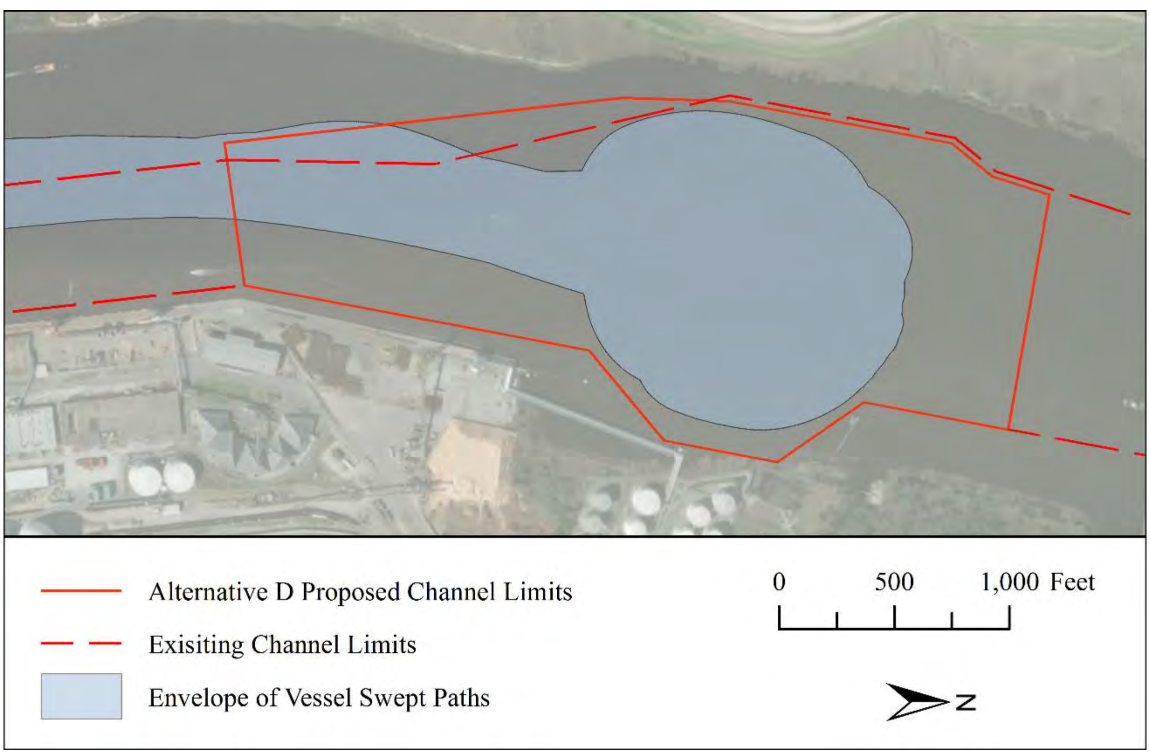


Figure 3-9: Alternative D - Composite of Vessel Swept Paths

3.5. Alternative E - 1400' Turning Basin

Alterative E (see Figure 3-10 and Appendix E) keeps the existing 1400' turning basin width but extends it along the river for 1000'. This 1400' width is only 16.7% longer than the length of the design vessel, but the additional length of the turning basin along the river may allow this alternative to be sufficient as an "interim" solution to allow for the arrival of the design vessel under favorable wind and current conditions.

This alternative was not directly evaluated in the desktop navigation simulations. A composite of the vessel swept paths for the inbound port navigation simulations is shown in Figure 3-11. The envelope of the swept paths was shifted from the real-time simulation tracks to illustrate how the use of the turning basin during simulations could fit within the Alternative E geometry. This configuration also includes a widening taper on the southwest side of the turning basin thereby allowing safe passage of the vessel past any moored vessels at Berths 1, 2 and 3 while the rotation of the vessel is being completed before it begins to move back downriver to be berthed. It should be noted that vessels were assumed docked at Berths 3, 5 and 9 for these simulations; hence the bias to the west of the channel for the transit into and from the turning basin confirming the need for this widening taper. Similar to Alternatives C and D, the need for this widener on an interim basis may be eliminated if vessels are not docked at Berths 1, 2 or 3 during the transit of the design vessel, but this should be confirmed in discussions with the docking pilots.

The Berth 1 mooring dolphin may remain for this alternative, but the existing "Chevron" pier will need to be removed.

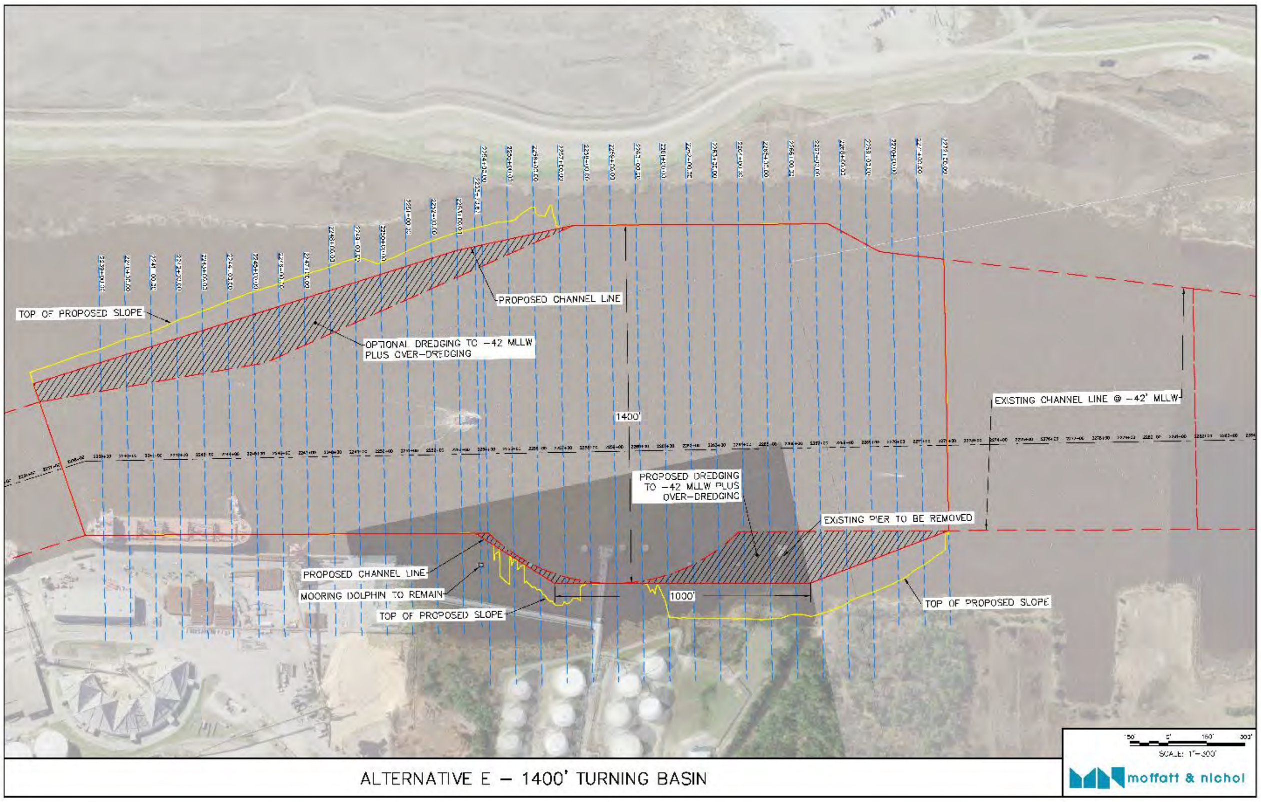


Figure 3-10: Alternative E

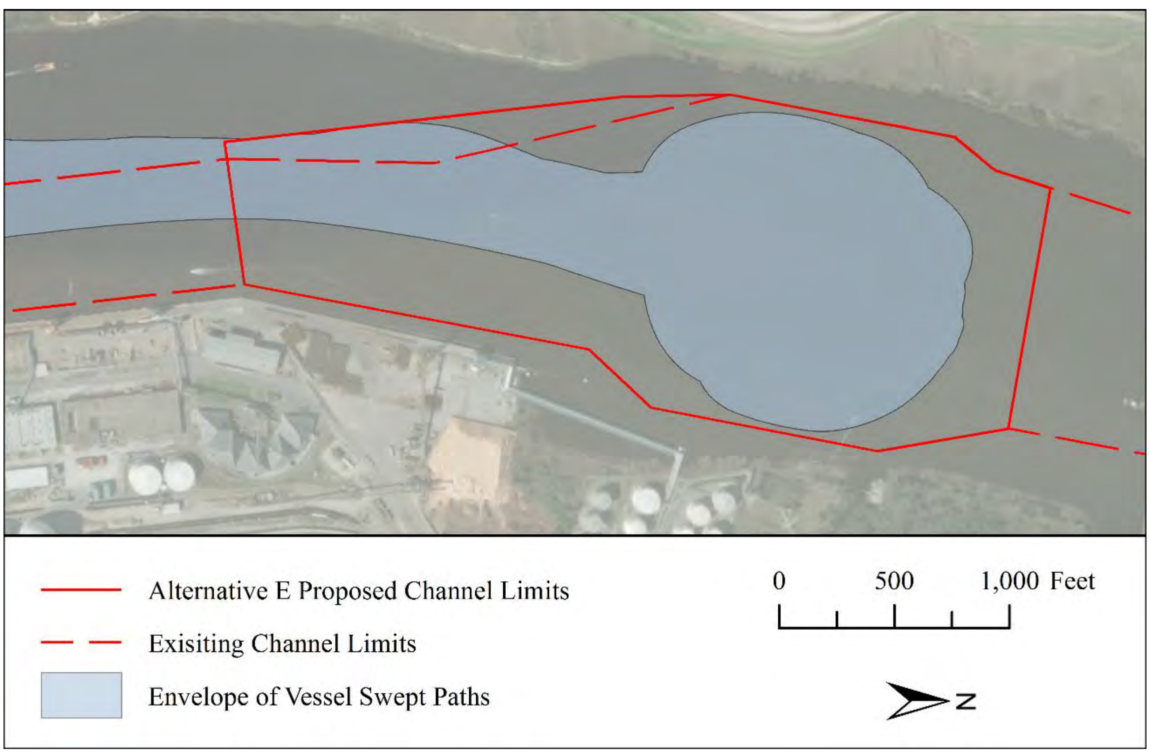


Figure 3-11: Alternative E - Composite of Vessel Swept Paths

4. Toe Wall Alternatives & Slope Protection

Two toe wall alternatives were evaluated for this project. In addition, the need for scour protection at the bottom of the wall and general slope protection was analyzed based on potential impacts from vessel and tug propellers.

4.1. Design Criteria

Two toe wall conceptual designs of either steel pipe king piles or steel sheet piles were developed for the walls in Alternatives A, B and D. The assumed maximum free height of the wall is approximately 43 feet, with the top of wall at El -10.00 MLLW and a potential future design over dredge of EL -53.00 MLLW. The free height of the new wall is based on the specified required dredge depth and the minimum bottom of a new slope which doesn't impact existing structures and allows for tidal flows in to adjacent wetlands.

Given the permanent submerged condition of the toe wall, no superimposed live loads were included in the analysis of the wall. The landside surface profiles were assumed to slope up to El +5.00 MLLW at a grade of 3 (H) to 1 (V). No seismic loads on the toe wall were considered at this stage of analysis. Toe walls are typically anchored or cantilevered, and due to the complexities of installing anchors more than 10 feet below water, only cantilevered walls were investigated. In a typical toe wall design, meeting allowable deflection criteria often controls over the flexural strength of the wall. However, since the new wall will be permanently submerged, larger wall deflections were deemed to be acceptable.

4.2. Geotechnical Properties

The general soil characteristics consist of a cemented sand or marl layer, overlaid by a sandy layer and very soft organic silt. In some locations on the east bank, the organic silt extends up to the mudline and in other locations the top soil layer is a sandy fill material. On the Eagle Island side of the Turning Basin, a silt and clay layer exists from the mudline to approximately El -6.00 MLLW. The marl layer, which is very dense and strong, generally starts at about El -45.00 MLLW to El -50.00 MLLW. The top and bottom elevations of the organic silt layer vary significantly among the different historical borings in the vicinity of the wall alignments.

Soil parameters and toe wall design recommendations were derived as part of a review of historical boring logs in the vicinity of the Turning Basin provided by Catlin Engineers & Scientists (see Chapter 2). Based on experience with the materials, the organic silt layer is not expected to consolidate over the lifespan of the wall due to its submerged condition and will have a maximum unit weight of approximately 90-95 pounds per cubic foot.

Due to the large difference between the very strong sand and marl layers and the very weak organic silt layer, the wall design is highly dependent on the location of soil layers and their properties. Small variations in the design soil profile can have large impacts on the size of wall needed. Therefore, it is recommended that sufficient borings be performed along any selected wall alignment to accurately analyze the wall before final design and construction.

4.3. Sheet Pile Wall Options

Different sheet pile wall options (see Figure 4-1) were developed for each wall alignment. Computer analysis was performed using the program CWALSHT to calculate wall loads and deflections. For Alternative A, the design wall sizes are AZ38-700N interlocking steel sheet piles along the east wall and AZ26-700 interlocking steel sheet piles along the west wall. For Alternatives B and D, the design wall size is an AZ52-700 interlocking steel sheet pile. (See Figure 4-2 for sheet pile details).

The sheet piles are anticipated to be 70-feet long, penetrating into the marl layer. Experience on previous nearby projects indicates that sheet piles with a thickness of approximately ½-inch or greater can be seated into this hard soil layer. A protective coating will be applied to both sides of the sheet pile to 10-feet below the design dredge elevation. Corrosion potentials on the wall are reduced since the top of wall will be permanently submerged and not subject to wetting and drying.

To provide an indication of where the underwater wall is located, additional H-Piles will be installed in the recess of sheet piles with solar powered navigation lights installed on top of the pile at El +10.0 MLLW.

4.4. King Pile Wall Options

King Pile walls (see Figure 4-3) are a combination of steel pipe piles with intermediary connecting steel sheet piles. The pipe pile, or king pile, is connected to the sheet piles through interlocks welded to the pipe pile. The lateral soil pressures calculated for the sheet pile wall design by CWALSHT are used to develop tributary lateral loads on the king pile. These loads are then used in a program called LPile, which analyzes a soil-pile interaction model of the king pile to determine if the selected king pile is sufficient for the load.

The design intermediary steel sheet piles are an AZ14-770 (see Figure 4-2), and are the same for all walls considered. The size of the king pile varies based on the soil pressures loading the wall. For Alternative A, the design east side king pile is a 36-inch diameter pipe pile while the west side wall uses a smaller 30-inch diameter steel pipe pile. For Alternatives B and D, the design king pile is a 48” diameter steel pipe pile.

The king piles are intended to be 85-feet long, which will extend approximately 45-feet into the marl. Similar to the sheet piles, the king piles have wall thicknesses of 5/8-inch or greater for penetration into the hard soil layer. Both the king piles and the sheet piles will be coated to protect against corrosion.

To provide an indication of where the underwater wall is located, select king piles will extend above the water line with solar powered navigation lights installed on top of the pile at El +10.0 MLLW.

Figure 4-1: Sheet Pile Wall Option

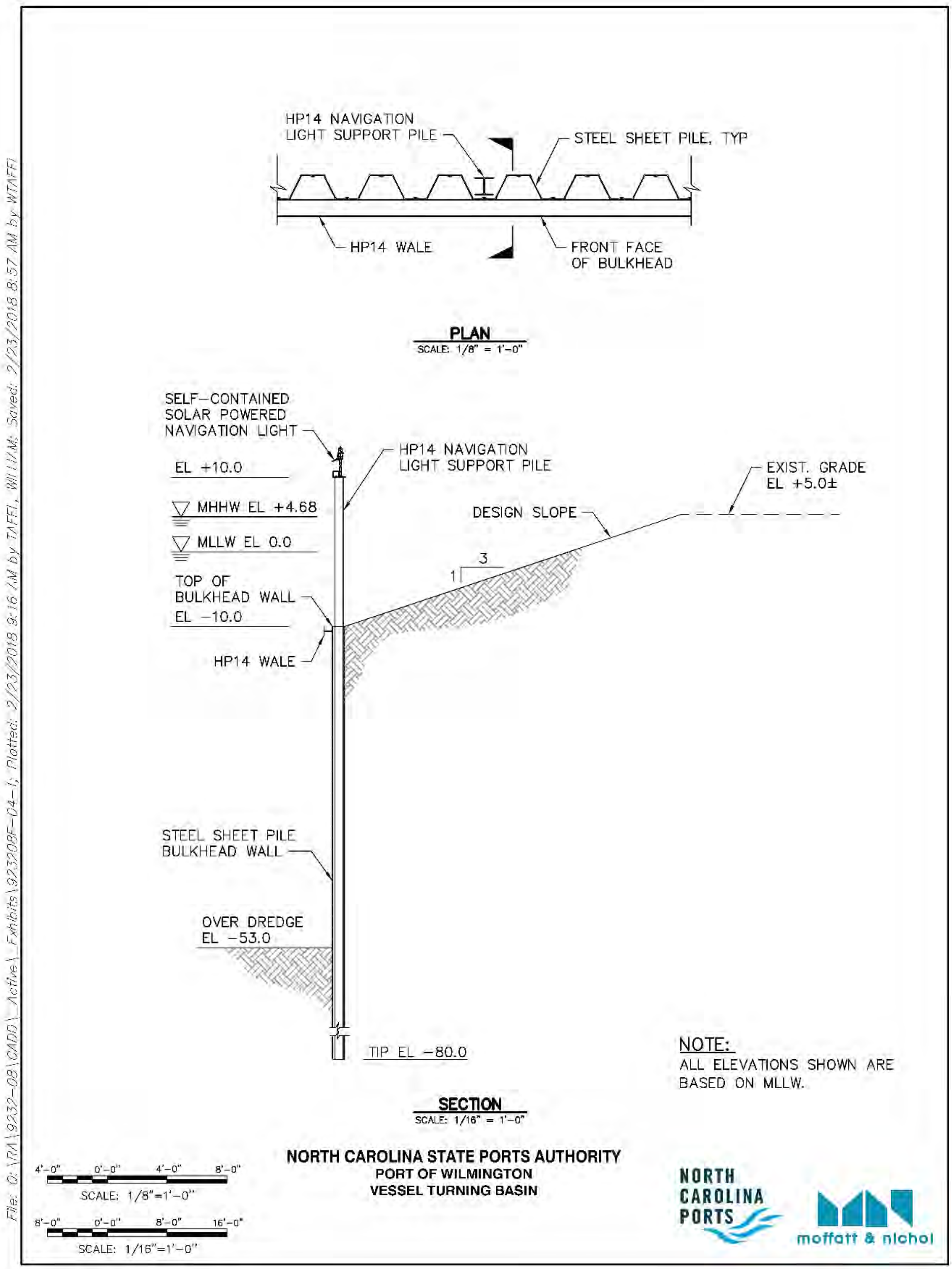


Figure 4-2: Sheet Pile Details

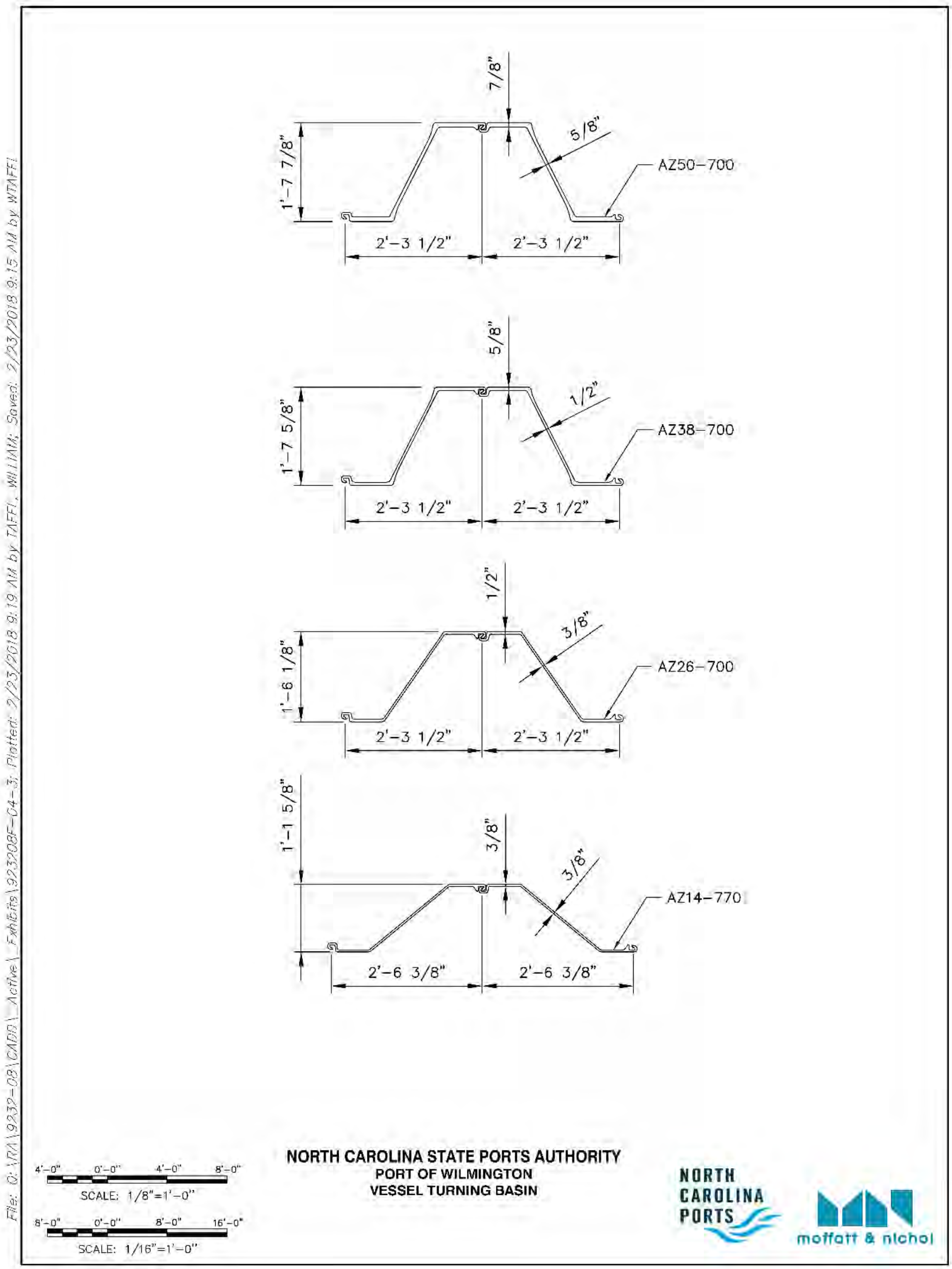
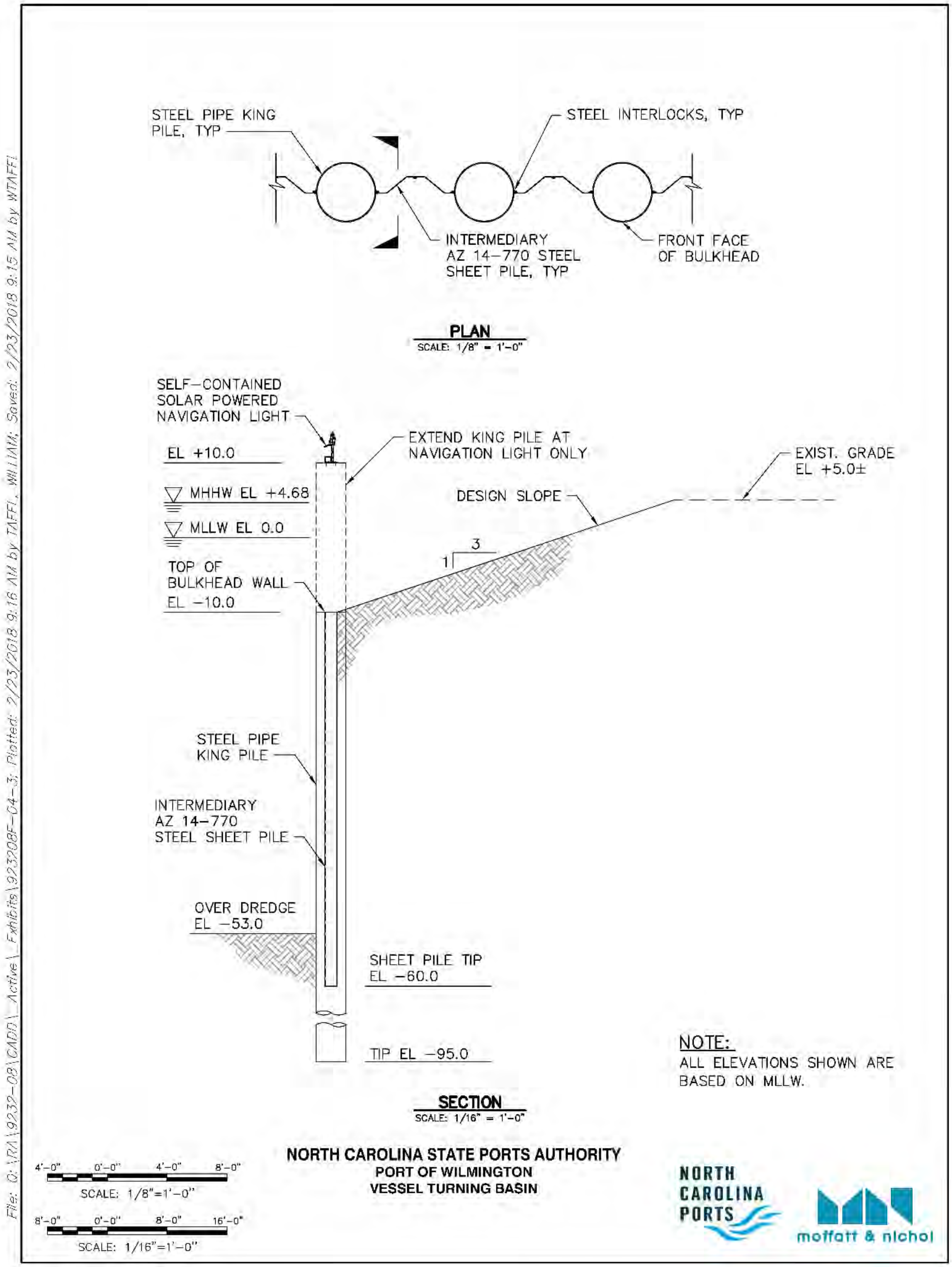


Figure 4-3: King Pile Wall Option



4.5. Estimated Costs

The estimated costs for both toe wall concepts for each Alternative is shown in Table 4-1

Table 4-1: Toe Wall Estimated Costs

Alternative	Wall Type	Length	Cost per LF	Total Cost
A	Sheet Pile	3189	$4,700 (avg)	$14,988,300
A	King Pile	3189	$5,300 (avg)	$16,901,700
B	Sheet Pile	1612	$6,500	$10,478,000
B	King Pile	1612	$7,200	$11,606,400
D	Sheet Pile	684	$6,500	$4,446,000
D	King Pile	684	$7,200	$4,924,800

The sheet pile wall options have lower costs compared to the king pile wall due to using less steel and simpler templates allowing for faster installation. Alternatives B and D use the largest sheet pile available, so if further geotechnical investigations indicate that a larger section is needed, then a sheet pile wall will not be an option. In contrast, king pile walls have large flexibility in the capacity as the wall capacity can be modified by varying the king pile size, wall thickness or spacing. King pile walls can be further strengthened through filling the pipe pile with reinforced concrete. Alternative A has reduced soil pressures resulting in smaller required wall sizes compared to Alternatives B and D.

4.6. Wall and Slope Protection

A scour analysis was performed to assess the potential for scour at the toe of the proposed wall or along the slope of the eastern extent of the turning basin due to the propeller wash from the main engine of vessels calling at the port. During the typical turning maneuvers to port (counterclockwise), a strong water jet can be produced by the design vessel and directed toward the eastern bank of the turning basin.

For the five turning basin configurations being considered there are two alternatives for stabilizing the east bank of the river. The first alternative is a toe wall with a crest elevation of -10 ft MLLW constructed along the eastern extent of the turning basin (Alternatives A, B & D). The second alternative for the eastern bank eliminates the toe wall and instead has a 3:1 dredged slope (Alteratives C & E) which would be protected by riprap.

In 2015, the World Association for Waterborne Transport Infrastructure (PIANC) issued Report No. 180-2015, *Guidelines for Protecting Berthing Structures from Scour Caused by Ships* [1]. PIANC 180-2015 provides a quantitative approach for estimating water velocities at the bed caused by vessel propellers. PIANC [1] provides two distinct methods for calculating the scour velocities generated by ship propellers: 1) the “German Method” and 2) the “Dutch Method”. Each method includes guidance for computing scour velocities on sloping revetments and at the toe of bulkhead walls. For this exercise both the German and Dutch methods were considered for the 3:1 slope alternative. Only the Dutch Method was used for computing scour velocity at the base of the toe wall, because the German method coefficients are outside the range of applicability for the toe wall. The German and Dutch methods both characterize the propeller efflux as a jet that decays both axially (along the jet) and radially (away from the jet axis). The methods differ by various assumptions and coefficient choices.

The scour protection design was performed based on the project design vessel (Table 4-2). The design vessel characteristics in Table 4-2 are based on the *Significant Ships* Publication [2] and *Clarkson World Fleet Register* [3]. Based on the feasibility study navigation simulations and the PIANC guidance, an engine order of slow ahead was assumed for this analysis. Typically, the main propeller would be used only to arrest the vessel drifting sternward toward the edge of the turning basin. As such, the propeller jet during the maneuver would be directed at the eastern bank when ships turn to port (counterclockwise, the orientation for each simulated maneuver). The analysis was conducted for design draft vessels at mean lower low water when the propeller is at minimum distance above sea bed and closest to the dredged slope.

Furthermore, based on the feasibility navigation simulations, it was determined that the propeller wash of an assisting tug would not impact the slope due to the location and orientation of the tugs throughout the maneuver. Tug thrusts will be directed parallel to or directed away from the dredged slope, and hence propeller scour due to tugs is not considered in this analysis.

Table 4-2: Propeller Scour Design Vessel Characteristics

Vessel Parameter	Value
Height of Thruster Centerline Above Keel [ft]	14.1
Beam [ft]	159.0
LOA [ft]	1200.0
Propeller type	Fixed Pitch Propeller
Distance from Propeller to Vessel Stern [ft]	42.2
Diameter of Propeller [ft]	30.5
Installed Engine Power [Watts]	72,240,000
Maneuver Engine Order	Slow ahead
Depth of Propeller Below Water [ft]	28.9

For the turning basin alternatives considered in this study, the channel boundary aligns either with a toe wall (Alternatives A, B, & D) or the toe of the dredged slope (Alternatives C & E). Table 4-3 summarizes the geometric characteristics for the analysis. A sensitively analysis was completed for the distance from the vessel stern to the channel boundary. A distance of 40 feet was used as the controlling value based on the proximity of the vessel stern to the channel boundary during the feasibility navigation simulations.

Table 4-3: Summary of Geometric Design Parameters

Geometry Parameters	Value
Distance from Vessel Stern to Channel Boundary [ft]	40
Dredge Side Slope [V:H]	1:3
Distance from Propeller to Channel Boundary [ft]	82

For the dredged slope alternative at 42 feet, the analysis indicated a maximum scour velocity on the bed of 9.1 ft/s and 11.8 ft/s using the Dutch and German Methods, respectively. A maximum scour velocity of 15.6 ft/s was calculated at the toe of the vertical wall using the Dutch Method. The results are summarized in Table 4-4 including the variability in maximum scour velocity with varying vessel distances to the channel boundary.

Table 4-4: Propeller Scour Velocity Results

Profile	Stern Distance from Channel Boundary [ft]	Dutch Method	German Method
		Velocity [ft/s]	Velocity [ft/s]
3:1 Slope	40	9.1	11.8
3:1 Slope	50	8.5	11.0
3:1 Slope	100	6.7	8.2
Vertical Wall	40	15.9	--
Vertical Wall	50	14.4	--
Vertical Wall	100	9.9	--

Based on the resulting scour velocities, estimates of appropriate scour protection rock size were determined. It is important to use a compatible method for computing scour velocity and rock size [1]. The Dutch Method computes the 50 percent passing stone diameter (D_{50}), whereas the German Method computes the 85 percent passing stone diameter (D_{85}). For both methods the density of granite (165 pcf) was used as a typical armor stone density. With a fresh water density of 62.4 pcf, the relative buoyant density (Δ) is 1.65.

For the dredged slope alterative, the Dutch Method recommended rock size is 14.6 inches (D_{50}), which corresponds roughly to a 299 lb (W_{50}) rock for the controlling vessel distance of 40 ft. Comparatively, using the German Method an armor rock size of 31 inches (D_{85}) was calculated, which corresponds roughly to 2924 lb (W_{85}) rock.

For the vertical toe wall alternative, the Dutch Method computes a D_{50} rock size of 44 inches (8281 lb). The results are summarized in Table 4-5, including the variability in rock size with varying vessel distances to the channel boundary.

Table 4-5: Protection Rock Sizing Results

Profile	**Stern Distance from Channel Boundary [ft]**	**Dutch Method**		**German Method**	
		D_{50} [in]	**Rock Weight (dry) [lb]**	**D_{85} [in]**	**Rock Weight (dry) [lb]**
3:1 Slope	40	14.6	299	31.3	2924
3:1 Slope	50	12.6	195	27.2	1914
3:1 Slope	100	7.9	46	15.1	329
Vertical Wall	40	44.3	8281	--	--
Vertical Wall	50	36.6	4682	--	--
Vertical Wall	100	17.3	497	--	--

It is recommended the dredged sloped alternatives (C & E) be constructed with scour protection using NCDOT 2012 Standard Specifications Section 1042 [4] riprap Class 2 for the toe and the entire dredge slope up to approximately mean high water. The Class 2 riprap has a midrange of 14 inches (Table 4-6) which is comparable to the Dutch Method, and slightly smaller than the German Method.

Table 4-6: NCDOT Riprap Class 2 Requirements

Criteria	**Required Stone Size (in)**
Minimum (5%)	9
Midrange	14
Maximum (90%)	23

For the toe wall alternatives (A, B & D), armor is not recommended at this time. The proposed walls were design for potential future dredging down to a depth of -53 ft-MLLW and it appears from the geotechnical analyses that hard “rock” material is present above this depth which should be resistant to propeller scour. This assumption, though, should be confirmed as part of the final design process.

REFERENCES

[1] World Association of Waterborne Transport Infrastructure (PIANC), "Guidelines for Protecting Berthing Structures from Scour Caused by Ships," 2015.

[2] Royal Institution of Naval Architect, "Significant Ships of 2010," 2010.

[3] Clarksons Research, World Fleet Register, www.clarksons.net, Accessed February 2018

[4] North Carolina Department of Transportation, Standard Specifications for Roads and Structures, Section, 1042, 2012.

5. Dredging Quantities and Costs

Dredging quantities were determined for each of the alternative configurations (Tables 5-1 through 5-5) for the design depth of -42 ft-MLLW and including a two foot overdredge (one foot required, one foot allowable paid) to -44 ft-MLLW. It is recommended, though, that the project be permitted for a depth of -46-ft MLLW to allow for an additional two feet of unpaid overdredging. Additionally, areas where "rock" may be present were identified and these quantities calculated.

Table 5-1: Alternative A - Dredging Quantities

	Silt / Sand (cy)	"Rock" (cy)	Total (cy)
East Side (-42')	170,700	4,100	174,800
East Side (2' overdredge)	17,100	8,900	26,000
East Side Total	***187,800***	***13,000***	***200,800***
West Side (-42')	201,600	9,900	211,500
West Side (2' overdredge)	37,200	16,900	54,100
West Side Total	***238,800***	***26,800***	***265,600***
Total	**426,600**	**39,800**	**466,400**

Table 5-2: Alternative B - Dredging Quantities

	Silt / Sand (cy)	"Rock" (cy)	Total (cy)
East Side (-42')	324,700	5,500	330,200
East Side (2' overdredge)	26,800	11,900	38,700
East Side Total	***351,500***	***17,400***	***368,900***
West Side (-42')	159,300	5,200	164,500
West Side (2' overdredge)	30,600	11,100	41,700
West Side Total	***189,900***	***16,300***	***206,200***
Total	**541,400**	**33,700**	**575,100**

Table 5-3: Alternative C - Dredging Quantities

	Silt / Sand (cy)	"Rock" (cy)	Total (cy)
East Side (-42')	85,100	100	85,200
East Side (2' overdredge)	16,600	600	17,200
East Side Total	***101,700***	***700***	***102,400***
West Side (-42')	162,700	5,200	167,900
West Side (2' overdredge)	31,600	11,300	42,900
West Side Total	***194,300***	***16,500***	***210,800***
Total	**296,000**	**17,200**	**313,200**

Table 5-4: Alternative D - Dredging Quantities

	Silt / Sand (cy)	"Rock" (cy)	Total (cy)
East Side (-42')	138,700	200	138,900
East Side (2' overdredge)	16,100	1,400	17,500
East Side Total	***154,800***	***1,600***	***156,400***
West Side (-42')	159,200	5,200	164,400
West Side (2' overdredge)	30,500	11,000	41,500
West Side Total	***189,700***	***16,200***	***205,900***
Total	**344,500**	**17,800**	**362,300**

Table 5-5: Alternative E - Dredging Quantities

	Silt / Sand (cy)	"Rock" (cy)	Total (cy)
East Side (-42')	195,000	3,200	198,200
East Side (2' overdredge)	25,400	7,000	32,400
East Side Total	***220,400***	***10,200***	***230,600***
West Side (-42')	162,700	5,200	167,900
West Side (2' overdredge)	31,600	11,300	42,900
West Side Total	***194,300***	***16,500***	***210,800***
Total	**414,700**	**26,700**	**441,400**

Based on the bids received for the previous turning basin enlargement in 2016, it was estimated that the dredging costs are about $32 / cy for the east side where substantial woody material was encountered and $24 / cy for the west side, assuming disposal at Eagle Island as before. No cost differential was assumed for the "rock" as it was previously successfully dredged with the large clam shell that was used for the entire project. It should be noted that some cost reductions might be realized if the material could be disposed of offshore, but this would require further investigations into the permitting requirements and means of separating out the woody material.

Table 5-6 presents the dredging cost for each alternative including a $2.5 million mobilization cost.

Table 5-6: Estimated Dredging Costs

	Estimated Dredging Costs
Alternative A	$15,300,000
Alternative B	$19,253,600
Alternative C	$10,836,000
Alternative D	$12,446,400
Alternative E	$14,938,400
Alternative C (without optional west side)	$5,776,800
Alternative D (without optional west side)	$7,504,800
Alternative E (without optional west side)	$9,879,200

6. Summary

6.1. Other Considerations

Additional considerations regarding this project include:

- The proposed dredged slopes will likely impact existing wetlands on the east side. However, these wetlands have not previously been delineated so the amount of impact could not be estimated. The degree of these impacts would affect the required mitigation and associated costs for each alternative, but it does not appear that the impact differences between alternatives is significant enough to cause major changes in the amount of environmental documentation and permitting efforts required for each alternative.

- If this project proceeds, additional geotechnical investigations will be required to confirm the stability of the dredged slopes and the soil properties assumed for the proposed toe wall.

- Since the vessel simulations were only performed for Alternative A, further discussions with the docking pilots should be held regarding the other alternatives. Additional Transas simulations and / or Full Mission Bridge Simulations are recommended for the chosen alternative to confirm its viability.

- As discussed previously, while the NCSPA will incur the costs of enlarging the turning basin in plan and possibly constructing the toe wall up front, these costs would not have to be borne by the proposed navigation improvement project nor included in its cost / benefit analyses, which may be advantageous to its ultimate approval.

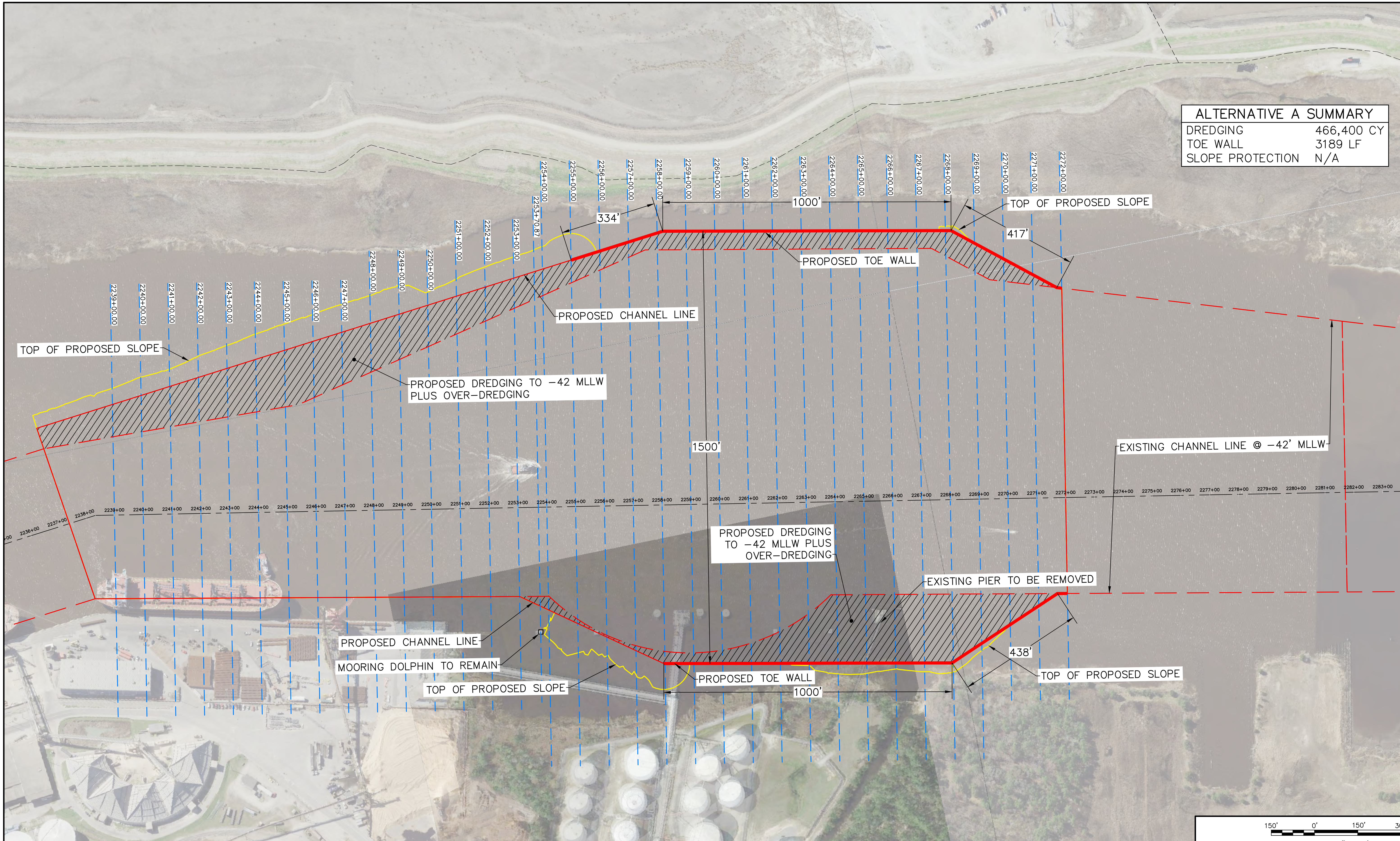
6.2. Alternative Cost Estimates

The total cost for each alternative was estimated as shown in Table 6-1. These costs include the toe wall construction (if applicable), dredging costs, demolition of the Chevron Pier and riprap slope protection (if applicable). They are not inclusive, though, of any further engineering design, vessel simulations, geotechnical investigations, environmental documentation, permitting support, or mitigation required for this project. However, a 20% contingency has been added.

Table 6-1: Alternative Cost Estimates

	Toe Wall	Dredging	Demo, Berm Relocation & Slope Protection	Subtotal	Contingency (20%)	Total
Alt. A	$14,988,300	$15,300,000	$100,000	$30,388,300	$6,077,660	$36.5 mil
Alt. B	$10,478,000	$19,253,600	$100,000	$29,831,600	$5,966,320	$35.8 mil
Alt. C	n/a	$10,836,000	$860,000	$11,696,000	$2,339,200	$14.0 mil
Alt. D	$4,446,000	$12,446,400	$100,000	$16,992,400	$3,398,480	$20.4 mil
Alt. E	n/a	$14,938,400	$1,600,000	$16,538,400	$3,307,680	$19.8 mil
Alt. C (w/o opt. west side)	n/a	$5,776,800	$860,000	$6,636,800	$1,327,360	$8.0 mil
Alt. D (w/o opt. west side)	$4,446,000	$7,504,800	$100,000	$12,050,800	$2,410,160	$14.5 mil
Alt. E (w/o opt. west side)	n/a	$9,879,200	$1,600,000	$11,479,200	$2,295,840	$13.8 mil

Appendix A – Alternative A Plan and Sections



ALTERNATIVE A – 1500' TURNING BASIN CENTERED WITH TWO TOE WALLS

moffatt & nichol

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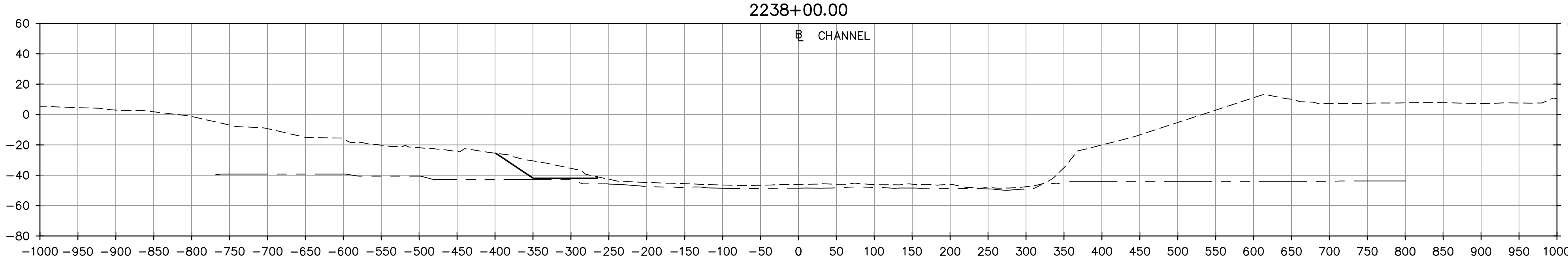

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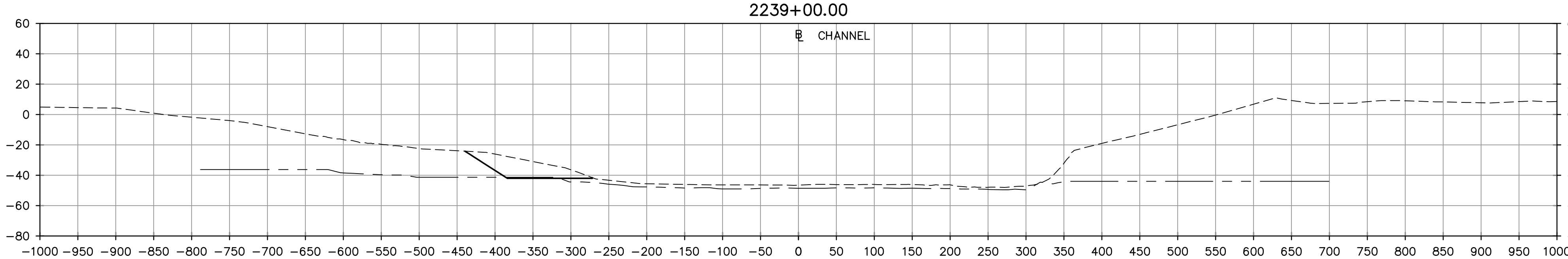

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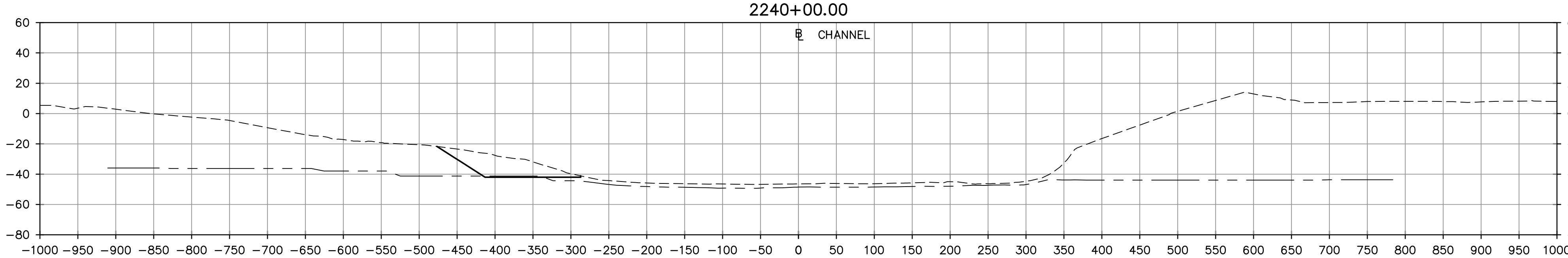

TURNING BASIN ALTERNATIVE A
SECTIONS 1 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

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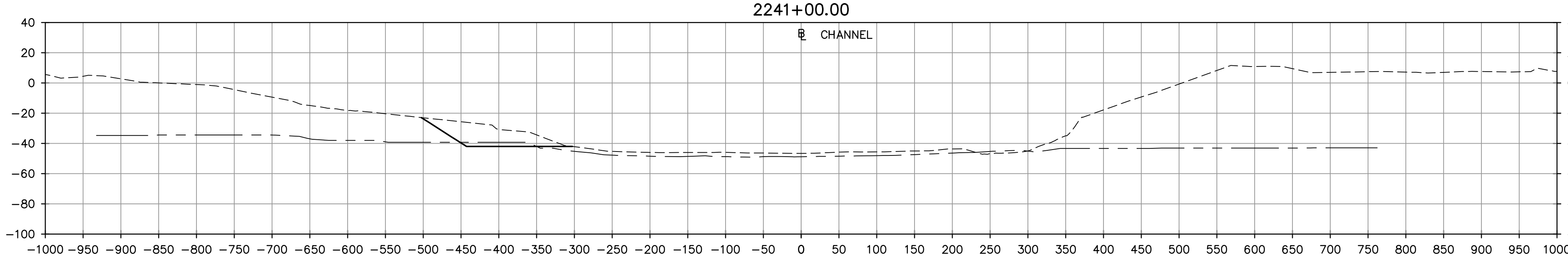

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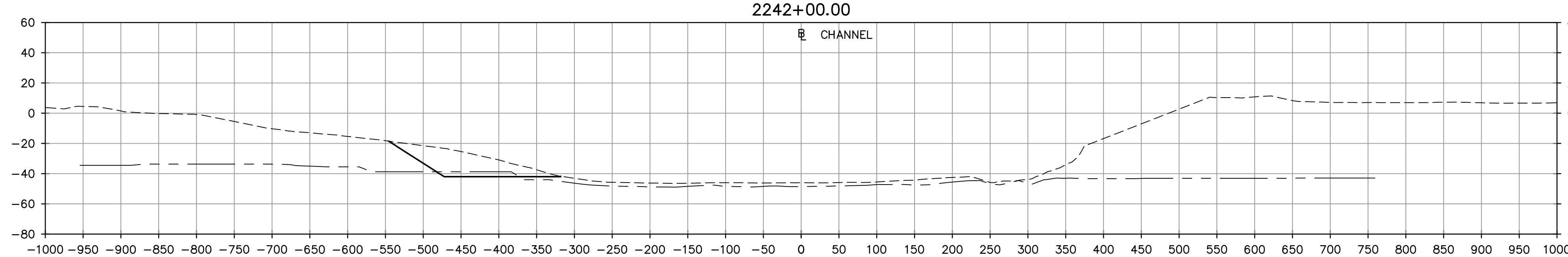

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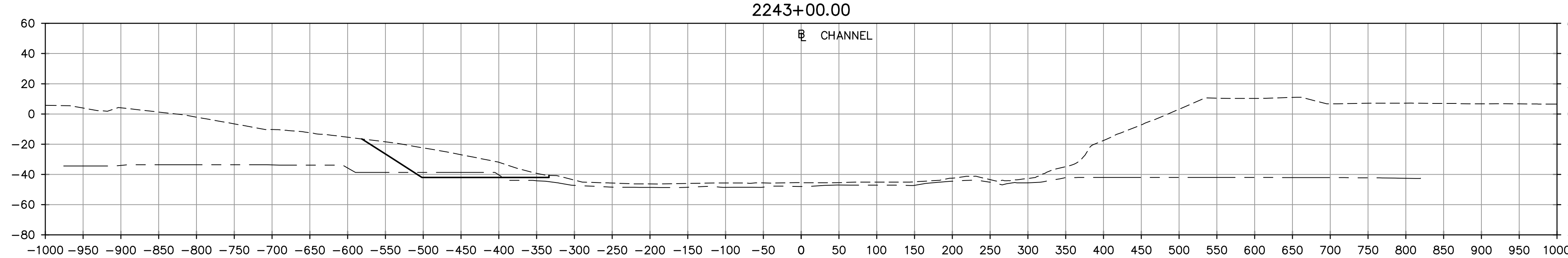

TURNING BASIN ALTERNATIVE A
SECTIONS 2 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

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100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

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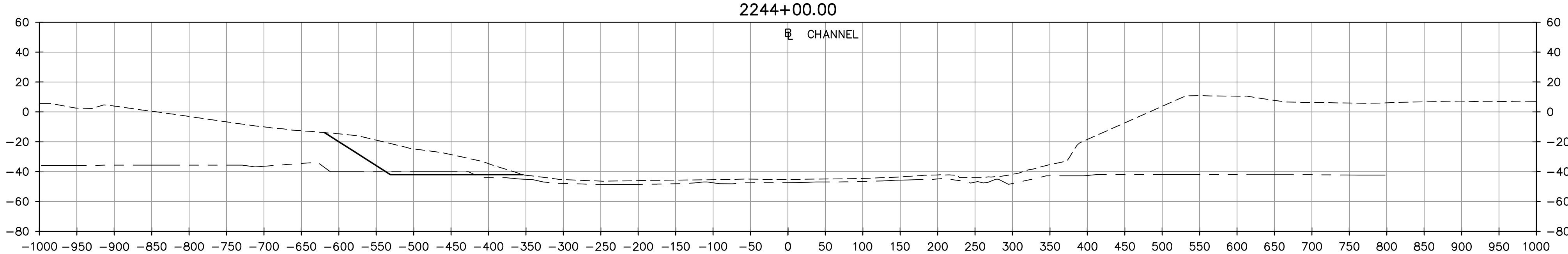

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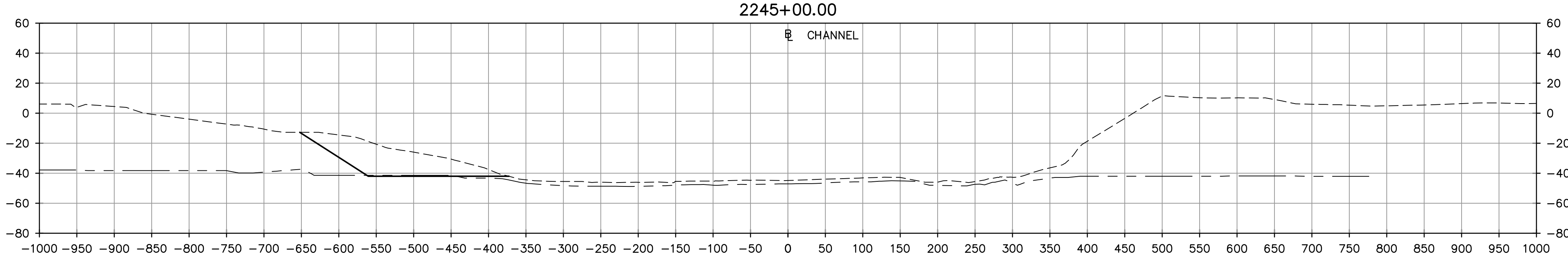

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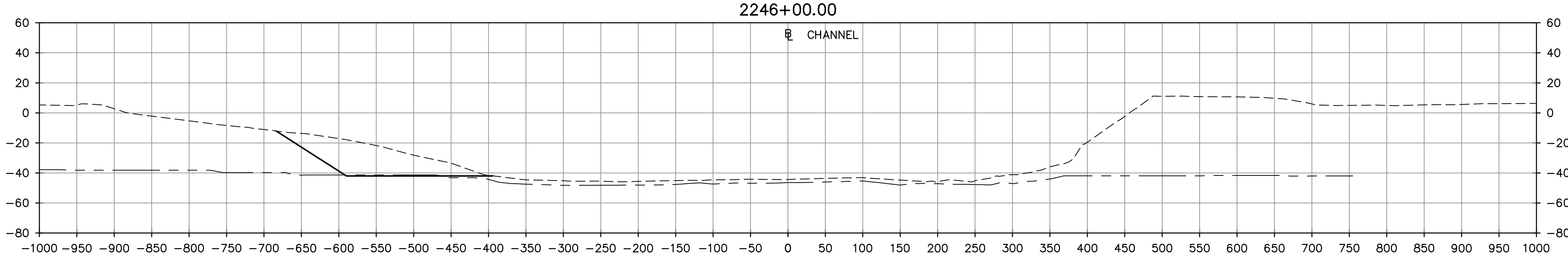

TURNING BASIN ALTERNATIVE A
SECTIONS 3 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

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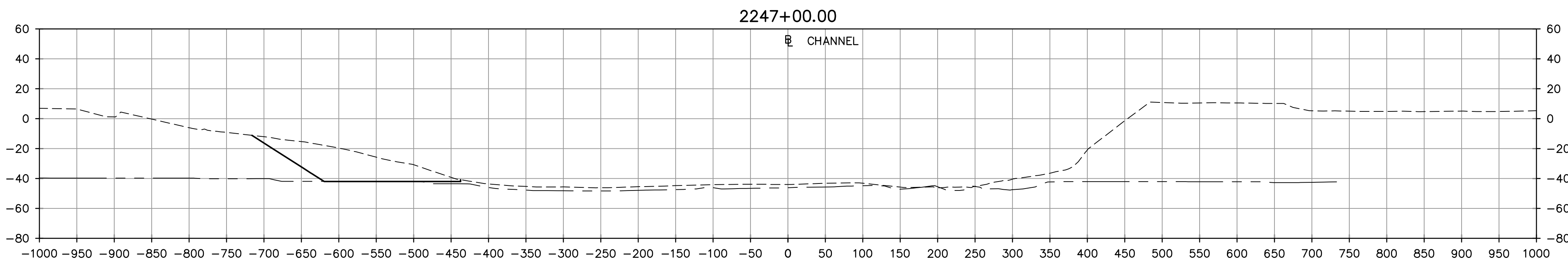
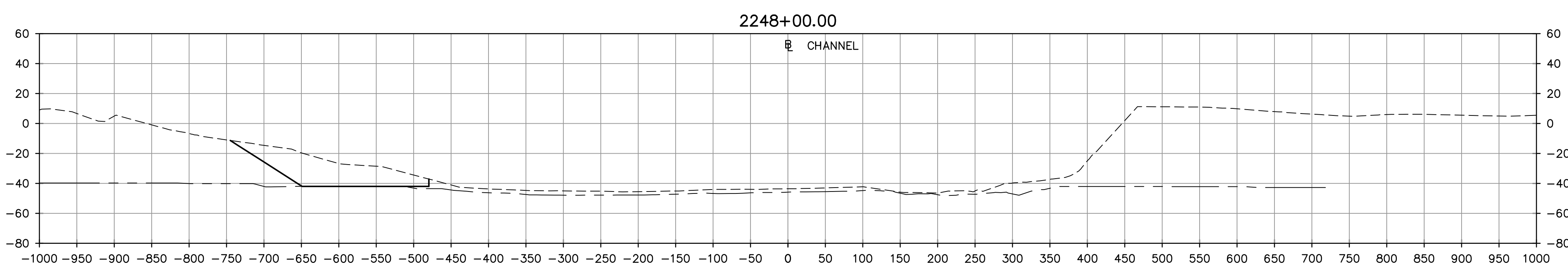
VERTICAL SCALE: 1"=100'

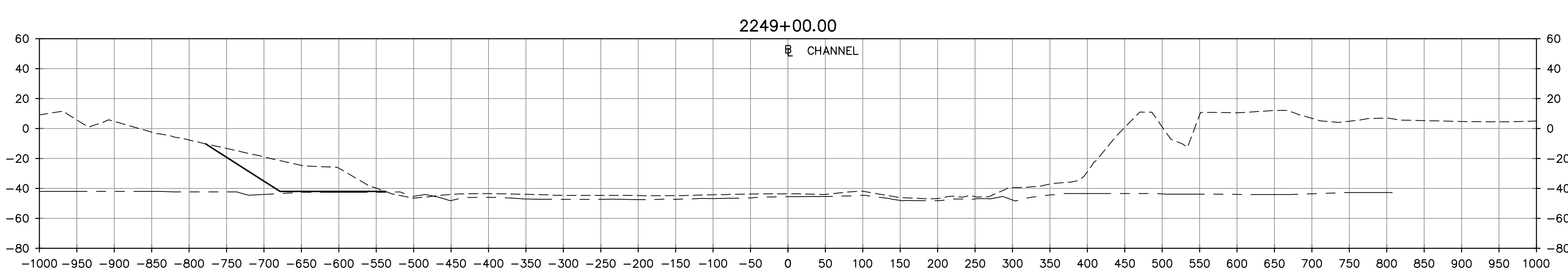
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE A
SECTIONS 4 OF 12

LEGEND

APPROXIMATE EXISTING GROUND
APPROXIMATE EXISTING ROCK
PROPOSED CHANNEL DEPTH

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100' 0' 100' 200'
HORIZONTAL SCALE: 1"=200'

moffatt & nichol

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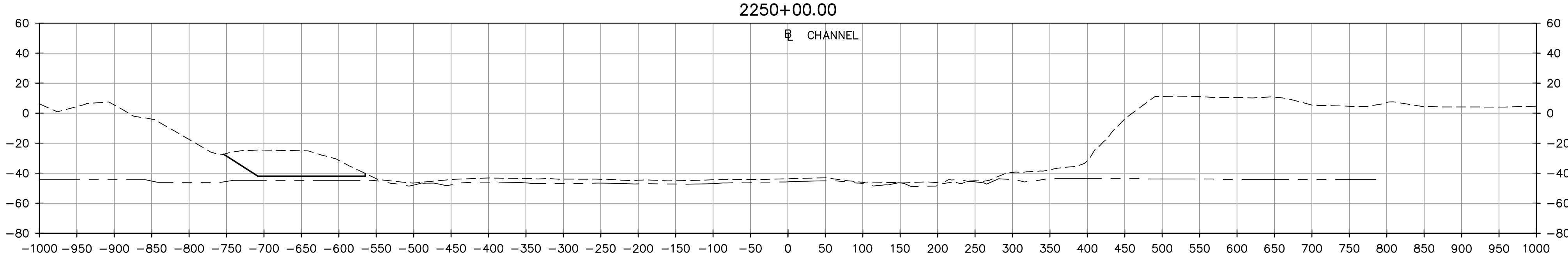

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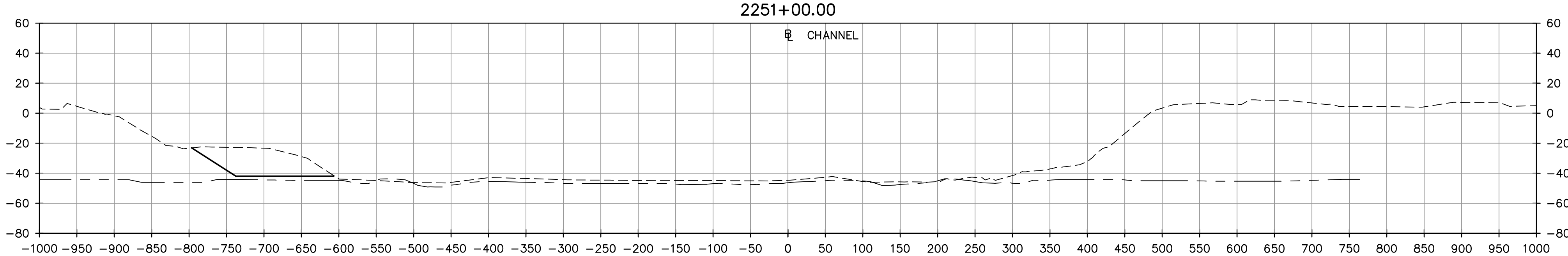

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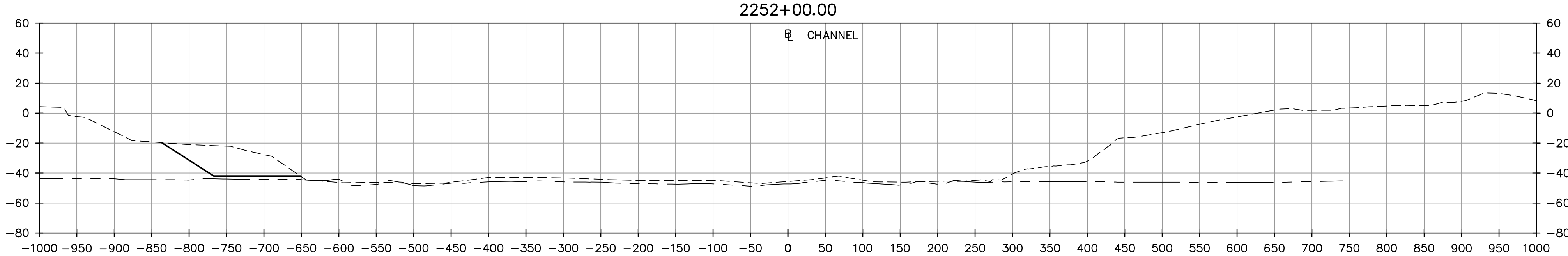

TURNING BASIN ALTERNATIVE A
SECTIONS 5 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

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100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

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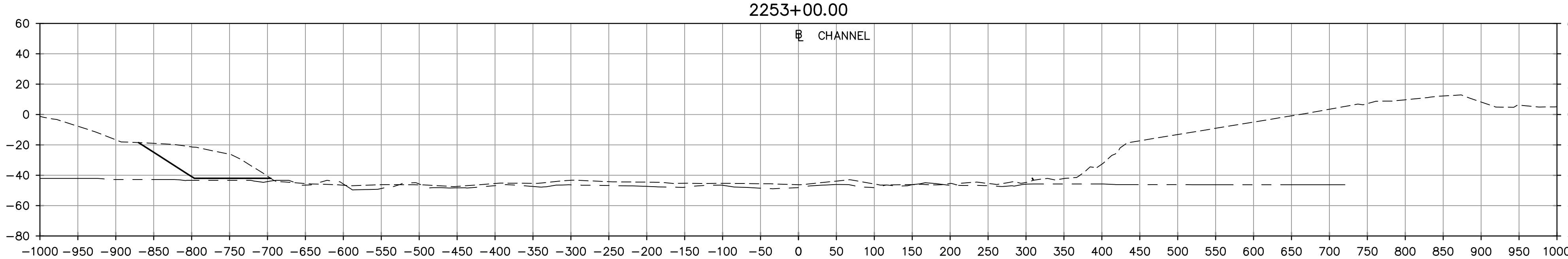

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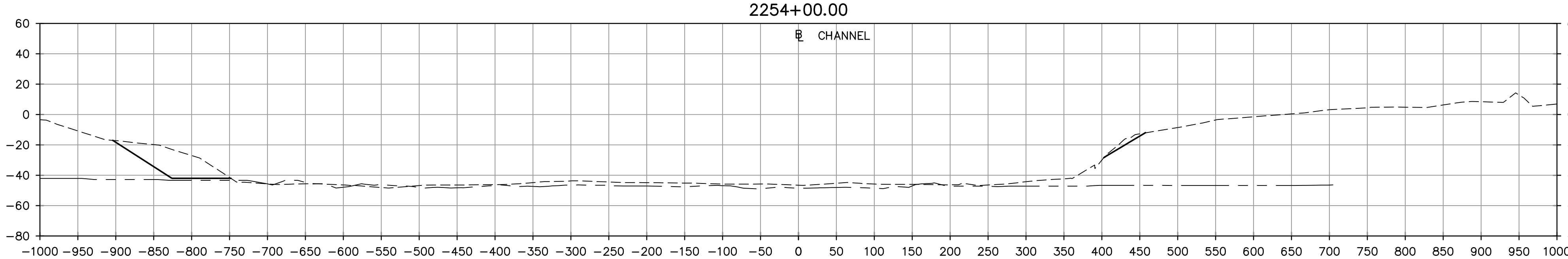

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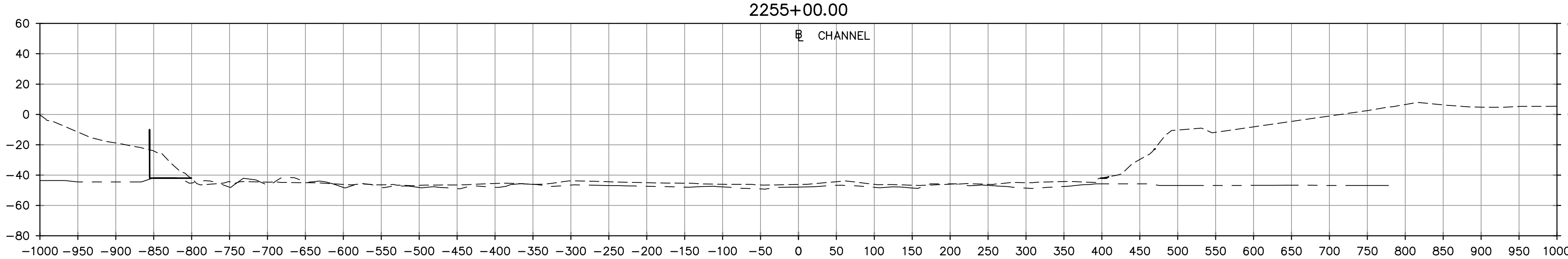

TURNING BASIN ALTERNATIVE A
SECTIONS 6 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

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100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

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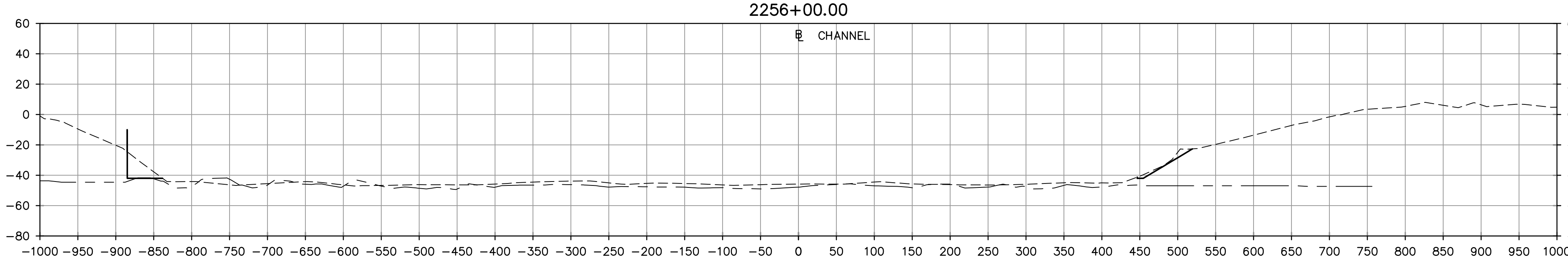

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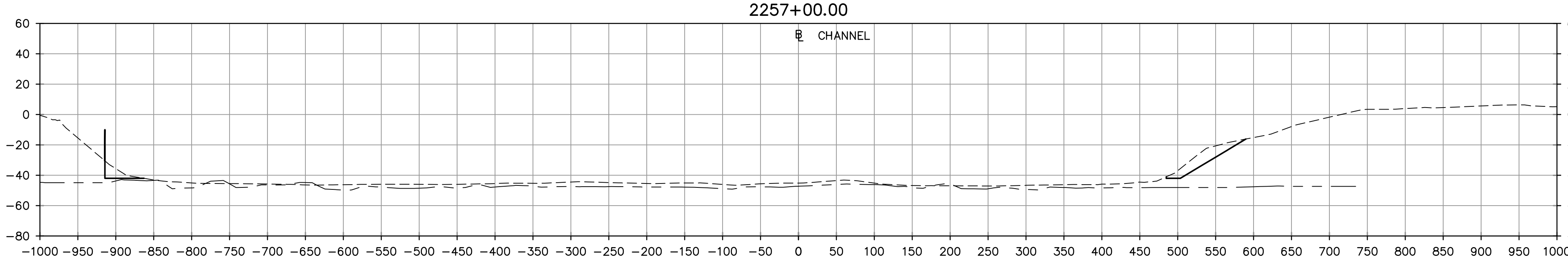

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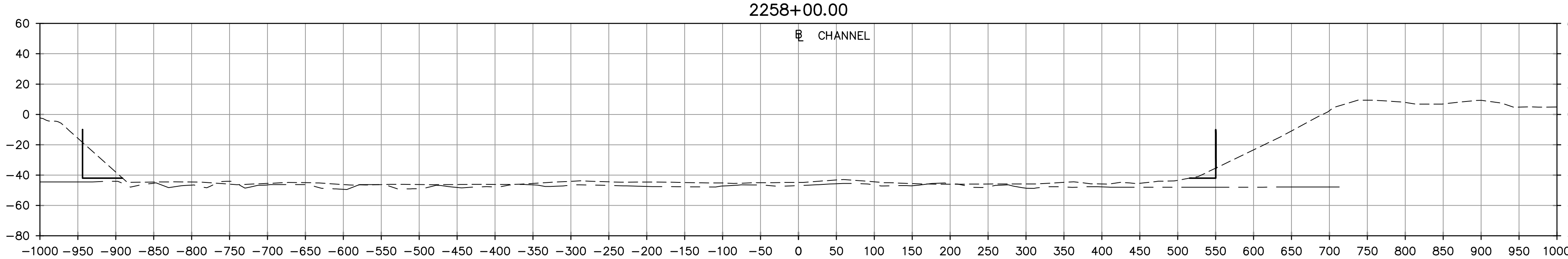

TURNING BASIN ALTERNATIVE A
SECTIONS 7 OF 12

LEGEND

APPROXIMATE EXISTING GROUND
APPROXIMATE EXISTING ROCK
PROPOSED CHANNEL DEPTH

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100' 0' 100' 200'
HORIZONTAL SCALE: 1"=200'

moffatt & nichol

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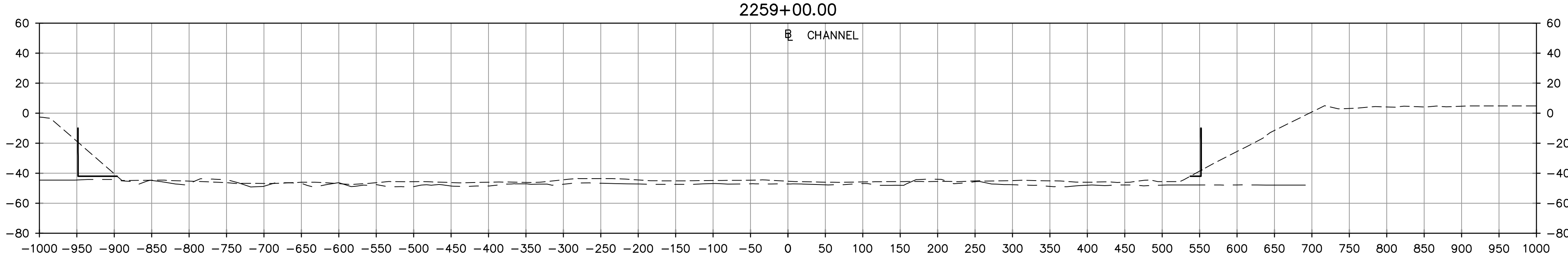

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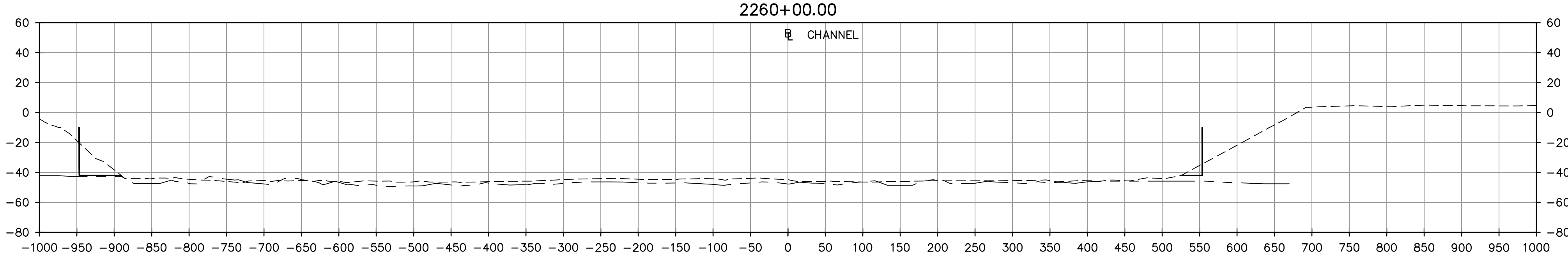

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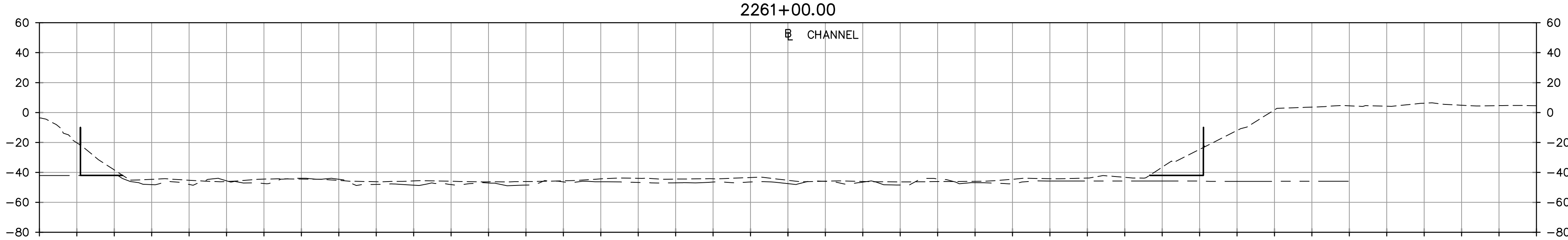

TURNING BASIN ALTERNATIVE A
SECTIONS 8 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

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100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

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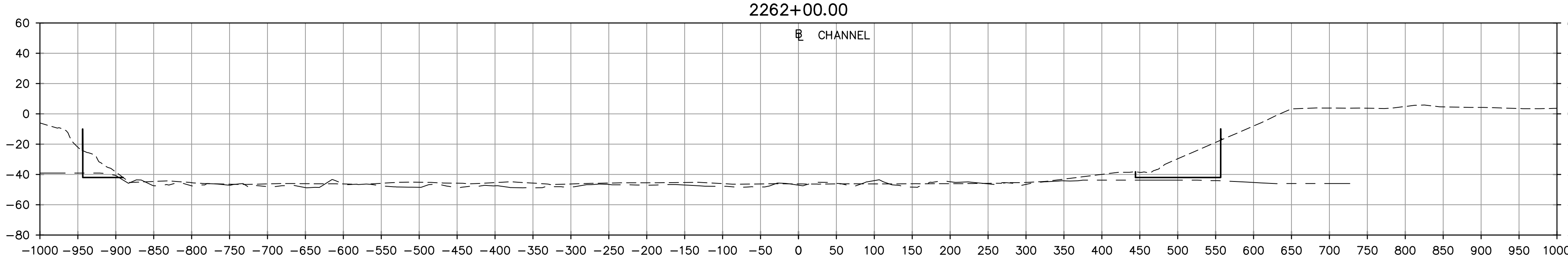

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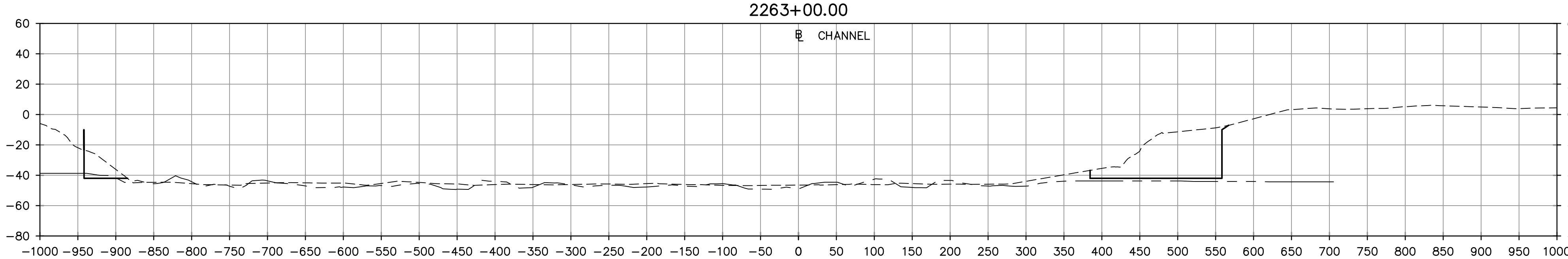

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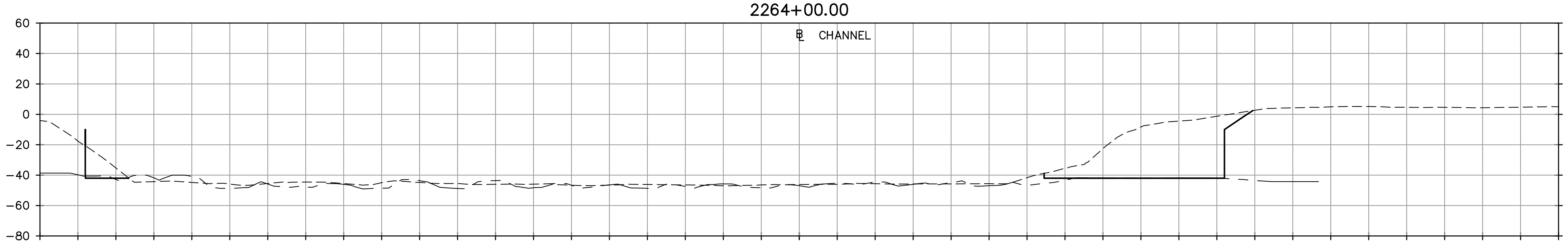


TURNING BASIN ALTERNATIVE A
SECTIONS 9 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

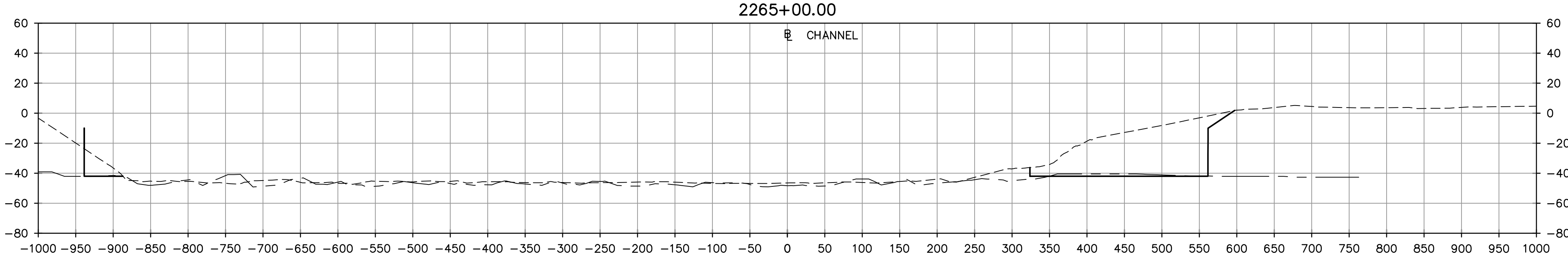
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2265+00.00



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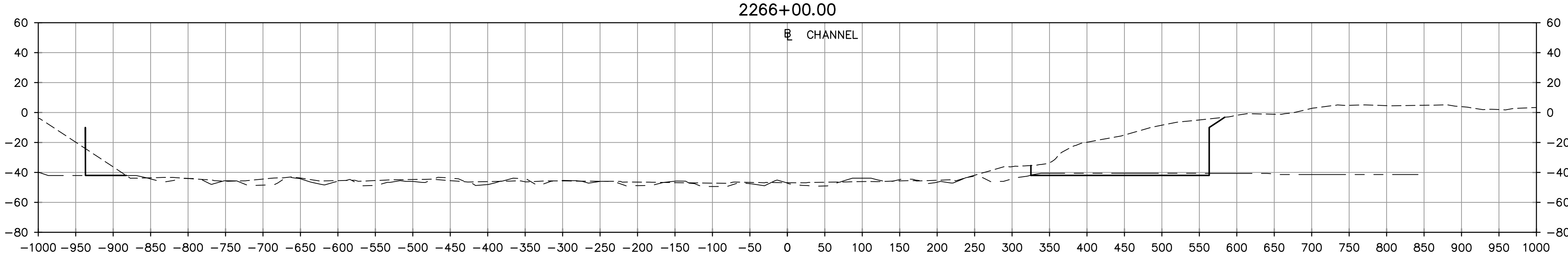

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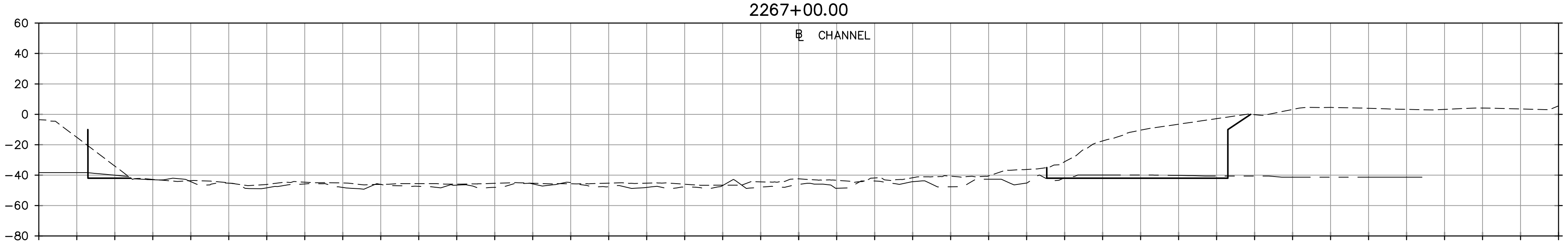


TURNING BASIN ALTERNATIVE A
SECTIONS 10 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

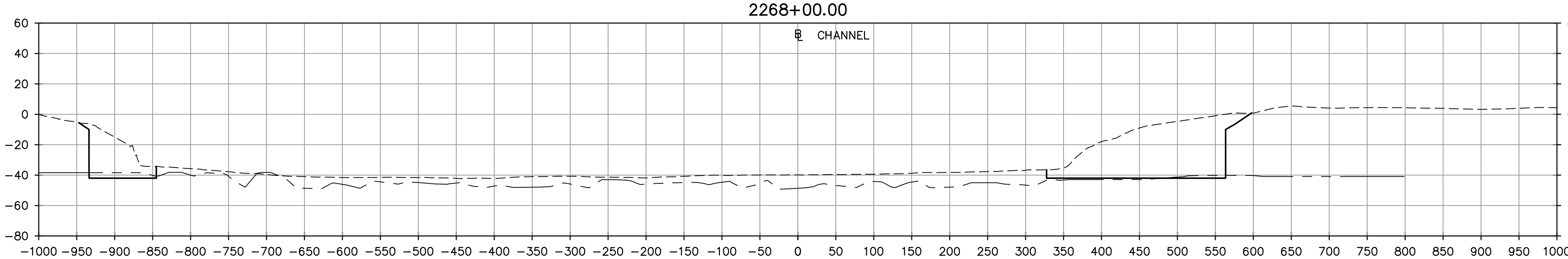
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2268+00.00



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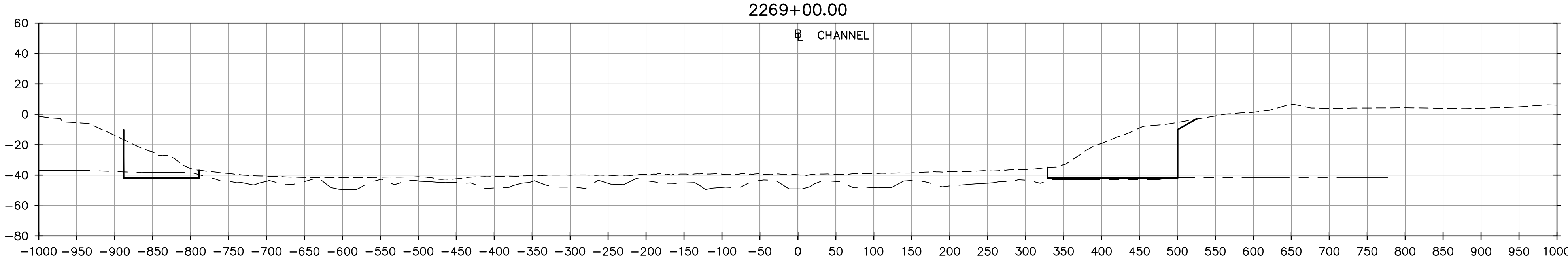

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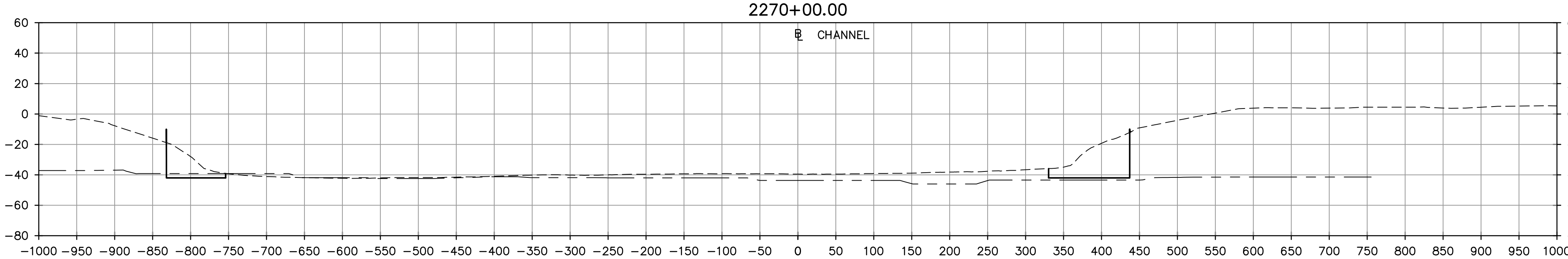


TURNING BASIN ALTERNATIVE A
SECTIONS 11 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

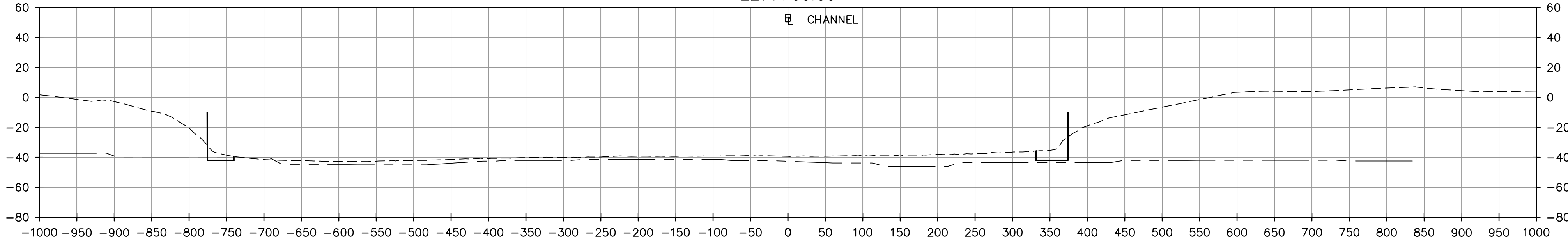
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2271+00.00



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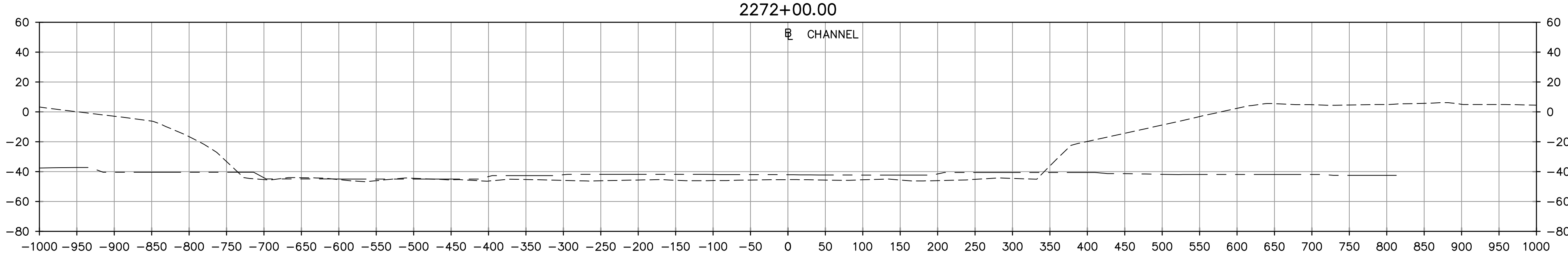

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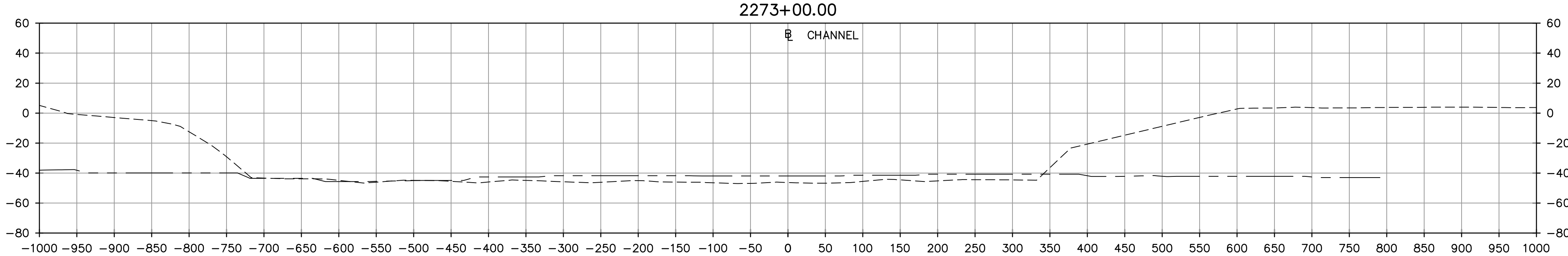


TURNING BASIN ALTERNATIVE A
SECTIONS 12 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

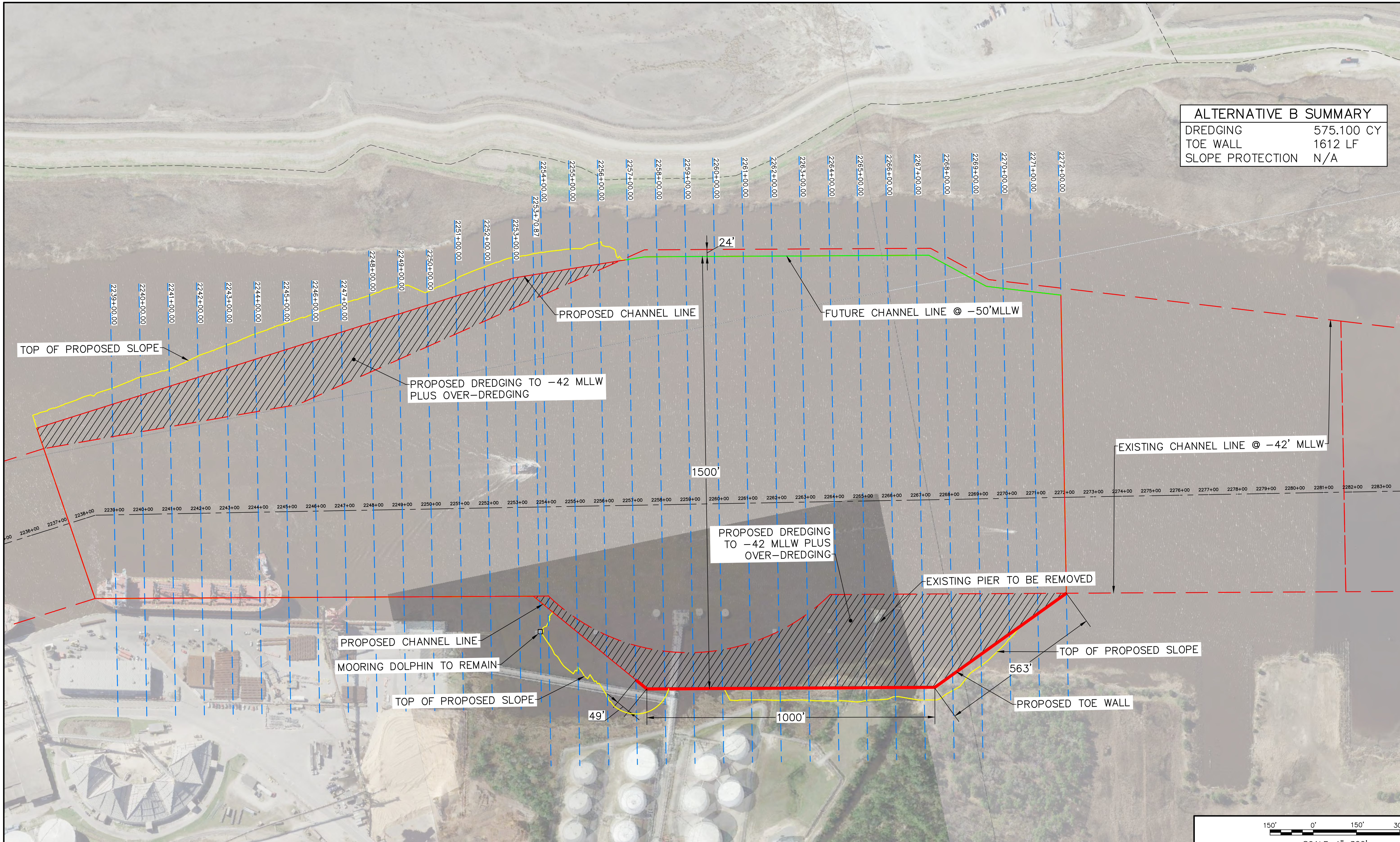
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

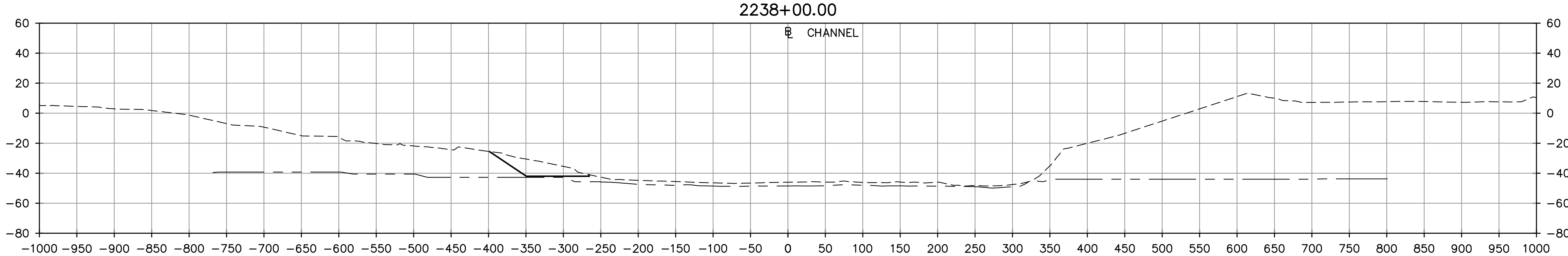
Appendix B – Alternative B Plan and Sections



ALTERNATIVE B – 1524' TURNING BASIN SHIFTED EASTWARD WITH ONE TOE WALL

moffatt & nichol

2238+00.00



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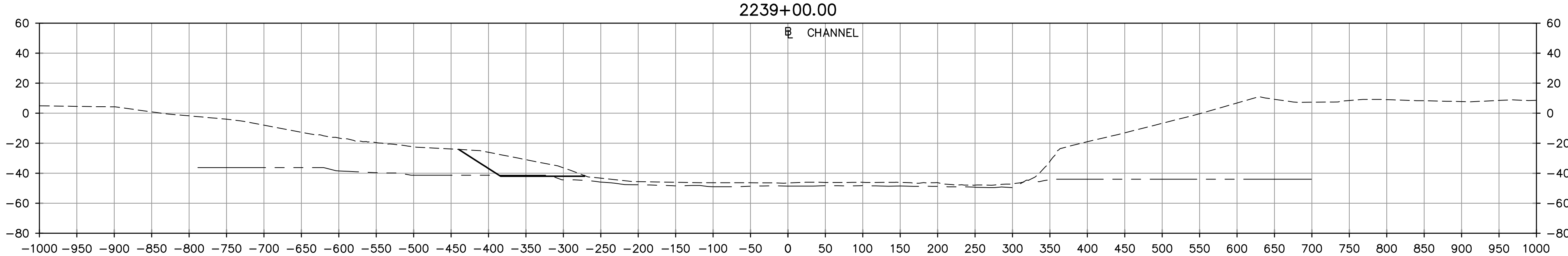

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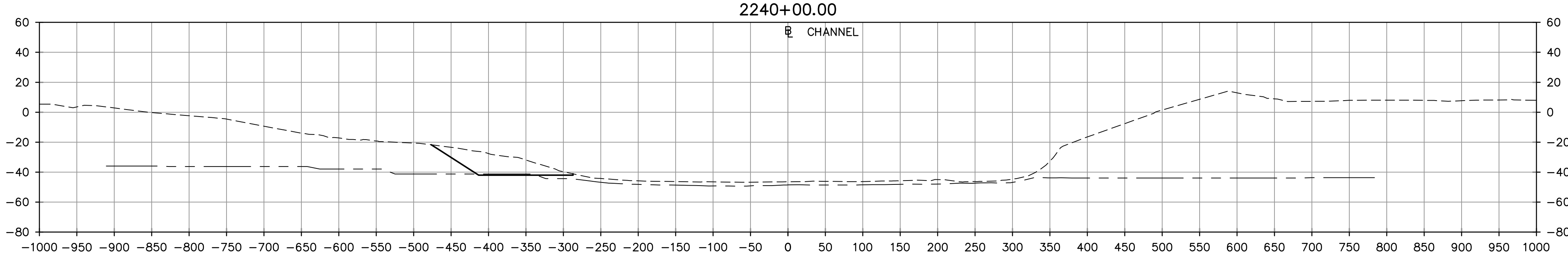


TURNING BASIN ALTERNATIVE B
SECTIONS 1 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

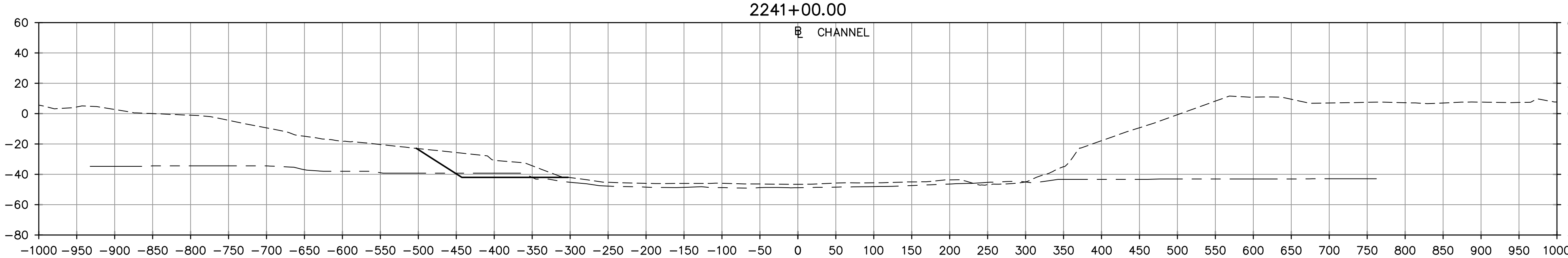
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

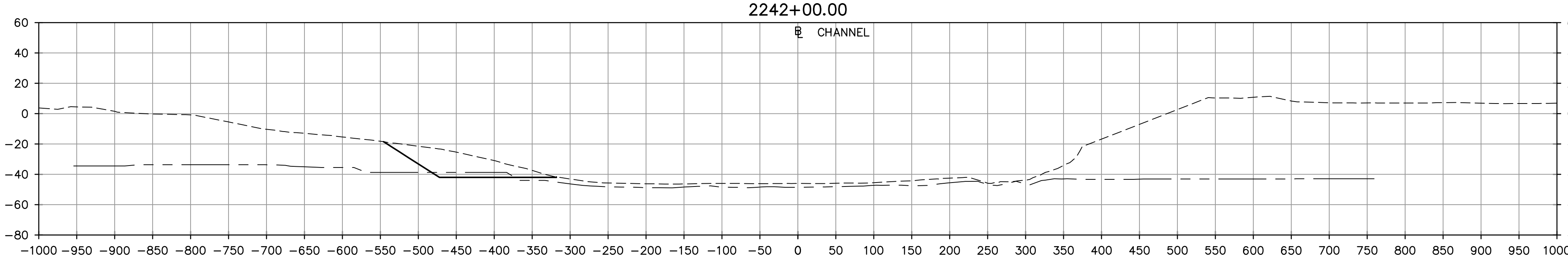
HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2241+00.00



2242+00.00



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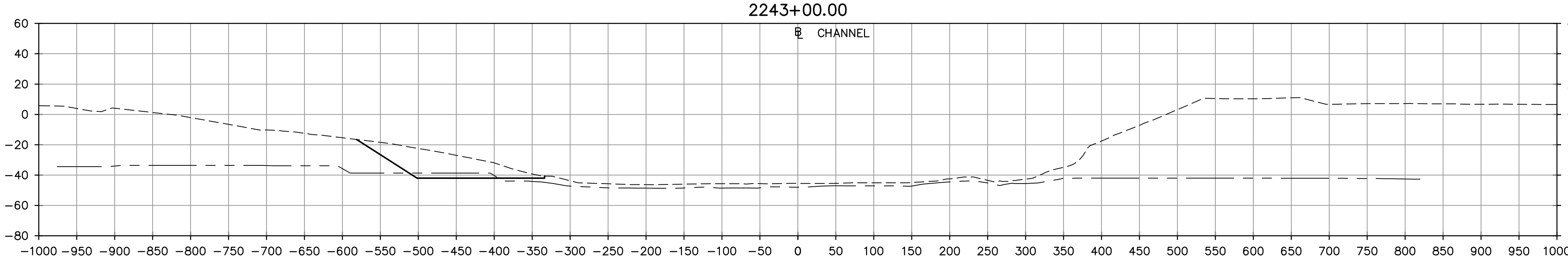


TURNING BASIN ALTERNATIVE B
SECTIONS 2 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

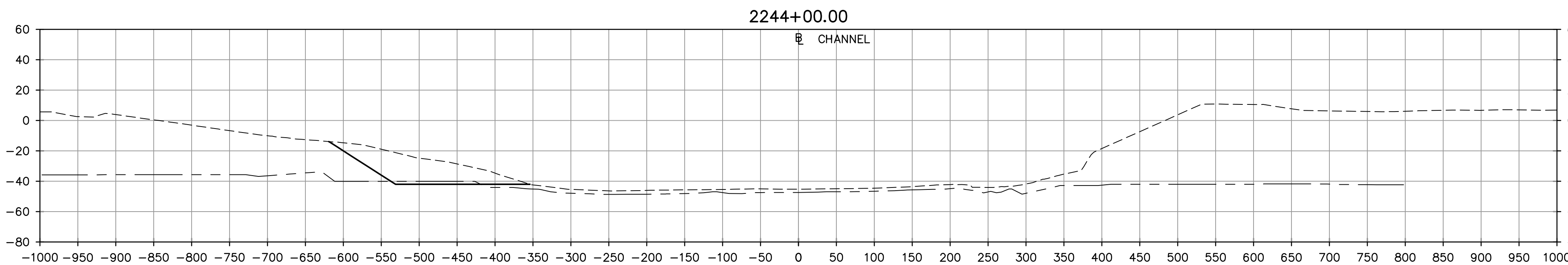
50' 0' 50' 100'

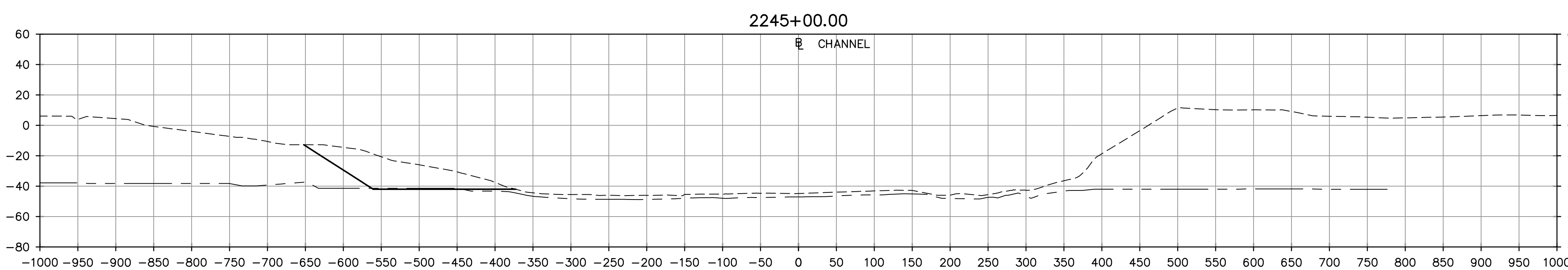
VERTICAL SCALE: 1"=100'

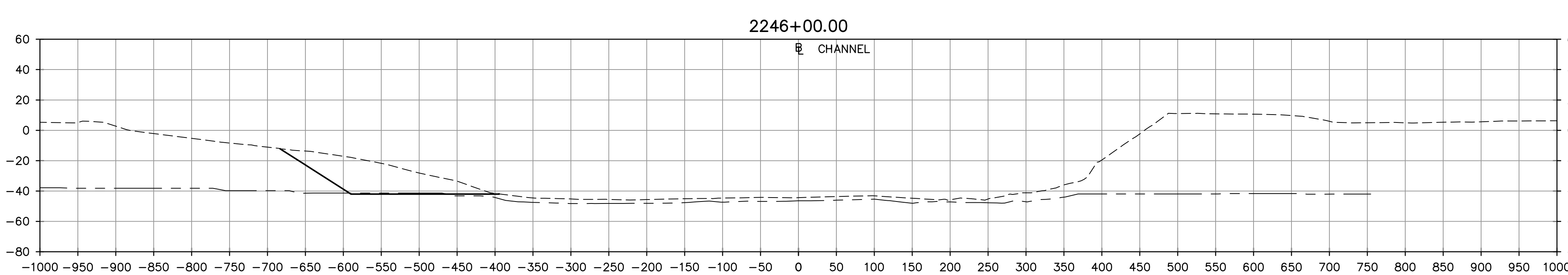
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE B
SECTIONS 3 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

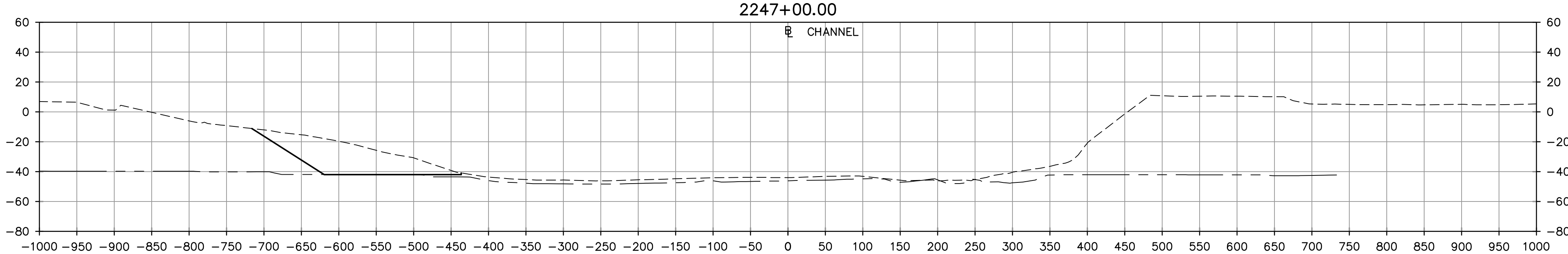
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2247+00.00



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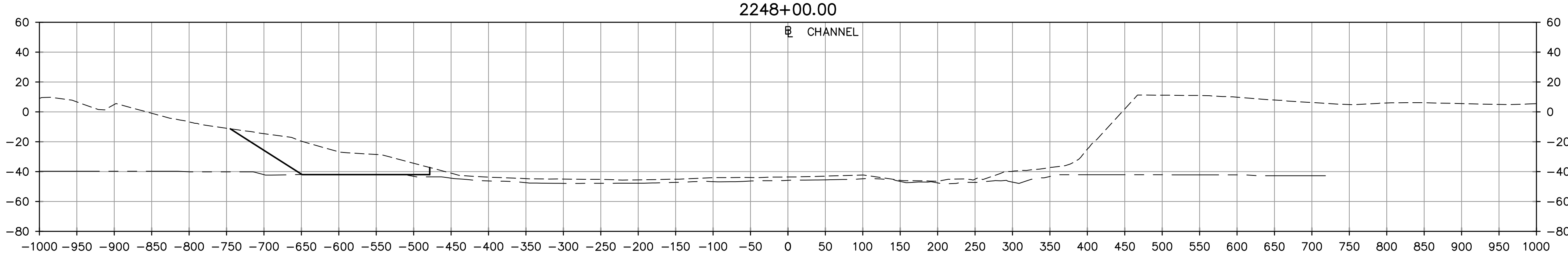

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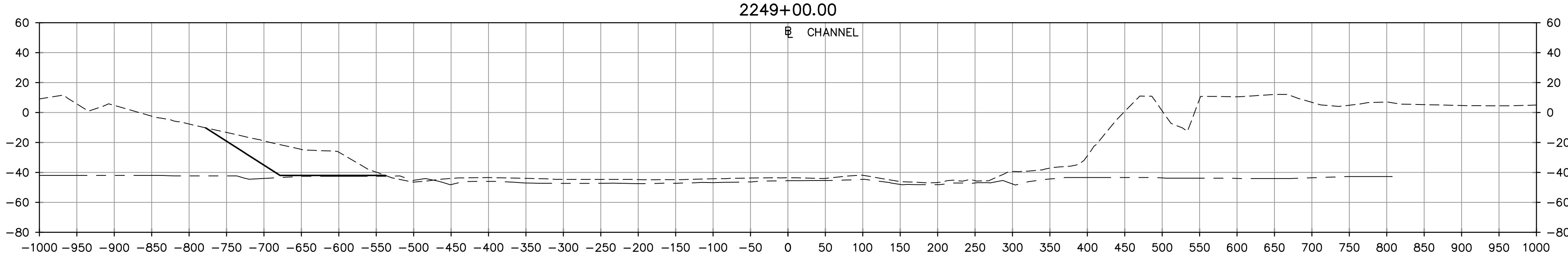


TURNING BASIN ALTERNATIVE B
SECTIONS 4 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

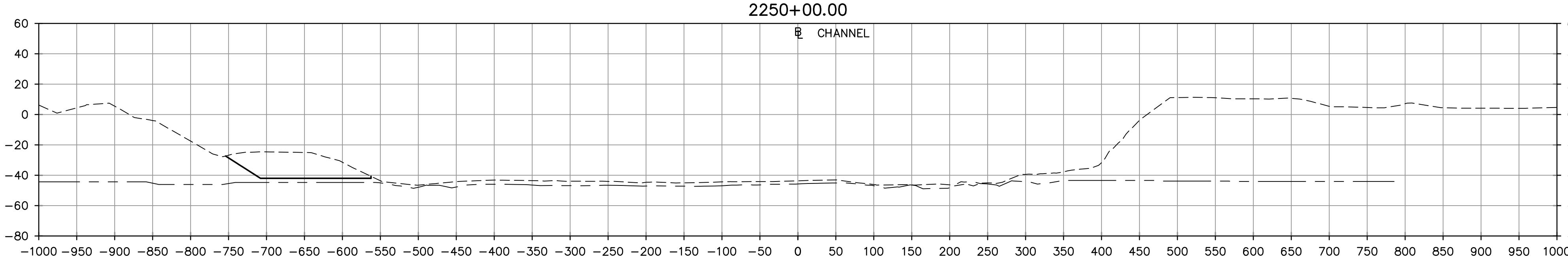
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2250+00.00



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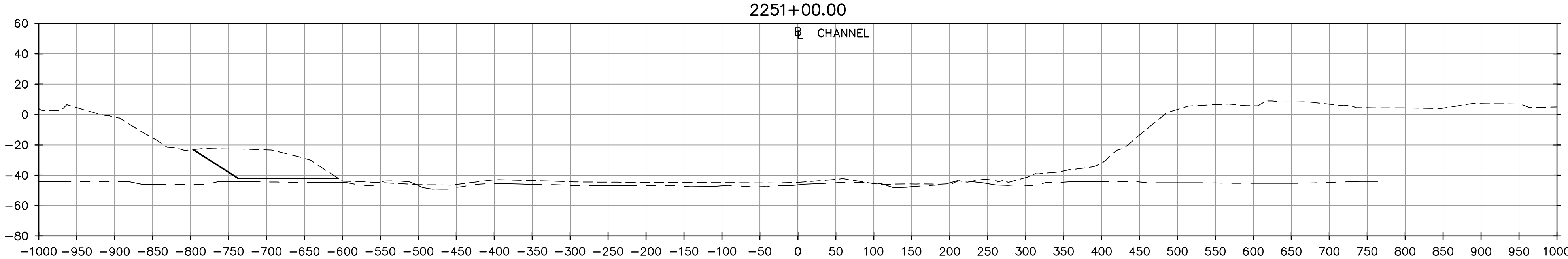

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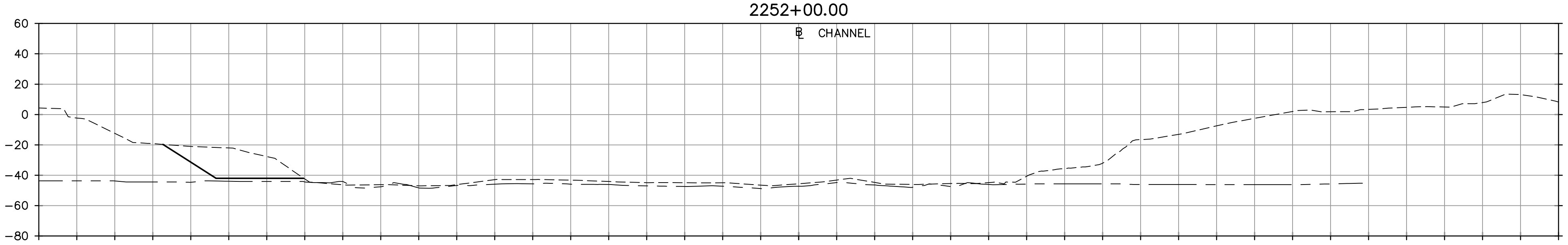


TURNING BASIN ALTERNATIVE B
SECTIONS 5 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

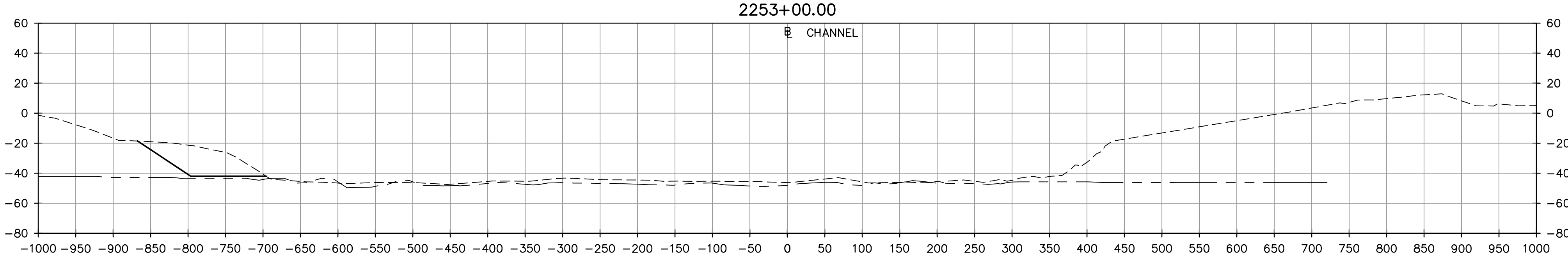
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2253+00.00



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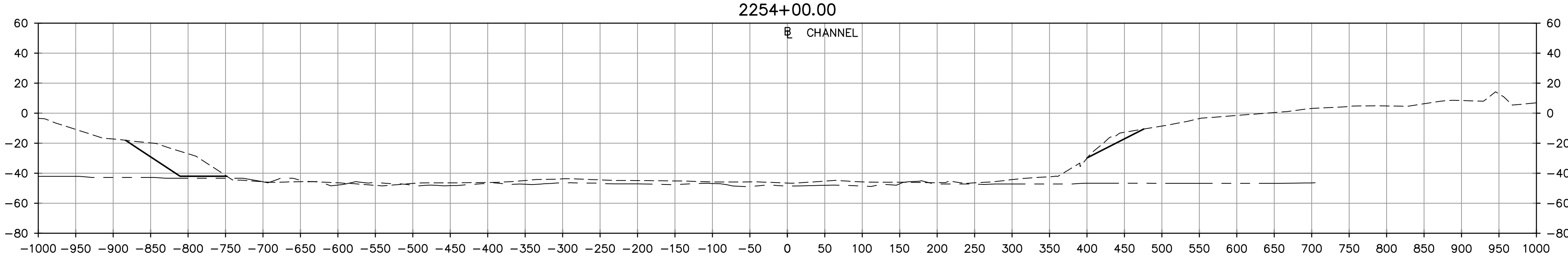

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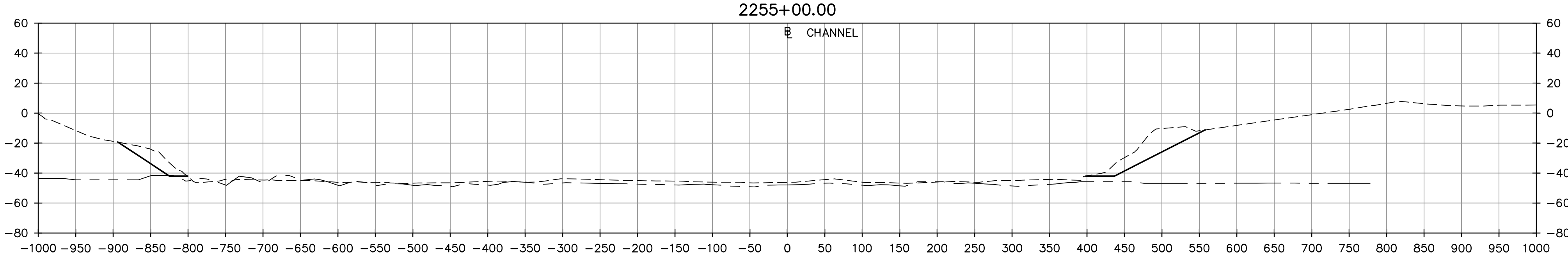


TURNING BASIN ALTERNATIVE B
SECTIONS 6 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

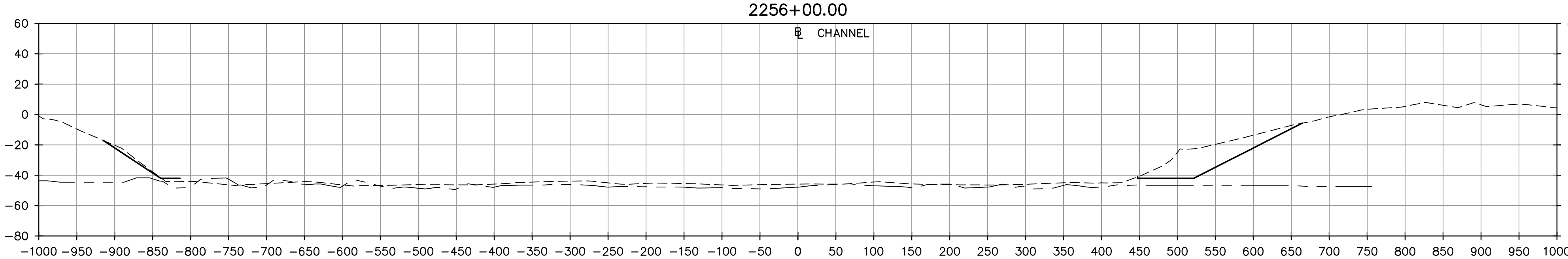
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2256+00.00



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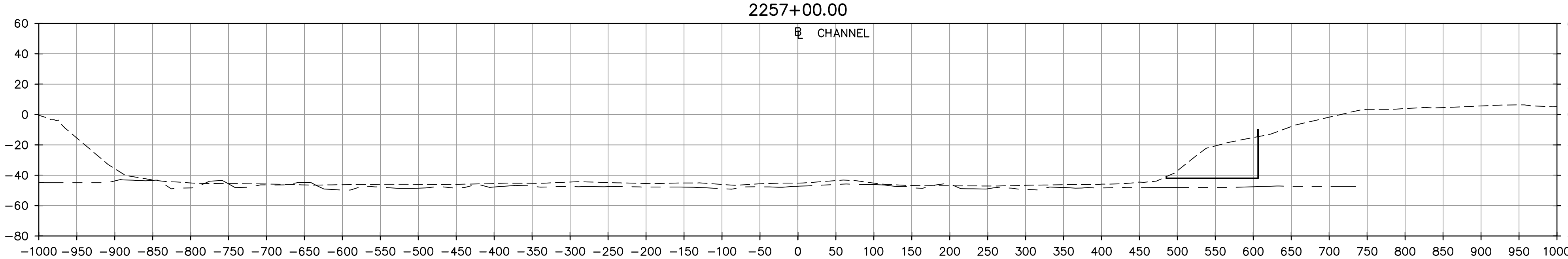

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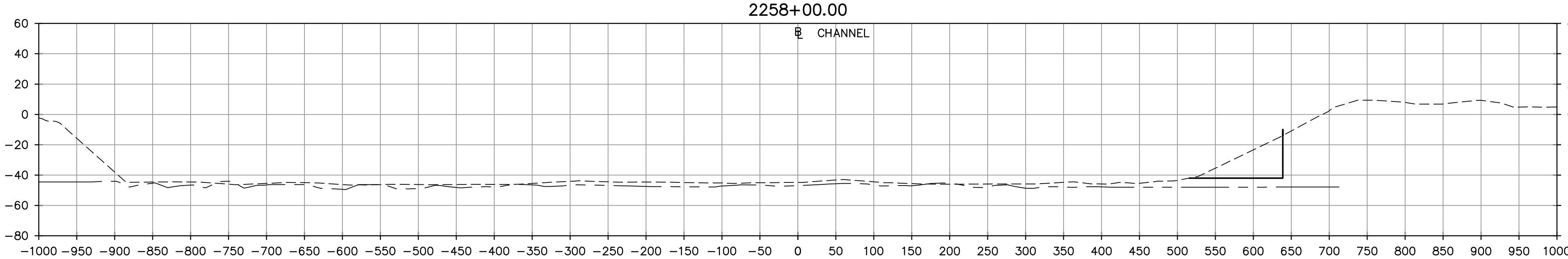


TURNING BASIN ALTERNATIVE B
SECTIONS 7 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

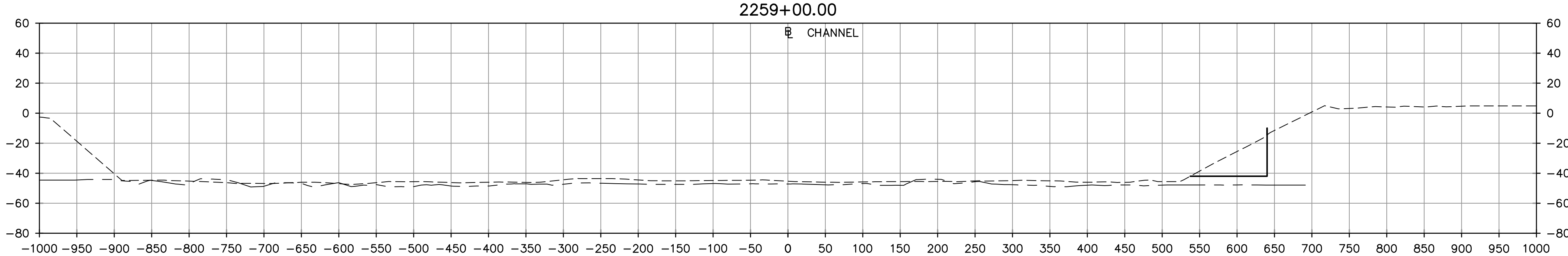
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2259+00.00



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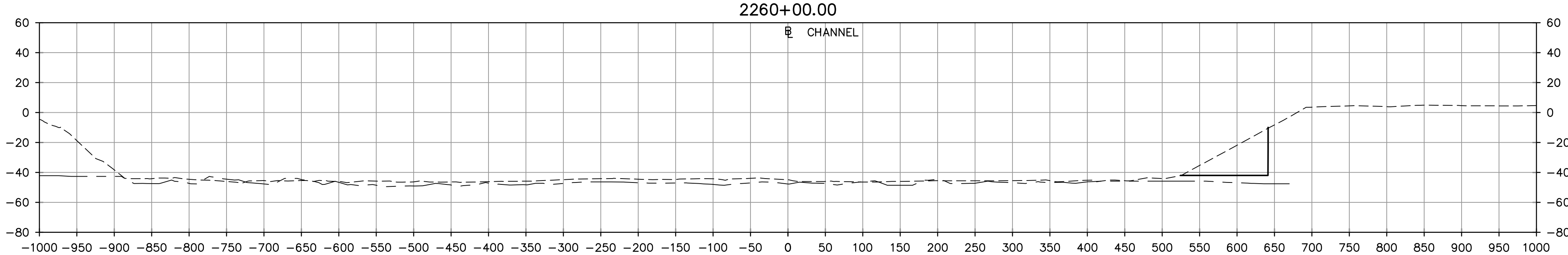

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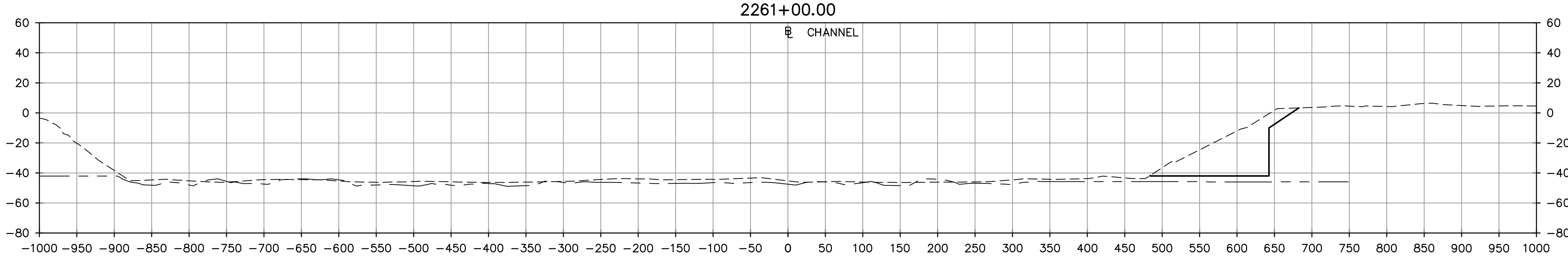


TURNING BASIN ALTERNATIVE B
SECTIONS 8 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

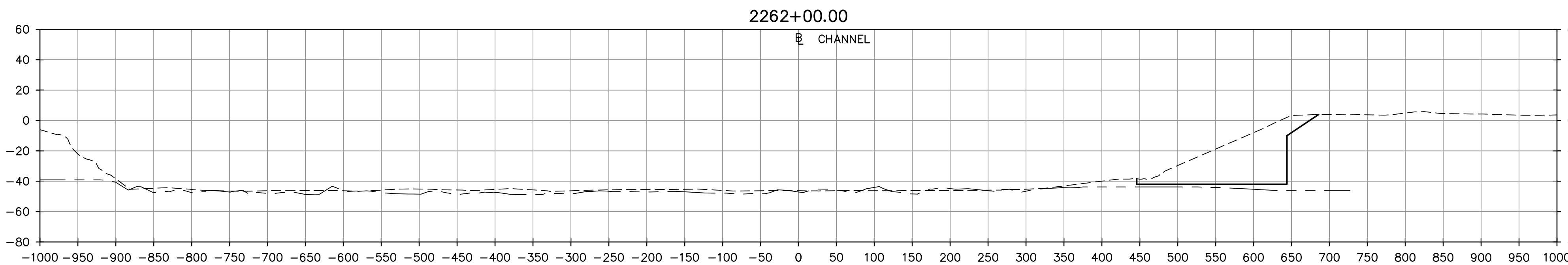
50' 0' 50' 100'

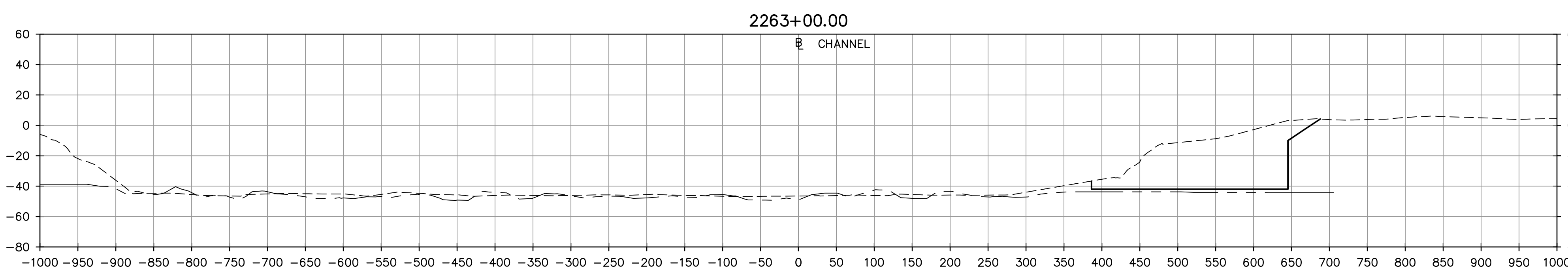
VERTICAL SCALE: 1"=100'

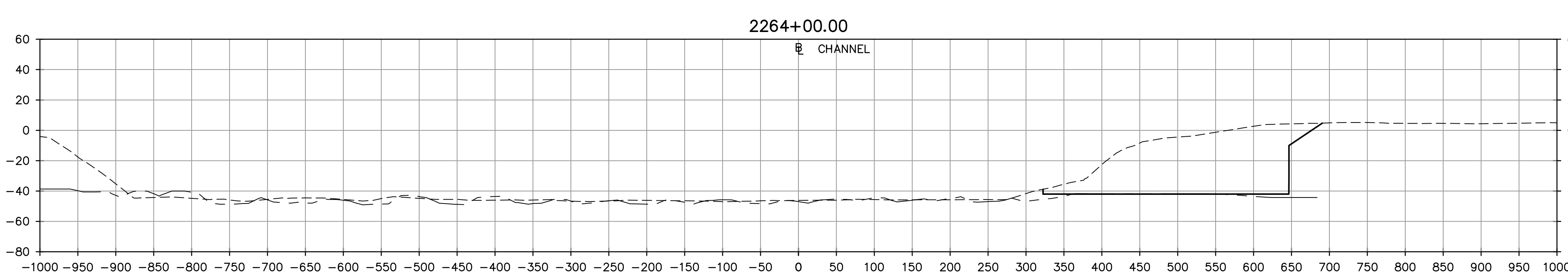
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE B
SECTIONS 9 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

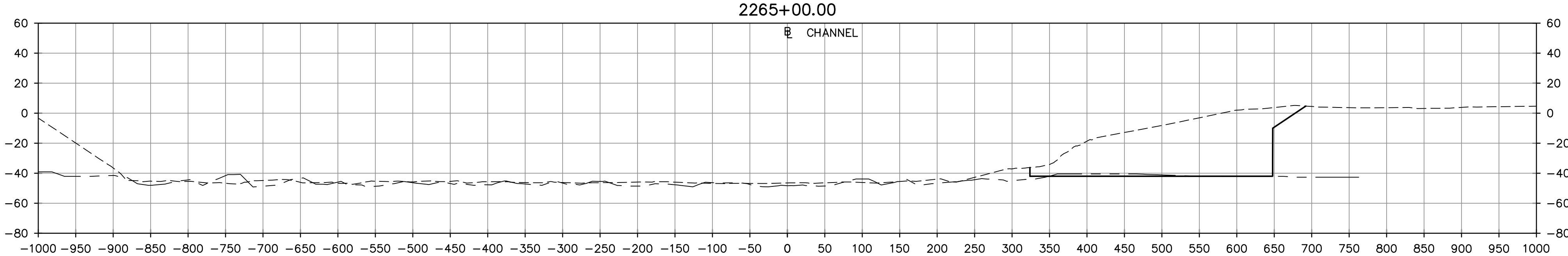
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2265+00.00



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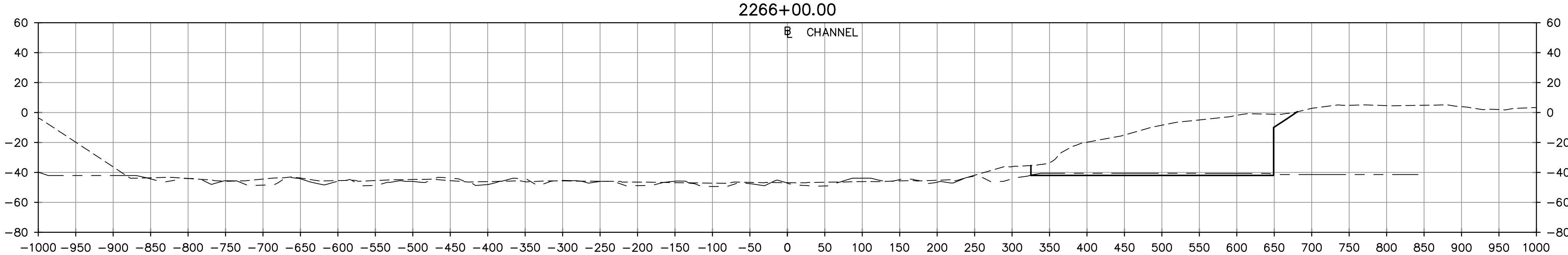

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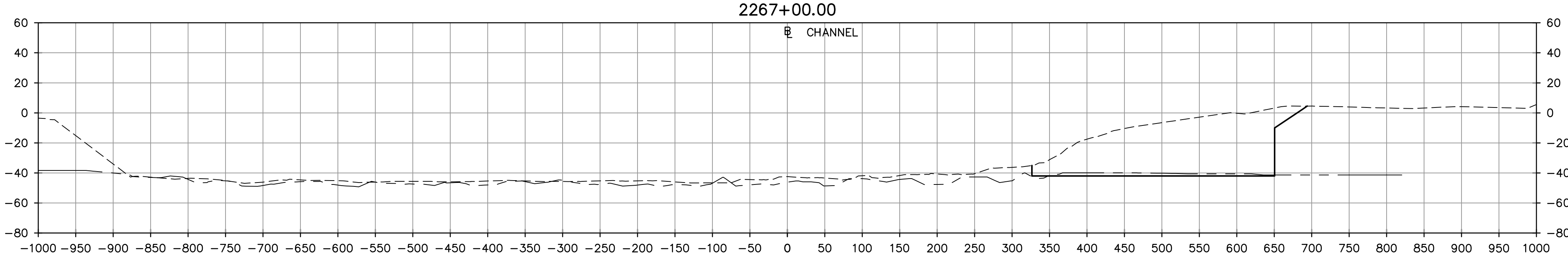


TURNING BASIN ALTERNATIVE B
SECTIONS 10 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

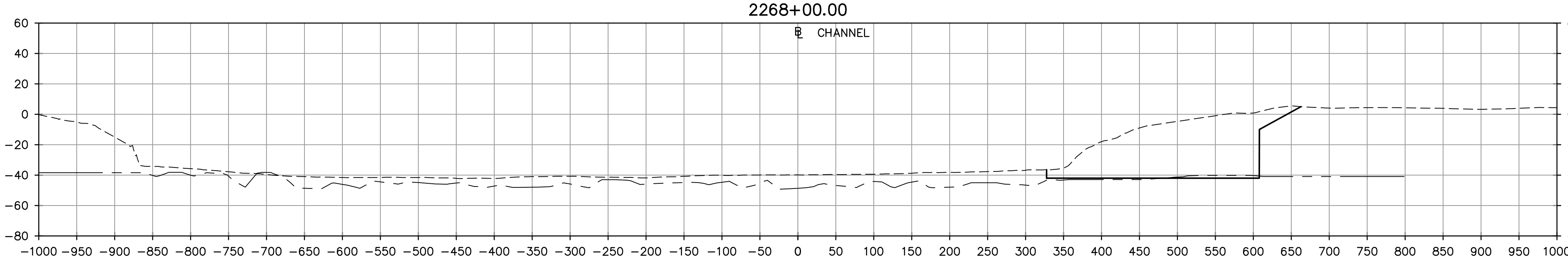
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2268+00.00



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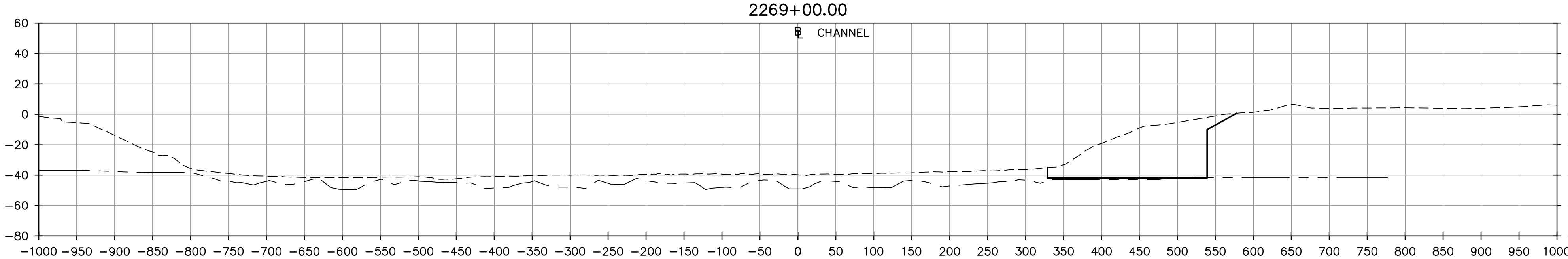

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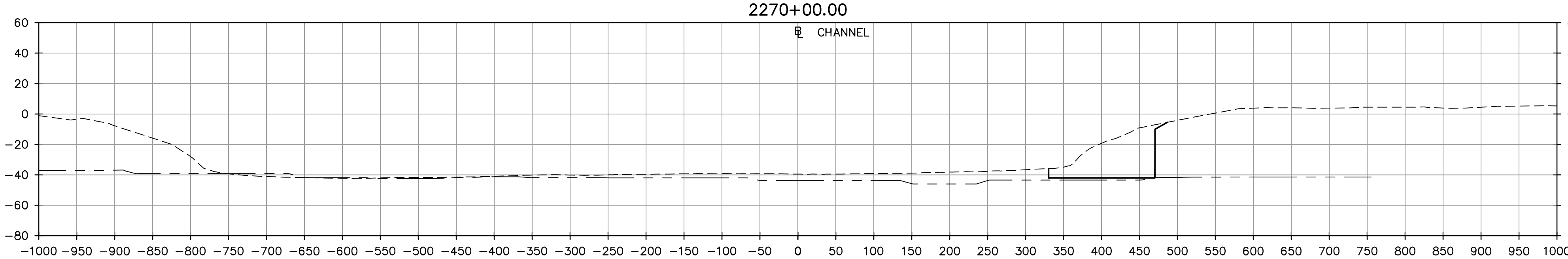


TURNING BASIN ALTERNATIVE B
SECTIONS 11 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

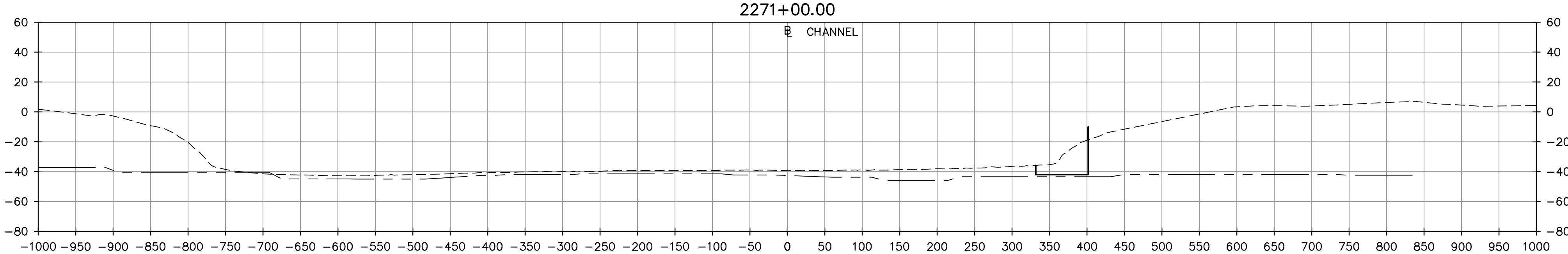
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2271+00.00



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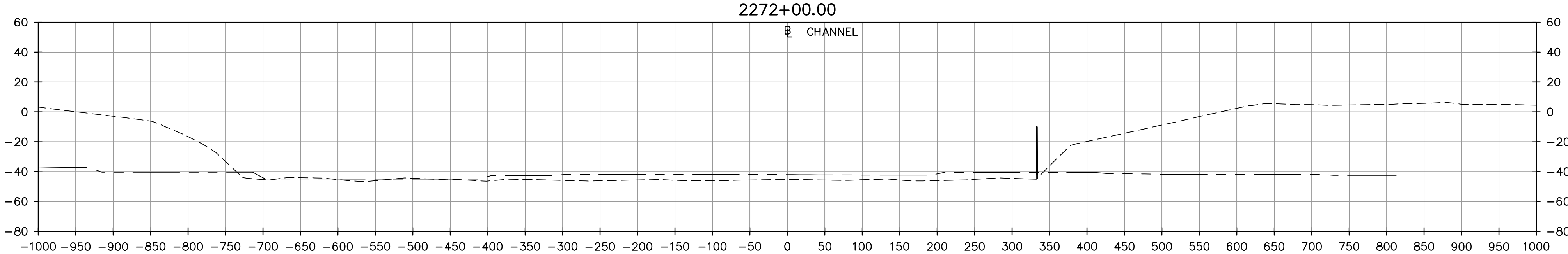

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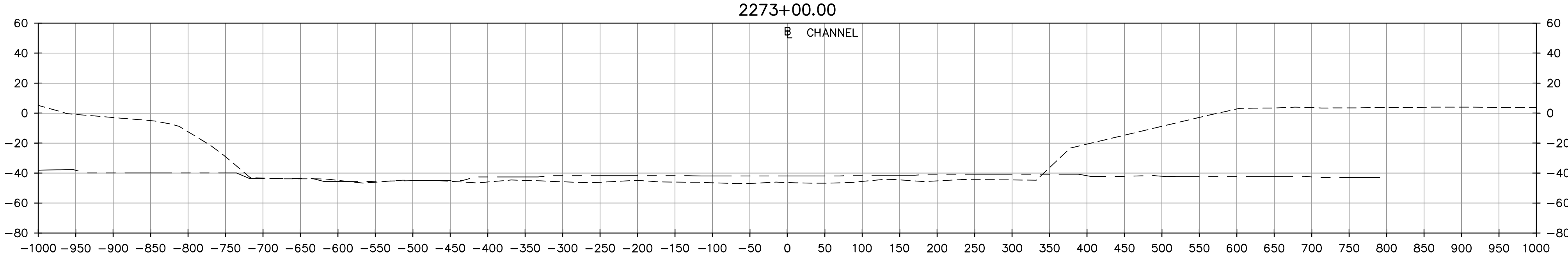


TURNING BASIN ALTERNATIVE B
SECTIONS 12 OF 12

LEGEND

- APPROXIMATE EXISTING GROUND
- APPROXIMATE EXISTING ROCK
- PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

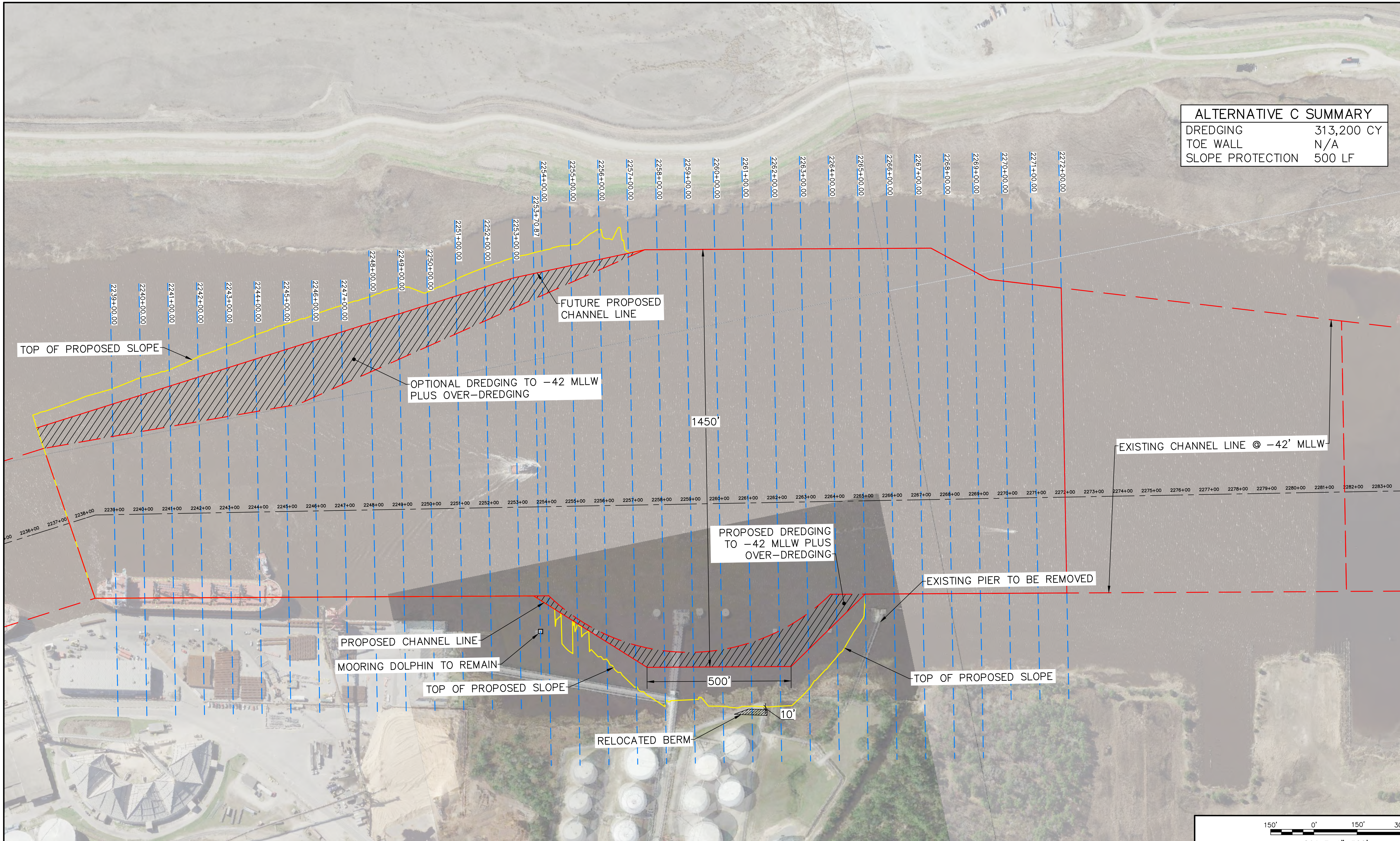
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

Appendix C – Alternative C Plan and Sections



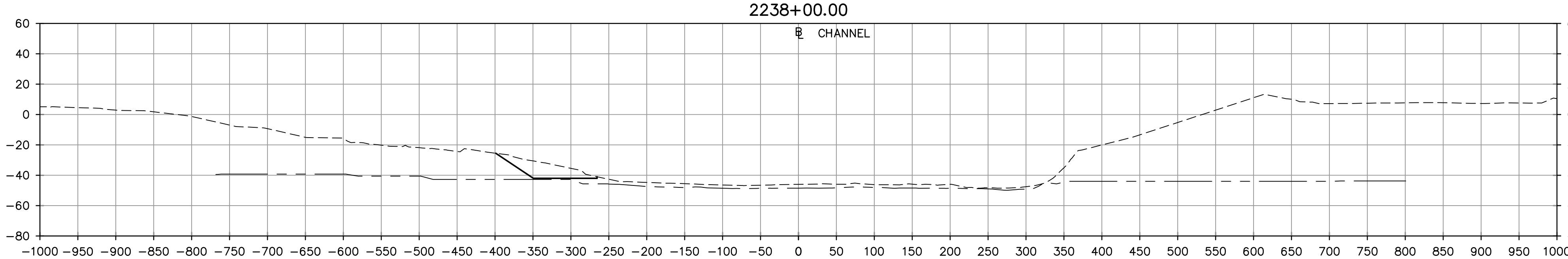
ALTERNATIVE C SUMMARY	
DREDGING	313,200 CY
TOE WALL	N/A
SLOPE PROTECTION	500 LF

SCALE: 1"=300'

ALTERNATIVE C – 1450' TURNING BASIN (SHORTENED) WITH NO WALLS

moffatt & nichol

2238+00.00



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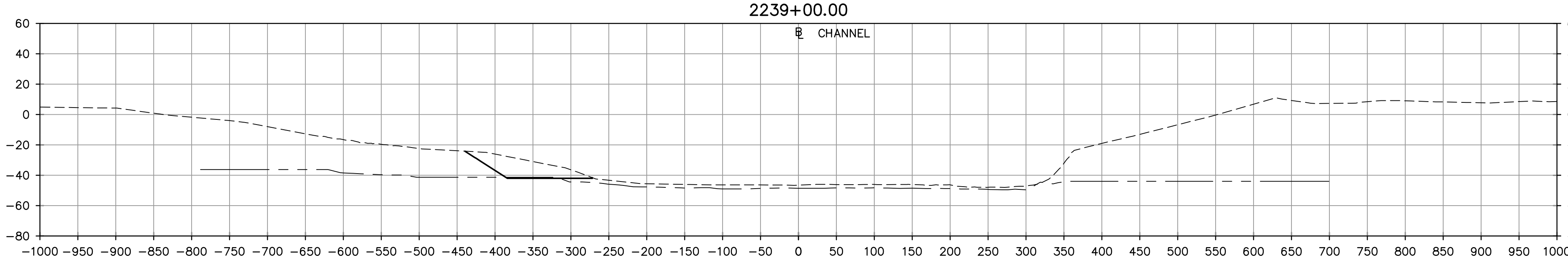

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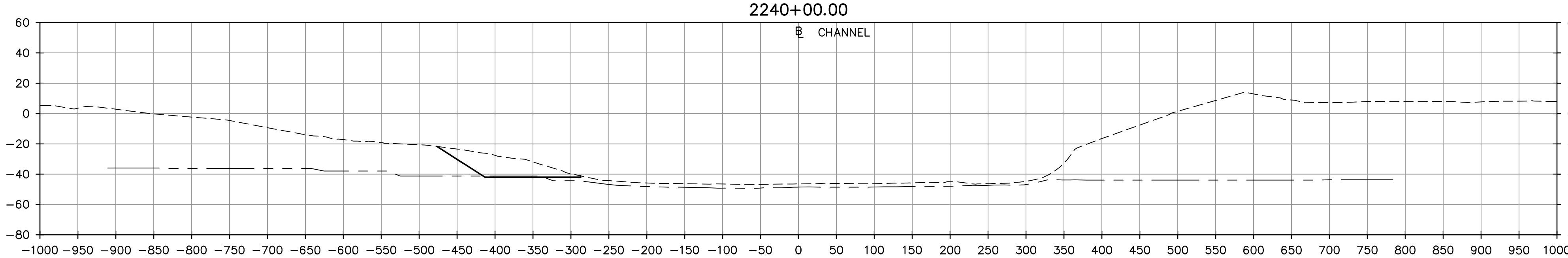


TURNING BASIN ALTERNATIVE C
SECTIONS 1 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

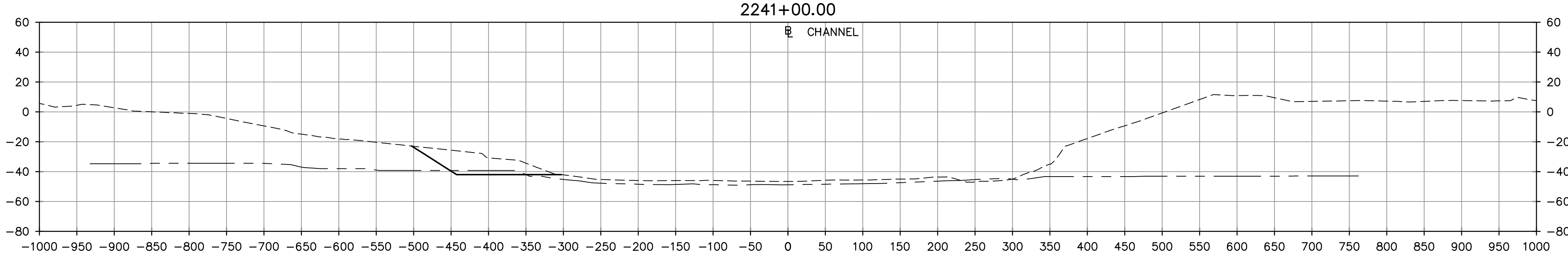
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

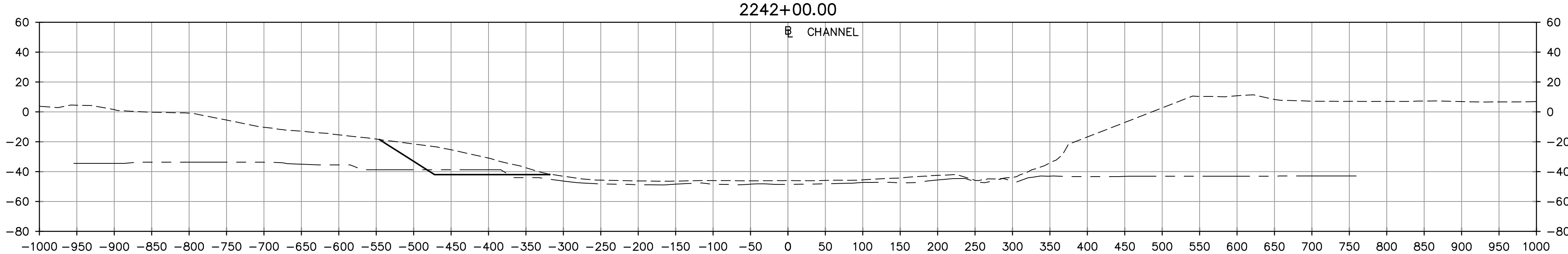
HORIZONTAL SCALE: 1"=200'

moffatt & nichol

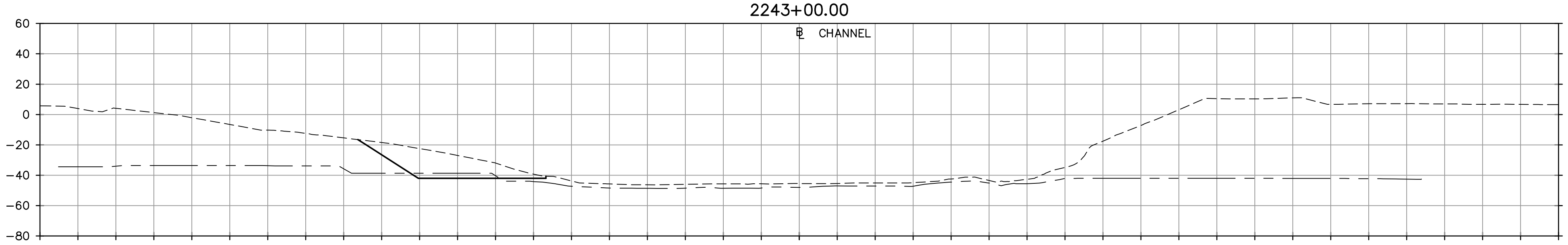
2241+00.00



2242+00.00



2243+00.00



TURNING BASIN ALTERNATIVE C
SECTIONS 2 OF 12

LEGEND

- - - - - - APPROXIMATE EXISTING GROUND

—— – – —— APPROXIMATE EXISTING ROCK

———— PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

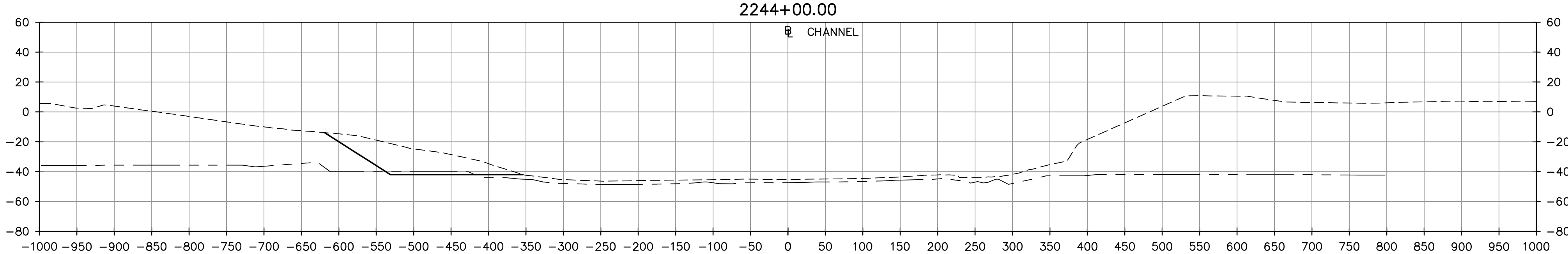
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2244+00.00



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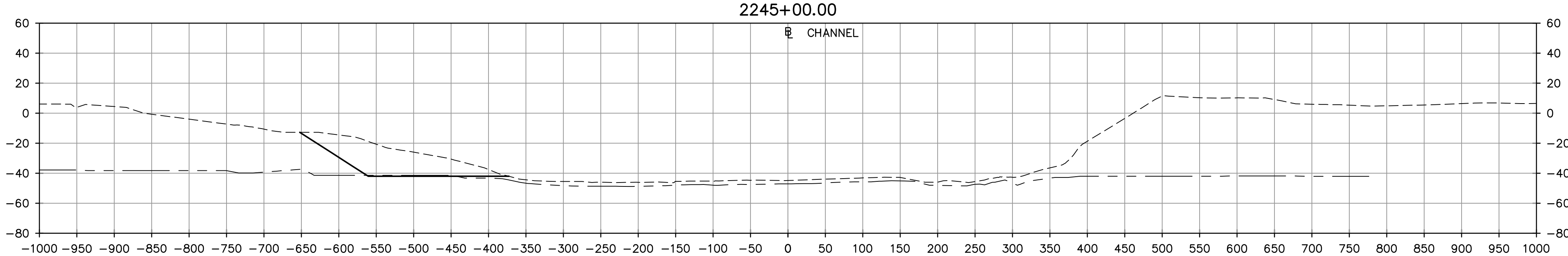

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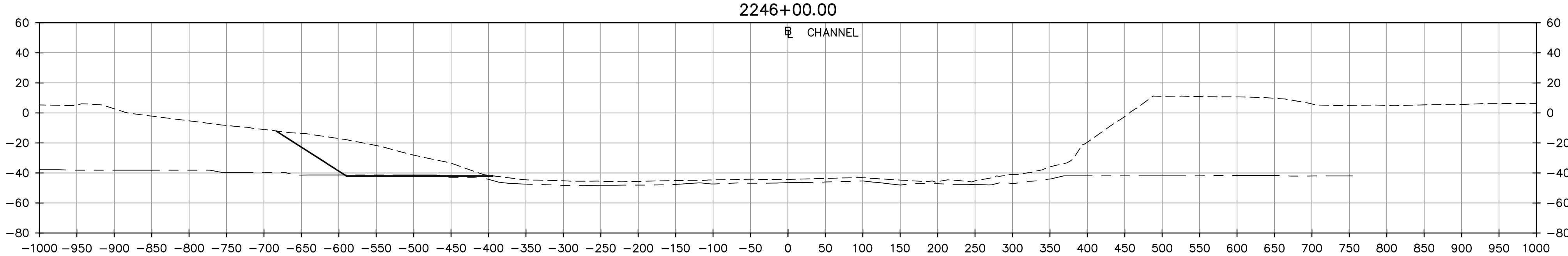


TURNING BASIN ALTERNATIVE C
SECTIONS 3 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

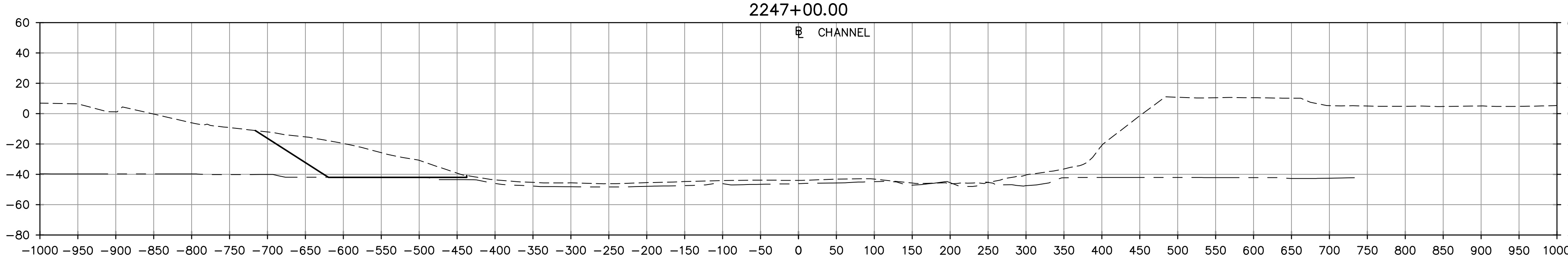
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2247+00.00



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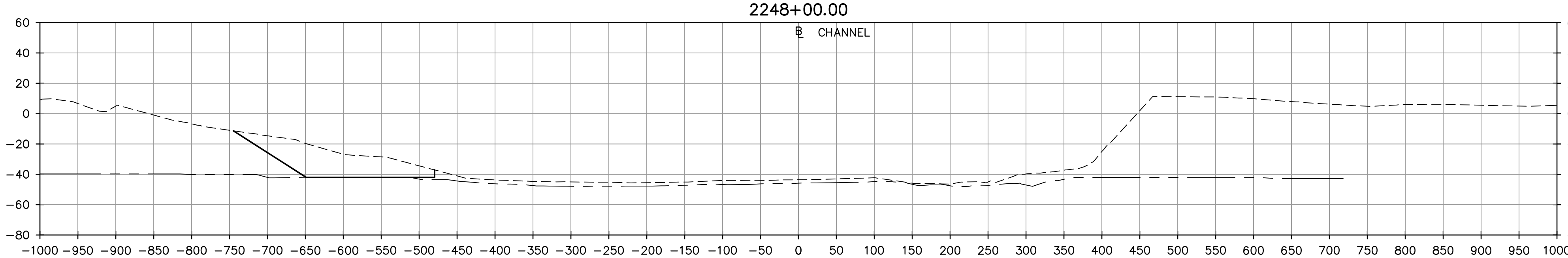

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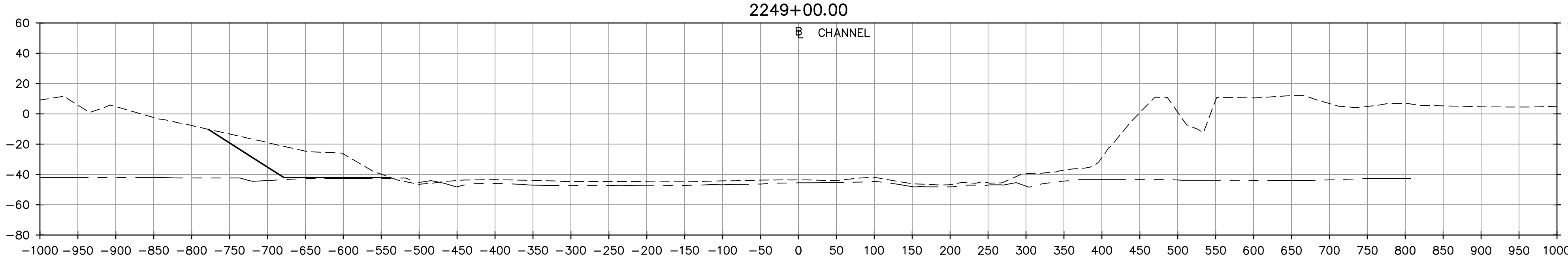


TURNING BASIN ALTERNATIVE C
SECTIONS 4 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

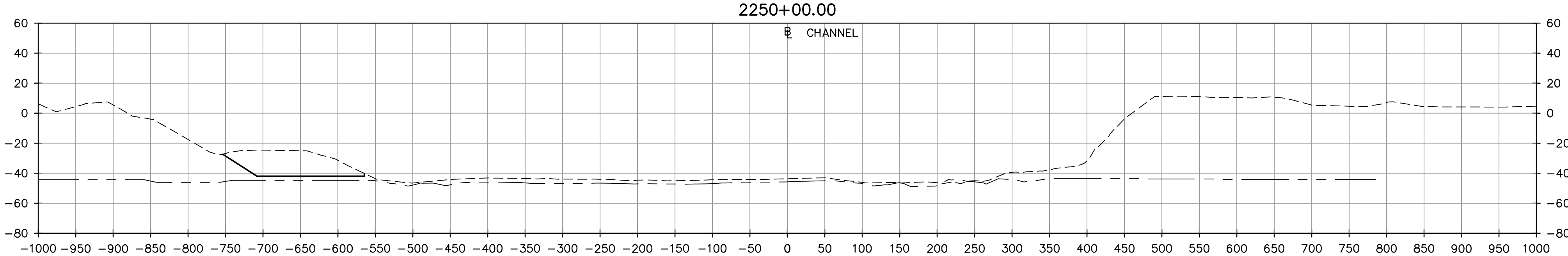
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2250+00.00



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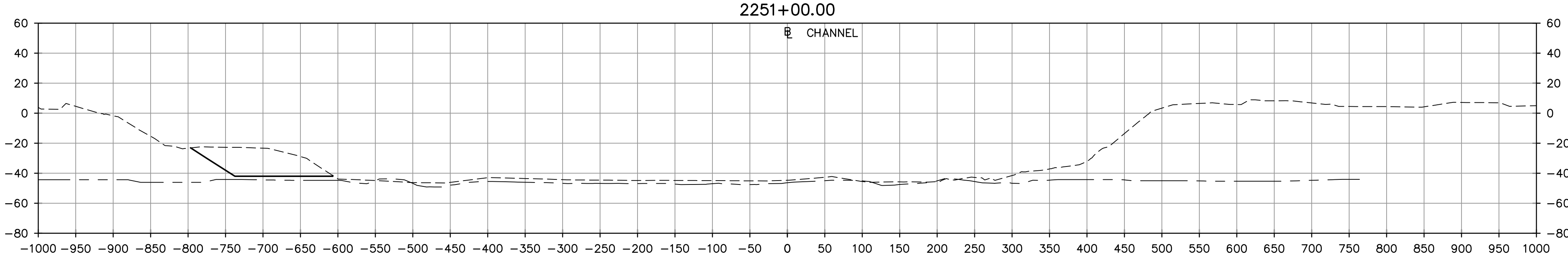

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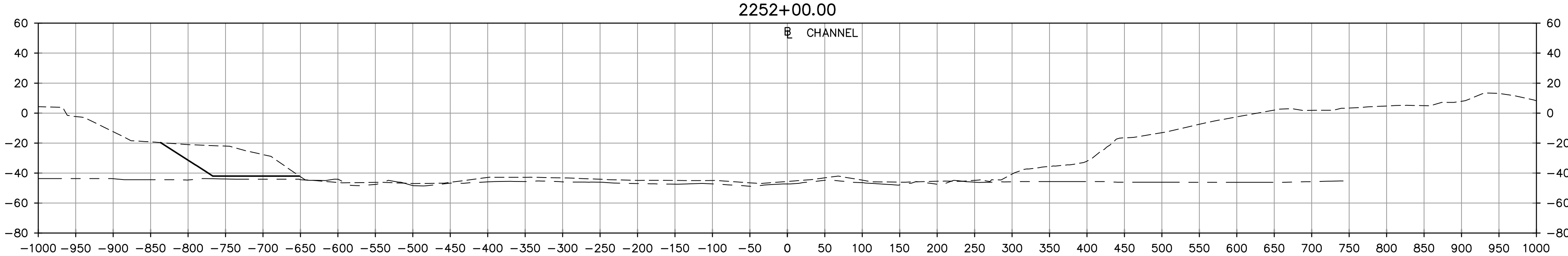


TURNING BASIN ALTERNATIVE C
SECTIONS 5 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

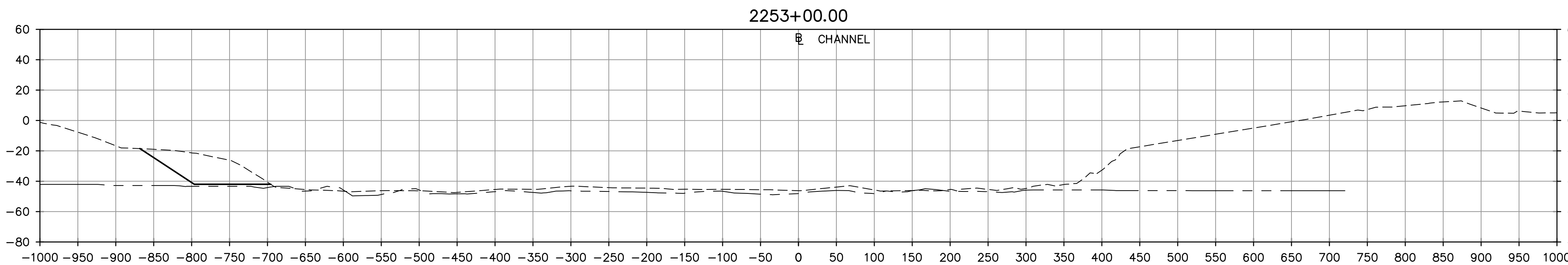
50' 0' 50' 100'

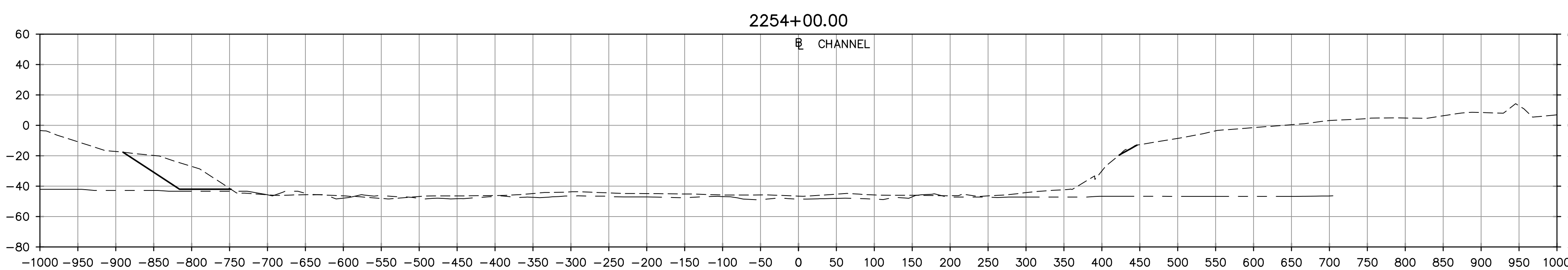
VERTICAL SCALE: 1"=100'

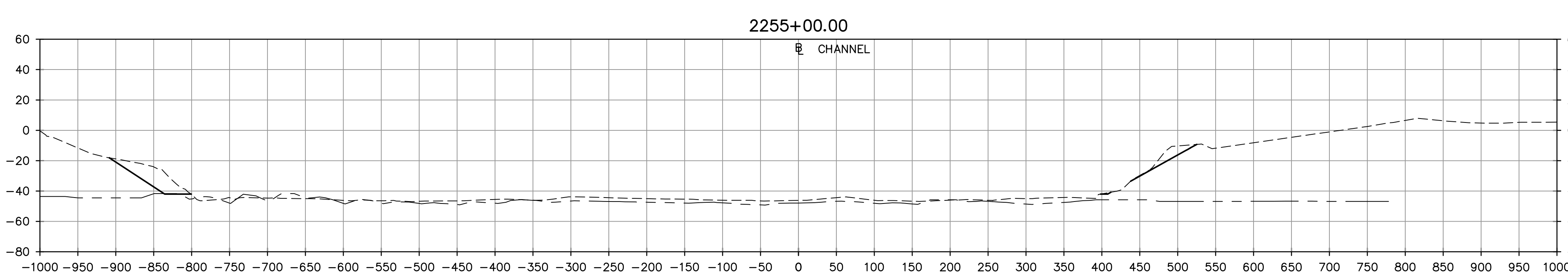
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE C
SECTIONS 6 OF 12

LEGEND

- APPROXIMATE EXISTING GROUND
- APPROXIMATE EXISTING ROCK
- PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

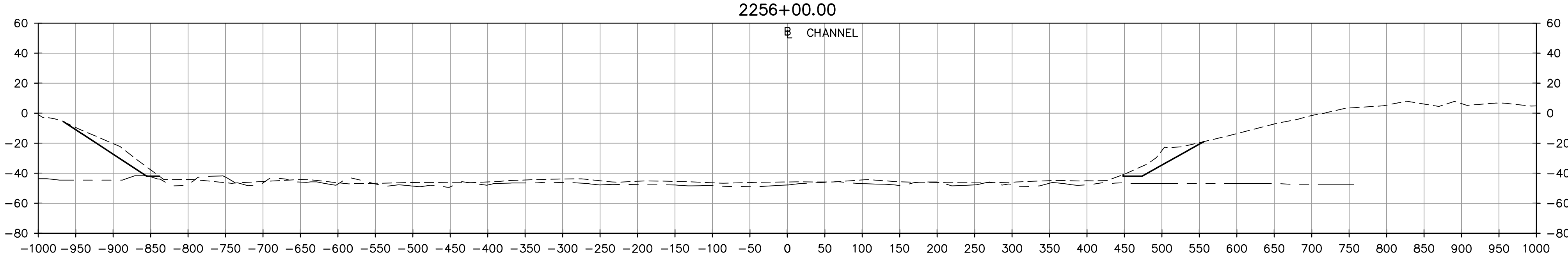
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2256+00.00



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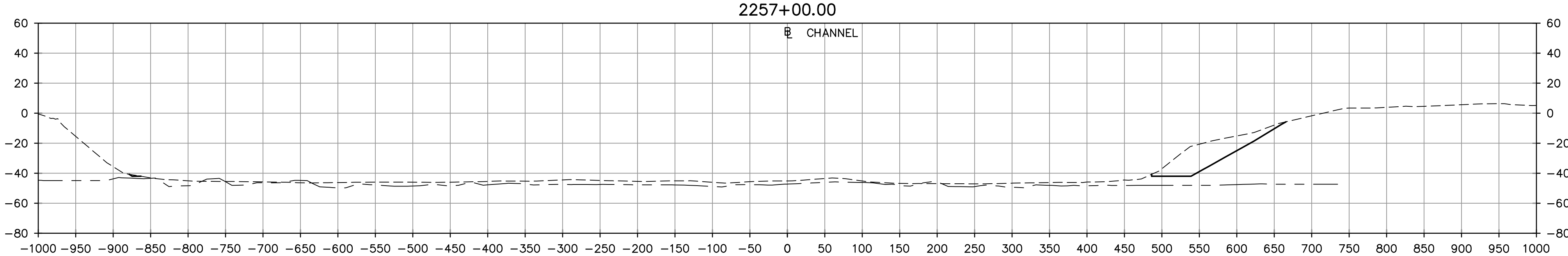

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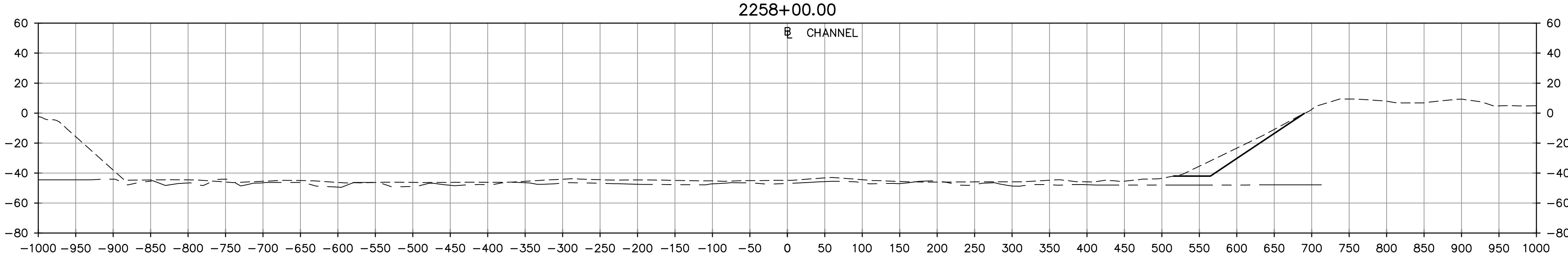


TURNING BASIN ALTERNATIVE C
SECTIONS 7 OF 12

LEGEND

- - - - - - APPROXIMATE EXISTING GROUND

—— – —— APPROXIMATE EXISTING ROCK

——— PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

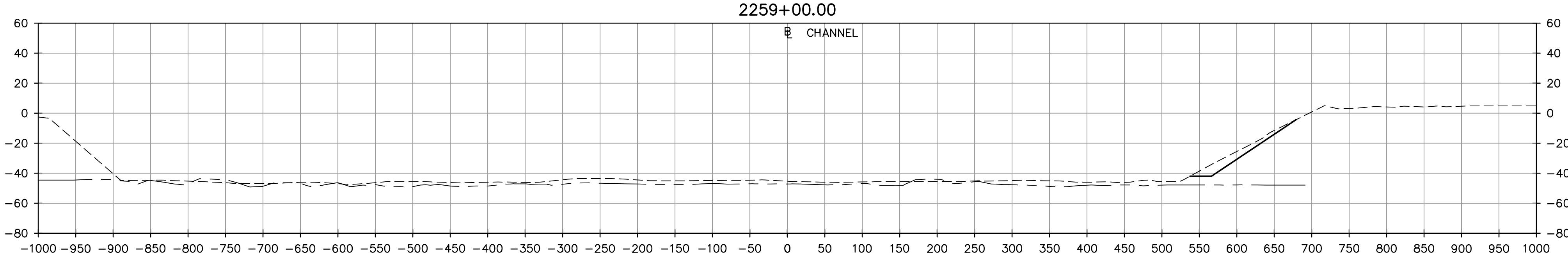
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2259+00.00



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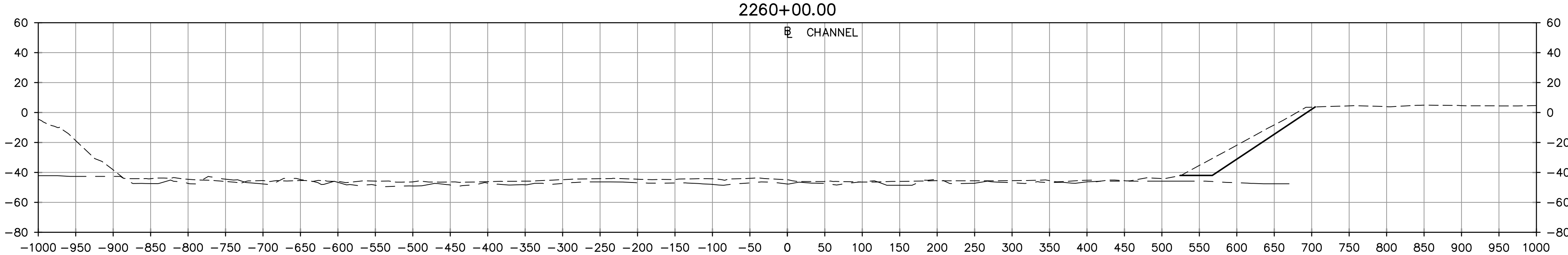

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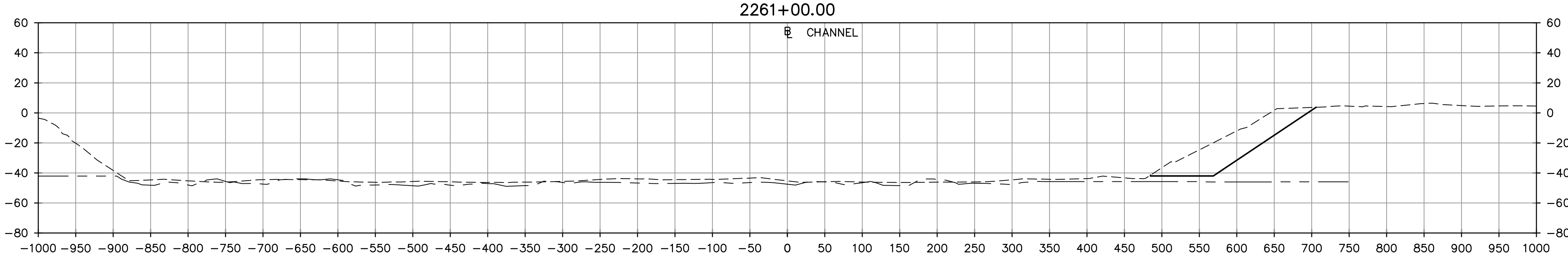


TURNING BASIN ALTERNATIVE C
SECTIONS 8 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

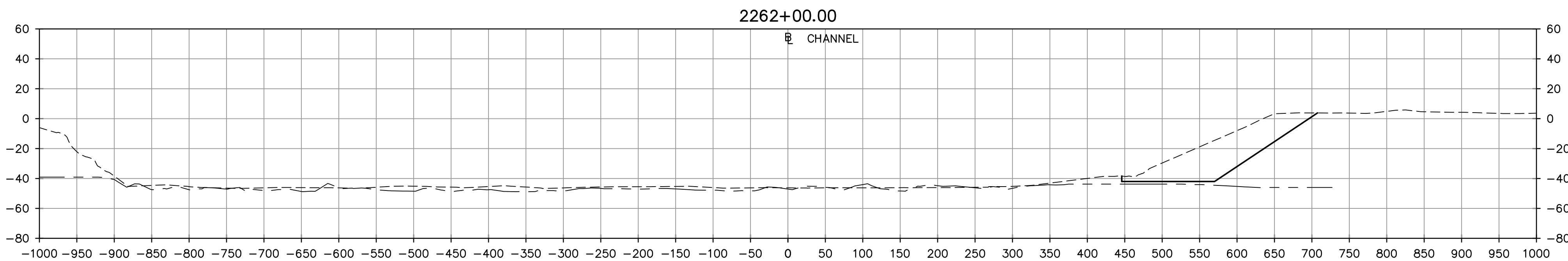
50' 0' 50' 100'

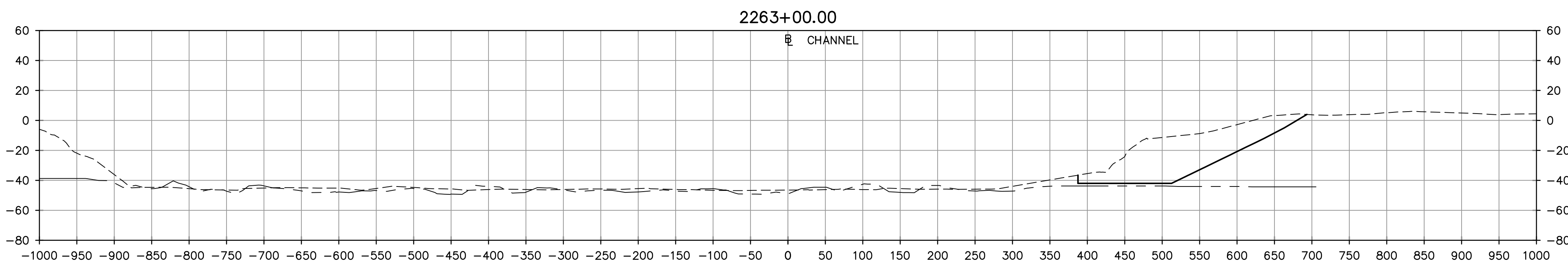
VERTICAL SCALE: 1"=100'

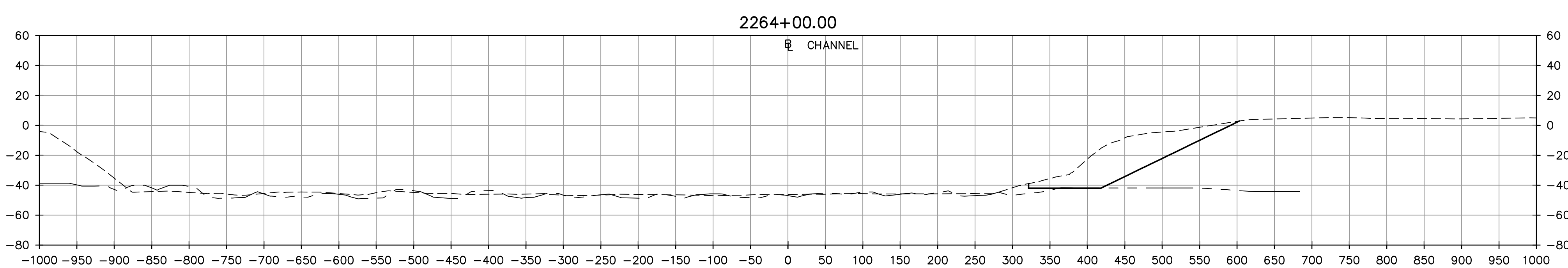
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE C
SECTIONS 9 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

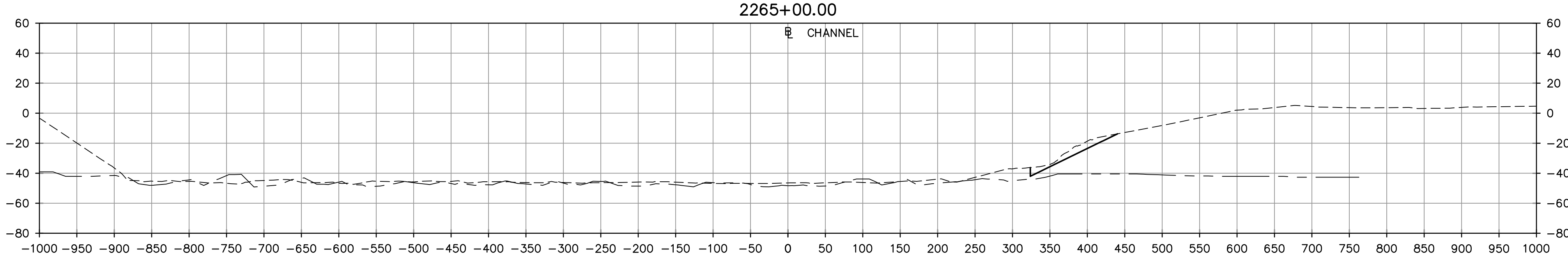
PROPOSED CHANNEL DEPTH

VERTICAL SCALE: 1"=100'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2265+00.00



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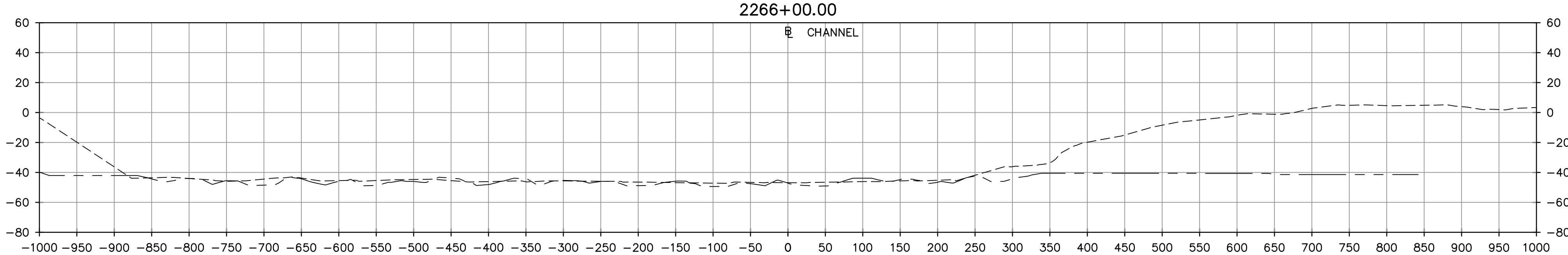

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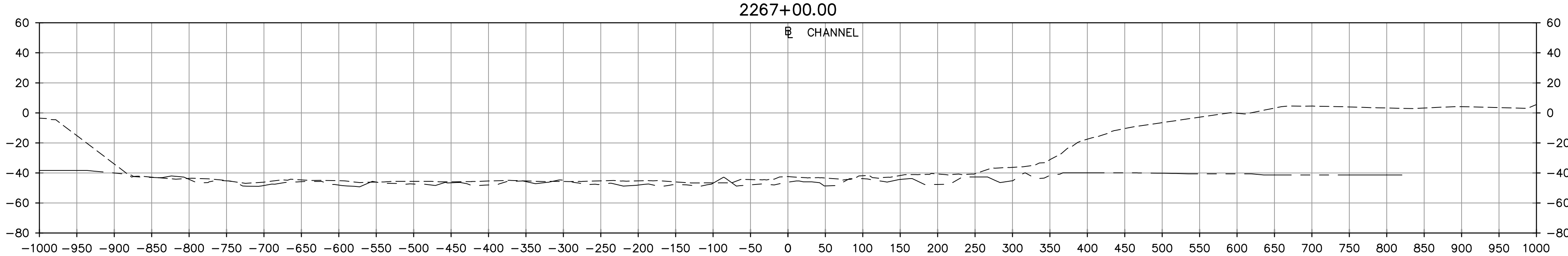


TURNING BASIN ALTERNATIVE C
SECTIONS 10 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

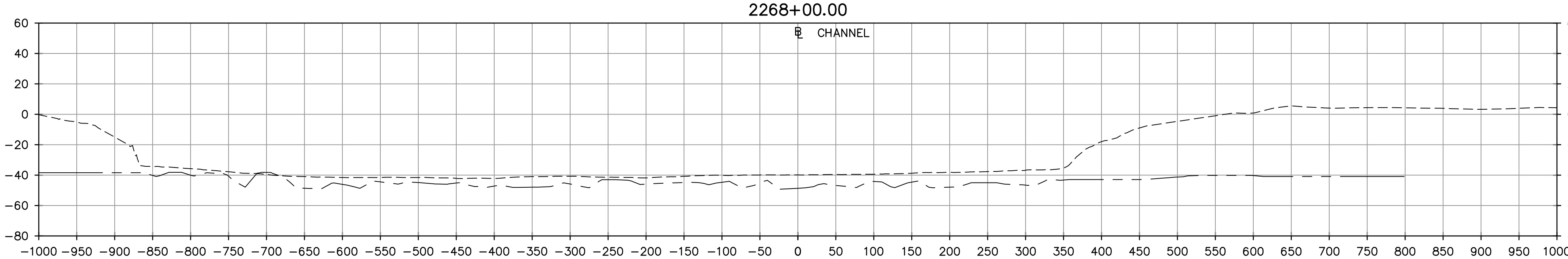
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2268+00.00



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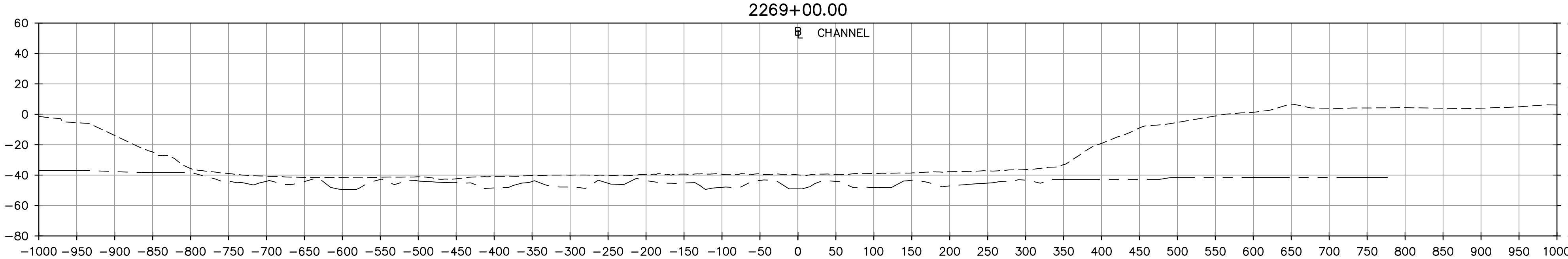

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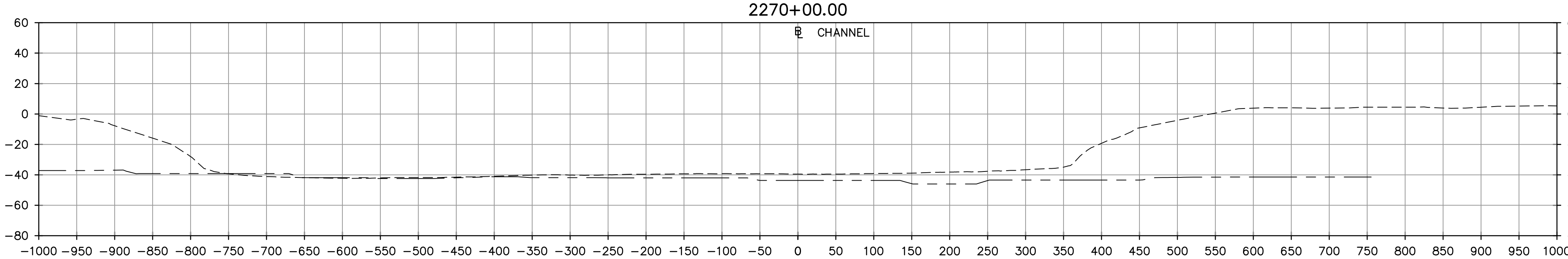


TURNING BASIN ALTERNATIVE C
SECTIONS 11 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

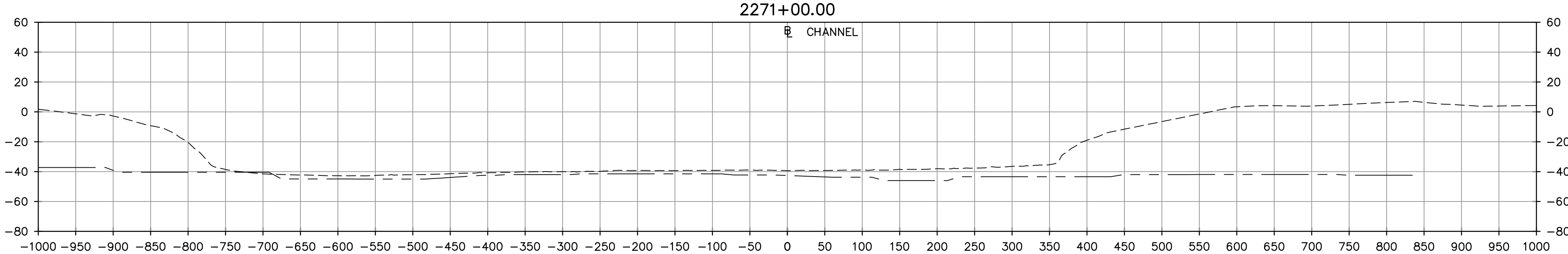
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2271+00.00



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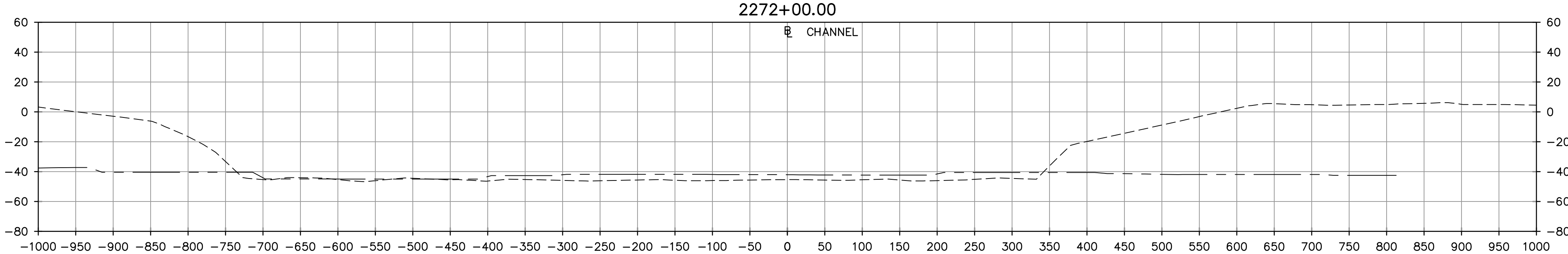

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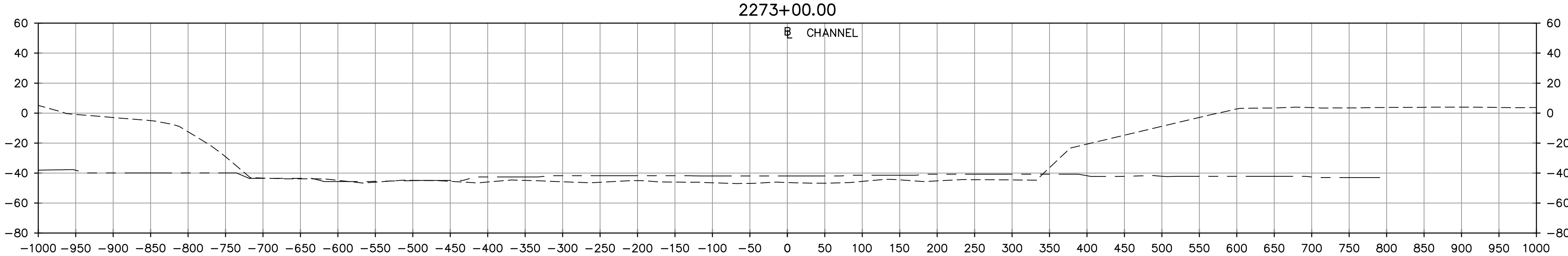


TURNING BASIN ALTERNATIVE C
SECTIONS 12 OF 12

LEGEND

- - - - - APPROXIMATE EXISTING GROUND
—— — — —— APPROXIMATE EXISTING ROCK
———— PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

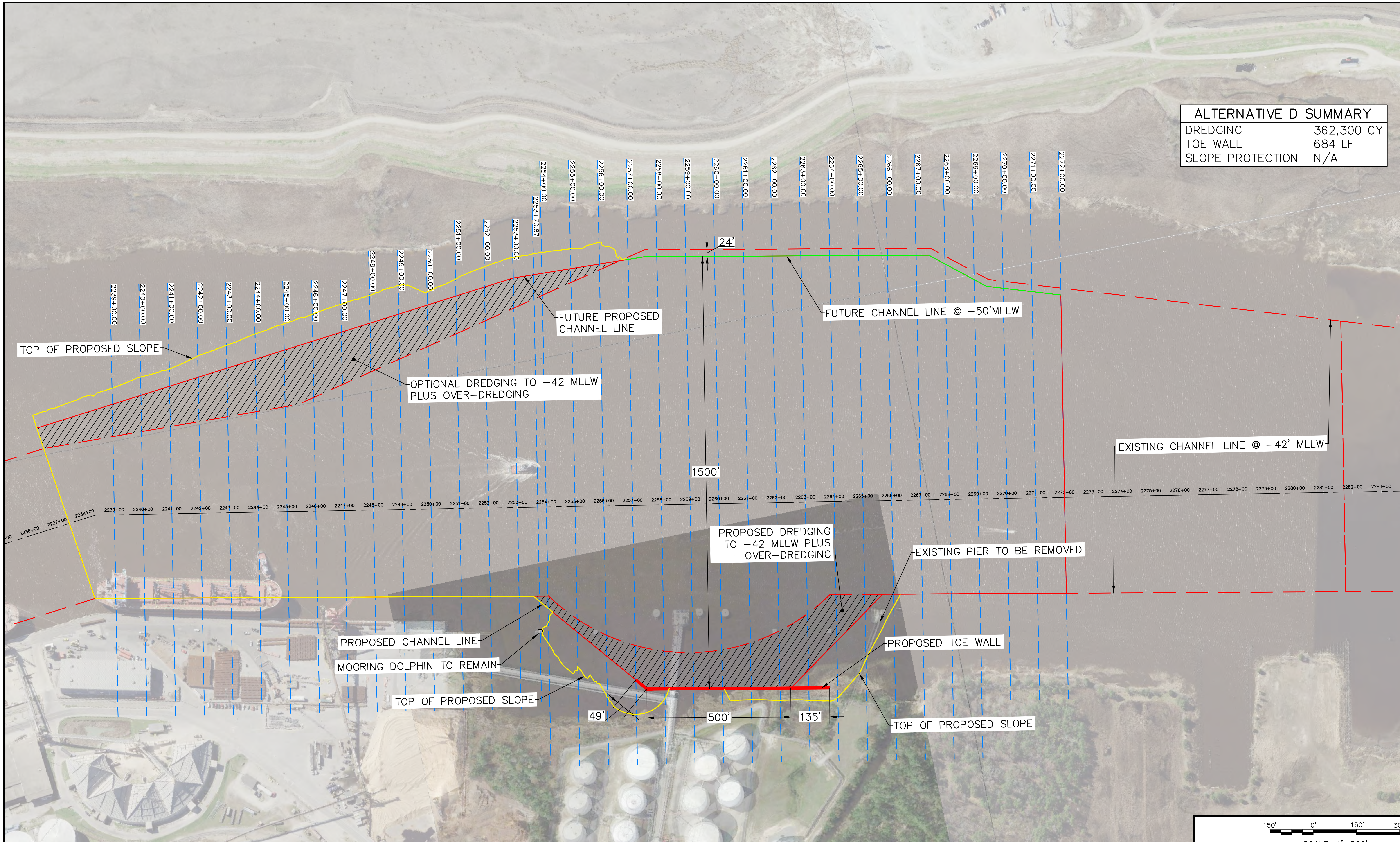
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

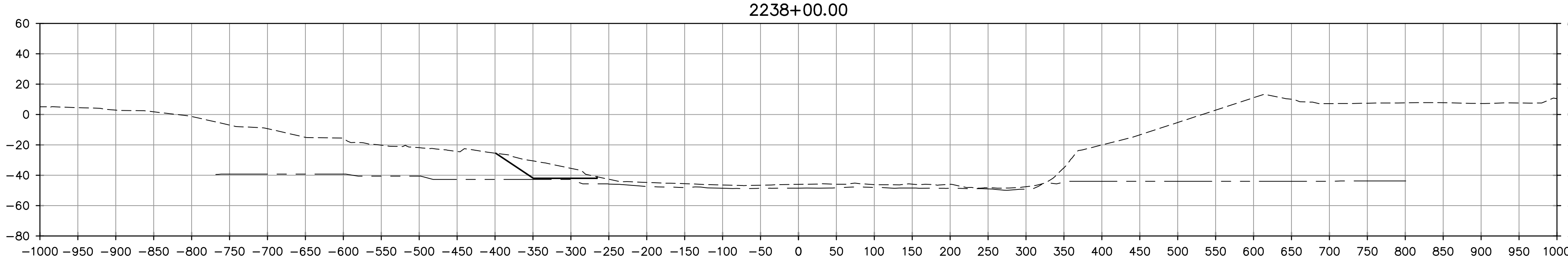
Appendix D – Alternative D Plan and Sections



ALTERNATIVE D – 1524' TURNING BASIN (SHORTENED) SHIFTED EASTWARD WITH ONE TOE WALL

moffatt & nichol

2238+00.00



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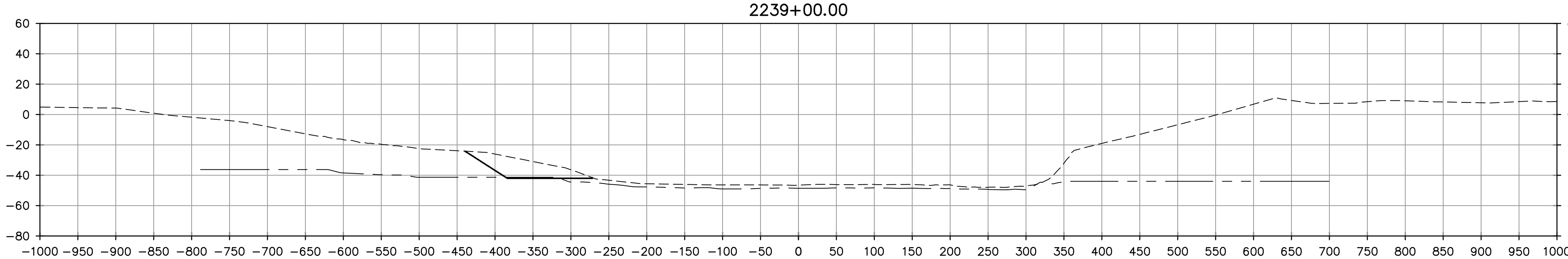

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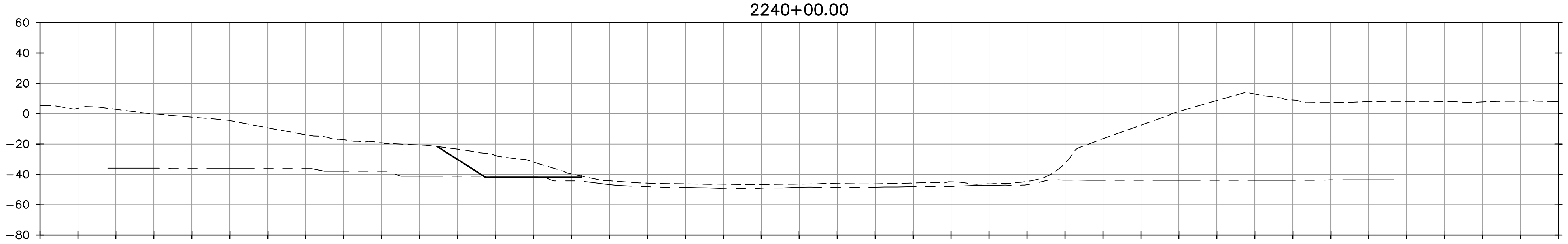


TURNING BASIN ALTERNATIVE D
SECTIONS 1 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

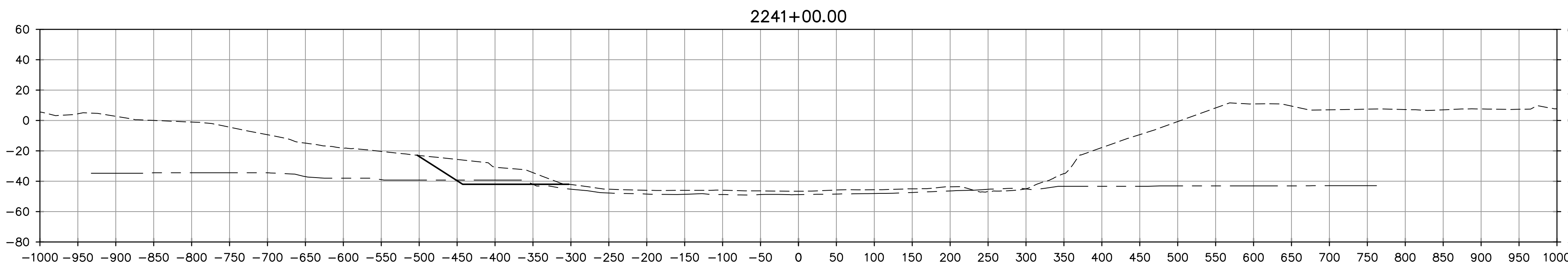
APPROXIMATE EXISTING ROCK

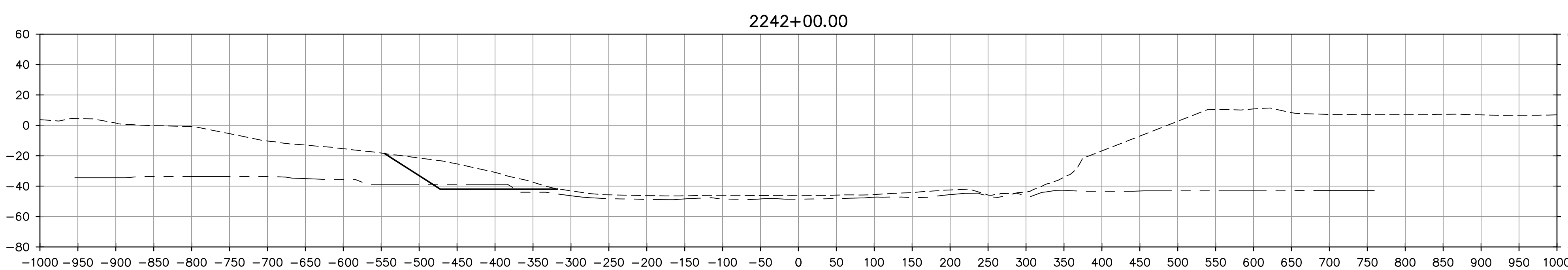
PROPOSED CHANNEL DEPTH

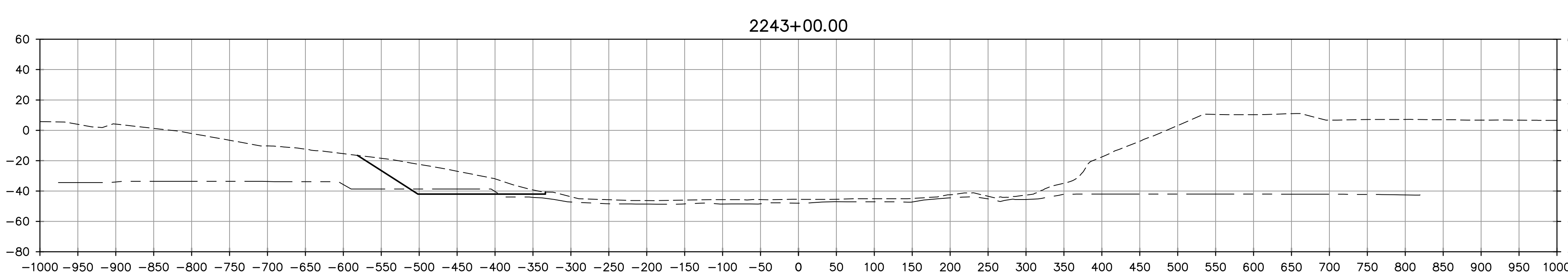
50' 0' 50' 100'
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'
HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE D
SECTIONS 2 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

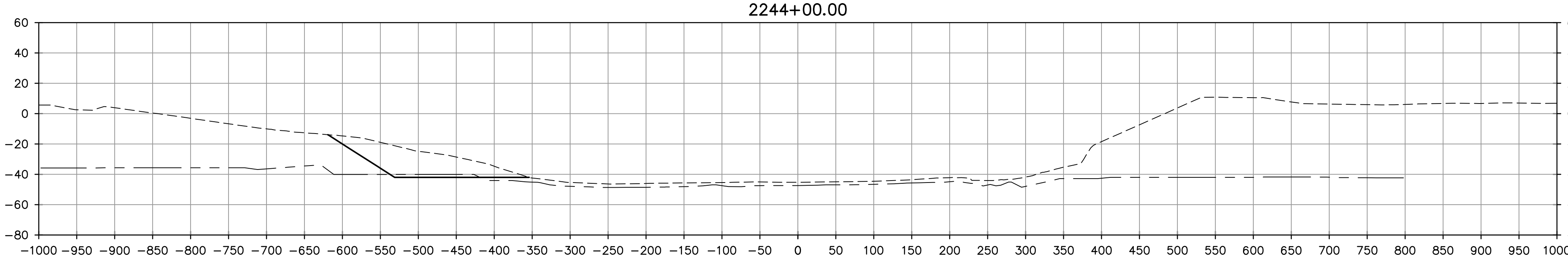
PROPOSED CHANNEL DEPTH

VERTICAL SCALE: 1"=100'

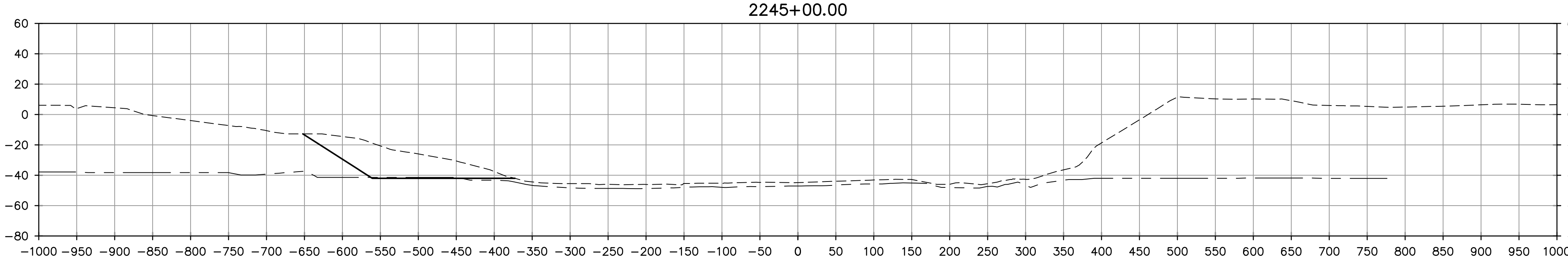
HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2244+00.00



2245+00.00



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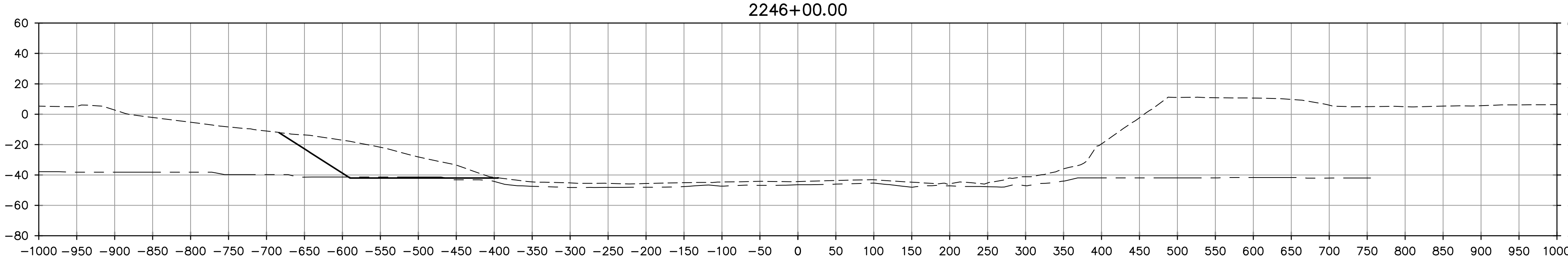


TURNING BASIN ALTERNATIVE D
SECTIONS 3 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

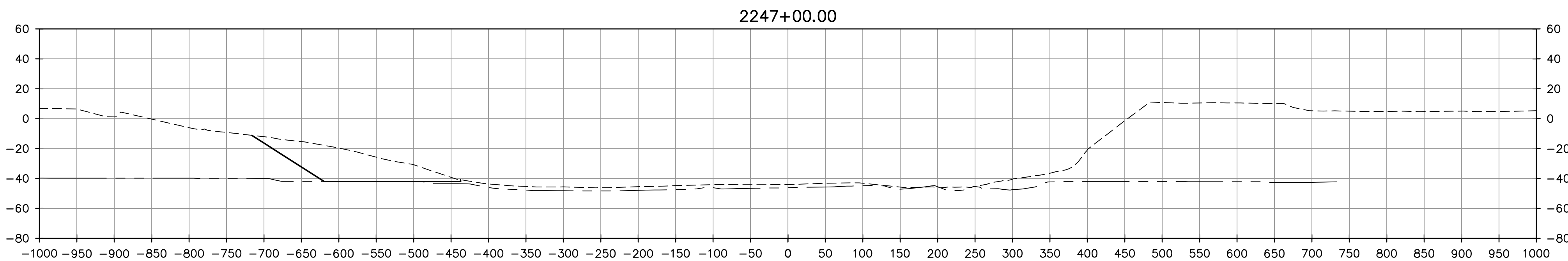
50' 0' 50' 100'

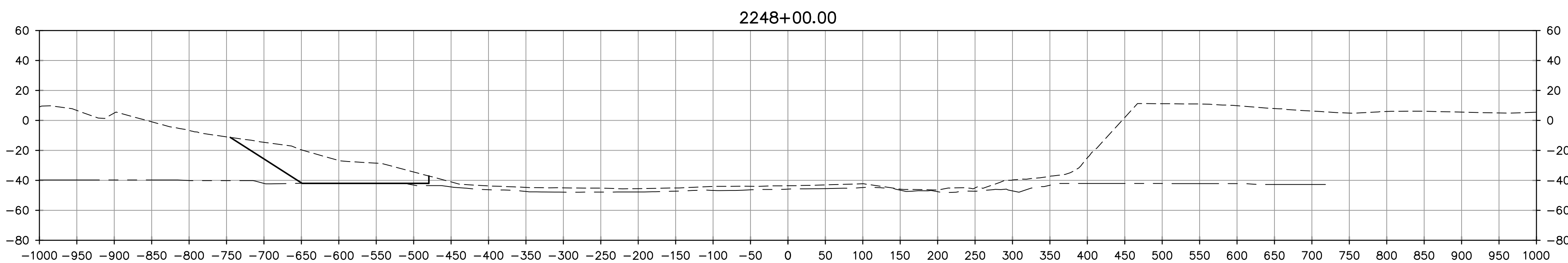
VERTICAL SCALE: 1"=100'

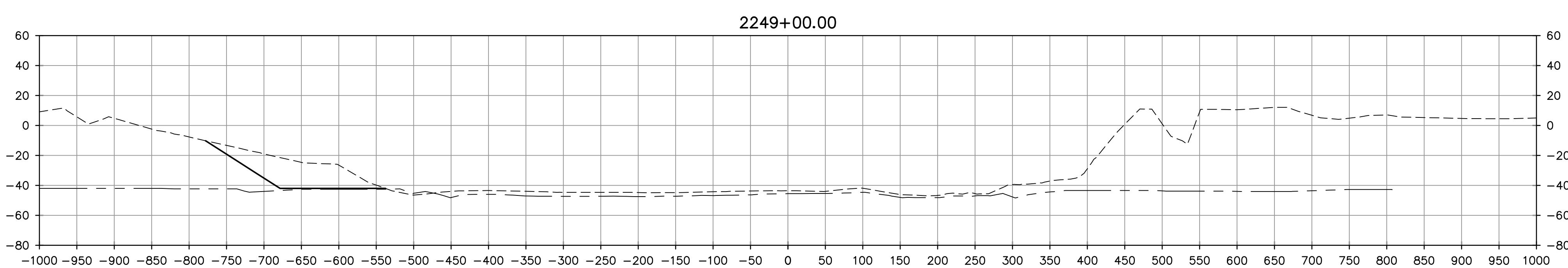
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE D
SECTIONS 4 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

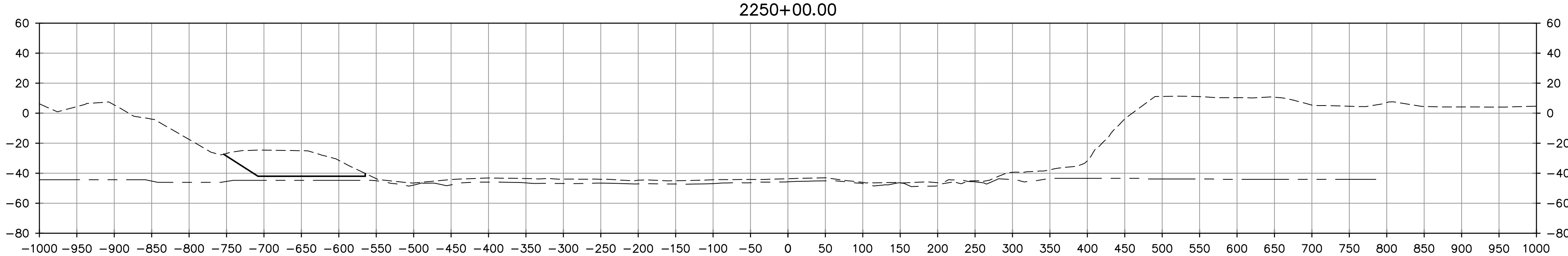
PROPOSED CHANNEL DEPTH

VERTICAL SCALE: 1"=100'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2250+00.00



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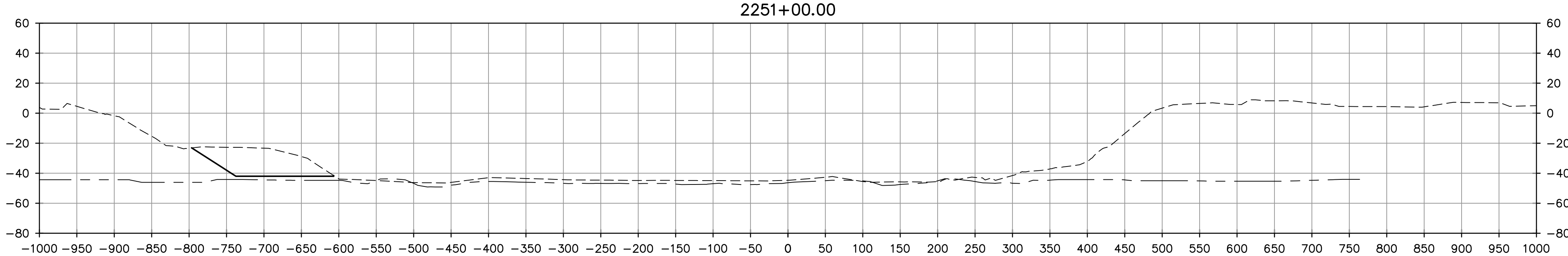

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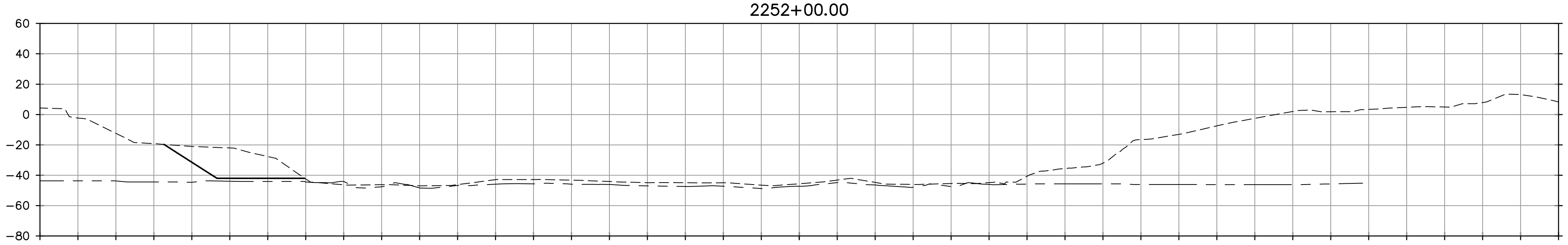


TURNING BASIN ALTERNATIVE D
SECTIONS 5 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

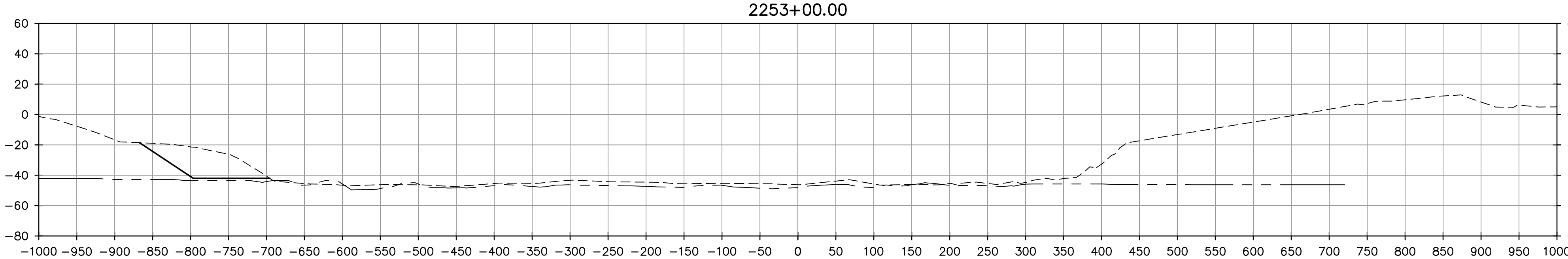
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2253+00.00



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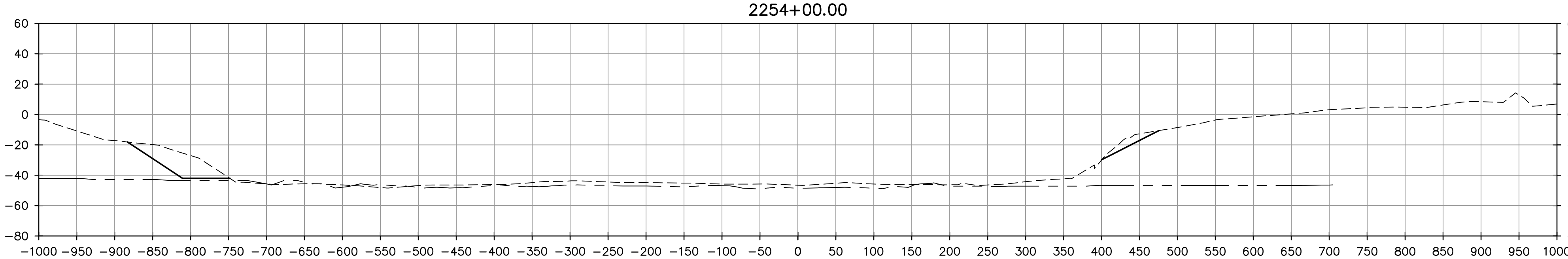

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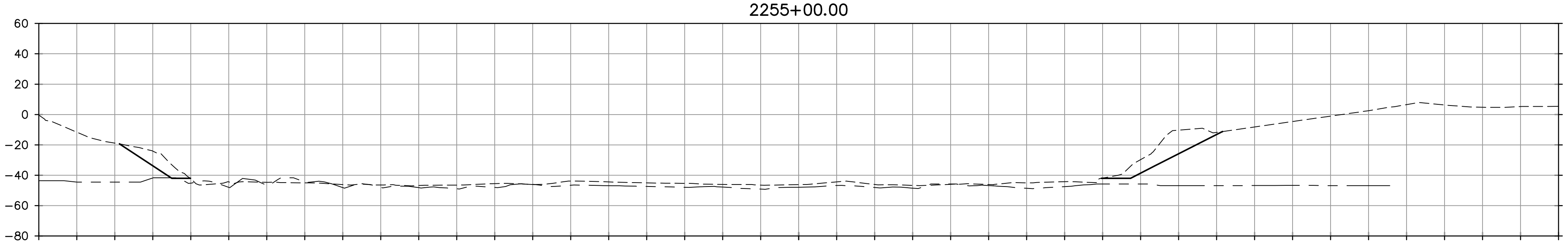


TURNING BASIN ALTERNATIVE D
SECTIONS 6 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

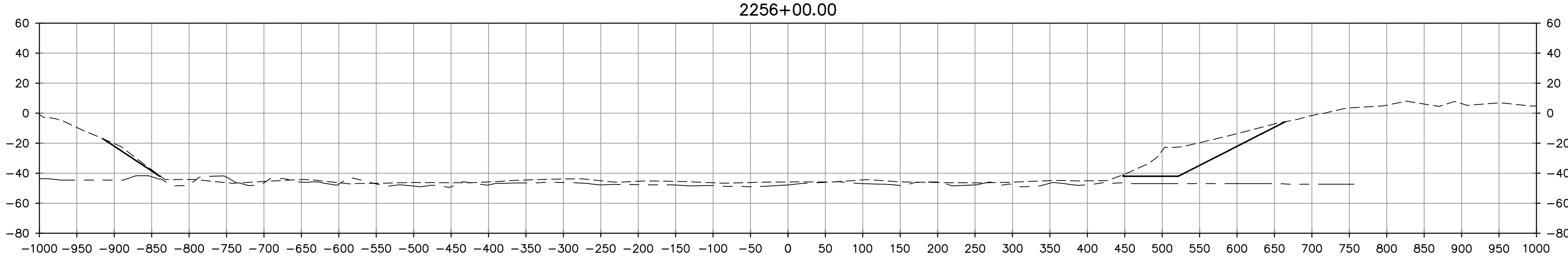
PROPOSED CHANNEL DEPTH

50' 0' 50' 100'
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'
HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2256+00.00



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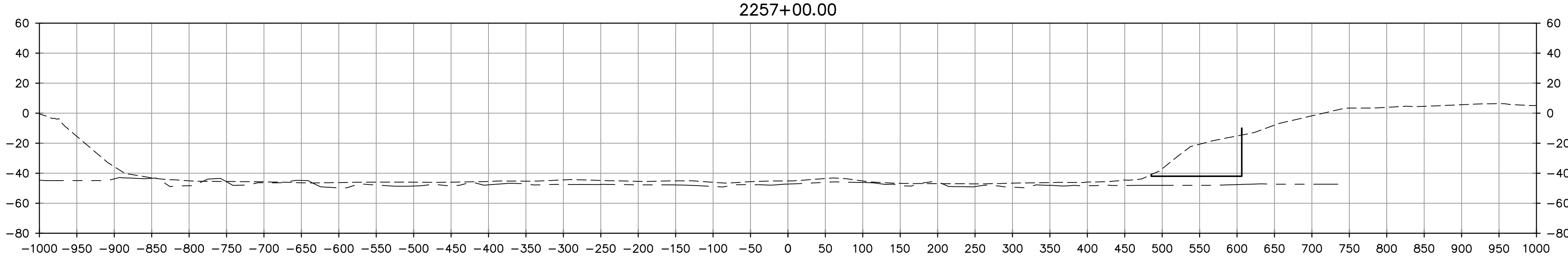

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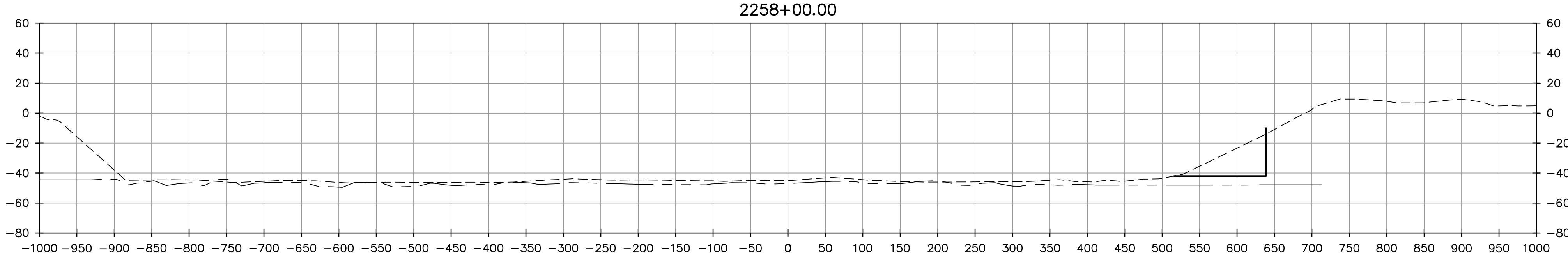


TURNING BASIN ALTERNATIVE D
SECTIONS 7 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

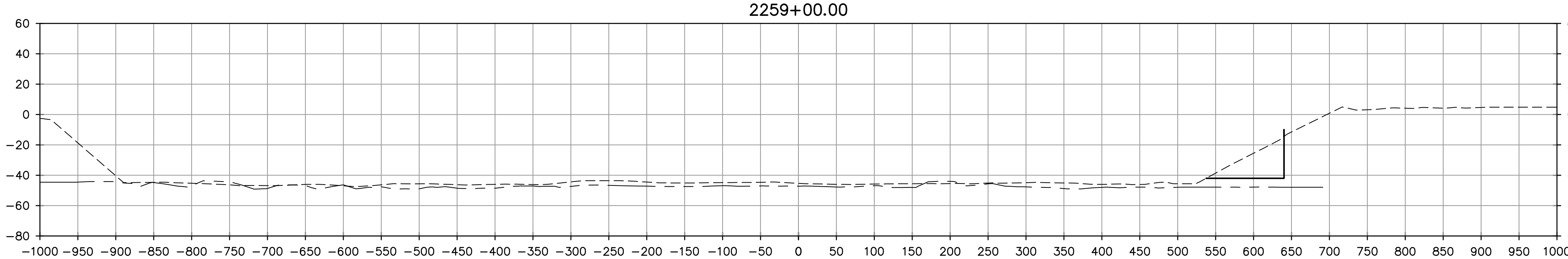
50' 0' 50' 100'

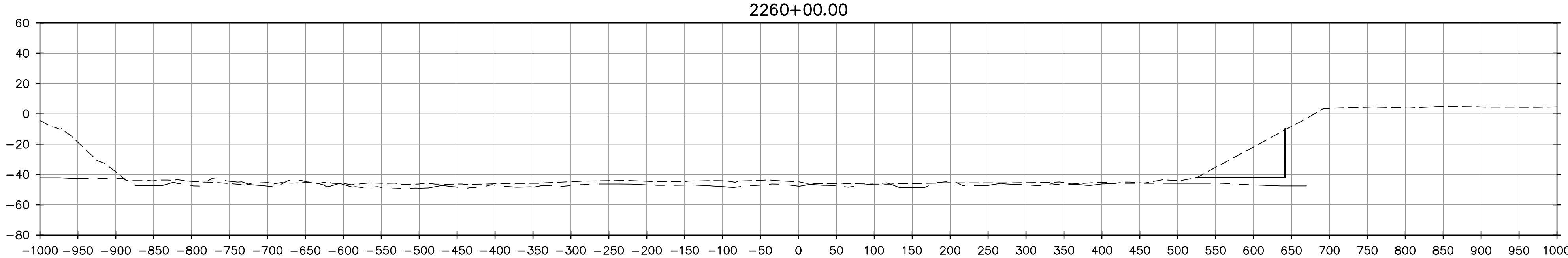
VERTICAL SCALE: 1"=100'

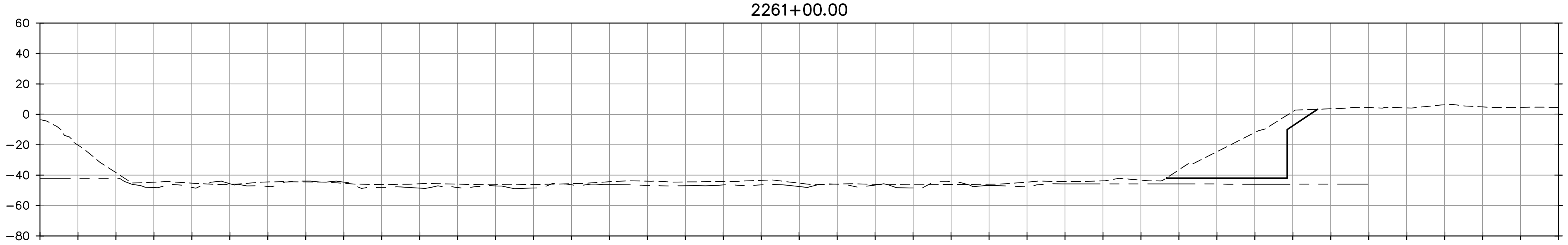
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE D
SECTIONS 8 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

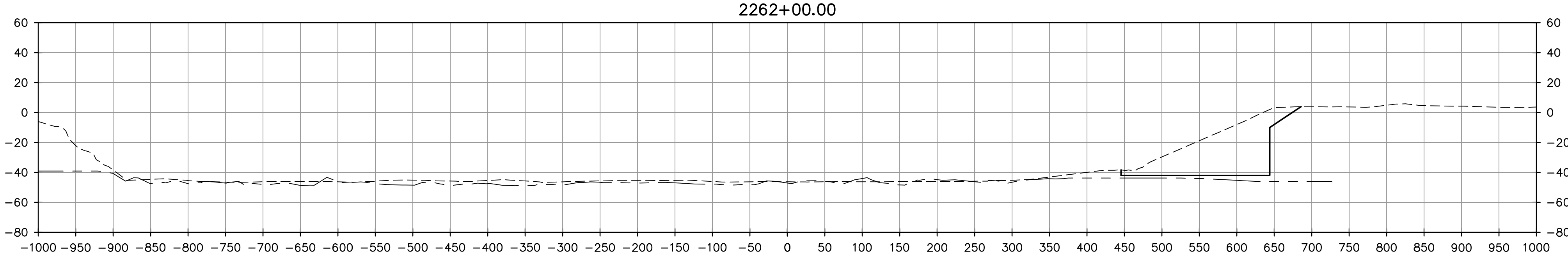
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2262+00.00



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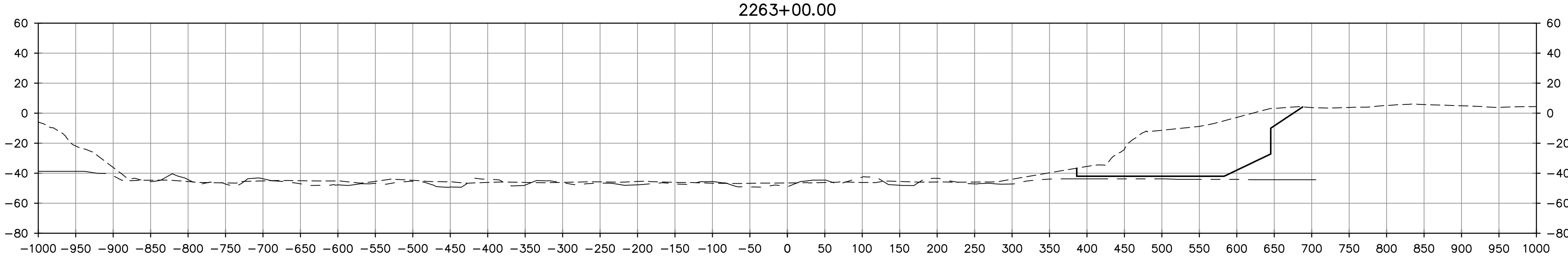

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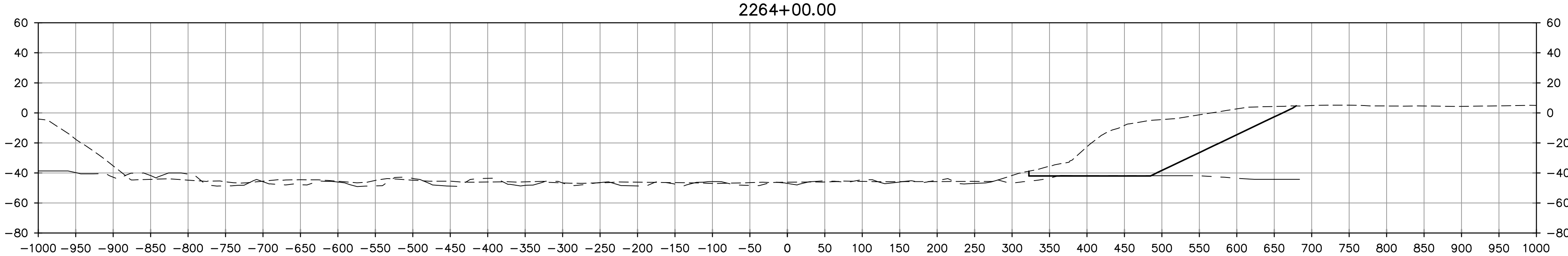


TURNING BASIN ALTERNATIVE D
SECTIONS 9 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

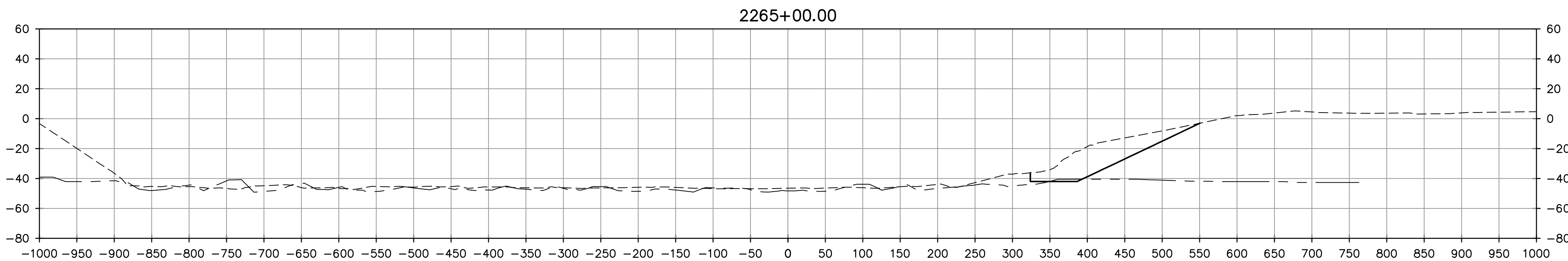
50' 0' 50' 100'

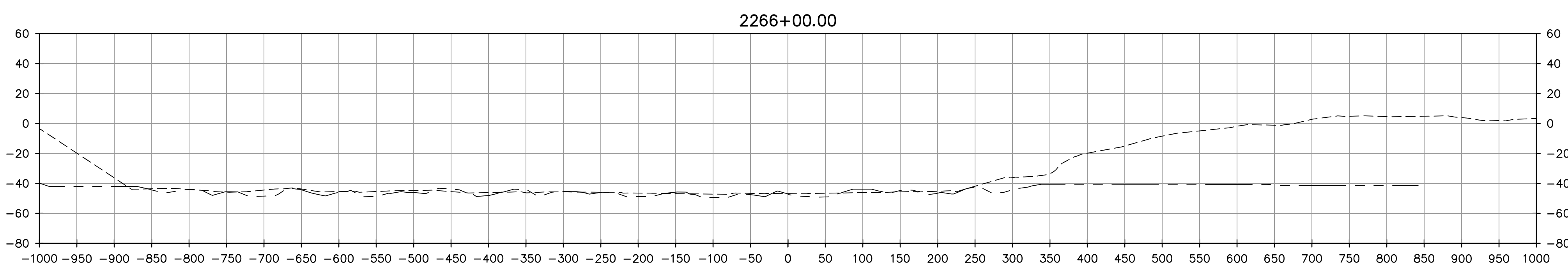
VERTICAL SCALE: 1"=100'

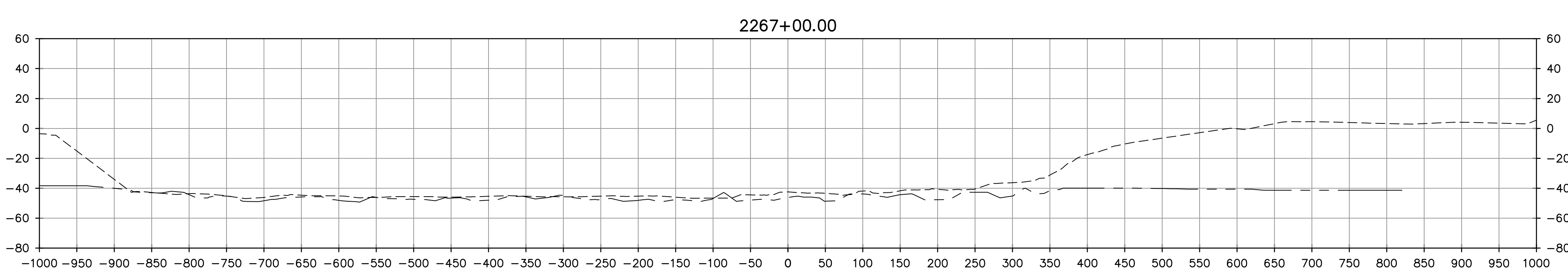
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE D
SECTIONS 10 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

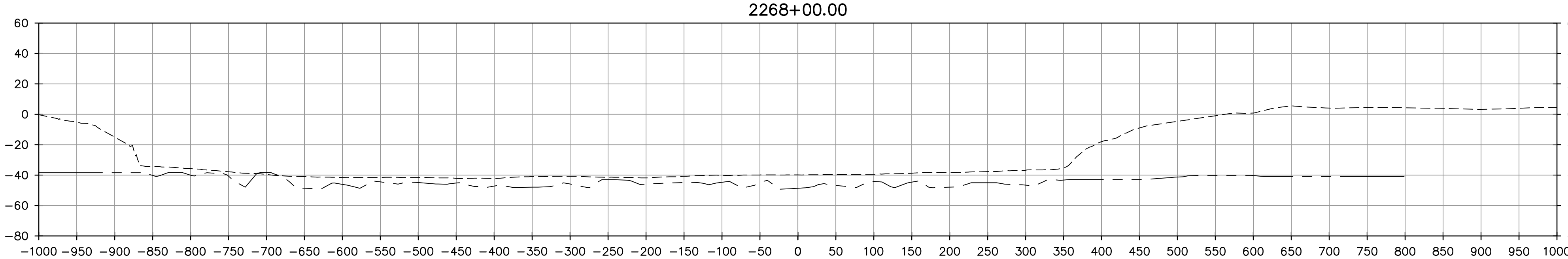
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2268+00.00



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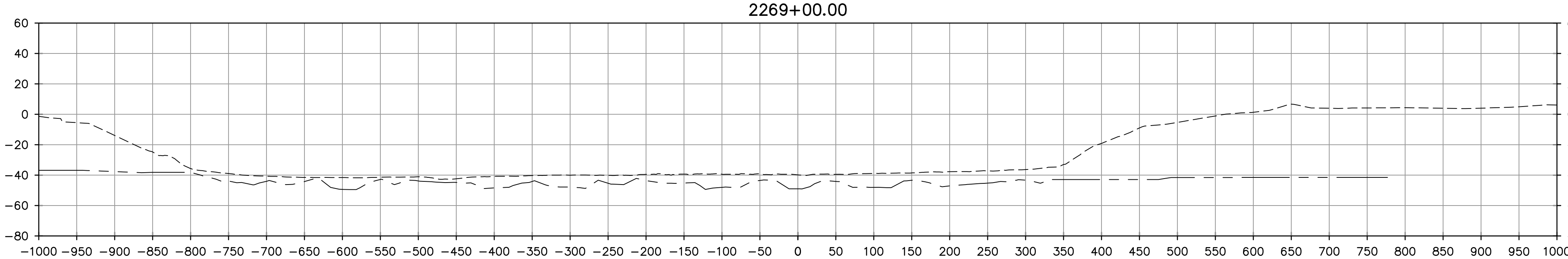

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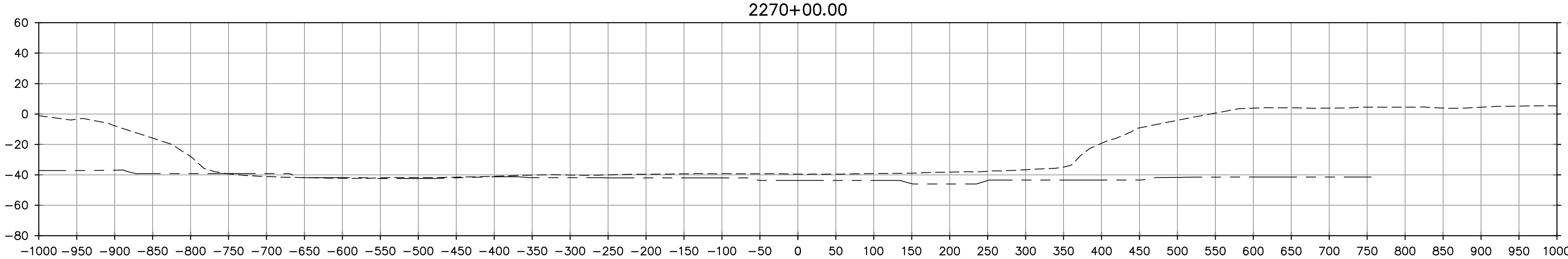


TURNING BASIN ALTERNATIVE D
SECTIONS 11 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

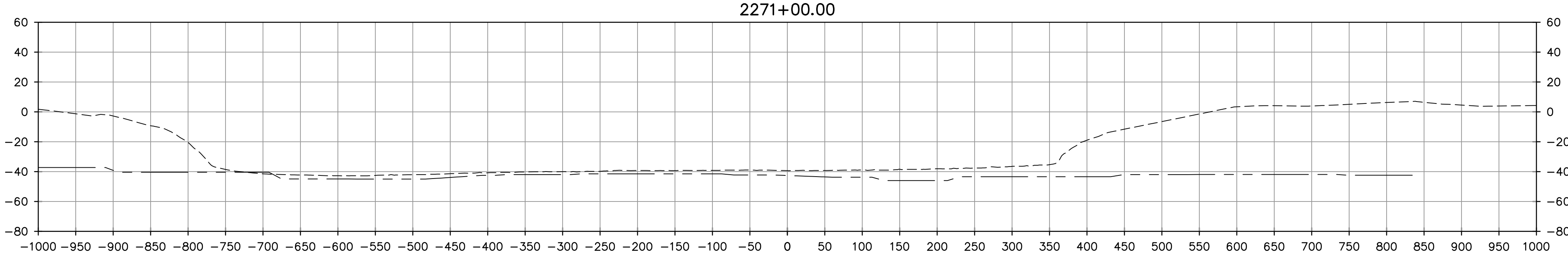
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2271+00.00



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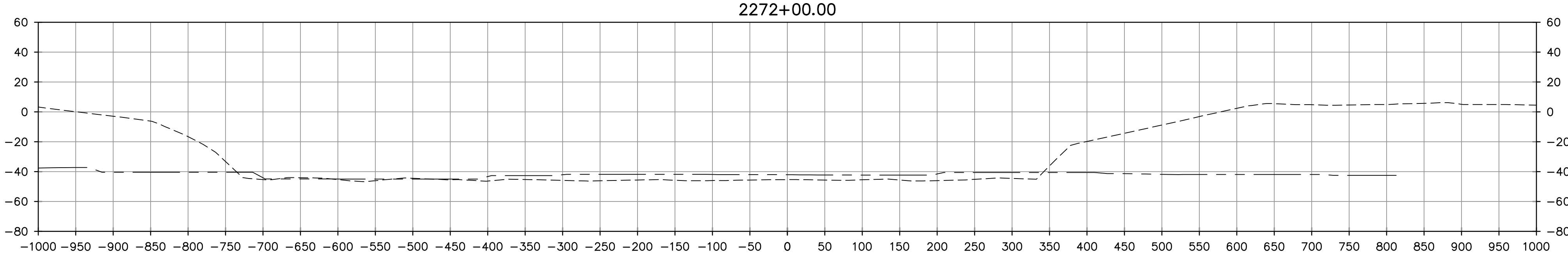

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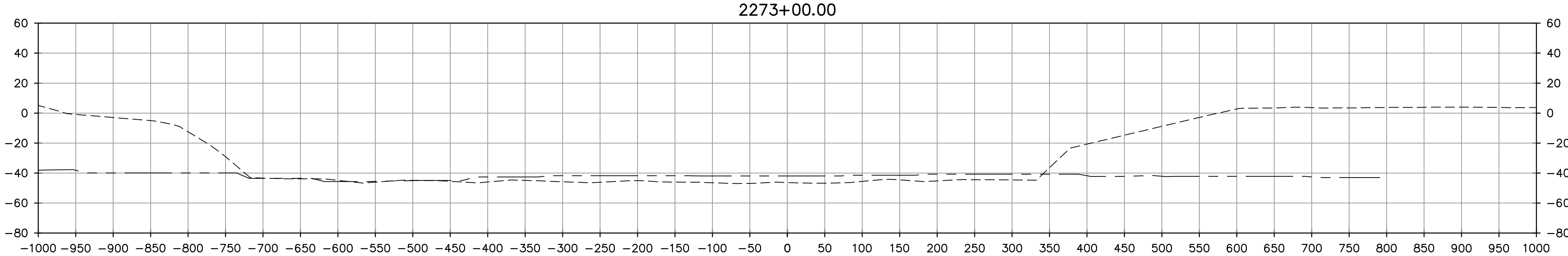


TURNING BASIN ALTERNATIVE D
SECTIONS 12 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

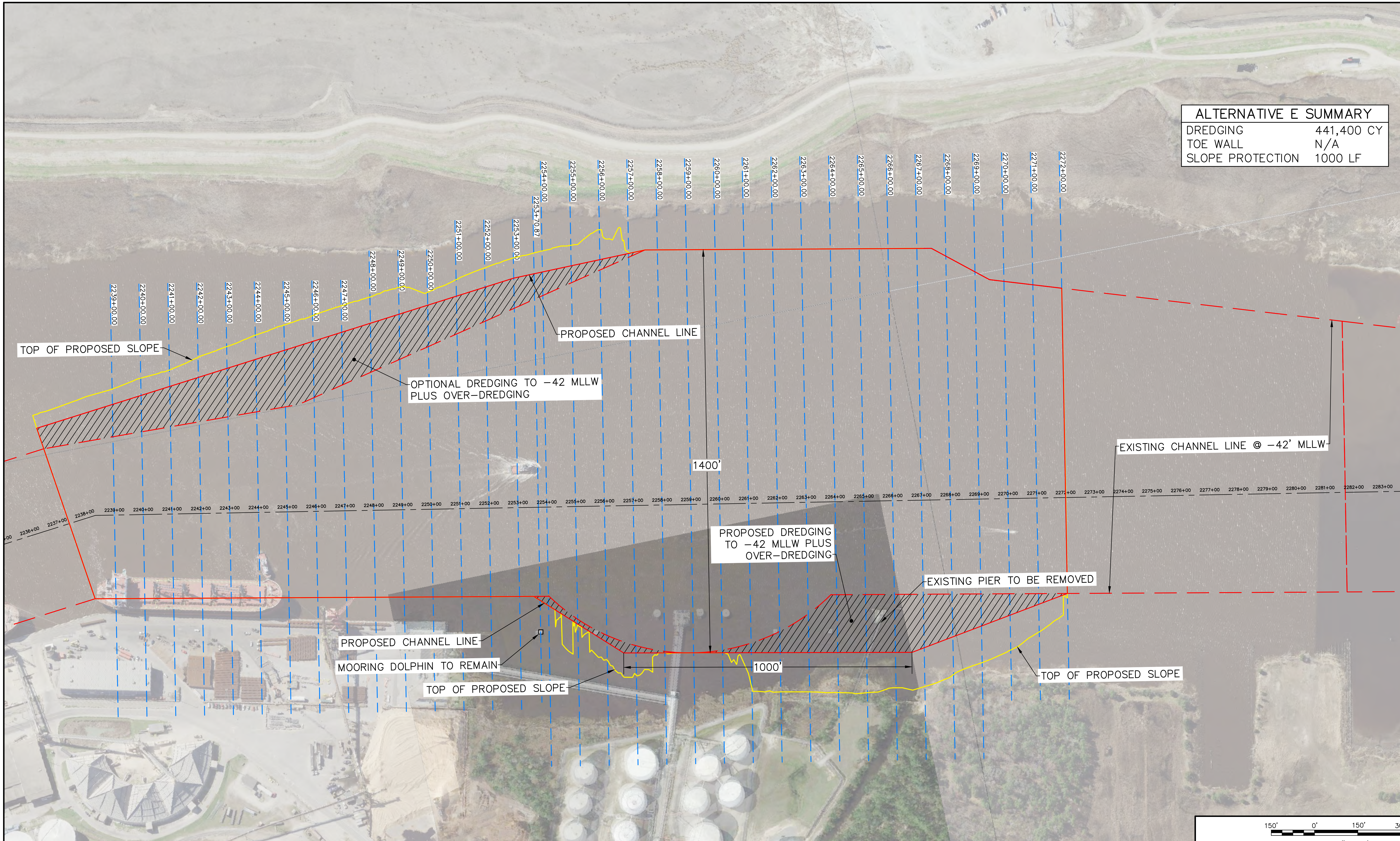
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

Appendix E – Alternative E Plan and Sections



ALTERNATIVE E — 1400' TURNING BASIN

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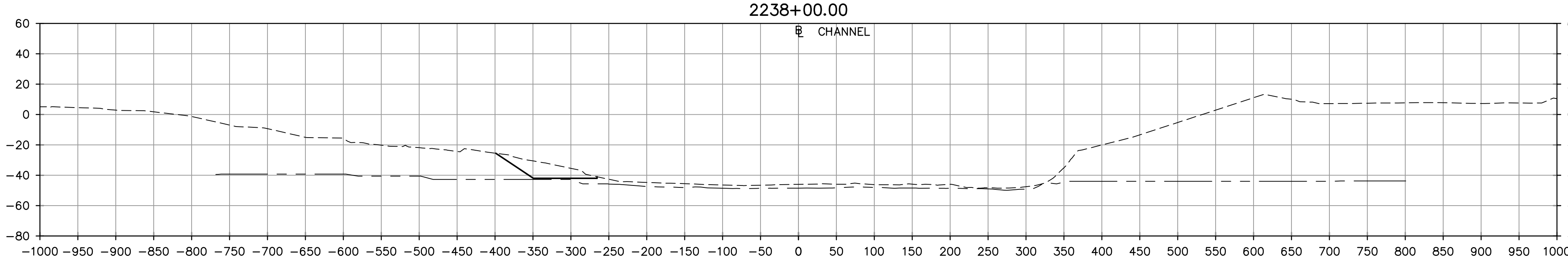
2238+00.00



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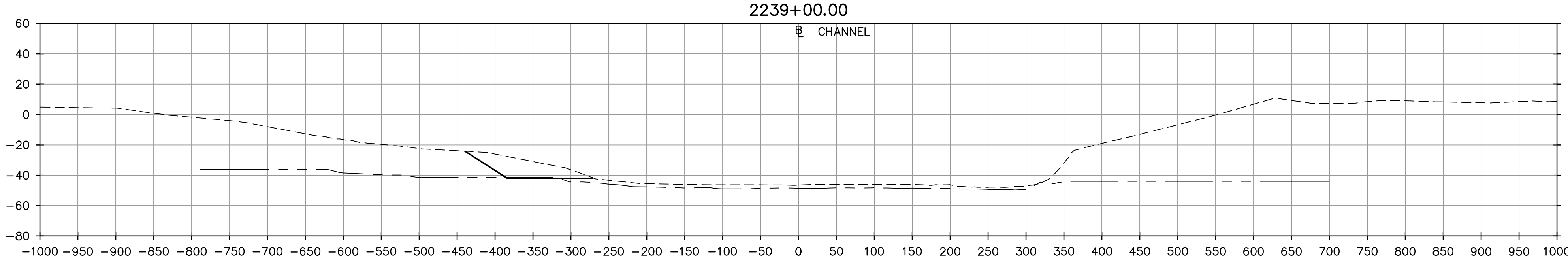

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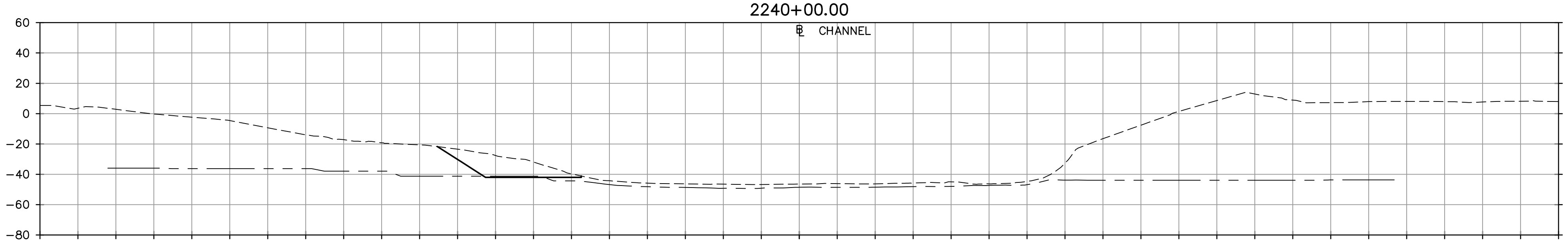


TURNING BASIN ALTERNATIVE E
SECTIONS 1 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

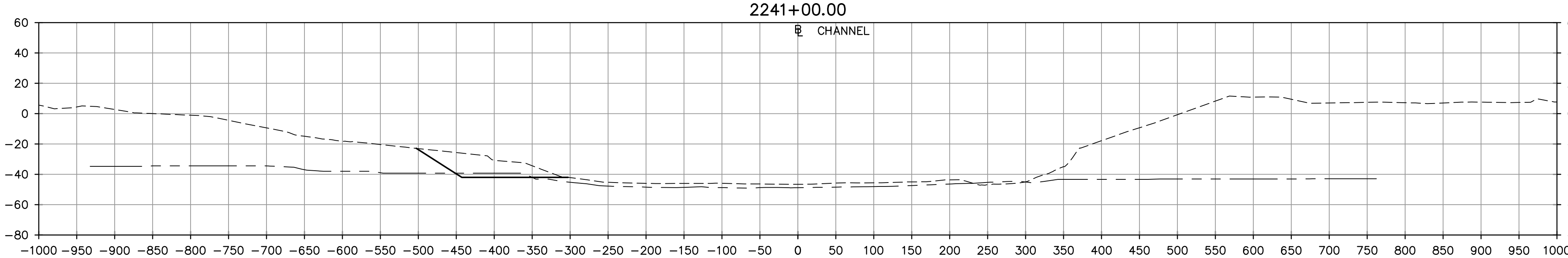
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2241+00.00



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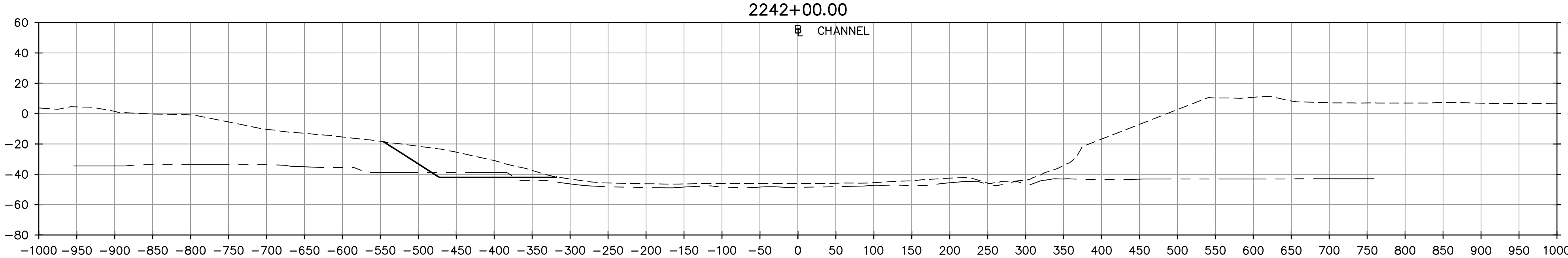

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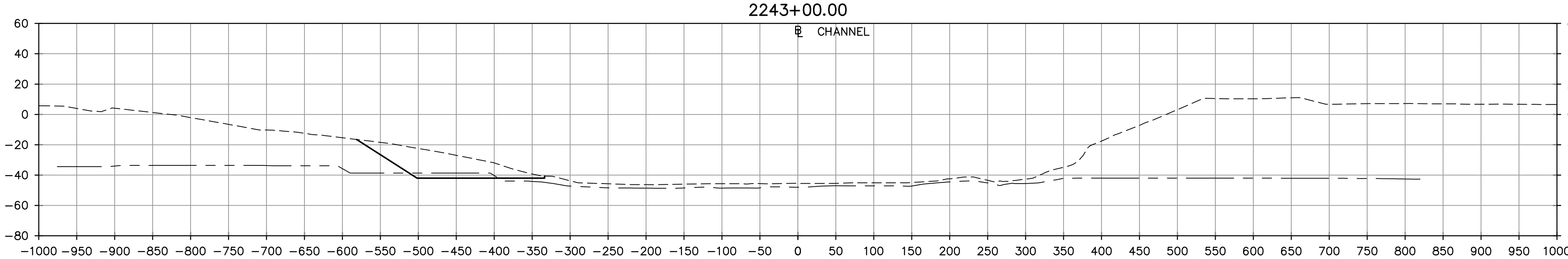


TURNING BASIN ALTERNATIVE E
SECTIONS 2 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

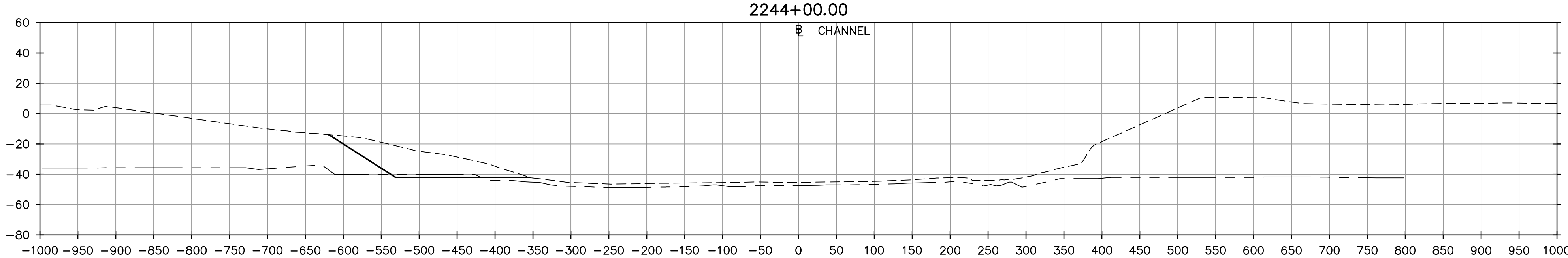
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2244+00.00



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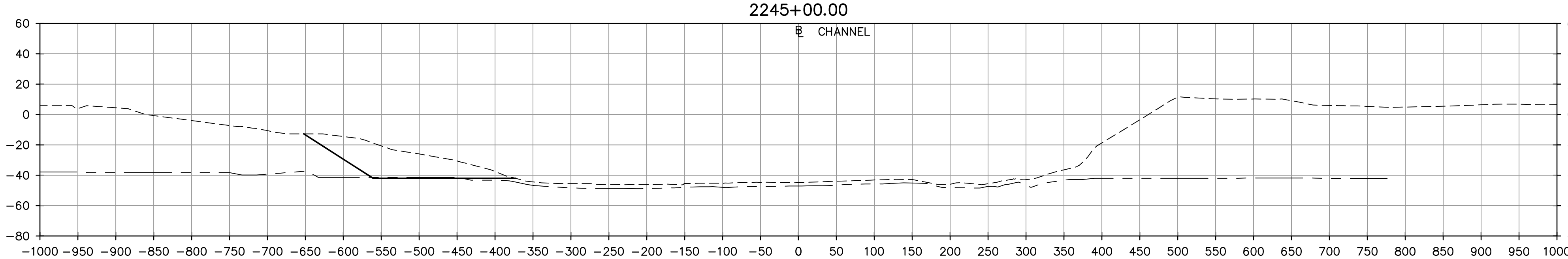

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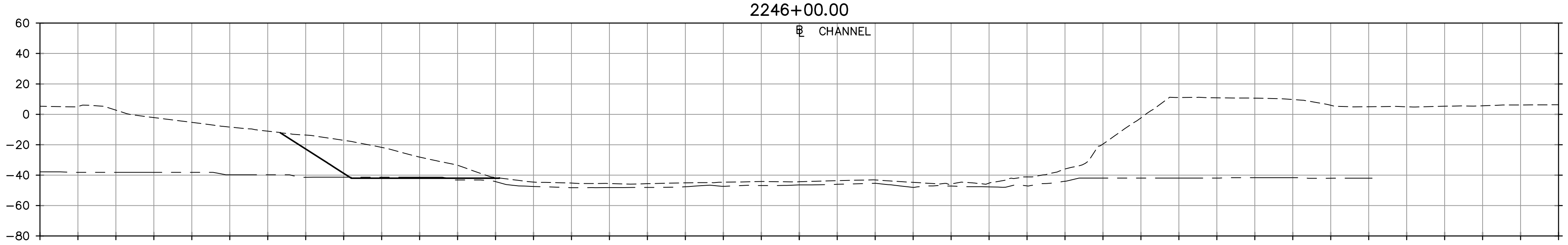


TURNING BASIN ALTERNATIVE E
SECTIONS 3 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

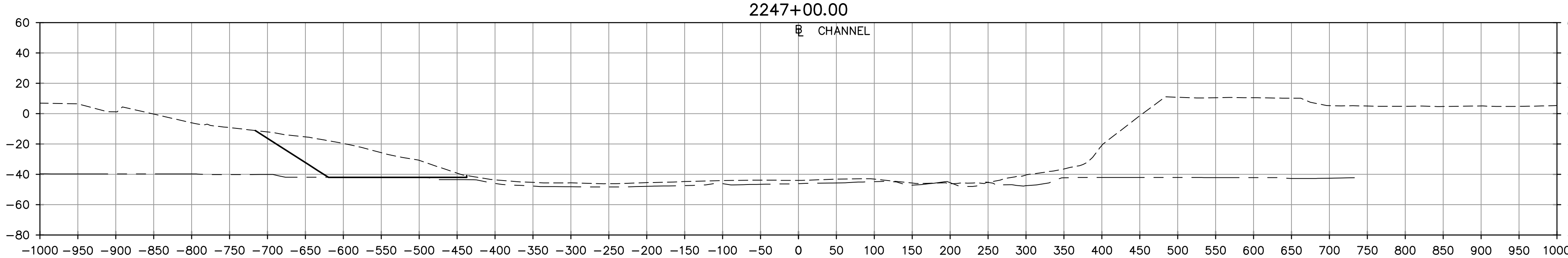
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2247+00.00



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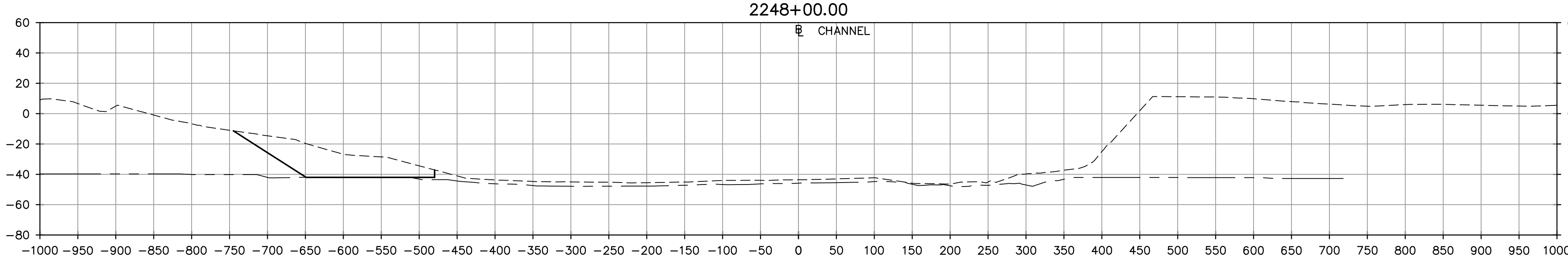

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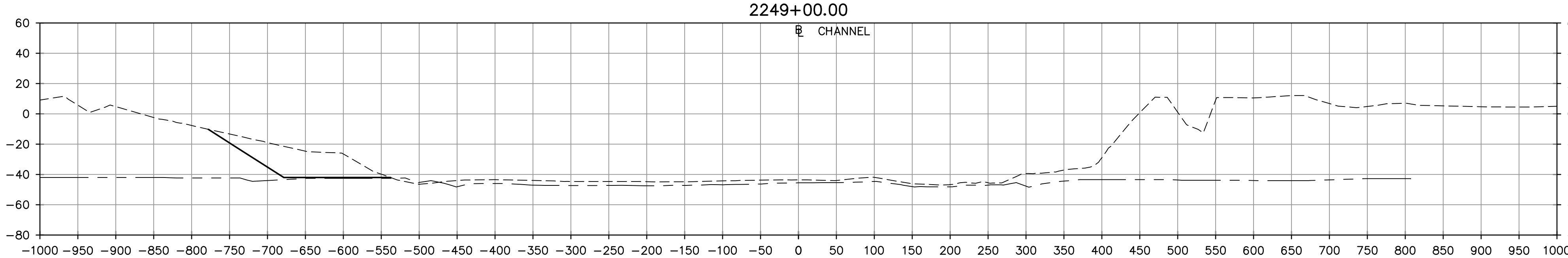


TURNING BASIN ALTERNATIVE E
SECTIONS 4 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

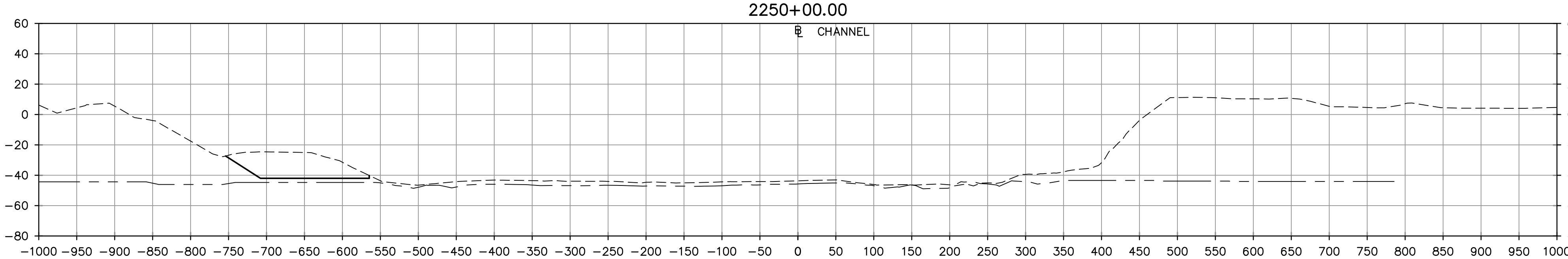
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2250+00.00



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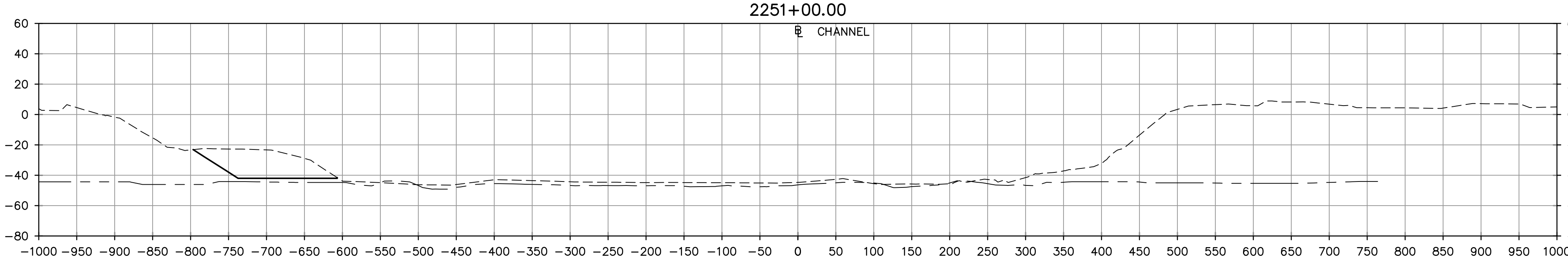

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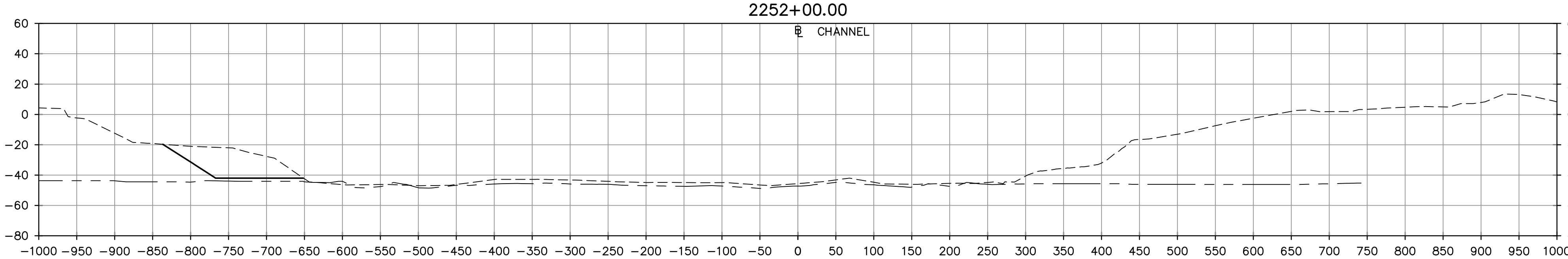


TURNING BASIN ALTERNATIVE E
SECTIONS 5 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

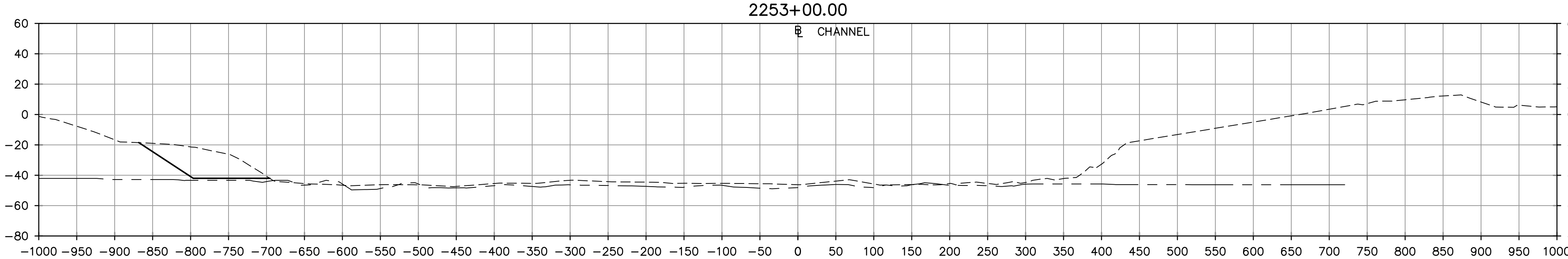
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2253+00.00



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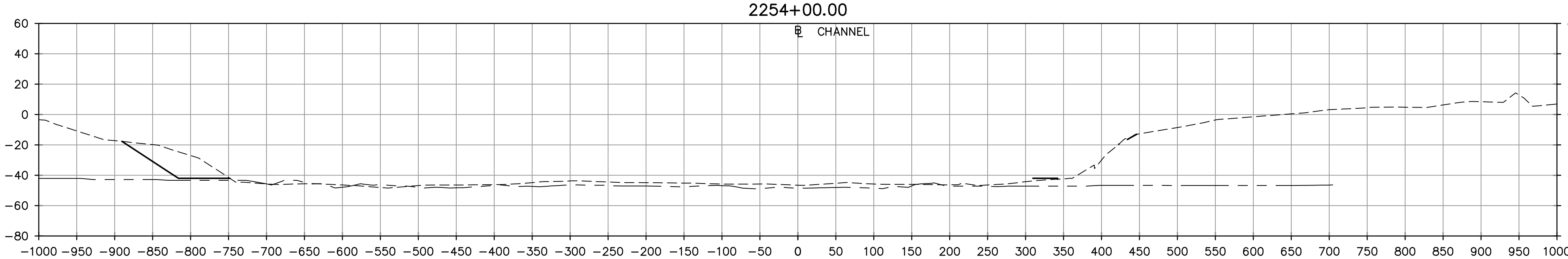

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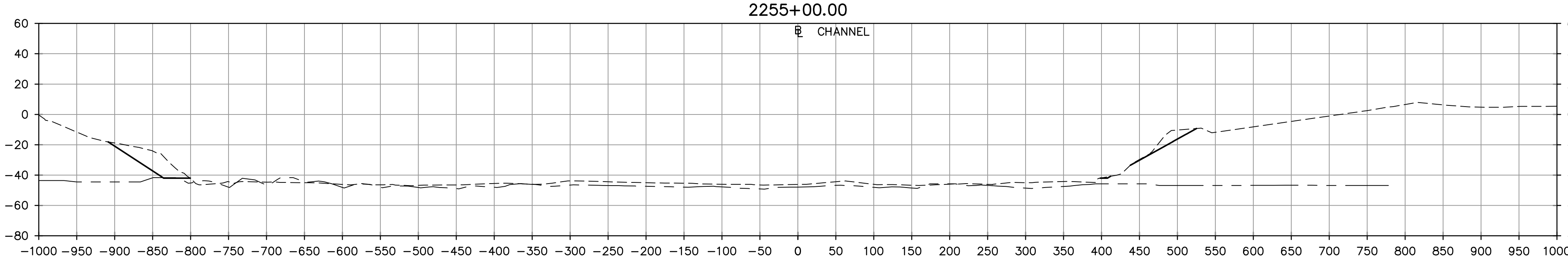

TURNING BASIN ALTERNATIVE E
SECTIONS 6 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

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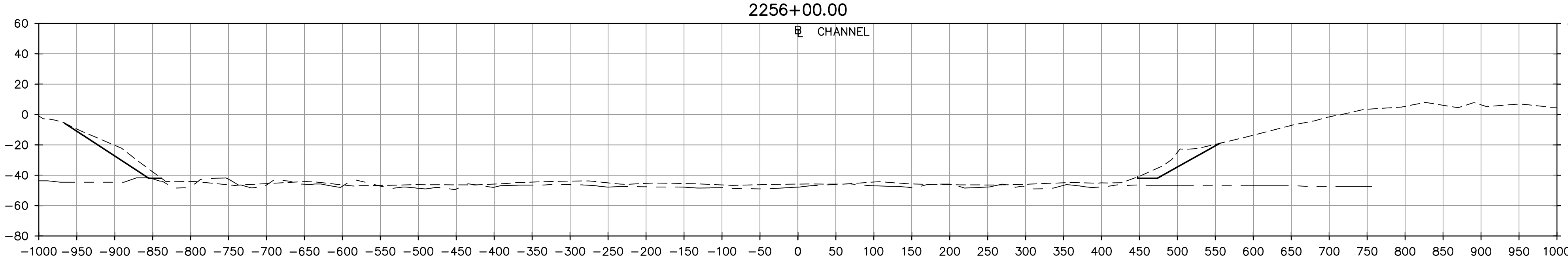
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2256+00.00



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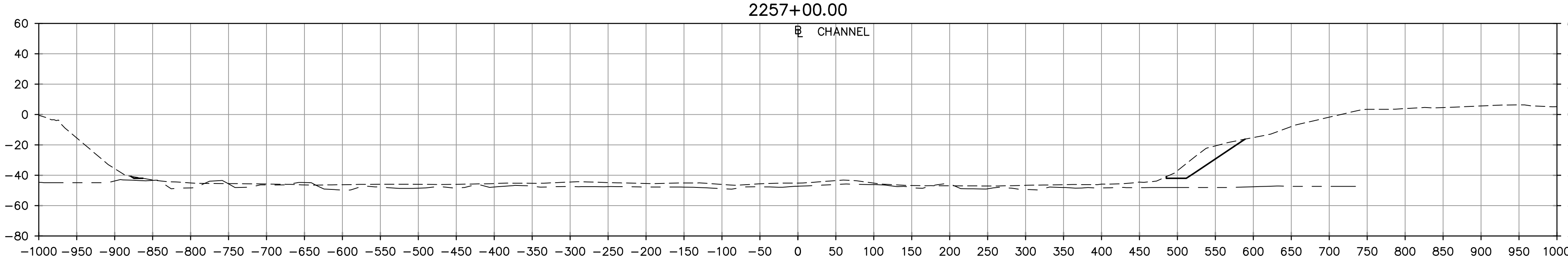

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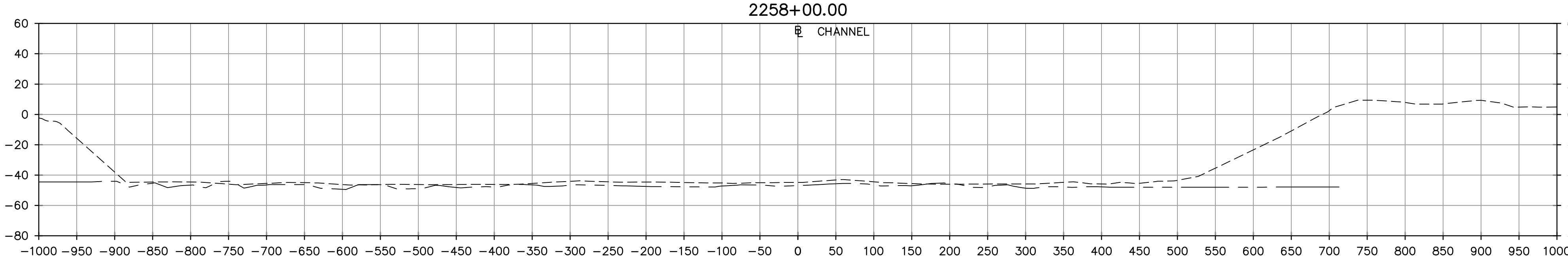


TURNING BASIN ALTERNATIVE E
SECTIONS 7 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

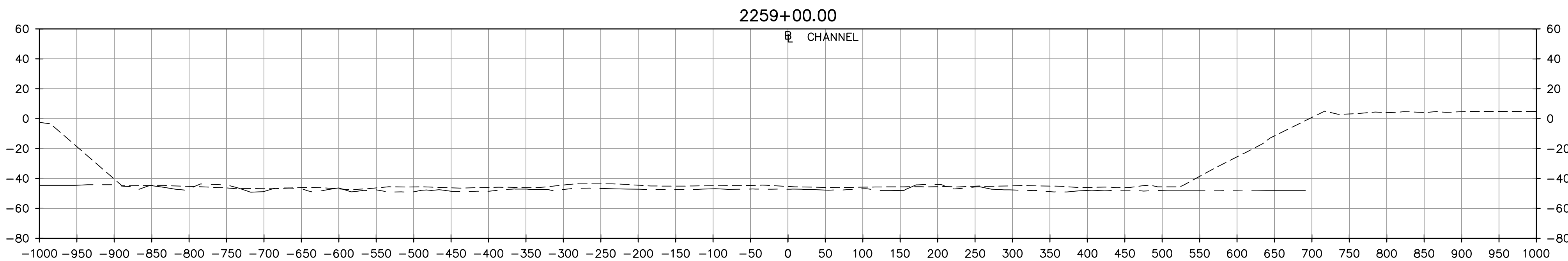
50' 0' 50' 100'

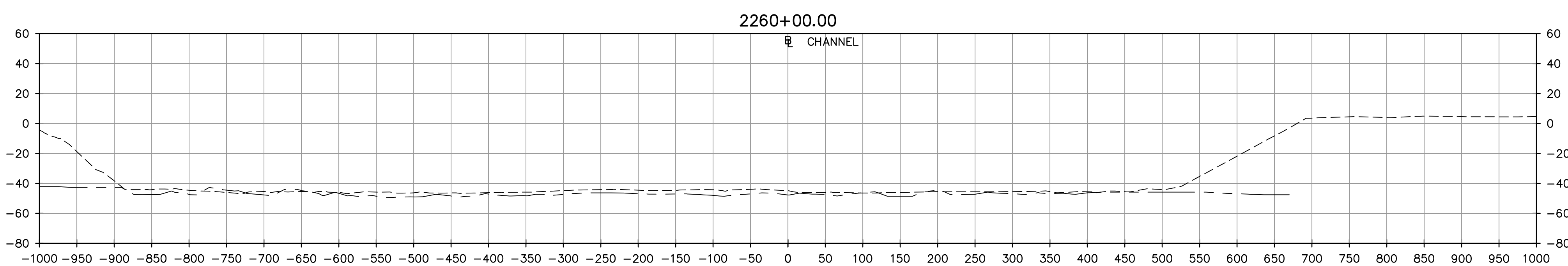
VERTICAL SCALE: 1"=100'

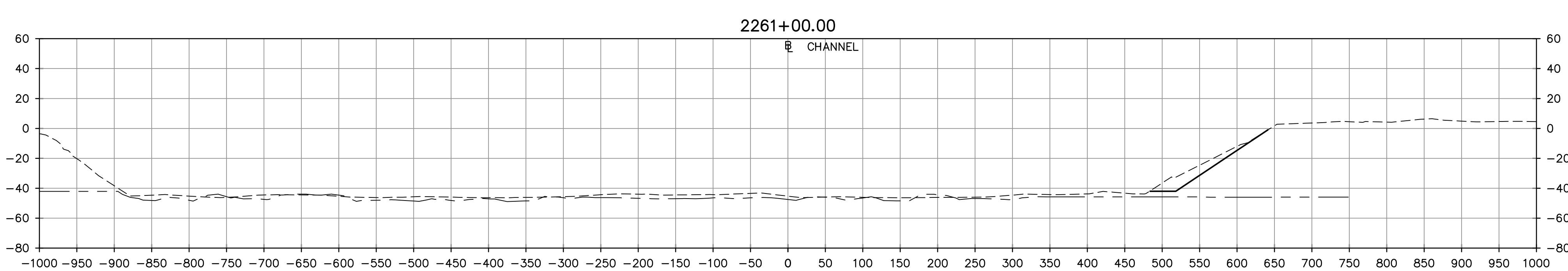
100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol







TURNING BASIN ALTERNATIVE E
SECTIONS 8 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

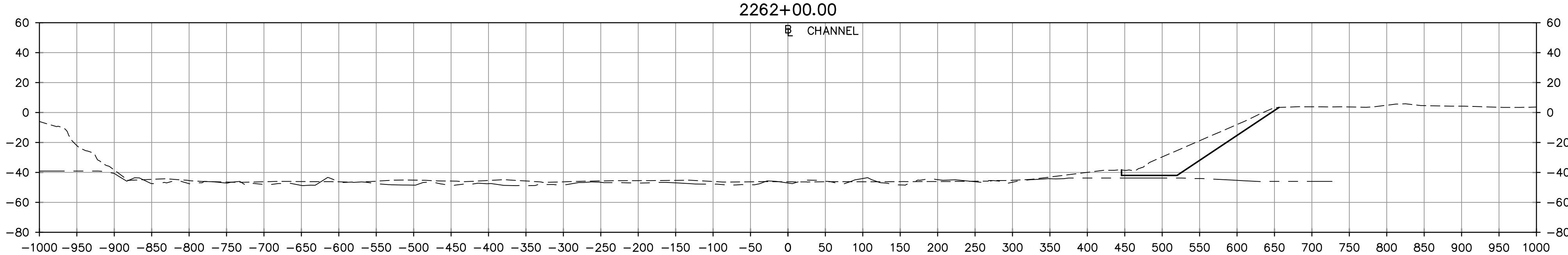
PROPOSED CHANNEL DEPTH

VERTICAL SCALE: 1"=100'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2262+00.00



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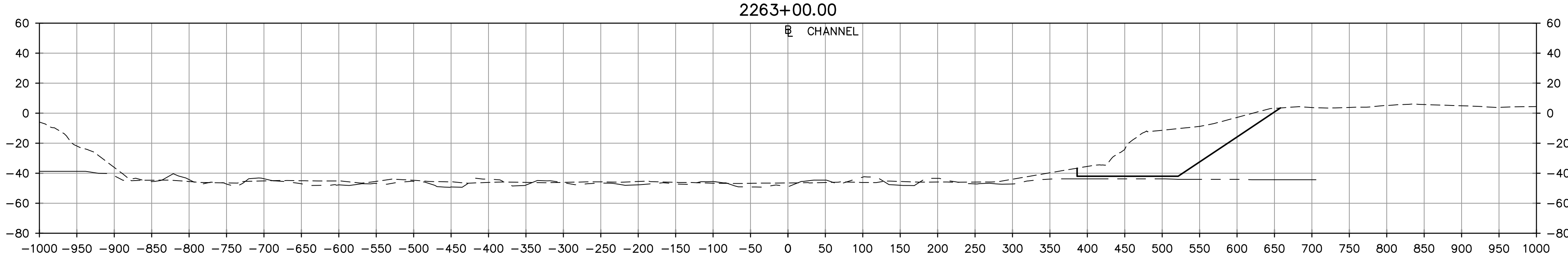

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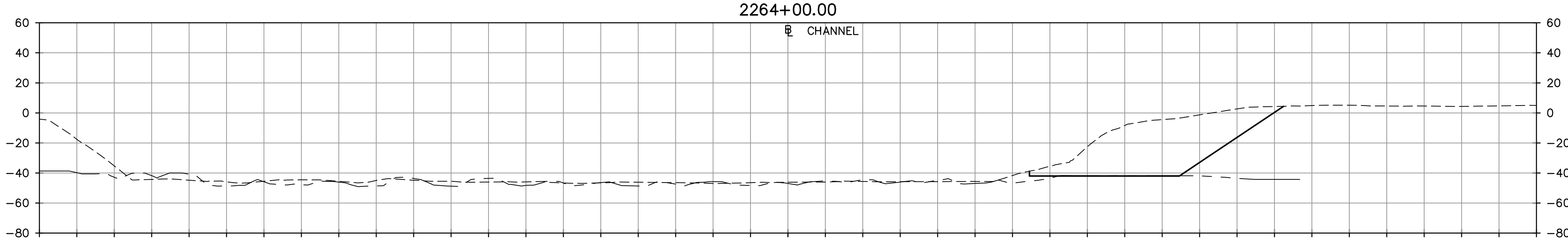


TURNING BASIN ALTERNATIVE E
SECTIONS 9 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

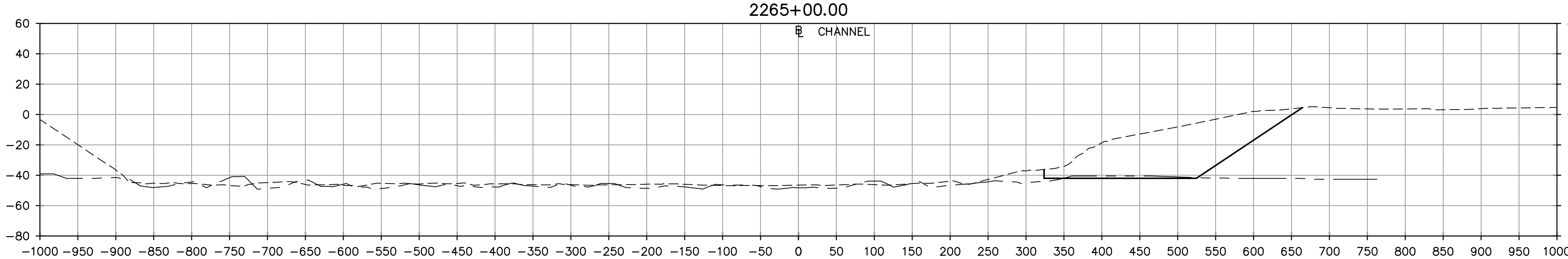
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2265+00.00



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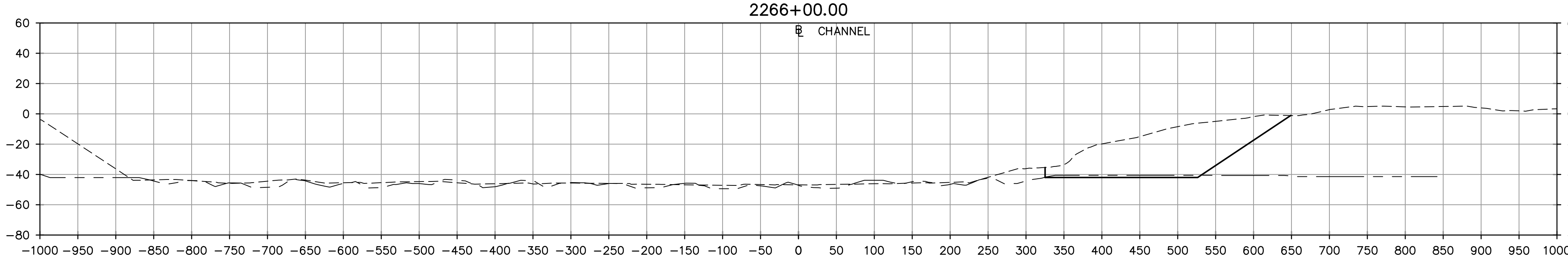

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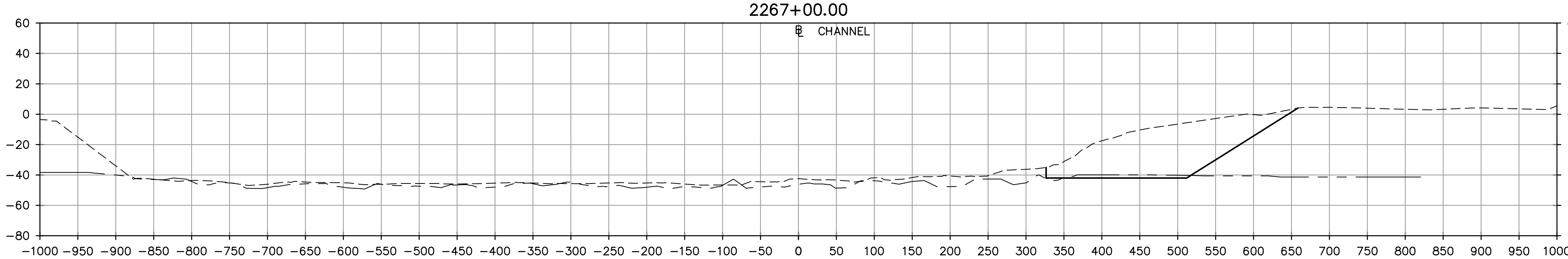


TURNING BASIN ALTERNATIVE E
SECTIONS 10 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

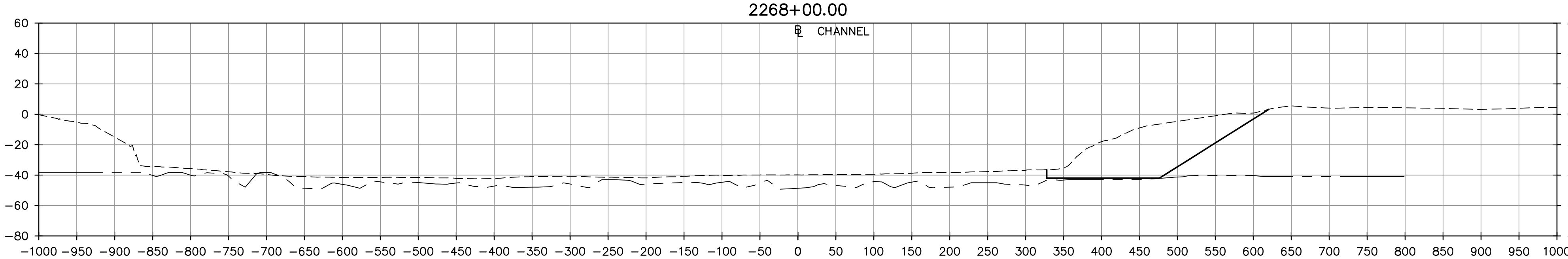
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2268+00.00



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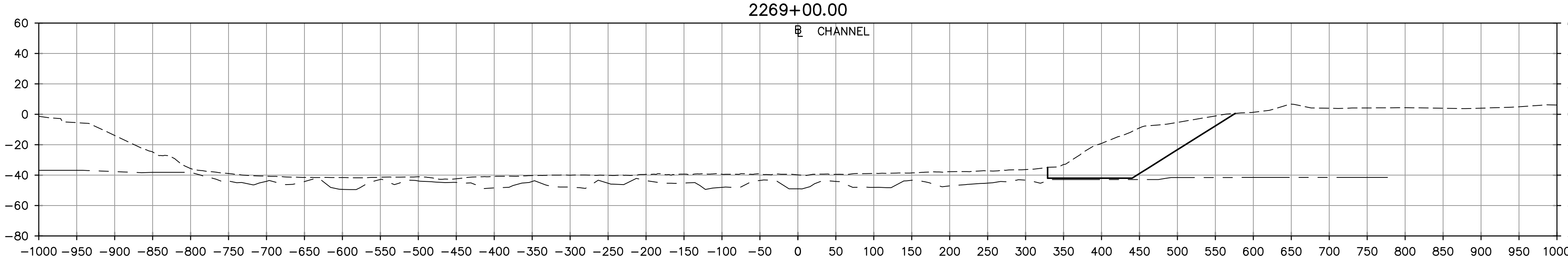

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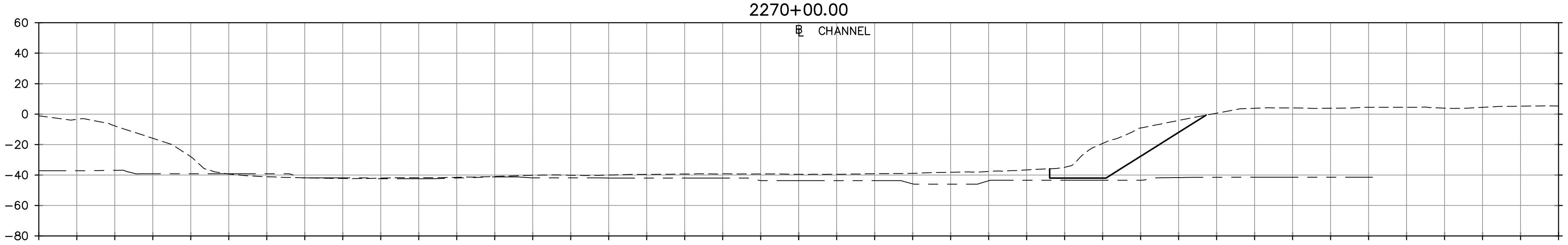


TURNING BASIN ALTERNATIVE E
SECTIONS 11 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

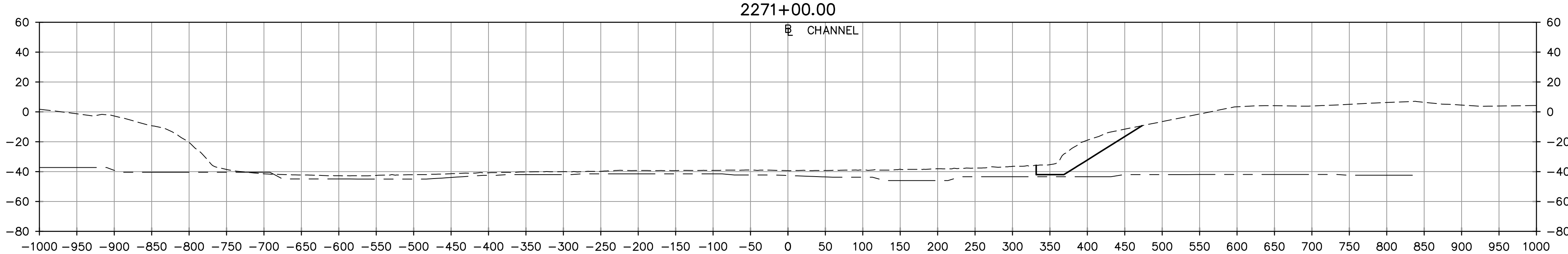
VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol

2271+00.00



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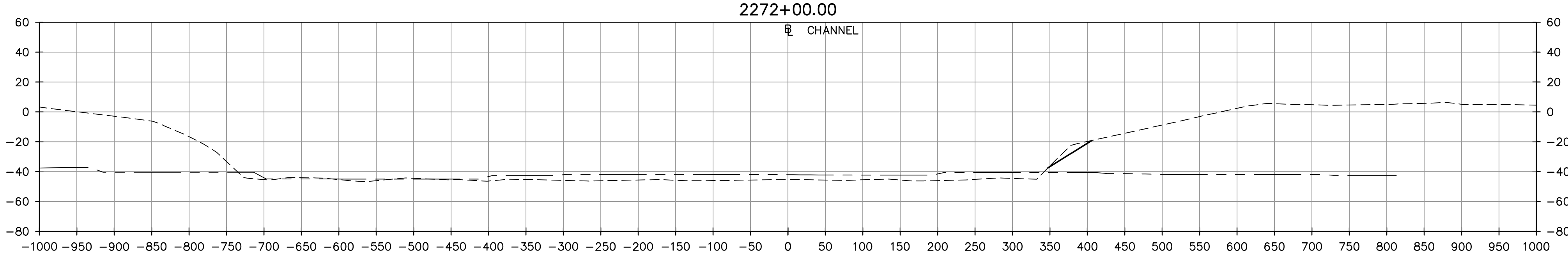

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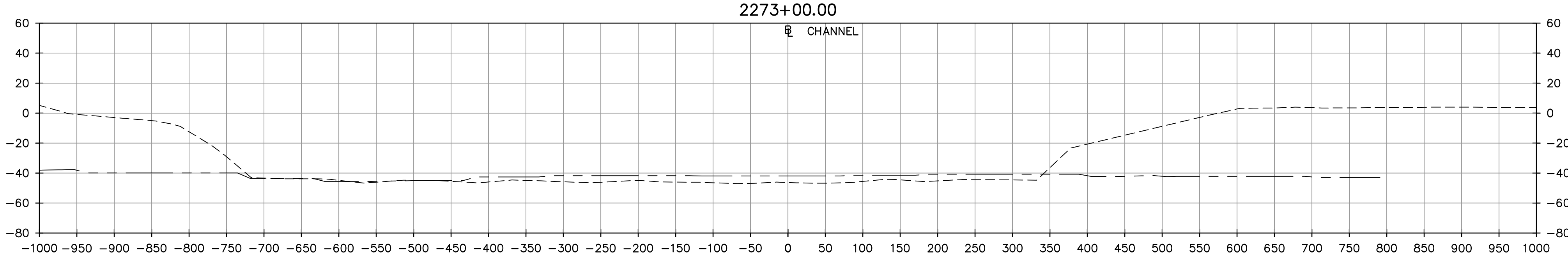

TURNING BASIN ALTERNATIVE E
SECTIONS 12 OF 12

LEGEND

APPROXIMATE EXISTING GROUND

APPROXIMATE EXISTING ROCK

PROPOSED CHANNEL DEPTH

50' 0' 50' 100'

VERTICAL SCALE: 1"=100'

100' 0' 100' 200'

HORIZONTAL SCALE: 1"=200'

moffatt & nichol