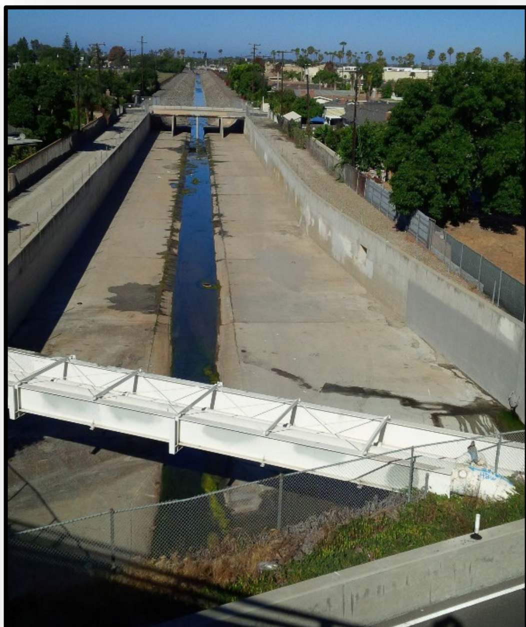
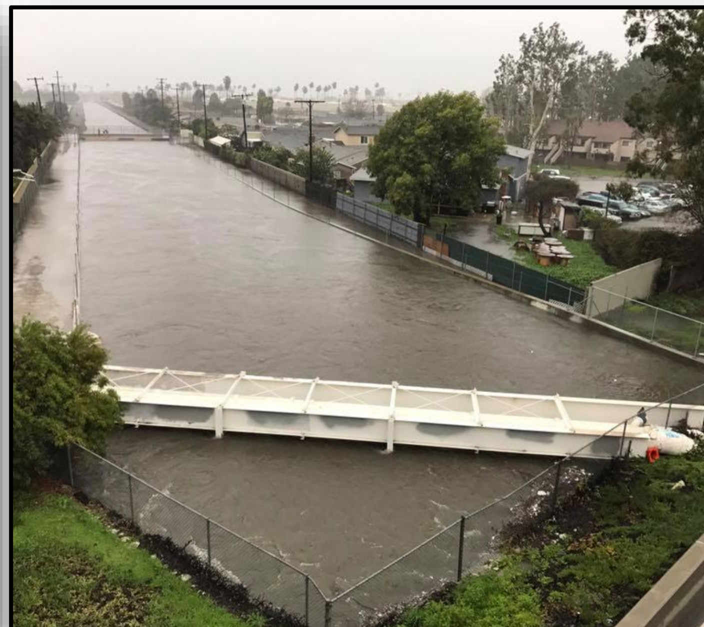
APPENDIX A – HYDROLOGY AND HYDRAULICS

For

WESTMINSTER, EAST GARDEN GROVE FLOOD RISK MANAGEMENT STUDY





December 2019

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COUNTY OF ORANGE CALIFORNIA

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For
WESTMINSTER, EAST GARDEN GROVE
FLOOD RISK MANAGEMENT STUDY

1.0 Introduction

The U.S. Army Corps of Engineers, Chicago District (USACE), is currently conducting the Flood Risk Management Feasibility Phase of the Westminster East Garden Grove Study, a cost shared effort between the U.S. Army Corps of Engineers and the County of Orange and OCFCD.

The purpose of the Westminster Feasibility Study is to develop and evaluate potential non-structural and engineered solutions to address flooding issues for the two main drainage systems: the Bolsa Chica (C02)/Westminster (C04) Channels and the East Garden Grove – Wintersburg (C05)/Ocean View (C06) Channels within and near the in the cities of Anaheim, Stanton, Cypress, Garden Grove, Westminster, Fountain Valley, Los Alamitos, Seal Beach, and Huntington Beach within Orange County, California.

Hydraulic analysis for the Westminster channels was conducted using Hydrologic Engineering Center River Analysis System (HEC-RAS), HEC-GeoRAS, Water surface profiles were produced for existing conditions and alternative conditions. Alternatives included minimum channel improvements, maximum channel improvements, and moderate channel improvements. Water surface profiles and inundation maps were produced for the 1-,5-,10-,25-, 50-, 100-, 200-, and 500-year (99, 20, 10, 4, 2, 1, 0.5 and 0.2% Annual Exceedance Probability {AEP}) events for both Existing Conditions and alternative conditions. The existing condition's 10, 4, 2, 1, and 0.2% AEP floodplains display flooding in the both overbank, including comingling flooding between channel systems. Flooding begins at approximately the 10% AEP flood event throughout the project area and is caused by overtopping of the channels as well as failure of the levees in the downstream reaches of the C05 channel systems. Overtopping and failure of the levees the downstream reach of C04 occurs at approximately the 2% AEP flood event.

2.0 General Description of Study

The U.S. Army Corps of Engineers, Chicago District is currently conducting the Flood Risk Management Feasibility Phase of the Westminster Study, a cost shared effort between the U.S. Army Corps of Engineers (USACE) and the Orange County Flood Control District. The purpose of the Westminster Feasibility Study is to develop and evaluate potential nonstructural and engineered solutions to address flooding issues consisting of portions of the cities of Santa Ana, Orange, Garden Grove, Anaheim, Westminster, Fountain Valley, and Huntington Beach. The study team considered an array of measures that support the primary purpose of flood risk management. There is also an opportunity to provide much-needed recreational opportunities concurrent with flood risk management.

The purpose of this appendix is to document the hydrology & hydraulic analyses completed in support of the Westminster East Garden Grove Flood Risk Management Study in Orange County, California.

2.1 Study Area

The two main drainage systems that are part of the study area include the Bolsa Chica (C02)/Westminster Channels (C04) and the East Garden Grove Wintersburg (C05)/Ocean View Channels (C06).

The long-term average rainfall in Orange County is 14 inches per year, with intense storms between October and March. It is not unusual for a majority of the annual precipitation to fall during a few storms within short periods of time. Rainfall patterns are subject to extreme variations from year to year and long term-term wet and dry cycles. The combination of brief intense storms and extreme temporal variability in rainfall result in flashy system where stream discharge can vary by several orders of magnitude over very short periods of time (IRWMP, 2018).

The East Garden Grove-Wintersburg Channel (EGGW) sub-watershed lies on a flat coastal plain surrounded generally by the Santa Ana River to the east, the Talbert Valley watershed and the Pacific Ocean to the south, and the C02 sub-watershed to the west and north. The watershed is drained by the manmade channel system consisting of Orange County drainage facilities EGGW Channel (C05); Oceanview Channel (C06); Slater Channel (C05S04) and pump station; Haster Basin; C05 channel upstream of Haster Basin; and storm drains C05P19, C05P21, C05P22 that contribute storm runoff to the Haster Basin. These facilities collect storm runoff from a 27.3 square-mile drainage area consisting of portions of the cities of Santa Ana, Orange, Garden Grove, Anaheim, Westminster, Fountain Valley, and Huntington Beach. The channels terminate at the Pacific Ocean through Bolsa Bay in the City of Huntington Beach.

The upper Haster Basin drainage area consists of the C05 channel (from Haster Basin to Chapman Avenue); P21—Spinnaker storm drain (from Katella Avenue to Chapman Avenue); and P22—Holiday storm drain (along Chapman Avenue to State College Boulevard), which discharges to the C05 channel upstream of Haster Basin (from Chapman Avenue to Haster Basin); and P19—Oertley storm drain (from Chapman Avenue to Haster Basin).

Of the 28.0 square-miles drainage area for the EGGW sub-watershed, 5.1 square miles are tributary to the Oceanview Channel and 3.9 square miles are tributary to the Slater Channel. Elevations in the EGGW watershed range from 175 feet at the upper end of the basin to sea level at Bolsa Bay, with an average basin slope of 2 feet per 1,000 feet (12 ft/mi). Elevations in the Oceanview drainage area range from 64 feet at the upper end to 23 feet at the confluence with the EGGW Channel, with an average basin slope of 1.5 feet per 1,000 feet (8 ft/mi). Elevations in the Slater Channel drainage area range from 110 feet in the southern portion to sea level near the pump station, with an average basin slope of 6 feet per 1,000 feet (33 ft/mi).

The drainage area for the Westminster Channel (C04) is approximately 10.9 square miles and is located in the cities of Garden Grove, Huntington Beach, Santa Ana and Westminster. The topography of the land is relatively flat; however, it slopes gradually in a southwesterly direction. Ground surface elevations vary from 10 feet at the Bolsa Chica Channel to 107 feet at the intersection of Chapman Avenue and 9th Street, giving the area an average slope of 2.4 feet per 1,000 feet (0.002). The drainage area is assumed to be fully developed. Land use includes 37% single family dwellings, 36% commercial/industrial, and the remainder consists of apartments, condominiums, schools, public parks and mobile home parks (land use estimates based on various public record sources).

The drainage area for the Bolsa Chica Channel (C02) consists of approximately 36.4 square miles and includes portions of the Cities of Anaheim, Cypress, Garden Grove, Los Alamitos, Stanton and unincorporated Orange County territory. The topography is relatively flat. Elevations in the area vary from 91 feet at the intersection of Ball Road and Gilbert Street, to 15 feet at the San Diego Freeway (I-405), with an average slope of 1.8 feet per 1,000 feet (.0018). The land use is predominately residential and commercial.

The total drainage area upstream of the Haster Retarding Basin (Basin) is approximately 1,845 acres (2.9 square miles) and receives stormwater flows from the cities of Anaheim, Orange and Garden Grove. The fully developed drainage area is relatively flat and slopes gently in a southwesterly direction. Land use is predominantly residential and commercial. The Basin is located in the Haster Basin Recreational Park, at the southwest corner of Haster Street and Lampson Avenue. The two primary inlets to the Basin are the East Garden Grove-Wintersburg Channel, Facility No. C05, which drains approximately 1,195 acres (1.86 square miles) and Oertley Storm Drain, Facility No. C05, P19, which drains approximately 625 acres (0.97 square miles). The remaining 25 acres (0.04 square miles) drain directly to the Basin.

2.2 Study Authority

The study was authorized by a resolution adopted by the House of Representatives Committee on Public Works, dated 08 May 1964, which reads as follows:

> "*Resolution by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports on (a) San Gabriel River and Tributaries, published as House Document No. 838, 76th Congress, 3d Session; (b) Santa Ana River and Tributaries, published as House Document No. 135, 81st Congress, 1st Session; and (c) the project authorized by the Flood Control Act of 1936 for the protection of the metropolitan area in Orange County, with a view to determining the advisability of modification of the authorized projects in the interest of flood control and related purposes.*"

2.3 Previous Reports

Many federal and non-federal studies have been conducted pertaining to water and related land resources within the study area. The Army Corps of Engineers has conducted the following associated studies in the Westminster watershed Orange County and vicinity:

- Derivation of a Rainfall-Runoff Model to Compute N-year Floods for Orange County Watersheds. USACE – Los Angeles District and Orange County Flood Control District, November 1987.
- Hydraulics Appendix, San Diego Creek Watershed Management Study, F3 Feasibility Phase, USACE – Los Angeles District, August 2001.
- Hydrology Documentation for Feasibility Study, Santa Ana River Basin and Orange County, Interim 3, East Garden Grove – Wintersburg Channel, U.S. Army Corps of Engineers, Los Angeles District, September 1988.
- Santa Ana River Basin and Orange County, Final Feasibility Report, USACE – Los Angeles District, July 1992.

Other Federal Agencies have conducted the following studies in the Westminster watershed and vicinity:

- Orange County Flood Insurance Study, Volume 1-4, & Flood Insurance Rate Maps. FEMA, November 1993.
- Orange County Soil Survey. U.S. Department of Agriculture, Soil Conservation Service, September 1978.

Private Consultants and local government agencies have conducted the following studies in the Westminster watershed and vicinity:

- Consolidated Report, FEMA Submittals Detailed Flood Insurance Study, Shea Homes Parkside Estates Tentative Tract Nos. 15377 & 15419, Expanded Watershed Analysis of East Garden Grove-Wintersburg Channel Watershed from Tide Gates to I-405 Freeway, Exponent, August, 2002.
- Hydrology Report No. C04-4, Westminster Channel Entire Drainage System Hydrology, Public Facility & Resources Department, County of Orange, December 2002.
- Hydrology Report No. C01-3, Hydrology Report for Los Alamitos Channel from Rossmoor Retarding Basin Outlet to Los Alamitos Retarding Basin, Public Facilities & Resources Department, County of Orange, July 2002.
- Approximate 100-year Floodplain Delineation Study Report, East Garden Grove-Wintersburg Channel (C05) / Ocean View Channel (C06) and Laterals, Agreement No. D97-043, Work Order No. 5, West Consultants, Inc., February 2000.
- Hydrology Documentation, San Juan Creek Watershed Management Study, F3 Feasibility Phase Appendices, Simons, Li & Associates, Inc., July 1999.
- Hydrology Report No. C05-13S, Hydrology Study for the Floodplain Analysis of East Garden Grove-Wintersburg Channel System Facility No. C05 Entire Drainage System, Public Facilities & Resources Department, County of Orange, December 1999.
- Hydrology Report No. C01-2, Hydrology Report of Entire Drainage System of the Los Alamitos Channel Facility No. C01, Public Facilities & Resources Department, County of Orange, June 1998.

- Hydrology Report No. C02-3A, Bolsa Chica Channel Facility No. C02 San Diego Freeway to Holland Avenue, Environmental Management Agency, County of Orange, June 1998.
- Project Report for East Garden Grove – Winterburg (C05) and Oceanview (C06) Channels, Williamson & Schmid, December 1994.
- Hydraulic Evaluation of the East Garden Grove Wintersburg (C05) Channel Outlet, Supplement to the East Garden Grove Wintersburg (C05) and Oceanview (C06) Channels Project Report, Williamson & Schmid, June 1993.
- Hydrology Report for East Garden Grove – Wintersgurg Channel (Facility No. C05) (Bolsa Chica Bay to Vermont Avenue), Environmental Management Agency, County of Orange, July 1990.
- Hydrology Report No. C06-2, Hydrology Report, Ocean View Channel, Facility No. C06 Entire Drainage System, Environmental Management Agency, County of Orange, November 1989.
- Hydrology Report No. C03-4, Hydrology Report Anaheim-Harbor City Channel, Facility No. C03 Entire Drainage System, Flood Program Division, Public Works Department, County of Orange, September 1986.
- Hydrology Report No. C02-3, Hydrology Report Bolsa Chica Channel Facility No. C02 Upstream of Huntley Avenue Including Tributary Facility Numbers C02S01, C02S03, C02P03, and C02P07, Orange County Environmental Management Agency, County of Orange, May 1978.
- Model Documentation for C02-C04, TetraTech, April 2018.
- Model Documentation for C05-C06, TetraTech, March 2018.

2.4 Present and Future Conditions

The Westminster Watershed is a highly developed and urbanized area and the watershed is not expected to change significantly in the foreseeable future. Therefore, the present and the future conditions are the same. This assumption will be used for both hydrologic and hydraulic analyses. The effects of sea level change are described later in the report.

3.0 Data Collection

3.1 Topographic Data

Digital topographic data were obtained from Orange County. The topographic data were collected during December 17, 2011 to February 9, 2012 by USGS and processed through the Digital Elevation Model (DEM) unto digital topographic data set. The DEM data set has horizontal datum in the CCS83, Zone VI (US Feet) and has vertical datum in NAVD 88 (US Feet).

3.2 As-Built Drawings

Most of the channels as-built drawings are based on NGVD 29 datum except as-built drawing C05-501-1A on C05 in the vicinity of Garden Grove Freeway which is based on NAVD 88 datum. Many of the drawings were dated earlier than 1980 and associated benchmarks are no longer in existence, therefore, current Orange County benchmarks are used in computing an average vertical datum adjustment. There are total of 35 benchmarks used (8 in the vicinity of C06, 9 in the vicinity of C05 below C06, and 18 in the vicinity of C05 above C06) and results in an average vertical datum adjustment value of 2.42 feet (i.e., NAVD 88 elevation = NGVD 29 elevation + 2.42').

3.3 Field Investigation

The USACE performed site visits were conducted in June 2005 as part of the previously conducted sedimentation analysis sampling. Subsequent visits were conducted on 13 and 22 August 2012 to verify channel improvements and structural dimensions used the hydraulic analysis and models. Personnel who attended were Van Crisostomo, Mylene Perry, and Simon Evans from the Hydraulics Section; Scott Sanderson from Planning Division (Los Angeles District); and Justin Golliher from OCFCD. The drainage systems are further broken down into Reaches, which are described later in this Appendix.

3.4 Sediment Samples

Sediment Samples were collected in June 2005 along C05 and C06. A total of 21 samples were collected. Among these samples, eleven samples were taken from the streambed and ten samples were taken from the stream bank. Samples were taken from approximately the top one foot of the bed layer. There is a small percentage of gravel and cobles in the EGGW Channel (C05) and Oceanview Channel (C06). Most of the samples consist of different grades of sand and silt.

3.5 Westminster Planning Charette

The Project Delivery Team (PDT) met on 22 September 2014 for a one day plan formulation charette workshop that was held in Los Angeles, California. The primary purpose of the charette was to use this collaborative process to expedite plan formulation for the preliminary array of alternatives. The intent of the charette was to formulate alternatives and identify study objectives as well as address problems, opportunities, and constraints. Participants in the charette workshop included representatives from the USACE and the OCFCD.

4.0 Datum and Tidal Information

4.1 Downstream Water Levels

Both C05 and C02/C04 outlet to Huntington Harbour, which is connected to Anaheim Bay. Water surface elevations in the leveed reaches of C02/C04 and C05 are impacted by downstream water surface elevations during rainfall events, and water levels are influenced by both tidal and non-tidal residual. Non-tidal residual has the potential to increase downstream water surface elevation due to wind setup and atmospheric pressure. These factors, along with the astronomical tide, determine the total water surface elevation downstream of project area.

4.1.1 Tidal Influence

The National Oceanic and Atmospheric Agency (NOAA) operates a tide gage (Los Angeles, CA - Station ID: 9410660) approximately 10 miles northwest of the Anaheim Bay. This tide gage is the closest to the project, and had been operated since 1923. Figure 1 displays the duration curve for the gage based on the 96 year period of record. Figure 2 displays the tidal datums and extreme water levels for the gage.

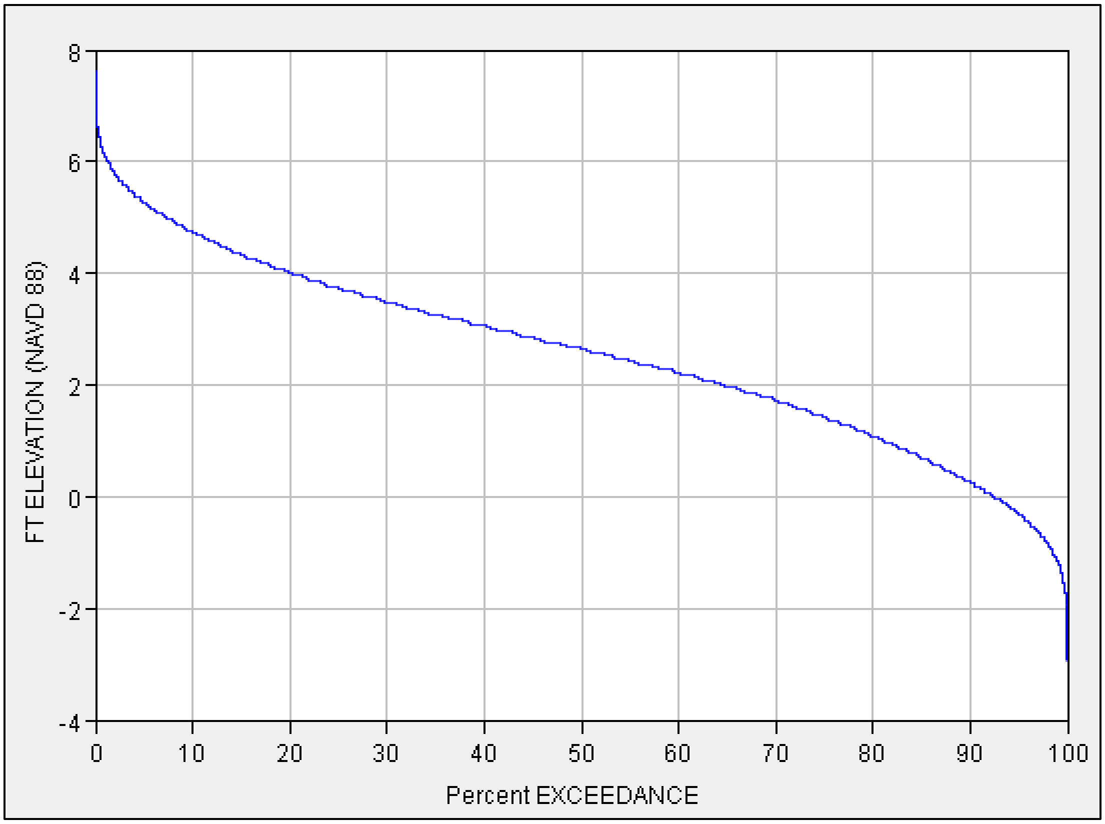

Figure 1: Elevation (NAVD 88) duration curve for Los Angeles, CA - Station ID: 9410660

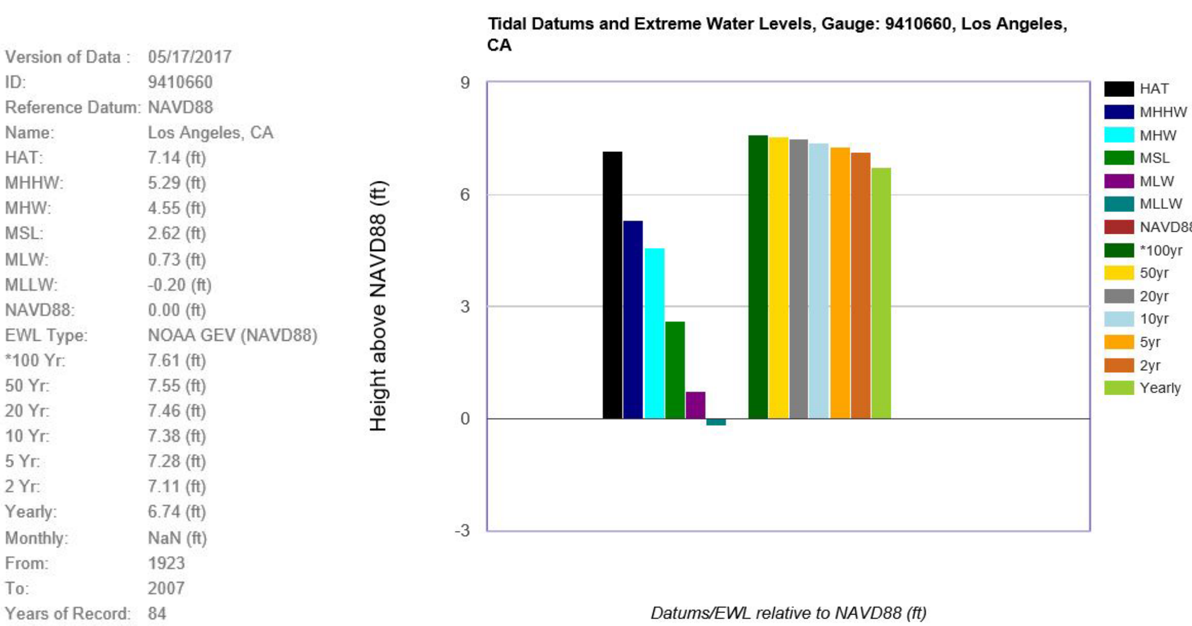

Figure 2. Tidal datums and extreme water for Los Angeles, CA - Station ID: 9410660

4.1.2 Non-Tidal Residual

The Environmental Impact Statement for the Bolsa Chica Wetland Restoration Project references a previous study conducted by TetraTech (1984) that looked at the correlation between riverine storm intensity and wave setup during a storm. The results showed no correlation between storm intensity and storm setup. The average wave setup, hindcasted from wind data for the six most severe storms in Orange County from 1932 to 1983, was estimated to be approximately 0.7 ft. Since this analysis is based on records more than 35 years old, an additional analysis was performed on the tidal record through 2018. One-hour data for both predicted and observed water level for Station 9410660 was used to calculate the non-tidal residual. A frequency analysis was performed on the annual maximum non-tidal residual for the full period of record (Figure 3).

According to the updated frequency analysis, the average non-tidal residual estimated from the 1984 study closely matches the 50% AEP non-tidal residual.

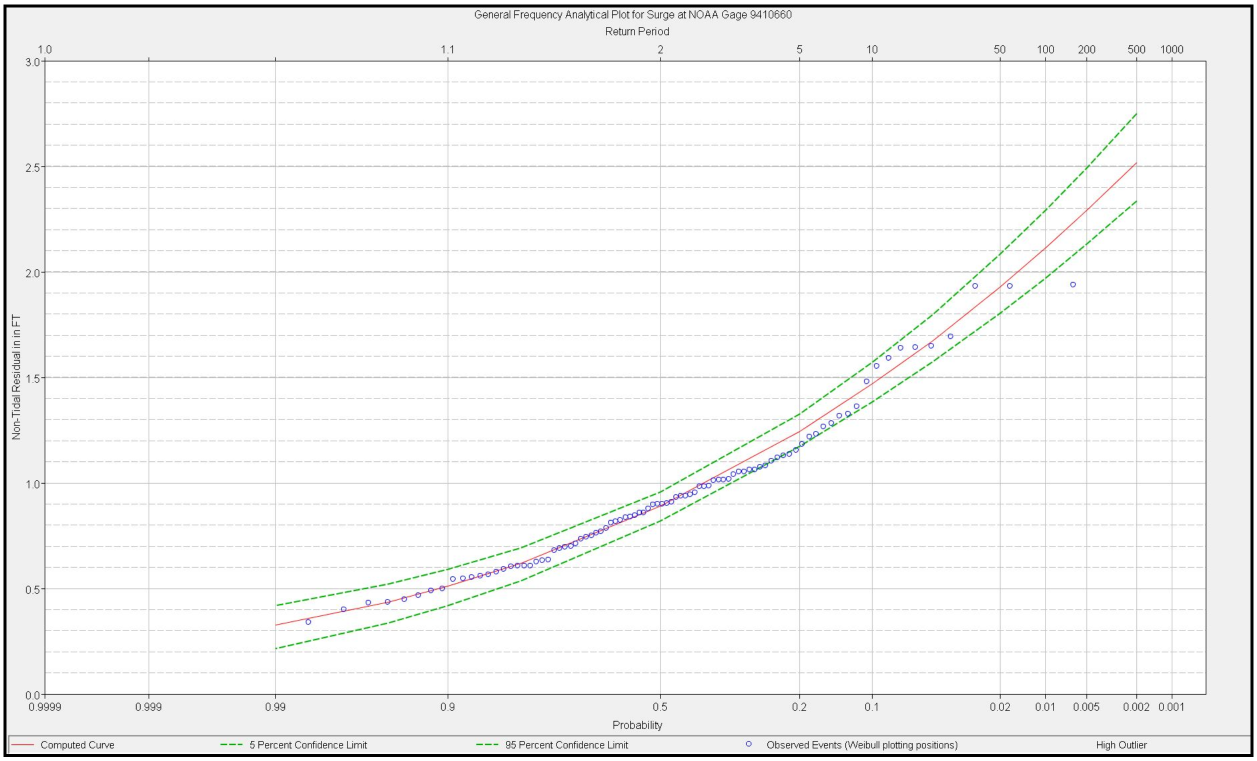

Figure 3. Non-tidal residual frequency analysis for Los Angeles, CA - Station ID: 9410660

5.0 Existing Conditions

5.1 Westminster Watershed

The Westminster Study Area, consisting of the C02, C04, C05, and C06 Channels, lay within the historic overflow path of the Santa Ana River, which flowed through the downtown Anaheim area prior to the 1918 diversion of the Santa Ana River into its present alignment. Since the diversion of the Santa Ana River, the C02, C04, C05, and C06 Channels have served as local drainage facilities. These facilities have been improved at various locations on multiple occasions to account for development within the watershed. Downstream reaches of C02 and C05 are also affected by ocean backwater. Refer to Plates 62 and 63 for bathtub inundation for these systems.

5.1.1 Flood History

Significant regional storm events or floods have occurred over the last 175 years: 1825, 1862, 1884, 1891, 1916, 1927, 1938 (largest storm of record), 1941, 1969, 1974, 1978, 1980, 1983, 1993, 1995, 2010, and 2017. The historical storm seasons have consisted of nearly continuous periods of moderate to high intensity rainfall ranging from a few days to several weeks and have extended inland as far as the San Bernardino Mountains. Long duration storm events, covering large geographical areas are a threat to large drainage basins such as the Santa Ana River, but do not generally overburden local drainage facilities such as C02, C04, C05, and C06.

The major threat to local facilities, such as C02, C04, C05, and C06, are short duration high intensity storm events. Two storms of this type occurred in Orange County in 1974 and 1983. The storms of 04 December 1974 and 01 March 1983 were short duration, high intensity storms producing intense rainfall in excess of 1% AEP depths for several durations. Both flood events resulted in overflow from the C05 Channel at Golden West Street (upstream of Woodruff Street) and immediately upstream of the I-405. The 1974 storm also caused flooding on the C05 Channel near Bushard Street and on the C06 Channel immediately upstream of the 1-405 Freeway.

Additional, historic flooding events along the C02, C04, C05, and C06 have also occurred and been documented by Orange County in recent years. The floodplain mapping results were compared to these historic flooding events; however, associated discharges and frequencies are not available.

- Flooding at Goldenwest in 1974, 1983, 1993, and 1995 on C05
- Flooding at Euclid Street in 1986, 1992, and 2010 on C05
- Flooding at Haster Basin in 1986 and 1995
- Flooding between Newland Street and Magnolia Street in 1992 on C05
- Flooding between Lapson Avenue and Chapman Avenue in 1992
- Flooding at 1st Street in 1992 and 1995 on C05
- Flooding at Graham Street in 1993 on C05
    - Flooding at Warner Avenue, Springdale Street, Edwards Street, and downstream of
- Newland Street in 1995 on C05
- Flooding between Magnolia Street and Bushard Street (dates not specified) on C06
- Flooding between Bushard Street and Brookhurst Street (dates not specified) on C06
- Flooding between Euclid Street and Newhope Street in 2010 and other dates not specified on C06
- Flooding downstream of Valley View Street in 2010 and other dates not specified on C02
- Flooding at Beach Boulevard in 2010 and other dates not specified on C04

5.1.2 Floodplain Studies

The Westminster Study Area, consisting of the C02, C04, C05, and C06 Channels has been analyzed in multiple previous studies mentioned. Studies have included hydrologic, hydraulic, and sedimentation analysis, including floodplain studies. Detailed floodplain and flood insurance studies were conducted in 1993 and most recently in 2002 (FEMA August 2002).

FEMA's standards for certifying levees for 1% flood protection require that they have a minimum of 3 feet of freeboard.

The USACE process for the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) system evaluation is described in Engineering Circular (EC) 1110-2- 6067 (USACE 2010). The USACE probability of exceedance and uncertainty analysis procedure for proposed flood damage reduction plans is described in Chapters 4 and 5 of EM 1110-2-1619 (USACE 1996). Incised channels and those with levees require analysis to include the uncertainty in the discharge-probability function and in the stage discharge function. A Monte Carlo simulation in the USACE's Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) program was used to compute the uncertainty and assurance (conditional non exceedance probability {CNP}) of the incised channels, as well as the channels with levees, to reduce the flood risks from the 1% AEP (design discharge) (USACE 2010, 2008). Essentially, this means that levees and floodwalls must have a "conditional non-exceedance probability" (performance reliability) of 95%, with a minimum of 2 feet of residual bank height added to the computed water surface elevation using the median estimate of the 1% AEP. Assurance between 90 and 95% can be found in accordance with NFIP system evaluation requirements if it is at least the FEMA required residual bank height above the 1% AEP. Assurance less than 90% cannot be found in accordance with NFIP levee requirements (USACE 2010). Freeboard and performance requirements are considered preliminary and refinements to meet specific performance criterion would be addressed later in the Pre-Construction Engineering and Design (PED).

5.1.3 Existing Levees

Levees are currently located on the downstream reaches of C02/C04 and C05. Specifically, unarmored earthen levees align both banks for Reaches 23 of C02 and the upstream extent of Reach 1 on C05. Reinforced sheet pile levees align a portion of both banks of Reach 1 downstream of Warner Avenue Bridge on C05. The sheet pile levees were constructed in 2014 by the Orange County Flood Control District (OCFCD).

The existing unarmored earthen levees are not certified FEMA levees and are not expected to safely convey the 1% AEP storm event flows. The reinforced sheet pile levees were designed to convey the 1% AEP storm event flows based upon FEMA certification and Orange County design criteria.

The levees on C02/C04 and C05 are affected by downstream water surface elevations during storm events, and water levels are influenced by both tidal and non-tidal residual. An evaluation of existing condition water surface profiles shows that the exceedance capacity of the leveed systems on both C02/C04 and C05 demonstrates that the upstream most overtopping sections are not highly sensitive to tidally influenced downstream boundary conditions under current sea level conditions. On the C02 system, the tidal influence diminishes near Bolsa Chica Road. On the C05 system, the tidal influence is limited to Golden West Street.

5.2 Channel Reaches

The Westminster Study Area, consisting of the C02, C04, C05, and C06 Channels is comprised of multiple subdivided reaches, which are characterized by the channel geometry (shape) and channel materials.

5.2.1 Reach 1

Reach 1 is located on C05 and extends from the tidal gate to Golden West Street, which corresponds with approximate HEC-RAS stations 5+75 to 165+23. Reach 1 from the tide gate to approximately 60 feet upstream of Warner is partially constructed double reinforced sheet pile levee. From approximately 60 feet upstream of Warner Avenue to approximately 1,300 feet upstream of Edwards Street the earthen levees parallel the trapezoidal earthen channel with a riprap right bank between Warner Avenue and Springdale Street. C05 consists of rectangular concrete channel from approximately 1,300 feet upstream of Edwards Street to Goldenwest Street.

5.2.2 Reach 2

Reach 2 is located on C05 and spans Goldenwest Street to the confluence with C06, which corresponds with approximate HEC-RAS stations 165+23 to 192+93. C05 is an incised rectangular concrete channel in Reach 2.

5.2.3 Reach 3

Reach 3 is located on C05 and spans from the confluence with C06 to the I-405, which corresponds with approximate HEC-RAS stations 192+93 to 254+30. The confluence to Beach Boulevard of Reach 3 is an incised trapezoidal riprap channel. Woodruff to the I-405 is an incised rectangular concrete channel.

5.2.4 Reach 4

Reach 4 is located on C05 and spans from the I-405 to Bushard Street, which corresponds with approximate HEC-RAS stations 254+30 to 313+22. Reach 4 is an incised rectangular concrete channel from the I-405 to Quartz Street, then transitions to an incised trapezoidal riprap channel from Quartz Street to Bushard Street.

5.2.5 Reach 5

Reach 5 is located on C05 and spans from Bushard Street to 5th Street, which corresponds with approximate HEC-RAS stations 313+22 to 432+63. Reach 5 is an incised trapezoidal riprap channel from Bushard Street to Brookhurst Street. C05 from the Brookhurst Street to approximately 1,300 feet upstream from Brookhurst Street is an incised trapezoidal concrete channel, which then transitions to an incised trapezoidal riprap until 5th Street.

5.2.6 Reach 6

Reach 6 is located on C05 and spans from 5th Street to Rosita Park, which corresponds with approximate HEC-RAS stations 432+63 to 446+00. Reach 6 is an incised trapezoidal concrete channel.

5.2.7 Reach 7

Reach 7 is located on C05 and spans from Rosita Park to Hazard Avenue, which corresponds with approximate HEC-RAS stations 446+00 to 456+05. Reach 7 is a concrete conduit.

5.2.8 Reach 8

Reach 8 is located on C05 and spans from Hazard Avenue to the extension of Woodbury Road, which corresponds with approximate HEC-RAS stations 456+05 to 503+00. Reach 8 is an incised trapezoidal concrete channel.

5.2.9 Reach 9

Reach 9 is located on C05 and spans from the extension of Woodbury Road to Garden Grove Boulevard, which corresponds with approximate HEC-RAS stations 503+00 to 563+36. Reach 9 is an incised trapezoidal concrete channel.

5.2.10 Reach 10

Reach 10 is located on C05 and spans from Garden Grove Boulevard to Haster Basin, which corresponds with approximate HEC-RAS stations 563+36 to 578+49. Between Apenwood and Haster Basin, the channel is an incised rectangular concrete channel. The remaining section consisting of a single 11-foot wide by 6-foot tall reinforced concrete box.

5.2.11 Reach 11

Reach 11 is located on C05 and spans from Haster Basin to Twintree Circle, which corresponds with approximate HEC-RAS stations 596+61 to 608+22. Reach 11 is a covered concrete conduit, consisting of 9-foot wide by 6-foot tall reinforced concrete boxes.

5.2.12 Reach 12

Reach 12 is located on C05 and spans from Twintree Circle to Chapman Avenue, which corresponds with approximate HEC-RAS stations 608+22 to 622+76. Reach 12 is an incised trapezoidal concrete channel for approximately 1,400 feet upstream of Twintree Circle until transitioning to a covered concrete conduit for approximately 1,000 feet. The covered concrete conduit from 1,400 feet upstream of Twintree Circle to Chapman Avenue is not within the study area; therefore, it is not included in the modeling or analysis.

5.2.13 Reach 13

Reach 13 is located on C06 and spans from the confluence with C05 to Ross Lane, which corresponds with approximate HEC-RAS stations 2+30 to 68+98. Reach 13 is an incised rectangular concrete channel at the confluence with C05. The section is currently being repaired under the PL 84-99 program. Above the confluence with C05 to Beach Boulevard, C06 is an incised earthen trapezoidal channel. C06 is an incised trapezoidal channel with earthen invert and riprap side slopes from Beach Boulevard to Ross Lane.

5.2.14 Reach 14

Reach 14 is located on C06 and spans from Ross Lane to Riverbend Drive, which corresponds with approximate HEC-RAS stations 68+98 to 76+67. Reach 14 is an incised rectangular concrete channel.

5.2.15 Reach 15

Reach 15 is located on C06 and spans from Riverbend Drive to the I-405, which corresponds with approximate HEC-RAS stations 76+67 to 93+26. Reach 15 is a covered concrete conduit, consisting of two 11 feet wide by 9 feet tall reinforced concrete boxes.

5.2.16 Reach 16

Reach 16 is located on C06 and spans from the I-405 to Bushard Street, which corresponds with approximate HEC-RAS stations 93+26 to 113+84. Reach 16 is an incised rectangular concrete channel.

5.2.17 Reach 17

Reach 17 is located on C06 and spans from Bushard Street to Brookhurst Street, which corresponds with approximate HEC-RAS stations 113+84 to 140+28. Reach 17 is an incised trapezoidal channel with an earthen invert and riprap side slopes from Bushard Street to Tahoma Street. Upstream of Tahoma Street to Brookhurst Street the C06 channel transitions to an incised earthen trapezoidal configuration.

5.2.18 Reach 18

Reach 18 is located on C06 and spans from Brookhurst Street to Euclid Street through Mile Square Regional Park. Reach 18 corresponds with approximate HEC-RAS stations 140+28 to 193+74. Reach 18 is an incised trapezoidal channel with a concrete low-flow invert and earthen (grass) side slopes.

5.2.19 Reach 19

Reach 19 is located on C06 and spans from Euclid Street to Newhope Avenue, which corresponds with approximate HEC-RAS stations 194+29 to 217+84. Reach 19 is an incised trapezoidal channel with an earthen invert and riprap side slopes.

5.2.20 Reach 20

Reach 20 is located on C04 and spans from the confluence with Bolsa Chica Channel (C02) to the I-405, which corresponds with approximate HEC-RAS stations 89+11 to 150+74. C04 from the confluence with C02 to Bolsa Chica Street is a trapezoidal channel with an earthen invert, riprap side slopes, and a levee on the left bank. C04 is an incised trapezoidal earthen channel with a riprap on the left bank side slope from Bolsa Chica Street to Graham Street. C04 is an incised trapezoidal earthen channel from Graham Street to the intersection of McFadden Avenue and Springdale Street. C04 from the McFadden Avenue and Springdale Street intersection to Edwards Street is an incised trapezoidal channel with earthen invert and riprap side slopes, with the exception of bridge and culvert crossing, as well as two ninety degree bends, which include concrete armoring. Reach 20 from Edwards Street to approximately 100 feet downstream of Goldenwest Street is covered concrete conduit, consisting of three 14-foot wide by 9.5-foot tall reinforced concrete boxes. Reach 20 transitions at approximately 100 feet downstream of Goldenwest Street from the concrete conduit to an incised rectangular concrete channel for approximately 100 feet, before transitioning again to a covered concrete conduit to the I-405.

5.2.21 Reach 21

Reach 21 is located on C04 from the I-405 to Beach Boulevard, which corresponds with approximate HEC-RAS stations 150+74 to 313+68. Reach 21 from I-405 to Hoover Street is an incised rectangular concrete channel, while from Hoover to Beach Boulevard the reach is an incised rectangular concrete channel, with a parallel covered concrete conduit, consisting of two 12-foot wide by 6-foot tall reinforced concrete boxes.

5.2.22 Reach 22

Reach 22 is located on C04 from Beach Boulevard to the Garden Grove Freeway (SR-22), which corresponds to approximate HEC-RAS stations 313+68 to 502+20. Reach 22 from Beach Boulevard to Brookhurst Street is an incised rectangular concrete channel. C04 is an incised trapezoidal channel with earthen invert and a riprap side slopes from Brookhurst Street to Westminster Avenue. C04 from Westminster Avenue to SR-22 is an incised trapezoidal concrete channel.

5.2.23 Reach 23

This reach is located between the NWSSB and Huntington Harbour, which corresponds with approximate HEC-RAS stations 0+13 to 89+11. Reach 23 is earthen trapezoidal channel with earthen levees on both banks.

5.3 Haster Basin

Haster Basin is a multi-use 21.5-acre site owned and operated by the Orange County Flood Control District in the City of Garden Grove. The basin and pump station project was initially built in 1976 to reduce flood risk and provide recreation. In 2013 Haster Basin, which is also known as Twin Lakes Freedom Park, was improved to maximize available right of way for additional flood control capacity, deepened by 4 feet for water quality purposes, and updated recreational features to include a 4,000-foot long perimeter road around the basin, a decomposed granite jogging trail, a park plaza with 12 game tables, 11 exercise stations, and two large steel gazebos with cantilevered decks.

Haster Basin is designed to accept runoff equivalent to the 100-year (1% AEP) storm event, where the basin and pump station work in tandem. The pump station ensures that sufficient volume is available in the basin to accommodate the peak of the storm, while discharging flows to accommodate downstream channel constraints. Specifically, the basin is designed to receive the 100-year (1% AEP) discharge with a maximum outflow of 459 cfs.

The Haster Basin improvements are incorporated into the existing condition floodplains. Significant differences in the previously generated floodplains and those which were developed for this study are largely contributed to the increased available storage volume and improved operations of the basin.

5.4 Mile Square Park

Mile Square Park is owned and primarily operated by Orange County. The park consists of three golf courses, three soccer fields, three baseball and three softball diamonds, an archery range, and a nature area. In addition, there are two fishing lakes, concession operated bike and paddle boat operations, a wide expanse of picnic areas, and numerous picnic shelters.

Approximately 65 acres of the land located adjacent to Brookhurst Street is leased by the City of Fountain Valley for recreational purposes. This land has been developed by the city into a high-activity community park, including a community center building, ball diamonds, basketball courts, outdoor play areas, and a tennis court complex.

The C06 channel runs east to west along the southern portion of Mile Square Park, bisecting the park with a grass side slopes and concrete invert lined channel. C06 floods frequently, which results in inundation of Mile Square Park immediately adjacent to the channel. The Mile Square Park existing condition does not formerly function as a storage location for flood risk management; however, the site was considered for a potential storage location for this study.

5.5 Outer Bolsa Bay

Outer Bolsa Bay is an environmentally sensitive area that is located at the downstream extent (mouth) of the C05 channel system. Water exchange between the C05 channel and the bay is controlled by tide gates. Outer Bolsa Bay is connected to Inner Bolsa Bay and the Muted Tidal Pocket by separate tide gates. These tide gates allow water to flow from Outer Bolsa Bay into either Inner Bolsa Bay or the Muted Tidal Pocket. Water is discharged from Outer Bolsa Bay through the Warner Ave Bridge into Huntington Harbour. Outer Bolsa Bay is separated from the Pacific Ocean by Pacific Coast Highway and Bolsa Chica State Beach.

Analysis addressing improvements at the downstream extent of the C05 channel and Outer Bolsa Bay was conducted by or prepared for Orange County in the early 1990's. This analysis was documented in three reports published in the 1993 – 1994 timeframe, while a fourth draft report was produced in 2009 to summarize the findings and cumulative impacts. The findings of these reports concluded that in order for the 100-year (1% AEP) storm flows to safely exit the C05 channel system and discharge into Outer Bolsa Bay and Huntington Harbour without impacts and without damaging infrastructure, the tide gates, Pacific Coast Highway, and Warner Avenue Bridge must be modified. Modeling performed for this study also demonstrates that channel improvements on C05 will increase downstream discharges, and if improvements are not made to increase conveyance through the Warner Avenue Bridge opening, increased flooding will occur in Outer Bolsa Bay, Warner Avenue, and the Pacific Coast Highway.

5.6 Tides Gates

Tide gates are currently located on the downstream end of C05 just upstream of Outer Bolsa Bay. The tide gates currently consist of 12-5 foot diameter gated culverts that allow the conveyance of stormwater from the C05 system into Outer Bolsa Bay. Flap gates originally installed on the downstream end of culvert system prevented saltwater from moving upstream past the tide gates, but since some of the flap gates have failed and flow can be observed moving upstream past the flap gates during high tide.

Model studies conducted by other prior studies identified the hydraulic capacity of the existing tide gates as inadequate for conveyance of the stormwater from the proposed project improvements. Hydraulic modeling performed for this study confirmed the results of previous hydraulic modeling efforts. Increased head losses across the tides due to upstream channel improvements raises stages in the downstream leveed reach of C05 (Reach 5). Without replacing or removing the existing tide gates, higher head losses and increased water surface elevations in Reach 1 would require increased levee elevations or increased risk of overtopping. Both the replacement (larger culverts and flap gates) and removal of the existing tide gates were considered in this study to reduce head losses and reduce upstream water surface elevations in Reach 1 of C05.

6.0 Plan Formulation

Prior to the Corps of Engineers participation in this study, prior study efforts (Section 2.3) investigated alternatives for reducing flood damages. Below is a summary of alternatives considered as part of this study.

6.1 Tunnel Alternative

Consideration of a tunnel alternative was not part of any previous studies, but the Corps of Engineers – Chicago District investigated the potential for using a tunnel and drop shafts to convey storm water to an ocean outlet. Since features would be subsurface, this alternative offered the benefit of reducing flood damages without requiring limited real estate. It also had the potential to achieve project benefits without traffic delays due to construction. Hydraulic modeling was performed to estimate the tunnel size and develop cost estimates. The alternative was screened out due to cost. One of the limitations identified in the screening process was the inability to reduce flood risk in the lower leveed reaches of C02 and C05, where substantial flood damages exist. Since a gravity tunnel system is affected by downstream water levels, the tunnel size would need to be prohibitively large to reduce flood damages in the downstream leveed reaches.

6.2 National Economic Development (NED) Alternative

Consistent with the formulation strategy to "focus on improving channel conveyance," this alternative would reduce flood risk within the watershed by improving conveyance efficiency of existing channels. Trapezoidal channels within C04, C05, and C06 that currently have an earthen bottom and either earthen or riprap banks would be lined with concrete. There would be no alteration to reaches that are rectangular in shape or lined with concrete, nor to reaches of covered concrete conduit structures.

The leveed areas in the downstream reaches C05 would be improved to reduce the risk of levee failure. Improvements in these reaches would include installation of steel sheet pile channel walls and preservation of existing soft bottom, tidally-influenced habitat. On the leveed lower reach of C02, flood damages are not sufficient to support an expanded channel section. Instead, sheet pile will be drive in the existing leveed section and tied back upstream to reduce the probability of overtopping. The sheet pile will reduce the probability of failure if overtopped, and increase the resilience of the system, while preserving existing soft bottom, tidally-influenced habitat. Removal of earthen channel sections would also improve the resilience of the system by reducing the probability of debris induced blockages.

Additional downstream measures would be combined with the in-channel measures to address existing flooding in Outer Bolsa Bay and to account for increased flow volumes that result from increased conveyance capacity in the channels. The tide gates on C05 would be replaced with an access bridge in order to improve the flow conditions through the lower reaches of the C05 channel.

This alternative also includes the widening of the Outer Bolsa Bay channel just upstream of the Warner Avenue Bridge. Widening of the channel would require that the Warner Avenue Bridge and the pedestrian bridge at the Bolsa Chica Conservancy be widened as well. Widening of the Outer Bolsa Bay channel would improve conveyance as well as the hydraulic efficiency of the lower reaches of C05.

The channel conveyance improvements in this alternative reduce overbank flooding but also increases flow rates in Outer Bolsa Bay between the tide gates and the Warner Avenue Bridge.

Compatible nonstructural measures would be incorporated to lessen the life safety risk associated with flooding in the project area. Compatible nonstructural measures that were considered in the development of this alternative include development of a flood warning system and removal of impediments to flow.

If future rainfall patterns result in more frequent, higher rainfall totals, adaptive management strategies for this alternative could involve future expansion of the channel cross-section in select locations to reduce water surface elevations, expanding the channel cross-section on the downstream end of C02 (not currently economically justified) or raising the floodwall sections on the downstream reach of C05 in response to sea level change.

6.3 Locally Preferred Plan (LPP)

Consistent with the formulation strategies to "focus on improving channel conveyance" and "focus on improving channel capacity," this alternative will reduce flood risk within the watershed by improving both conveyance efficiency and capacity of existing channels. Trapezoidal channels within C02, C04, C05, and C06 will be replaced with rectangular concrete (or steel sheet pile) channels to contain a 1% AEP storm event.

Additionally, floodwalls would be constructed in the existing channel right of way where necessary. Soft channel bottoms would be preserved in the tidally influenced downstream reaches of C02 and C05 to avoid impacts to marine habitat.

Additional downstream measures would be combined with the in-channel measures to address existing flooding in Outer Bolsa Bay and to account for increased flow volumes that result from the improved conveyance capacity in the channels. The tide gates on C05 would be replaced with an access bridge in order to improve the flow conditions through the lower reaches of the C05 channel. The current tide gates leak and therefore allow saltwater to intrude upstream in C05. This saltwater influence extends upstream of Outer Bolsa Bay for approximately 2.5 miles. The replacement of the tide gates as part of this alternative would be configured to allow for continued tidal influence in the lower reaches of C05, thus lessening impacts to the existing ecological conditions. Removal of earthen channel sections would also improve the resilience of the system by reducing the probability of debris induced blockages.

This alternative also includes the widening of the Outer Bolsa Bay channel just upstream of the Warner Avenue Bridge. Widening of the channel would require that the Warner Avenue Bridge and the pedestrian bridge at the Bolsa Chica Conservancy be widened as well. Widening of the Outer Bolsa Bay channel would improve conveyance as well as the hydraulic efficiency of the lower reaches of C05.

Compatible nonstructural measures would be incorporated to lessen the life safety risk associated with flooding in the project area. Compatible nonstructural measures that were considered in the development of this alternative include development of a flood warning system and removal of impediments to flow.

While this alternative maximized the use of existing real estate, some reaches retain access roads adjacent to channel. If future rainfall patterns result in more frequent, higher rainfall totals, adaptive management strategies for this alternative could involve expansion of the channel in these locations, or raising the floodwall sections on the downstream reaches of C02 and C05 in response to sea level change.

7.0 Hydrology

Detailed hydrologic analysis for the study area including flood frequency analysis, rainfall runoff model development, and discharge-frequency calculations are presented in the F3 Hydrology Appendix (USACE 2007). The follow sections provide a summary of the methods used for the hydrology development.

Three rainfall-runoff models using the HEC-1 program were developed for the study. One model was developed for the C05 and C06 drainage area. The other two models were developed for C04 and C02 respectively. The major elements in the rainfall-runoff model development include watershed characteristics, basin "n" values, base flow, rainfall data, soil loss rate, S-graph, channel routing, detention basin routing, and model calibration.

7.1 Present and Future Condition

Since the Westminster Watershed is highly developed and urbanized, the watershed is not expected to significantly change in the foreseeable future. No modifications were to land cover or the hydrology to represent a future condition.

7.2 Description of Drainage Area

The East Garden Grove-Wintersburg Channel sub-watershed lies on a flat coastal plain surrounded generally by the Santa Ana River to the east, the Talbert Valley watershed and the Pacific Ocean to the south, and the Bolsa Chica Flood Control Channel sub-watershed to the west and north. The watershed is drained by the manmade channel system consisting of Orange County drainage facilities EGGW Channel (C05), Oceanview Channel (C06), Slater Channel (C05S04) and pump station, and storm drains. These facilities collect storm runoff from a 28.0 square drainage area consisting of portions of the cities of Santa Ana, Orange, Garden Grove, Anaheim, Westminster, Fountain Valley, and Huntington Beach. The channel mouth ends at the Bolsa Bay/Huntington Harbour in the city of Huntington Beach. Flow from Bolsa Bay/Huntington Harbour enters into the Pacific Ocean at the border of Sunset Beach and Seal Beach.

Of the 28.0 square drainage area, 5.1 square miles are tributary to Oceanview Channel and 3.9 square miles are tributary to Slater Channel. Elevations in the EGGW watershed range from 175 feet at the upper end of the basin to sea level at the Bolsa Bay, with an average basin slope of 2 feet per 1000 feet (12 ft/mi). Elevations in the Oceanview drainage area range from 64 feet at the upper end to 23 feet at the confluence with EGGW Channel, with an average basin slope of 1.5 feet per 1000 feet (8 ft/mi). Elevations in the Slater Channel drainage area range from 110 feet in the southern portion to sea level near the pump station, with an average basin slope of 6 feet per 1000 feet (33 ft/mi).

The drainage area for the Westminster Channel (C04) is approximately 10.9 square miles and is located in the Cities of Garden Grove, Huntington Beach, Santa Ana and Westminster. The topography of the land is relatively flat but slopes gradually in a southwesterly direction. Ground surface elevations vary from 10 feet at the Bolsa Chica Channel to 107 feet at the intersection of Chapman Avenue and 9th street giving the area an average slope of 2.4 feet per 1,000 feet (13 ft/mi). The drainage area is assumed to be completely developed. Land use includes 37% single family dwellings, 36% commercial/industrial, and the remainder consists of apartments, condominiums, schools, public parks and mobile home parks.

The drainage area for the Bolsa Chica Channel (C02) consists of approximately 36.4 mi^2 and includes portions of the cities of Anaheim, Cypress, Garden Grove, Los Alamitos, Stanton and unincorporated county territory. The topography is relatively flat. Elevations in the area vary from 91 feet at the intersection of Ball Road and Gilbert Street, to 15 feet at the San Diego Freeway, with an average slope of 1.8 feet per thousand feet. The hydrologic soil groups include A, B, and C. The land use is predominately residential and commercial.

7.2.1 Soils

The Soil Conservation Service (SCS) classifies soils into four hydrologic soil groups based on their infiltration characteristics and runoff potential. The description and characteristics are summarized in the Table 1. According to this classification, soil groups C and D will produce more runoff volume and higher peak flow than soil groups A and B, under a given rainfall condition.

The Westminster watershed is mostly comprised of the Hueneme-Bolsa Association: nearly level, poorly drained, calcareous fine sandy loams, silt loams and silty clay loams (hydrologic soil groups B and C). The upper portion of the watershed is mainly the Metz-San Emigdio Association: nearly level, well drained sandy loams (hydrologic soil groups A and B). Part of the area that is tributary to the Slater Channel is made up of the Myford Association: moderately steep, well drained sandy loam (hydrologic soil group D). The outlet of the watershed at the ocean comprises the Chino-Omni association: level, poorly drained silt loams to clays (hydrologic soil groups C and D).

Table 1. Hydrologic Soil Groups and Their Characteristics

Group	Infiltration Rate (in/hr)	Runoff Potential	Soil Components and Characteristics
A	High (> 2.5)	Low	Deep, well-drained sands or gravels.
B	Moderate (1.25 – 2.5)	Moderately low	Moderately deep & moderately well drained sandy-loam with moderately fine to coarse textures.
C	Moderate Low (0.4 – 1.25)	Moderate	Silty-loam soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture.
D	Low (0.2 – 0.4)	High	Clay soil with high swelling potential, soils with permanent high water table, soils with a clay pan or clay layer at or near the surface, or shallow soils over nearly impervious material

7.3 Land Use

Current land use consists of a mix of residential, schools, businesses and a few parks and golf courses. Commercial uses such as retail and office buildings are scattered throughout almost the entire channel system. Industrial uses include warehouses and distribution centers. Open space along the study channel system consists mainly of parks and a golf course, but open space comprises a very small percentage of the study area. Impervious cover (streets and roofs) is estimate to cover approximately 70% of the study area. Open land consists of scattered parks and golf courses. There is currently no plan to convert these remaining open areas into development.

Since the study area is nearly fully developed and highly impervious, the existing hydrologic condition was assumed represent the future without project condition and future with project condition.

7.4 Meteorology and Runoff

In general, the area has a mild Mediterranean type climate characterized by warm, dry summers and cool wet winters. Three types of storms produce precipitation in the area: general winter storms, general summer storms resulting from dissipating tropical cyclones, and thunderstorms. Due to climatic and drainage area characteristics, little stream flow occurs except during and immediately following rains, and runoff increases rapidly in response to rainfall excess. The main flood season is from November to April. The storms occurring during these months can last for several days, are widespread, and produce the largest floods. However, local thunderstorms may occur at any time of the year. Dry season without rain for several months during the summer is quite common. The average annual precipitation is about 13 inches near the coast.

7.5 HEC-1 Rainfall / Runoff Model Development

The major elements in the rainfall-runoff model development include watershed characteristics, basin "n" values, base flow, rainfall data, soil loss rate, S-graph, channel routing, detention basin routing, and model calibration.

7.5.1 Meteorology and Runoff

Watershed characteristics can be represented by the delineation of sub-basins and streams. Both the EGGW Channel sub-watershed and the Westminster Channel sub-watershed are located in a developed coastal area. The watershed area lies on a flat alluvial fan. Figure 1 is the drainage boundary for the C02, C04, C05 and C06 channel system. Each sub-watershed was delineated by length of the longest watercourse (L), length along longest watercourse from the outlet to the sub-basin centroid (L_{CA}), overall slope of longest watercourse between headwater and collection point (S), and basin roughness factor (n).

7.5.2 Basin "n"

Basin "n" is the basin roughness factor and is used to calculate the lag time. The basin "n" is estimated through field investigation of the watershed and following the guidelines described in Table 2. The estimated "n" is the initial basin "n" value used in the calibration process. The "n" value is one of the variables used to calibrate the different frequency floods. Tables 2, 3, 4 and 5 present the watershed characteristics for the study area including sub-watershed, drainage area, longest watercourse (L), length along longest watercourse from the outlet to the sub-basin centroid (L_{CA}), overall slope of longest watercourse between headwater and collection point (S), and basin roughness factor (n) for C05 & C06 drainage area, C04 drainage area, and C02 drainage area, respectively.

7.5.3 Base Flow

After model calibration runs, the base flow was adjusted to 0 cfs per square mile for the 100-year event since it did not have significant impact on peak discharge during the 100-year or greater frequency flood.

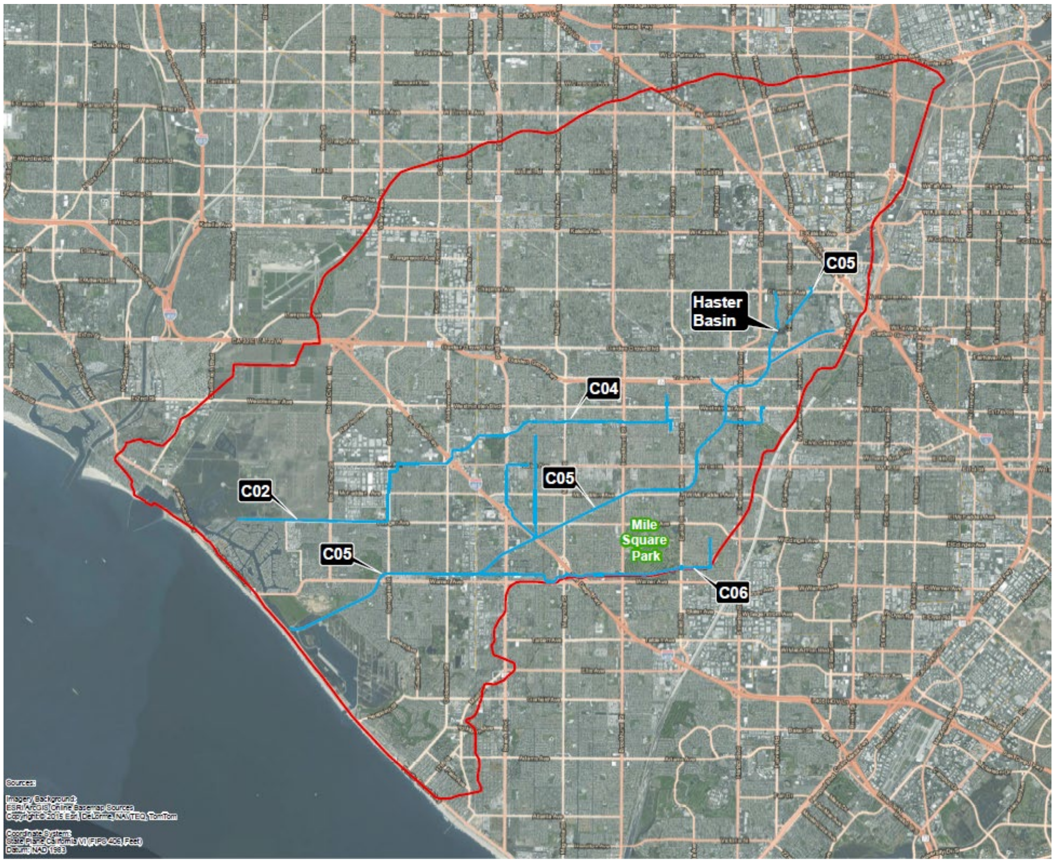

Figure 4: Drainage boundary for C04, C05 and C06

Table 2. Hydrologic Soil Groups and Their Characteristics

n = 0.015

1. Drainage area has fairly uniform, gentle slopes
2. Most watercourses either improved or along paved streets
3. Groundcover consists of some grasses - large % of area impervious
4. Main watercourse improved channel or conduit

n = 0.020

1. Drainage area has some graded and non-uniform, gentle slopes
2. Over half of the area watercourses are improved or paved streets
3. Groundcover consists of equal amount of grasses and impervious area
4. Main watercourse is partly-improved channel or conduit and partly greenbelt (see n = 0.025)

n = 0.025

1. Drainage area is generally rolling with gentle side slopes
2. Some drainage improvements in the area - street and canals
3. Groundcover consists mostly of scattered brush and grass and small % impervious
4. Main watercourse is straight channels which are turfed or with stony beds and weeds on earth bank (greenbelt type)

n = 0.030

1. Drainage area is generally rolling with rounded ridges and moderate side slopes
2. No drainage improvement exist in the area
3. Groundcover includes scattered brush and grasses
4. Watercourses meander in fairly straight, unimproved channels with some boulders and lodged debris

n = 0.040

1. Drainage area is composed of steep upper canyons with moderate slopes in lower canyons
2. No drainage improvements exist in the area
3. Groundcover is mixed brush and trees with grasses in lower canyons
4. Watercourses have moderate bends and are moderately impeded by boulders and debris with meandering courses

n = 0.050

1. Drainage area is quite rugged with sharp ridges and steep canyons
2. No drainage improvements exist in the area
3. Groundcover, excluding small areas of rock outcrops, includes many trees and considerable underbrush
4. Watercourses meander around sharp bends, over large boulders and considerable debris obstruction

n = 0.200

1. Drainage area has comparatively uniform slopes
2. No drainage improvements exist in the area
3. Groundcover consists of cultivated crops or substantial growths of grass and fairly dense small shrubs, cacti, or similar vegetation
4. Surface characteristics are such that channelization does not occur

Table 3. Watershed Characteristics of C05 / C06 Drainage Area

Subarea	Drainage Area (sq. mi.)	L (mi.)	Lca (mi.)	Representative Slope (ft./mi.)	Basin N
A1	1.867	3.552	1.776	17.589	.043
A2	0.977	2.379	1.190	12.156	.043
A3	0.625	1.805	0.902	13.804	.043
A4	0.65	1.849	0.925	2.973	.035
A5	0.18	0.836	0.418	19.15	.035
A6	2.436	4.188	2.094	10.816	.02
A7	0.106	0.602	0.301	8.309	.02
A8	0.555	1.677	0.838	14.308	.08
A9	0.542	1.653	0.826	7.259	.08
A10	0.291	1.125	0.562	8.005	.08
A11	1.308	2.850	1.425	10.000	.08
A12	0.803	2.108	1.054	9.963	.08
A13	0.238	0.993	0.497	4.030	.08
A14	0.806	2.112	1.056	14.440	.08
A15	0.522	1.615	0.807	10.218	.08
A16	0.494	1.560	0.780	5.125	.06
A17	2.077	3.794	1.897	6.588	.06
A18	0.609	1.776	0.888	7.319	.06
A19	1.645	3.285	1.642	7.611	.12
A20	0.745	2.012	1.006	6.461	.12
A21	0.719	1.968	0.984	5.589	.06
A22	4.228	5.890	2.945	14.261	.06
A23	0.316	1.184	0.592	43.935	.06
6A1	0.766	2.046	1.023	10.458	.04
6A2	0.172	0.812	0.406	28.324	.04
6A3	0.188	0.857	0.428	19.138	.04
6A4	0.484	1.542	0.771	20.239	.12
6A5	1.047	1.720	0.860	12.326	.11
6A6	0.188	0.857	0.428	20.072	.05
6A7	0.359	1.282	0.641	15.059	.05
6A8	0.484	1.542	0.771	10.833	.07
6A9	0.156	0.766	0.383	18.811	.07
6A10	0.172	0.812	0.406	14.109	.10
6A11	0.813	2.123	1.061	22.468	.12
6A12	0.172	0.812	0.406	32.388	.03
6A13	0.281	1.101	0.551	27.877	.03

Table 4. Watershed Characteristics of C04 Drainage Area

Subarea	Drainage Area (sq. mi.)	L (mi.)	Lca (mi.)	Representative Slope (ft./mi.)	Basin N
A1	1.38	2.18	1.63	16.89	0.035
A2	0.15	0.75	0.56	14.61	0.040
A3	0.34	0.99	0.75	20.11	0.039
A4	0.18	0.89	0.67	14.53	0.039
A5	0.39	1.09	0.82	13.71	0.039
A6	2.48	3.69	2.77	12.93	0.039
A7	0.83	2.46	2.00	11.39	0.050
A8	0.15	0.88	0.66	12.49	0.045
A9	0.76	2.13	1.60	13.61	0.050
A10	1.09	1.85	1.48	10.83	0.050
A11	0.44	1.52	1.14	9.21	0.050
A12	0.18	0.55	0.42	10.83	0.050
A13	0.52	1.43	1.20	9.06	0.100
A14	0.43	1.26	0.95	7.91	0.050
A15	0.19	0.98	0.74	6.12	0.050
A16	0.60	1.41	1.05	2.13	0.080
A17	0.27	0.64	0.32	4.69	0.015
A18	0.40	1.15	0.58	4.78	0.015
A19	0.09	0.72	0.36	2.76	0.015

Table 5. Watershed Characteristics of C02 Drainage Area

Subarea	Drainage Area (sq. mi.)	L (mi.)	Lca (mi.)	Representative Slope (ft./mi.)	Basin N
A1	0.58	1.35	0.68	3.69	0.041
A2	0.98	2.59	1.29	12.77	0.038
A3	3.31	4.64	2.32	7.11	0.032
A4	0.43	0.89	0.45	14.53	0.015
A5	0.53	1.29	0.64	6.21	0.015
A6	0.17	0.93	0.46	7.54	0.015
A7	0.20	2.46	1.23	2.78	0.015
A8	1.35	2.93	1.47	10.58	0.045
A9	0.46	1.33	0.66	10.78	0.030
A10	0.08	1.86	0.93	10.78	0.015

7.5.4 Rainfall

The N-year point rainfall depths for coastal (below 2000 feet) areas within Orange County were adopted from the Orange County Hydrology Manual (OCHM, 1987) because the entire study area is below 2000 feet elevation. The Orange County rainfall frequency duration table only presents up to the 100-year frequency.

The Orange County 24-hour rainfall distribution is coded in the LAPRE-1 computer program, which is a preprocessor to HEC-1. Precipitation input requirements for LAPRE-1 are contributing area, and the 5-

minute, 30-minute, 1-hour, 3-hour, 6-hour, and 24-hour point rainfall depths. The required point rainfall depths for 2-, 25-, 50-, 100-year rainfall from Orange County are listed in Table 6. Point rainfall depth from Orange County compares very favorably with the values from the NOAA Atlas 14.

In general, the average rainfall depth and intensities for a single storm event tend to decrease with respect to increasing area. The adopted precipitation depth-area adjustment for duration 5 minutes to 24 hours is given in the OCHM. It is also coded in the LAPRE-1 computer program so there is no need to adjust the point rainfall externally. There is no change in the depth-area adjustment for drainage areas larger than 150 square miles.

Since the rainfall does not change with development, the same rainfall depths will be used for present and future conditions. The rainfall depth for each subarea depends on elevation, which can be either mountain rainfall depths or coastal rainfall depths according to the Orange County method.

Table 6. Orange County N-year 24 Hour Point Rainfall

Frequency (year)	5-min. (inches)	30-min. (inches)	1 hour (inches)	3 hour (inches)	6 hour (inches)	24 hour (inches)
Point Precipitation for Mountain Area (above 2000 feet)						
2	0.26	0.45	0.66	1.34	2.09	3.81
25	0.63	1.04	1.51	3.08	4.81	8.86
50	0.71	1.19	1.73	3.52	5.51	10.02
100	0.78	1.34	1.94	3.96	6.19	11.27
Point Precipitation for Coastal Area (below 2000 feet)						
2	0.19	0.4	0.53	0.89	1.22	2.05
25	0.4	0.87	1.15	1.94	2.71	4.49
50	0.45	0.98	1.3	2.19	3.02	5.07
100	0.52	1.09	1.45	2.43	3.36	5.63

7.5.5 Loss Rate

The precipitation loss rate function used in this calibration study is based on the OCHM method, which is based on the Natural Resources Conservation Services (NRCS, formerly Soil Conservation Services or SCS) curve number (CN) approach, but modified to have an upper and lower bound. The loss rate, f(t), in in/hr is defined by:

$$f(t) = Y * I(t) \quad for \quad Y * I(t) \quad less \quad than \quad F_m$$

$$F_m \quad , \quad otherwise$$

where,

Y = the low loss fraction

F_m = the maximum loss rate (in/hr), and

I(t) = the design storm rainfall intensity (in/hr) at storm time (t).

The low loss fraction Y, acts as a lower bound fixed loss rate fraction, whereas F_m serves as an upper bound to the possible values of f(t)= Y*I(t). This loss accounting procedure is a hybridization of the NRCS CN approach. The low loss rate fraction is used to develop runoff hydrograph yields that are comparable to the NRCS 24-hr storm yields, and the peak rainfall loss rates are representative of values developed from the rainfall-runoff reconstitution studies.

Maximum Loss Rate (F_m). The maximum loss rate F_m is defined by:

$$F_m = A_p * F_p$$

where,

A_p = the actual* pervious area fraction of a subarea with corresponding maximum loss rate of F_p; and

F_p = the maximum loss rate for the pervious area fraction A_p for appropriate CN and antecedent moisture condition (AMC).

*Note – Actual pervious/impervious area is defined as the map measured value. In many instances it is necessary to distinguish between actual impervious area and hydraulically connected (or effective) impervious area because these values may differ significantly.

The maximum infiltration rate for impervious area is set at zero. Values for F_p can be calibrated to values obtained from rainfall-runoff reconstitution studies.

Low Loss Rate Fraction (Y). The low loss rate fraction is estimated from the NRCS loss rate equation by:

$$\mathrm{Y} = 1 - Y$$

where Y is the catchment yield (percent of 24-hour rain that runs off) computed by:

$$Y = \sum A * Y_A$$

with,

A	=	catchment area fraction with corresponding Y_A
Y_A	=	catchment yield in percent for catchment area fraction A.

Y_A is estimated using the NRCS CN by:

$$Y_A = \frac{(P_{24} - I_a)^2}{(P_{24} - I_a + S) * P_{24}}$$

where,

P_{24}	=	the 24-hour n-year precipitation depth.
I_a	=	initial abstraction (0.2S)
S	=	(1000/CN) – 10

Note, for P_{24} less than I_a, $Y_A = 0$.

The catchment yield for impervious areas is computed using a CN of 98. A CN of 98 is used rather than 100 to account for some depression storage.

Antecedent Moisture Conditions (AMC). The AMC I, II, and III conditions represent adjustments for antecedent soil moisture conditions of dry, average and wet, respectively. The designation of a particular AMC condition of a specific storm is usually determined by the evaluation of prior rainfall. The effect of AMC is built into the runoff curve number determination by providing adjusted CNs for AMC I and III, with the CN table based on AMC II. The prior rainfall criteria used to adjust the CN is based on the data used in the original estimation of the CN table. The AMC I and III CNs represent the extremes on the graphs of rainfall versus runoff volume.

The SCS Curve Numbers for developed and undeveloped areas were determined according to the soil and vegetation types using the tables published in the OCHM (Table 7). The percentage of actual impervious cover for developed areas was also determined using the table published in the OCHM (Table 8).

Orange County PFRD Geomatics/LIS Division provided digitized GIS data for hydrologic soil groups and vegetation cover of the whole Orange County area. The area extent of hydrologic soil groups, vegetation covers and land use for each sub-area were estimated from maps provide by Orange County.

Following the OCHM method above, the Low Loss Rate and Maximum Loss Rate for each subarea were computed for the 2-, 5-, 10-, 25-, 50-, and 100-year floods. The results were used as the initial loss rate for the 2-, 5-, 10-, 25-, 50-, and 100-year flood calibrations (described in the following sections). For the 200- and 500-year floods, the 100-year loss rate data was used as initial loss rate in the calibration process. The loss rate is one of the variable factors in rainfall-runoff calibrations.

Table 9 lists the final calibrated Low Loss Fraction and Maximum Loss Rate for each sub-area under present condition for the C05 & C06 drainage area.

Tables 10 and 11 list the final calibrated Low Loss Fraction and Maximum Loss Rate for each sub-area under present condition for the C04 and C02 drainage area respectively.

Table 7. Curve Number of Hydrologic Soil-Cover Complexes

Cover Type	Quality of Cover	Soil Group A	Soil Group B	Soil Group C	Soil Group D
NATURAL COVERS					
Barren					
(Rockland, eroded and graded land)		78	86	91	93
Chaparral, Broadleaf	Poor	53	70	80	85
(Manzonita, ceanothus and scrub oak)	Fair	40	63	75	81
	Good	31	57	71	78
Chaparral, Narrowleaf	Poor	71	82	88	91
(Chamise and redshank)	Fair	55	72	81	86
Grass, Annual or Perennial	Poor	67	78	86	89
	Fair	50	69	79	84
	Good	38	61	74	80
Meadows or Cienegas	Poor	63	77	85	88
(Areas with seasonally high water table,	Fair	51	70	80	84
Principal vegetation is sod forming grass)	Good	30	58	71	78
Open Brush	Poor	62	76	84	88
(Soft wood shrubs - buckwheat, sage, etc.)	Fair	46	66	77	83
	Good	41	63	75	81
Woodland	Poor	45	66	77	83
(Coniferous or broadleaf trees predominate.	Fair	36	60	73	79
Canopy density is at least 50 percent.)	Good	25	55	70	77
Woodland, Grass	Poor	57	73	82	86
(Coniferous or broadleaf trees with canopy	Fair	44	65	77	82
density from 20 to 50 percent)	Good	33	58	72	79
URBAN COVERS					
Residential or Commercial Landscaping	Poor	32	56	69	75
(Lawn, shrubs, etc.)					
Turf	Poor	58	74	83	87
(Irrigated and mowed grass)	Fair	44	65	77	82
	Good	33	58	72	79

Table 7 continued

	Quality of Cover	Soil Group			
		A	B	C	D
AGRICULTURE COVERS					
Fallow					
(Land plowed but not tilled or seeded)		77	86	91	94
Legumes, Closed Seeded	Poor	66	77	85	89
(Alfalfa, sweetclover, timothy, etc.)	Good	58	72	81	85
Orchard, Evergreen	Poor	57	73	82	86
(Citrus, avocados, etc.)	Fair	44	65	77	82
	Good	33	58	72	79
Pasture, Dryland	Poor	68	79	86	89
(Annual grasses)	Fair	49	69	79	84
	Good	39	61	74	80
Pasture, Irrigated	Poor	58	74	83	87
(Legumes and perennial grass)	Fair	44	65	77	82
	Good	33	58	72	79
Row Crops	Poor	72	81	88	91
(Field crops – tomatoes, sugar beets, etc.)	Good	67	78	85	89
Small grain	Poor	65	76	84	88
(Wheat, oats, barley,etc.)	Good	63	75	83	87

Notes:

1. All curve numbers are for Antecedent Moisture Condition (AMC) II
2. Quality of cover definitions:
   Poor-Heavily grazed, regularly burned areas, or areas of high burn potential.
   Less than 50 percent to 75 percent of ground surface is protected by plant cover or brush and tree Canopy.
   Fair-Moderate cover with 50 percent to 75 percent of ground surface protected.
   Good-Heavy or dense cover with more than 75 percent of the ground surface protected.
4. Impervious areas are assigned curve number 98.

Table 8. Impervious Cover for Developed Areas

Land Use Percent	Range-Percent	Recommended Value For Average Conditions -
Natural or Agriculture	0 - 0	0
Public Park	10 - 25	15
School	30 - 50	40
Single Family Residential:		
2.5 acre lots	5 - 15	10
1 acre lots	10 - 25	20
2 dwelling/acre	20 - 40	30
3-4 dwelling/acre	30 - 50	40
5-7 dwelling/acre	35 - 55	50
8-10 dwelling/acre	50 - 70	60
More than 10 dwelling/acre	65 - 90	80
Multiple Family Residential:		
Condominiums	45 - 70	65
Apartments	65 - 90	80
Mobile Home Park	60 - 85	75
Commercial, Downtown Business or Industrial	80 - 100	90

Notes:

1. Land use should be based on ultimate development of the watershed. Long range master plan for the County and incorporated cities should be reviewed to insure land use assumptions.
2. Recommended values are based on average conditions which may not apply to a particular study area. The percentage impervious may vary greatly even on comparable sized lots due to differences in dwelling size, improvements, etc. Landscape practices should also be considered as it is common in some areas to use ornamental gravel underlain by impervious plastic materials in place of lawns and shrubs. A field investigation of a study area shall always be made, and a review of aerial photos, where available, may assist in estimating the percentage of impervious cover in the developed areas.
3. For typical equestrian subdivisions increase impervious area 5 percent over the values recommended in the table above.

Source:OCHM

Table 9. Summary of Calibrated Orange County Loss Rates for C05 and C06 Drainage Area

Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)	Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)
A1	0.247	0.0656	A19	0.249	0.0946
A2	0.247	0.0656	A20	0.350	0.1508
A3	0.239	0.0629	A21	0.306	0.1369
A4	0.454	0.1313	A22	0.300	0.1318
A5	0.372	0.1172	A23	0.195	0.0736
A6	0.369	0.1147	6A1	0.471	0.1347
A7	0.134	0.0300	6A2	0.471	0.1347
A8	0.323	0.0872	6A3	0.471	0.1347
A9	0.448	0.1283	6A4	0.608	0.1856
A10	0.211	0.0529	6A5	0.644	0.2262
A11	0.251	0.0665	6A6	0.363	0.1206
A12	0.421	0.1345	6A7	0.445	0.1376
A13	0.418	0.1423	6A8	0.202	0.0612
A14	0.316	0.1022	6A9	0.133	0.0350
A15	0.325	0.1173	6A10	0.355	0.1187
A16	0.333	0.1374	6A11	0.309	0.1010
A17	0.373	0.1309	6A12	0.288	0.0927
A18	0.278	0.1144	6A13	0.221	0.0868

Table 10. Summary of Calibrated Orange County Loss Rates for C04 Drainage Area

Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)	Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)
A1	.4000	.1500	A11	.5000	.2000
A2	.4500	.1750	A12	.5000	.2000
A3	.4000	.1500	A13	.5500	.2250
A4	.4000	.1500	A14	.5000	.2000
A5	.4000	.1500	A15	.5000	.2000
A6	.4000	.1500	A16	.5000	.2000
A7	.5000	.2000	A17	.3000	.0800
A8	.4500	.1750	A18	.4000	.1500
A9	.5000	.2000	A19	.3000	.0800
A10	.5000	.2000			

Table 11. Summary of Calibrated Orange County Loss Rates for C02 Drainage Area

Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)	Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)
A1	0.547	0.1730	A6	0.509	0.1938
A2	0.623	0.1420	A7	0.511	0.1940
A3	0.724	0.0990	A8	0.672	0.1224
A4	0.648	0.1310	A9	0.631	0.1404
A5	0.711	0.1066	A10	0.895	0.0277

7.5.6 Unit Hydrograph Procedure

The unit hydrograph is the hydrograph of direct surface discharge, at the concentration point of that drainage area, resulting from a unit effective rainfall. Unit rainfall is the net rainfall (excess) of 1 inch which occurs over all parts of a drainage area at a uniform rate during a specified unit period of time. The unit hydrograph is computed by the Los Angeles District unit hydrograph procedure through use of an S-graph. The S-graph is the time distribution of runoff as a function of basin lag time. Lag time is defined as the elapsed time (in hours) from beginning of unit effective rainfall (excess) to the instant that the summation hydrograph for the concentration point of that drainage area reaches 50 percent of ultimate discharge (in volume), or simply the time in hours for 50 percent of the total volume of runoff of the unit hydrograph to reach the outlet.

Since the watershed is located in a coastal alluvial fan area and the area is fully developed, a Coast Developed S-graph was adopted for this hydrologic study. The Coast Developed S-graph is coded within LAPRE-1.

7.5.7 Detention Basin Routing

Haster Retarding Basin is a dual purpose basin with an area of 22.4 acres. The basin initially was designed to be used as a flood control facility for the C05 channel only. However, in 1972 by a mutual agreement between the Orange County Flood Control District and the City of Garden Grove, it was agreed to develop the basin into a community park (Twin Lake Park) as a secondary use of the site. Levees of the basin were raised slightly in 1985 to accommodate more capacity for the 1820 acres tributary to the basin. A 9'H x 6'W RCB and a 96" RCP inlet discharge into the basin from the north.

In the rainfall-runoff model, the relationship between the detention basin volume, elevation, and discharge is shown in Table 12.

Table 12: Volume, Elevation, and Discharge Relationship for Haster Detention Basin

Volume (acre-ft)	0	50	75	100	125	150	175	200	225	250
Elevation (ft)	92.5	99	102.5	103.5	105.5	107	108.5	110.5	112	113.5
Discharge (cfs)	0	450	450	450	450	450	450	450	450	450

The Haster Basin information and data were based on the Orange County report entitled "Hydrology Report for East Garden Grove – Winterburg Channel (Facility No. C05) (Bolsa Chica Bay to Vermont Avenue), Volumes I and II" dated July 1990 and approved by the county on December 1, 1993.

7.5.8 Channel Routing

The Muskingum-Cunge method was used to route subarea hydrographs to the outlet. Muskingum-Cunge is physically based and is considered reliable. The Muskingum-Cunge method was applied with eight-point standard channel cross-section data. Topography data was available for the entire reach of EGGW Channel. The channel and overbank Manning's "n" coefficient were estimated based on channel materials, i.e., concrete riprap or earth, etc, vegetation cover, and topographic characteristics.

Table 13 lists the characteristics of each reach and input parameters for the Muskingum-Cunge routing method for the C05 & C06 channel drainage area rainfall-runoff model. Tables 14 and 15 list the Muskingum-Cunge routing parameters for the C04 and C02 drainage area rainfall-runoff models, respectively.

Table 13. HEC-1 Parameters for Muskingum-Cunge Routing for C05 and C06 Drainage Area

A1 to A2								
KK	Haster Basin Outlet(31.1)-GG Blvd							
KM	578+30 - 567.87 (11X6)							
RD								
RC	0.013	0.013	0.013	0.013	1043	0.0022		
RX	0	0.01	0.02	0.02	11.02	11.02	11.03	11.04
RY	6	6	6	0	0	6	6	6
KK	GG Blvd-GH Freeway(32)							
KM	563+87 - 551+03 (12X6.5)							
RD								
RC	0.06	0.014	0.06	1284	.0041			
RX	0	5	10	10	22	22	27	32
RY	6.5	6.5	6.5	0	0	6.5	6.5	6.5
A2 to A3								
KK	A3_RT							
KM	Garden Grove Freeway(32)-Trask Av(33):551.03 - 534.94 (20X7.5)							
RC	0.06	0.014	0.06	1609	.0029			
RX	0	5	10	10	30	30	35	40
RY	7.5	7.5	7.5	0	0	7.5	7.5	7.5
A3 to A4								
KK	A4_RT							
KM	Trask Av(33)-Harbor Blvd(34):534.94 - 514.70 (25X9)							
RC	0.06	0.014	0.06	2024	.0024			
RX	0	5	10	10	35	35	40	45
RY	9	9	9	0	0	9	9	9
A4 to A5								
KK	A5_RT							
KM	Harbor Blvd(34)-Pacific RR(35.1):534.94 – 500.03 (25X8)							
RC	0.06	0.014	0.06	3491	.0023			
RX	0	5	10	10	35	35	40	45
RY	8	8	8	0	0	8	8	8
A5 to A6								
KK	A6_RT							
KM	Pacific RR(35.1)-Westminster Ave(36):500.03-487.19 (30X11.5)							
RC	0.06	0.014	0.06	3491	.0027			
RX	0	5	10	10	40	40	45	50
RY	11.5	11.5	11.5	0	0	11.5	11.5	11.5
A6 to A7								
KK	A7_RT							
KM	Westminster Ave(36)-Morningside Ave(37):487.19-475.60 (40X11)							
RC	0.06	0.014	0.06	1159	.0011			
RX	0	5	10	10	50	50	55	60
RY	11	11	11	0	0	11	11	11

Table 13 Continued

A7 to A8								
KK	A8_RT1							
KM	Morningside Ave(37)-Hazard St(37.1):475.60-456.10 (40X12)							
RC	0.06	0.014	0.06	1950	.0039			
RX	0	5	10	10	50	50	55	60
KK	A8_RT2							
KM	Hazard St(37.1)-(37.2):456.10-446.04 (16X10)							
RC	0.06	0.014	0.06	1006	.0028			
RX	0	50	100	100	116	116	166	216
RY	12	10	10	0	0	10	10	12
KK	A8_RT3							
KM	(37.2)-Fifth Ave(38):446.04-438.08 (30X12)							
RC	0.06	0.014	0.06	796	.0014			
RX	0	5	10	10	40	40	45	50
RY	12	12	12	0	0	12	12	12
A8 to A9								
KK	A9_RT							
KM	Fifth Ave(38)-Bolsa St(39):438.08-424.49 (40X11.5)							
RC	0.06	0.014	0.06	1359	.0039			
RX	0	5	10	10	50	50	55	60
RY	11.5	11.5	11.5	0	0	11.5	11.5	11.5
A9 to A10								
KK	A10_RT							
KM	Bolsa St(39)-C-5_F Channel(40):424.49-402.98 (40X11.5)							
RC	0.06	0.014	0.06	2151	.0025			
RX	0	5	10	10	50	50	55	60
RY	11.5	11.5	11.5	0	0	11.5	11.5	11.5
A10 to A11								
KK	A11_RT1							
KM	C-5_F Channel(40)-Euclid St(40.1):402.98-396.47 (40X11.5)							
RC	0.06	0.014	0.06	649	.0034			
RX	0	5	10	10	50	50	55	60
RY	11.5	11.5	11.5	0	0	11.5	11.5	11.5
KK	A11_RT2							
KM	Euclid St(40.1)-Deming St:396.47-387.18 (40X10.5)							
RC	0.06	0.014	0.06	929	.0020			
RX	0	5	10	10	50	50	55	60
RY	10.5	10.5	10.5	0	0	10.5	10.5	10.5
KK	A11_RT3							
KM	Deming St-Ward St(41):387.18-370.05 (45X10)							
RC	0.06	0.014	0.06	1713	.0022			
RX	0	5	10	10	55	55	60	65
RY	10	10	10	0	0	10	10	10
A11 to A12								
KK	A12_RT							
KM	Ward St(41)-Brookhurst St(42):370.05-342.76 (45X10)							
RC	0.06	0.014	0.06	2729	.0015			
RX	0	5	10	10	55	55	60	65
RY	10	10	10	0	0	10	10	10

Table 13 Continued

A12 to A13								
KK	A13_RT							
KM	Brookhurst St(42)-(43):342.76-332.55 (50X11)							
RC	0.06	0.014	0.06	1021	.0032			
RX	0	5	10	10	60	60	65	70
RY	11	11	11	0	0	11	11	11
A13 to A14								
KK	A14_RT							
KM	(43)-Bushard St.(44):332.55-313.22 (50X11)							
RC	0.06	0.014	0.06	1933	.0006			
RX	0	5	10	10	60	60	65	70
RY	11	11	11	0	0	11	11	11
A14 to A15								
KK	A15_RT							
KM	Bushard St.(44)-Magnolia St.(45):313.22-283.64 (50X11.5)							
RC	0.06	0.014	0.06	2958	.0010			
RX	0	5	10	10	60	60	65	70
RY	11.5	11.5	11.5	0	0	11.5	11.5	11.5
A15 to A16								
KK	A16_RT							
KM	Magnolia St.(45)-San Diego FWY(47):283.64-254.30 (60X12.5)							
RC	0.06	0.014	0.06	2934	.0004			
RX	0	5	10	10	70	70	75	80
RY	12.5	12.5	12.5	0	0	12.5	12.5	12.5
A16 to A17								
KK	A17_RT							
KM	San Diego FWY(47)-Beach Blvd.(48):254.30-224.72 (60X12)							
RC	0.06	0.014	0.06	2958	.0009			
RX	0	5	10	10	70	70	75	80
RY	12.0	12.0	12.0	0	0	12.0	12.0	12.0
A17 to A18								
KK	A18_RT							
KM	Beach Blvd.(48)-Union Pacific RR(49):224.72-191.67 (60X14)							
RC	0.06	0.014	0.06	3305	.0019			
RX	0	5	10	10	70	70	75	80
RY	14.0	14.0	14.0	0	0	14.0	14.0	14.0
A18 to A19								
KK	A19_RT							
KM	Golden West St. (50)-Edwards St. (51):165.22.67-138.80 (146X14.5)							
RC	0.06	0.018	0.06	2642	.0007			
RX	0	100	200	200	346	346	446	546
RY	16.5	14.5	14.5	0	0	14.5	14.5	16.5
A19 to A20								
KK	A20_RT							
KM	Edwards St. (51)-Springdale St. (52):138.80-112.39 (146X14.5)							
RC	0.06	0.022	0.06	2461	.0004			
RX	0	100	200	200	346	346	446	546
RY	16.5	14.5	14.5	0	0	14.5	14.5	16.5

Table 13 Continued

A20 to A21								
KK	A21_RT							
KM	Springdale St. (52)-Slater Ext Bridge(54):112.39-57.77 (146X14.5)							
RC	0.06	0.022	0.06	5462	.00017			
RX	0	100	200	200	346	346	446	546
RY	16.5	14.5	14.5	0	0	14.5	14.5	16.5
A21 to A22								
KK	A22_RT							
KM	Slater Ext Bridge(54)-Outlet Structure(55):57.77-6.08 (146X14.5)							
RC	0.06	0.022	0.06	4969	.0004			
RX	0	100	200	200	346	346	446	546
RY	16.5	14.5	14.5	0	0	14.5	14.5	16.5
KK	6A1_RT							
KM	Newhope st(112)-(114):(Trap:9X12)Earth Channel							
RC	0.06	0.030	0.06	1320	.0012			
RX	0	5	10	28	37	55	60	65
RY	12.0	12.0	12.0	0	0	12.0	12.0	12.0
6A2								
KK	6A2_RT							
KM	Corta Dr(114)-Euclid St(115):(Trap:8X10)Earth Channel							
RD								
RC	0.06	0.030	0.06	1320	.0018			
RX	0	5	10	25	33	48	53	58
RY	10.0	10.0	10.0	0	0	10.0	10.0	10.0
6A3								
KK	6A3_RT							
KM	Euclid St(115)-(116):(Trap:40X7) Trap Channel							
RC	0.06	0.030	0.06	680	.0012			
RX	0	5	10	20.5	40.5	51	56	61
RY	7.0	7.0	7.0	0	0	7.0	7.0	7.0
6A4								
KK	6A4_RT							
KM	(116)-Brookhurst St(117):(Trap40X7) Trap Channel							
RC	0.06	0.030	0.06	680	.0012			
RX	0	5	10	20.5	40.5	51	56	61
RY	7.0	7.0	7.0	0	0	7.0	7.0	7.0
6A5								
KK	6A5_RT							
KM	Brookhurst St.(117)-(118):(10X12)Earth Trap. Channel							
RC	0.06	0.030	0.06	1240	.0008			
RX	0	5	10	28	38	56	61	66
RY	12	12	12	0	0	12	12	12
6A6								
KK	6A6_RT							
KM	(118)-Bushard St.(119):(10X12) Earth Trap. Channel							
RC	0.06	0.030	0.06	1400	.0008			
RX	0	5	10	28	38	56	61	66
RY	12	12	12	0	0	12	12	12

Table 13 Continued

6A7								
KK	6A7_RT							
KM	Bushard St.(119)-San Diego Freeway(120):(20X10)Conc Rec. Channel							
RC	0.06	0.014	0.06	2000	.0012			
RX	0	5	10	10	30	30	35	40
RY	10	10	10	0	0	10	10	10
6A8								
KK	6A8_RT1							
KM	San Diego Freeway(120)-Magnolia(121):(20X10)Conc. Covered Conduit							
RC	0.06	0.013	0.06	700	.0024			
RX	0	5	10	10	30	30	35	40
RY	20	20	20	0	0	20	20	20
6A9								
KK	6A9_RT1							
KM	Magnolia(121)-(123):(R19X11) Conc. Rec. Channel							
RC	0.06	0.014	0.06	1540	.0011			
RX	0	50	100	100	119	119	169	219
RY	14	11	11	0	0	11	11	14
KK	6A9_RT2							
KM	(123)-Newland St.(124):(8X14) Riprap Trap Channel							
RC	0.06	0.035	0.06	1590	.0010			
RX	0	50	100	121	129	150	160	210
RY	11	8	8	0	0	8	8	11
6A10								
KK	6A10_RT							
KM	Newland St.(124)-(125):(8X14)Earth Trap Channel							
RC	0.06	0.030	0.06	730	.0014			
RX	0	50	100	121	129	150	160	210
RY	11	8	8	0	0	8	8	11
6A11								
KK	6A11_RT							
KM	(125)-Beach Blvd.(126):(8X14)Earth Trap Channel							
RC	0.06	0.030	0.06	1910	.0014			
RX	0	50	100	121	129	150	160	210
RY	11	8	8	0	0	8	8	11
6A12								
KK	6A12_RT							
KM	Beach Blvd.(126)-P.E.Rd(128):(8X14)Earth Trap Channel							
RC	0.06	0.030	0.06	2640	.0017			
RX	0	50	100	121	129	150	160	210
RY	11	8	8	0	0	8	8	11
6A13								
KK	6A13_RT1							
KM	Union Pacific RR(49)-Golden West St. (50):191.67-178.42 (60X13)							
RC	0.06	0.014	0.06	1325	.0017			
RX	0	5	10	10	70	70	75	80
RY	13.0	13.0	13.0	0	0	13.0	13.0	13.0
KK	6A13_RT2							
KM	Union Pacific RR(49)-Golden West St. (50):178.42-165.22 (75X13)							
RC	0.06	0.014	0.06	1275	.0013			
RX	0	5	10	10	85	85	90	95
RY	13.0	13.0	13.0	0	0	13.0	13.0	13.0

Table 14: HEC-1 Parameters for Muskingum-Cunge Routing for C04 Drainage Area

A1 to A2								
KK	RCH 1							
KM	Channel from Trask to Westminster							
RD								
RC	0.017	0.017	0.017	2174	.0027			
RX	0	1.5	3.5	13	17	26.5	28.5	30
RY	9	9.5	9.5	0	0	9.5	9.5	9
A2 to A3								
KK	RCH 2							
KM	Channel Westminster to STA 179+97.89							
RD								
RC	0.023	0.039	0.023	1456	.0023			
RX	0	1	20	36.5	49.5	64.5	69	70
RY	10.5	11	11	0	0	10	10	9.9
A3 to A4								
KK	RCH 3							
KM	Channel from STA 179+97.89 to STA 173+10.00							
RD								
RC	0.023	0.039	0.023	688	.0013			
RX	0	1	19	35.5	55	70.6	71	72
RY	11	11	11	0	0	10.4	10.4	10.4
A4 to A5								
KK	RCH 4							
KM	Channel from STA 173+10.00 to STA 143+000.26							
RD								
RC	0.023	0.039	0.023	3010	.0013			
RX	0	1	20.5	35.5	55	70	73	74
RY	10	10	10	0	0	10	10	10
A5 to A6								
KK	RCH 5							
KM	Rect. Channel from Brookhurst to Brushard – STA 143+.0026 TO STA 115+57.00							
RD								
RC	0.023	0.039	0.023	2743	.0014			
RX	0	0.01	0.02	0.03	35.03	35.04	35.05	35.06
RY	10	10	10	0	0	10	10	10
A6 to A7								
KK	RCH 6							
KM	Rect. Channel from Brushard to Magnolia – STA 115+57.00 TO 87+56.00							
RD								
RC	0.017	0.029	0.017	2801	.0031			
RX	0	0.01	0.02	0.03	35.03	35.04	35.05	35.06
RY	8	8	8	0	0	8	8	8
A7 to A8								
KK	RCH 7							
KM	Rect. Channel from Magnolia to Newland – STA 87+56.00 TO STA 61+94.63							
RD								
RC	0.023	0.023	0.023	2561	.0020			
RX	0	0.01	0.02	0.03	25.03	25.04	25.05	25.06
RY	9	9	9	0	0	9	9	9

Table 14 Continued

A8 to A9								
KK	RCH 8							
KM	Rect. Channel from Newland to C04O06 Inlet – STA 61+94.63 to 47+60.00							
RD								
RC	0.017	0.018	0.017	1435	.0022			
RX	0	0.01	0.02	0.02	25.03	25.04	25.05	25.06
RY	8.5	8.5	8.5	0	0	8.5	8.5	8.5
A9 to A10								
KK	RCH 9							
KM	Rect. Channel : C04P06 Inlet to Beach – STA 47+60.00 to STA 33+07.54							
RD								
RC	0.020	0.020	0.020	1452	.0020			
RX	0	0.01	0.02	0.03	25.03	25.04	25.05	25.06
RY	8.5	8.5	8.5	0	0	8.5	8.5	8.5
A10 to A11								
KK	RCH 10							
KM	Trap Channel from Beach to Cedarwood (30% Box Culvert)							
RD								
RC	0.023	0.023	0.029	1521	.0017			
RX	0	1	2	10.5	25.5	34.0	34.01	34.02
RY	8.7	8.5	8.5	0	0	8.5	8.5	8.5
A11 to A12								
KK	RCH 11							
KM	Rectangular Channel from Cedarwood to Hoover							
RD								
RC	0.023	0.023	0.023	1535	.0030			
RX	0	0.01	0.02	0.03	36.03	36.04	36.05	36.06
RY	8.5	8.5	8.5	0	0	8.5	8.5	8.5
A12 to A13								
KK	RCH 12							
KM	Rectangular Channel from Hoover to STA 177+27.00							
RD								
RC	0.018	0.020	0.018	2552	.0011			
RX	0	0.01	0.02	0.03	38.03	38.04	38.05	38.06
RY	11	11	11	0	0	11	11	11
A13 to A14								
KK	RCH 13							
KM	Rec Channel STA 177+27.00 TO 163+00.00 (part under 405) Avg of 2 Ch used							
RD								
RC	0.020	0.027	0.020	1427	.0025			
RX	0	0.01	0.02	0.03	33.03	33.04	33.05	33.06
RY	10	10	10	0	0	10	10	10
A14 to A15								
KK	RCH 14							
KM	Rec Channel STA 163+00.00 137+30.39							
RD								
RC	0.023	0.023	0.023	2570	.0012			
RX	0	0.01	0.02	0.03	42.03	42.04	42.05	42.06
RY	9.5	9.5	9.5	0	0	9.5	9.5	9.5

Table 14 Continued

A15 to A16								
KK	RCH 15							
KM	Trap Channel STA 137+30.39 to 118+06.19 (Includes Downstream Box Culvert)							
RD								
RC	0.031	0.040	0.034	1924	.0011			
RX	0	0.01	20.25	36.5	50	70.25	99	100
RY	13.9	13.9	13.5	0	0	13.5	13.9	13.9
A16 to A17								
KK	RCH 16							
KM	Trap Channel STA 118+06.09 to STA 104+94							
RD								
RC	0.029	0.042	0.033	1312	.0011			
RX	0	0.01	7.75	28	52	72.25	89.99	90
RY	13.87	13.87	13.5	0	0	13.5	13.87	13.87
A17 to A18								
KK	RCH 17							
KM	Trap Channel STA 104+94 to McFadden (Includes Downstream Box Culvert)							
RD								
RC	0.040	0.040	0.027	1950	.0013			
RX	0	0.01	7.75	28	52	72.25	89.99	90
RY	13.87	13.87	13.5	0	0	13.5	13.87	13.87
A18 to A19								
KK	RCH 18							
KM	Trap Channel STA 83+44.22 To STA 59+70							
RD								
RC	0.029	0.039	0.029	2574	.0005			
RX	0	0.01	17	35	75	93	99.99	100
RY	12.34	12.34	12	0	0	12	12.14	12.14
A19 to A20								
KK	RCH 19							
KM	Trap Channel to 30' RCP STA 59+70 to STA 30+45							
RD								
RC	0.029	0.039	0.029	2925	.0005			
RX	0	0.01	17	35	75	93	99.99	100
RY	12.34	12.34	12	0	0	12	12.14	12.14
A20 to A21								
KK	RCH 20							
KM	Trap Channel to C02 STA 30+45 to STA0+00							
RD								
RC	0.022	0.032	0.022	3045	.0004			
RX	0	0.01	16	31	79	94	99.99	100
RY	9.68	9.68	10	0	0	10	9.88	9.88

Table 15. HEC-1 Parameters for Muskingum-Cunge Routing for C02 Drainage Area

A1 to A2								
KK	RCH 1							
KM	Cerritos To So. Pacific							
RD								
RC	0.014	0.014	0.014	1184	.0012			
RX	0	0.01	0.02	0.03	14.03	14.04	14.05	14.06
RY	8	8	8	0	0	8	8	8
A2 to A3								
KK	RCH 2							
KM	So. Pacific Drive RR & Plaza Dr. to Katella							
RD								
RC	0.014	0.014	0.014	1184	.0012			
RX	0	0.01	0.02	0.03	14.03	14.04	14.05	14.06
RY	9	9	9	0	0	9	9	9
A3 to A4								
KK	RCH 3							
KM	Katella to S01							
RD								
RC	0.050	0.035	0.035	1217	.004			
RX	0	0.5	1.5	15	25	38.5	39.5	40
RY	9	9	9	0	0	9	9	9
A4 to A5								
KK	RCH 4							
KM	Stanton Storm Drain Channel to Naval Bridge							
RD								
RC	0.012	0.014	0.012	2086	.0017			
RX	0	1	8.75	24.5	39.5	55.25	74	75
RY	11	11	11	0	0	10.4	10.4	10.4
A5 to A6								
KK	RCH 5							
KM	Naval Bridge to p01							
RD								
RC	0.014	0.014	0.014	786	.0017			
RX	0	1	8.75	24.5	39.5	55.25	74	75
RY	10.5	10.5	10.5	0	0	10.5	10.5	10.5
A6 to A7								
KK	RCH 6							
KM	p01 to p02							
RD								
RC	0.028	0.033	0.028	700	.0012			
RX	0	1	8	26	38	56	74	75
RY	12	12	12	0	0	12	12	12
A7 to A8								
KK	RCH 7							
KM	p02 to Santa Catalina Ave							
RD								
RC	0.026	0.033	0.026	1540	.0012			
RX	0	1	8	26	38	56	73	74
RY	12	12	12	0	0	12	12	12

Table 15 Continued

A8 to A9								
KK	RCH 8							
KM	Santa Catalina Ave. to Holland							
RD								
RC	0.024	0.033	0.024	1260	.0012			
RX	0	1	8.75	26	38	55.25	74	75
RY	11.5	11.5	11.5	0	0	11.5	11.5	11.5
A9 to A10								
KK	RCH 9							
KM	Holland Ave to Belgrave Channel							
RD								
RC	0.024	0.033	0.024	1441	.0012			
RX	0	1	8.75	26	38	55.25	74	75
RY	11.5	11.5	11.5	0	0	11.5	11.5	11.5
A10 to A11								
KK	RCH 10							
KM	Belgrave to 405/22							
RD								
RC	0.014	0.014	0.014	3470	.0010			
RX	0	0.01	0.02	0.03	44.03	44.04	44.05	44.06
RY	11	11	11	0	0	11	11	11
A11 to A12								
KK	RCH 11							
KM	Triple Box Culvert Underneath 405/22 (256+17.25 250+69.85)							
RD								
RC	0.014	0.014	0.014	550	.0019			
RX	0	0.01	0.02	0.03	12.03	12.04	12.05	12.06
RY	10	10	10	0	0	10	10	10

7.5.9 Model Calibration

Stream gage peak discharges for San Diego Creek at Culver Drive were analyzed using the HEC-FFA program. Using the computed 100-year discharge at Culver Drive to relate to EGGW Channel at Gothard Street, the 100-year discharge for a drainage area of 20 square miles is 8,000 cfs. The HEC-1 rainfall runoff model for EGGW Channel was calibrated to this value.

The calibration parameters are loss rates, basin n, base flow, and Muskingum channel routing parameters. Initial model parameters were assumed based on the OCHM guideline. Model runs were conducted and the model discharge values at the CP18 (Gothard Street) were compared to the discharge value of 8,000 cfs. Then, the model parameters were adjusted and new model runs were conducted. Through iterative process the model was calibrated. The model calculated discharge at CP18 is 7,980 cfs which is 0.2% different from the calibration target value.

Orange County PF&RD also developed 100-year expected discharge values for C05 and C06 using Orange County Hydrology Manual procedures. Orange County Hydrology procedures were developed using stream gage data collected in all the county watersheds. The procedures use Orange County storm, rational method, and unit hydrograph. As mentioned in this report, the HEC-1 model developed for this study was based on the Orange County storm and county suggested parameters. The model was also calibrated against the San Diego Creek data of the county. Therefore, the county's 100-year expected discharge values provide an ideal reference to compare the calibrated HEC-1 model results. Table 16 presents the comparisons between Orange County 100-year expected discharge values and the calibrated HEC-1 model results for the C05 & C06 drainage area. As shown in the table, the calibrated model results are very close to the County's results.

Tables 17 and 18 present the comparisons between Orange County 100-year expected discharge values and the calibrated HEC-1 model results for the C04 drainage area and C02 drainage area respectively. As shown in the table, the calibrated model results are very close to the County's results.

Table 16. Comparisons between Orange County & HEC-1 100-year Discharge Values for C05 & C06 Drainage Area

Concentration Point	Drainage Area ($mile^2$)	County Q (cfs)	HEC-1 Model Q (cfs)	Difference in cfs	Difference in %
C05-CP2	3.47	990	980	10	1.0
C05-CP4	4.30	1540	1520	20	1.3
C05-CP6	6.84	3380	3330	50	1.5
C05-CP8	7.94	3790	3720	70	1.9
C05-CP10	9.54	4530	4460	70	1.6
C05-CP12	10.58	4770	4780	-10	-0.2
C05-CP14	11.91	5150	5210	-60	-1.1
C05-CP16	14.48	5910	5980	-70	-1.2
C05-CP18	20.37	7710	7980	-270	-3.4
C05-CP20	22.76	8300	8420	-120	-1.4
C05-CP22	27.70	9290	9340	-50	-0.5
C05-CP23	28.02	9290	9260	30	0.3
C06-CP2	1.12	920	920	0	0.0
C06-CP4	2.19	1280	1280	0	0.0
C06-CP6	3.20	1770	1640	130	7.9
C06-CP8	3.84	2020	2030	-10	0.5
C06-CP10	4.83	2310	2320	-10	0.4
C06-CP12	5.28	2420	2410	10	0.4

Table 17. Comparisons between Orange County & HEC-1 100-year Discharge Values for C04 Drainage Area

Table 18B – Comparisons between Orange County & HEC-1 100-year Discharge Values for C04 Drainage Area					
Concentration Point	Drainage Area ($mile^2$)	County Q (cfs)	HEC-1 Model Q (cfs)	Difference in cfs	Difference in %
C04-CP2	1.53	1220	1191	29	2.0
C04-CP4	2.06	1540	1576	-36	-2.0
C04-CP6	4.92	3010	2888	122	4.0
C04-CP8	5.91	3360	3244	116	3.0
C04-CP10	7.75	4000	4093	-93	-2.0
C04-CP12	8.38	4190	4275	-85	-2.0
C04-CP14	9.33	4310	4425	-115	-3.0
C04-CP16	10.12	4420	4645	-225	-5.0
C04-CP18	10.80	4520	4580	-60	-1.0

Table 18. Comparisons between Orange County & HEC-1 100-year Discharge Values for C02 Drainage Area

Table 18C – Comparisons between Orange County & HEC-1 100-year Discharge Values for C02 Drainage Area					
Concentration Point	Drainage Area ($mile^2$)	County Q (cfs)	HEC-1 Model Q (cfs)	Difference in cfs	Difference in %
C02-CP2	1.51	1200	1206	-6	0.0
C02-CP4	5.25	3000	2841	159	5.3
C02-CP6	5.95	3200	3141	59	1.8
C02-CP8	7.50	3800	3925	-125	-3.3
C02-CP10	8.76	4150	4051	99	2.4

7.5.10 Nth Value Flow Ratios

Nth value ratios were used to determine peak discharges for frequencies greater and less than the 100 year event. Table 19 shows the nth flow ratios used by Orange County that have been adopted for this study. In addition to San Diego Creek, a flow frequency analysis was completed for five gages operated by Orange County. These gage locations include Fullterton Creek (Station 2), Bolsa Chica (Station 225), Anaheim Barber (Station 232), East Garden Grove (217) and Westminster Channel (207). Figure 2 shows the comparison of the Nth value flow ratios for these gages. The orange line representing the ratios used by Orange County bounds the upper limit of most the computed ratios but shows a favorable comparison. Orange County has developed these Nth flow values based on comparisons with hydrologically similar basins.

Table 19. Nth flow values used by Orange County

Frequency	Nth Year Ratio
1	0.22
2	0.32
5	0.47
10	0.67
25	0.82
50	0.92
100	1.00
200	1.14
500	1.29

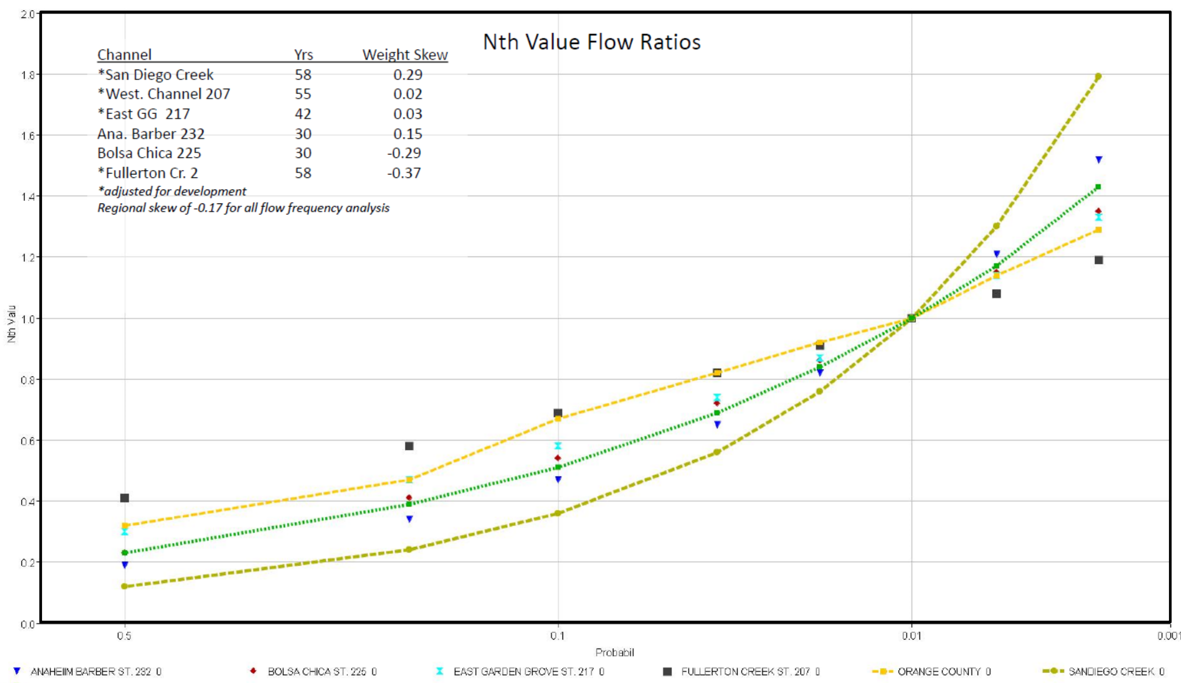

Figure 5. Comparison of between gages Nth value ratios and ratios used by Orange County.

7.5.11 Unsteady Model Discharges

The HEC-1 models for this study were developed for steady state analysis where channel routing was performed in the hydrologic model. HEC-1 hydrologic modeling was used along with and HEC-RAS steady state hydraulic models along with a FLO- 2D to evaluate overbank flooding in areas where breakouts occur.

Since the development of the original modeling suite using HEC-1, HEC-RAS (steady) and FLO-2D, HEC-RAS capabilities have expanded to include integrated one-dimensional, two-dimensional capabilities that will allow water movement both into and out of the channel. The HEC-RAS unsteady model developed for this study is later described in more detail Section 7. When the unsteady HEC-RAS model was used to route flows through the system, some notable differences in flow were observed in the flows. In generals flows exceeded the target calibration values by about 10% on the lower end of C05 and C04. As expected, some differences were observed between the Muskingum-Cunge routing and the unsteady model. To correct this issue, loss rate and 'Basin n' HEC-1 parameters were modified to provide a better match to the target flows for calibration.

Tables 20 and 21 present the watershed characteristics for the study area including along with the calibrated basin roughness factor (n) for C05 & C06 drainage area, C04 drainage area, respectively for the unsteady model. Tables 22 and 23 present the calibrated loss rates for the unsteady model. No model parameters were changed for C02. Figures 3, 4 and 5 present a comparison between the unsteady flow and steady flows.

Table 20. Watershed Characteristics of C05 / C06 Drainage Area (Basin N calibrated for unsteady model)

Subarea	Drainage Area (sq. mi.)	L (mi.)	Lca (mi.)	Representative Slope (ft./mi.)	Basin N
A1	1.867	3.552	1.776	17.589	.043
A2	0.977	2.379	1.190	12.156	.043
A3	0.625	1.805	0.902	13.804	.043
A4	0.65	1.849	0.925	2.973	.035
A5	0.18	0.836	0.418	19.15	.035
A6	2.436	4.188	2.094	10.816	.02
A7	0.106	0.602	0.301	8.309	.02
A8	0.555	1.677	0.838	14.308	.08
A9	0.542	1.653	0.826	7.259	.08
A10	0.291	1.125	0.562	8.005	.08
A11	1.308	2.850	1.425	10.000	.08
A12	0.803	2.108	1.054	9.963	.03
A13	0.238	0.993	0.497	4.030	.08
A14	0.806	2.112	1.056	14.440	.08
A15	0.522	1.615	0.807	10.218	.08
A16	0.494	1.560	0.780	5.125	.06
A17	2.077	3.794	1.897	6.588	.11
A18	0.609	1.776	0.888	7.319	.12
A19	1.645	3.285	1.642	7.611	.12
A20	0.745	2.012	1.006	6.461	.12
A21	0.719	1.968	0.984	5.589	.12
A22	4.228	5.890	2.945	14.261	.08
A23	0.316	1.184	0.592	43.935	.03
6A1	0.766	2.046	1.023	10.458	.04
6A2	0.172	0.812	0.406	28.324	.04
6A3	0.188	0.857	0.428	19.138	.04
6A4	0.484	1.542	0.771	20.239	.04
6A5	1.047	1.720	0.860	12.326	.04
6A6	0.188	0.857	0.428	20.072	.02
6A7	0.359	1.282	0.641	15.059	.02
6A8	0.484	1.542	0.771	10.833	.02
6A9	0.156	0.766	0.383	18.811	.12
6A10	0.172	0.812	0.406	14.109	.12
6A11	0.813	2.123	1.061	22.468	.12
6A12	0.172	0.812	0.406	32.388	.12
6A13	0.281	1.101	0.551	27.877	.12

Note: Changes made for the unsteady calibration are highlighted in red.

Table 21. Watershed Characteristics of C04 Drainage Area (Basin N calibrated for unsteady model)

Subarea	Drainage Area (sq. mi.)	L (mi.)	Lca (mi.)	Representative Slope (ft./mi.)	Basin N
A1	1.38	2.18	1.63	16.89	0.035
A2	0.15	0.75	0.56	14.61	0.040
A3	0.34	0.99	0.75	20.11	0.039
A4	0.18	0.89	0.67	14.53	0.039
A5	0.39	1.09	0.82	13.71	0.039
A6	2.48	3.69	2.77	12.93	0.039
A7	0.83	2.46	2.00	11.39	0.050
A8	0.15	0.88	0.66	12.49	0.045
A9	0.76	2.13	1.60	13.61	0.039
A10	1.09	1.85	1.48	10.83	0.060
A11	0.44	1.52	1.14	9.21	0.030
A12	0.18	0.55	0.42	10.83	0.030
A13	0.52	1.43	1.20	9.06	0.150
A14	0.43	1.26	0.95	7.91	0.015
A15	0.19	0.98	0.74	6.12	0.015
A16	0.60	1.41	1.05	2.13	0.015
A17	0.27	0.64	0.32	4.69	0.015
A18	0.40	1.15	0.58	4.78	0.015
A19	0.09	0.72	0.36	2.76	0.015

Note: Changes made for the unsteady calibration are highlighted in red.

Table 22. Summary of Calibrated Loss Rates for C05 and C06 Drainage Area (unsteady model)

Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)	Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)
A1	0.247	0.0656	A19	0.550	0.3318
A2	0.247	0.0656	A20	0.550	0.3318
A3	0.239	0.0629	A21	0.306	0.1369
A4	0.454	0.1313	A22	0.550	0.3318
A5	0.372	0.1172	A23	0.195	0.0736
A6	0.369	0.1147	6A1	0.471	0.1347
A7	0.134	0.0300	6A2	0.471	0.1347
A8	0.323	0.0872	6A3	0.471	0.1347
A9	0.448	0.1283	6A4	0.608	0.1856
A10	0.211	0.0529	6A5	0.644	0.2262
A11	0.251	0.0665	6A6	0.133	0.0350
A12	0.421	0.1345	6A7	0.133	0.0350
A13	0.418	0.1423	6A8	0.202	0.0612
A14	0.316	0.1022	6A9	0.133	0.0350
A15	0.325	0.1173	6A10	0.133	0.0350
A16	0.333	0.1374	6A11	0.309	0.1010
A17	0.373	0.1309	6A12	0.288	0.0927
A18	0.608	0.1856	6A13	0.221	0.0868

Note: Changes made for the unsteady calibration are highlighted in red.

Table 23. Summary of Calibrated Orange County Loss Rates for C04 Drainage Area

Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)	Subarea	Low Loss Rate (%)	Max. Loss Rate (in/hr)
A1	.4000	.1500	A11	.4000	.1500
A2	.4500	.1750	A12	.4000	.1500
A3	.4000	.1500	A13	.5500	.3000
A4	.4000	.1500	A14	.5500	.3000
A5	.4000	.1500	A15	.5500	.3000
A6	.4000	.1500	A16	.5500	.3000
A7	.5000	.2000	A17	.5500	.3000
A8	.4500	.1750	A18	.5500	.3000
A9	.4000	.1500	A19	.5500	.3000
A10	.2880	.0927			

Note: Changes made for the unsteady calibration are highlighted in red.

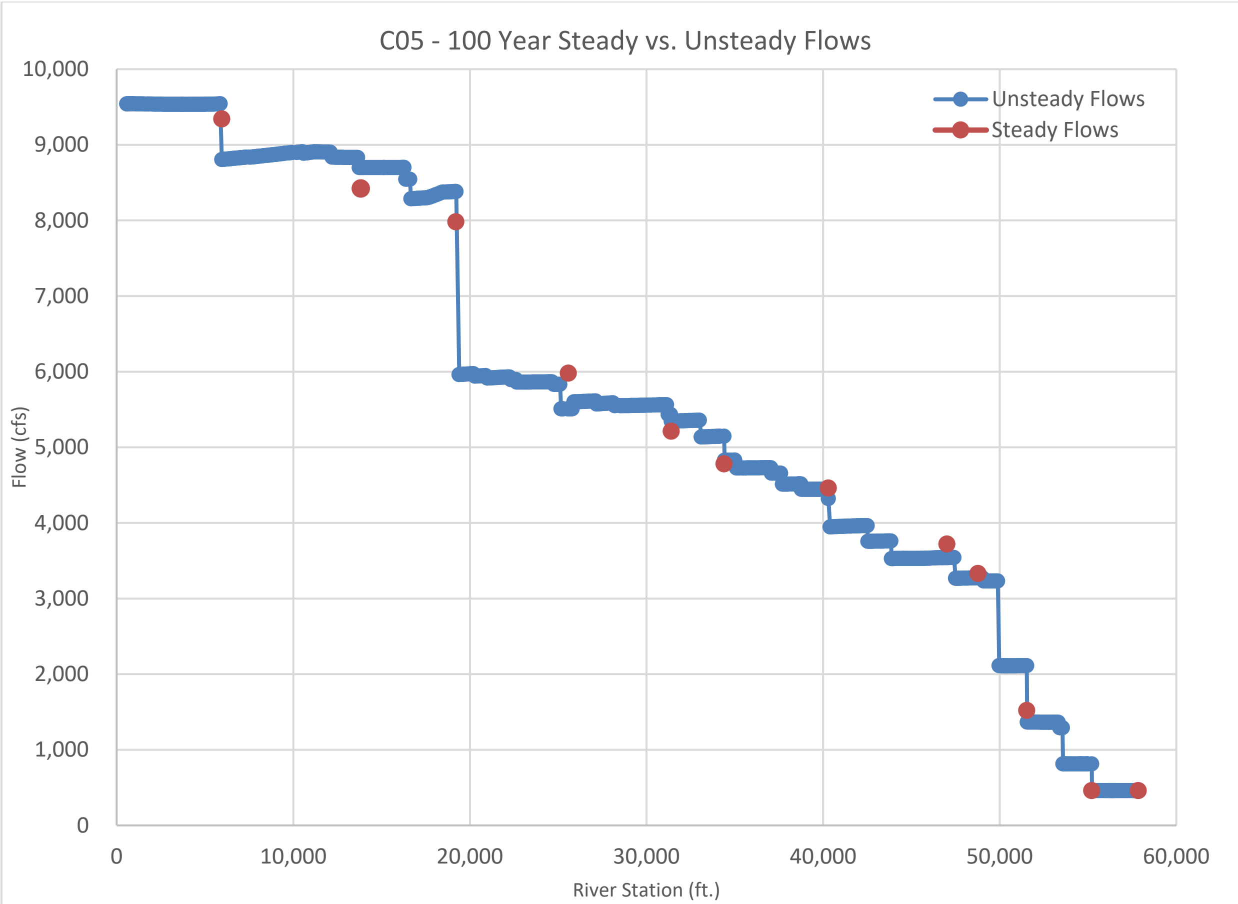

Figure 6: Comparison of 100 year steady and unsteady flows for C05

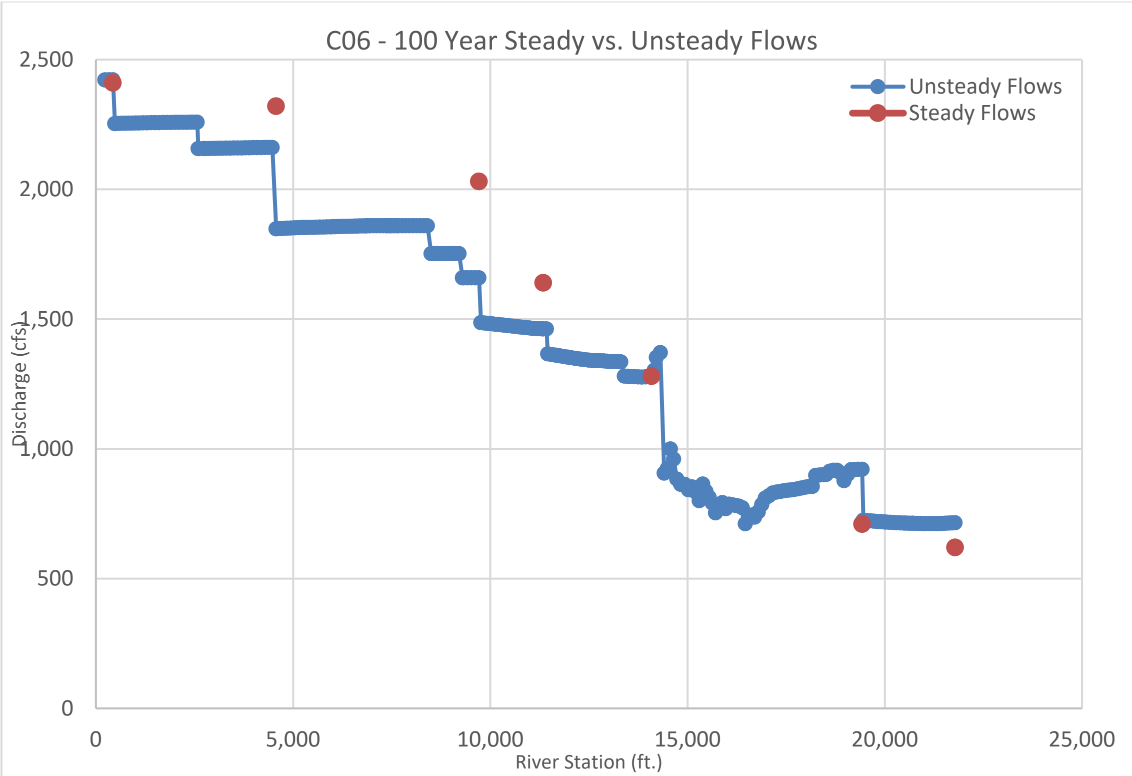

Figure 7: Comparison of 100 year steady and unsteady flows for C06

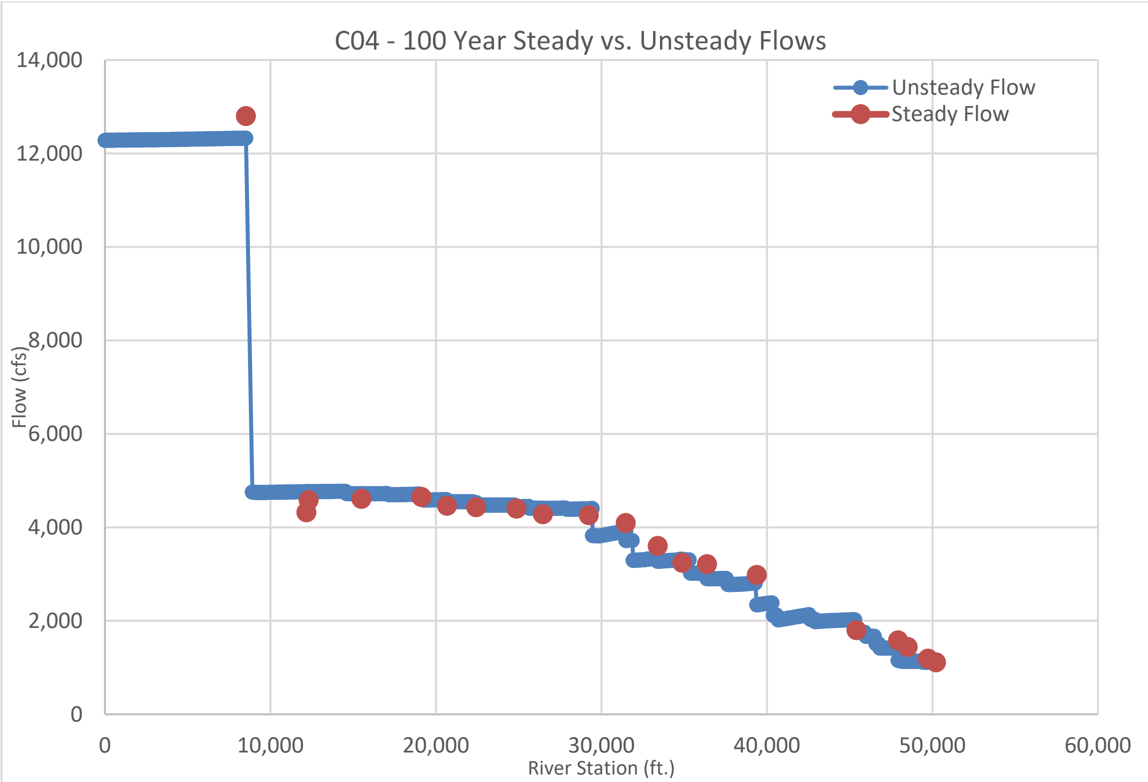

Figure 8: Comparison of 100 year steady and unsteady flows for C04

8.0 Climate Change

8.1 Inland Hydrology Climate Change

USACE Engineering and Construction Bulletin (ECB) 2018-14 (Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects), "provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaptation policy. This policy requires consideration of climate change in all current and future studies to reduce vulnerabilities and enhance the resilience of our water resources infrastructure." The document "helps support a qualitative assessment of potential climate change threats and impacts" related to USACE analyses.

Extreme seasonal conditions of temperature, rainfall and runoff may become more common in some regions. These conditions may be intensified by future changes in the condition of native vegetation and societal demands for energy and water. Therefore USACE projects, programs, missions, and operations must assess these potential changes to remain reliable in spite of this baseline shift. A qualitative assessment of potential climate change threats and impacts that may be potentially relevant to this study was conducted to address this issue. This qualitative assessment was performed under the guidance of ECB No. 2018-14 (USACE 2018).

The qualitative analysis required by ECB No. 2018-14 should focus on those aspects of climate and hydrology relevant to the project's problems, opportunities, and alternatives, and include consideration of both past (observed) changes as well as projected, future (modeled) changes. At the time of issuance of this ECB, the qualitative analysis is not expected to alter the numerical results of the calculations made for the other, non-climate aspects of the required hydrologic analyses. However, the qualitative analysis can inform the decision process related to future without project conditions, formulation, and evaluation of the performance of alternative plans, and other decisions related to project planning, engineering, operation, and maintenance.

Attachment C to the ECB, titled "Preview of Quantitative Analysis Requirements," highlights the three primary components of the anticipated future quantitative guidance:

- Detection of trends;
- Attribution of these trends to climate change; and
- Projection of future trends.

Climate change is a global-scale concern, but can be particularly important in the western United States where potential impacts on water resources can be significant to supplies for water agencies. Orange County is considering impacts of climate change and has conducted multiple studies regarding the effect on the sustainable and reliable water supply. One such report that Orange County prepared entitled the "Integrated Regional Water Management Plan" (IRWMP) was published in July 2013. Section 12 and Appendix J of the report discuss potential water reliability impacts that may occur as a result of climate change to the region and has proposed solutions (Orange County 2013).

For the study area, significant changes to the hydrology can be attributed to the development in the 1970s and 1980s. This conversion from agriculture has had a significant impact on the runoff potential. Since the study area is nearly built out, this change is not expected to continue in the future.

8.1.1 Climate Change Literature Review

USACE is undertaking its climate change preparedness and resilience planning and implementation in consultation with internal and external experts using the best available — and actionable — climate science. As part of this effort, the USACE has developed concise reports summarizing observed and projected climate and hydrological patterns, at a hydrologic unit code (HUC2) Watershed scale cited in reputable peer-reviewed literature and authoritative national and regional reports. The USACE literature review report focused on the California Region was finalized in July 2015 (USACE, 2015). Trends are characterized in terms of climate threats to USACE business lines. The reports also provide context and linkage to other agency resources for climate resilience planning, such as downscaled climate data for sub-regions, and watershed vulnerability assessment tools.

8.1.2 Observed Temperature Trends

A number of studies focusing on observed trends in historical temperatures were reviewed in the recent climate change literature review for the California Region (USACE 2015). These include both national-scale studies inclusive of results relevant to the California Region and regional studies focused more specifically and exclusively on the California Region.

At a national scale, a 2009 study by Wang et al. examined historical climate trends across the continental United States. Gridded (0.5 degrees x 0.5 degrees) mean monthly climate data for the period 1950 – 2000 were used. The focus of this work was on the link between observed seasonality and regionality of trends and sea surface temperature variability. The authors identified positive statistically significant trends in recent observed seasonal mean surface air temperature for most of the U.S. For the California Region, seasonal differences were identified in the historical mean air temperatures. A primarily positive historical warming trend was identified for the California Region in the winter (December – February) and spring (March – May), and a historical cooling trend was shown for the fall (September – November). Spatial variability in historical temperature trends throughout the California Region is shown in summer (June – August) with some areas showing increasing temperature trends and others showing decreasing temperature trends. The authors do not provide information on statistical significance of the presented observed trends.

An article by MacDonald (2010) evaluated average annual temperatures over 2001 – 2009 compared to 1951 – 1960. In the California Region annual temperatures were up to 1.5 standard deviations above the 20th century average. Details on statistical significance were not provided in the study.

A national study by Tebaldi (2012) evaluated average annual historical decadal changes in temperature. Based on data from 1912 – 2011, temperatures within the state of California (which the California Region is primarily within), increased in temperatures at a rate of 0.16 °F (0.09°C) per decade respectively with a 95% confidence interval.

Similarly, Hoerling et al. (2013) assessed annually averaged daily temperature trends in the Southwest using observed climate and paleoclimate record. In the California Region, a statistically significant (95% C.I.) increase in average annual daily temperature of 0.9 to 4.5 °F (0.5 – 2.5 °C) was identified between 1901 and 2010.

The fourth NCA report (Easterling et al., 2017) presents trends in historical annual average temperatures for the southwestern U.S. For the southwestern U.S., including the California Region, historical data shows a general warming of average annual temperatures in the early part of the 21st century. Details on statistical significance are not provided. When comparing a recent 22-year span (1991 – 2012) to a historical average (1901 – 1960), temperatures have increased throughout the California Region by up to 2 °F (1.11 °C (Walsh et al., 2014) This is consistent with an increasing trend in annual average temperatures within the California Region reported by MacDonald (2010), Tebaldi (2012), and Hoerling et al. (2013).

8.1.3 Projected Temperature Trends

GCMs have been used extensively to project future climate conditions across the country. At a national scale, model projections generally show a significant warming trend throughout the 21st century, with a high level of consensus across models and modeling assumptions. Results of studies inclusive of the California Region typically fall in line with these generalizations.

Elguindi and Grundstein (2013) present results of regional climate modeling of the U.S. focused on the Thornthwaite climate type – a measure of the combination of relative temperature and precipitation projections. For the California Region, results show a shift to a more arid climate by the period 2041 – 2070.

In a regional study, Cayan et al. (2013) investigated projected temperature trends for the southwestern U.S. Several Coupled Model Intercomparison Project 3 (CMIP3) GCMs were used, coupled with dynamically downscaled models and biased correction and spatial downscaling. The A2 (high) and B1 (low) emissions scenarios were evaluated for future projections. An increase in annual average temperature is predicted with high confidence for the southwestern U.S. from 2001 to 2100. Seasonal temperatures trends are projected to increase, with the highest increases in summer temperatures. Within the Klamath Basin in California, historical and projected temperature trends for January and July were evaluated for the A2 (high) and B1 (low) emissions scenarios from 1950 – 2100. Similar to the southwest U.S. as a whole, temperature increases are projected within the California Region for January and July, with the largest potential temperature increases in summer under high emissions scenarios. With the increase in temperatures, the length of the freeze-free season in the California Region is projected to increase by approximately 10 to 45 days, spatially varying, in 2041 – 2070 compared to a baseline period of 1971 – 2000. Specific information on confidence intervals was not provided with the study.

The fourth NCA (Easterling et al., 2017) generally supports the findings presented above. Climate model projections for the southwestern U.S., inclusive of the California Region, presented in this report indicate an increase in annual average temperature over the next century by up to 8.5 °F (4.7 °C) depending on emissions scenario.

For the California Region specifically, Cayan et al. (2008) evaluated future climate scenarios. Two GCMs were simulated with the B1 (low) and A2 (medium-high) emissions. The study predicted temperature increases of 1.5 ºC (2.7 ºF) to 4.5 ºC (8.1 ºF) by the end of the 21st century, depending on the model and emissions scenario evaluated, with the largest increases occurring in summer months.

Trends in minimum and maximum temperatures across the continental U. S. were the focus of a study by Ashfaq et al. (2010). The study applied a single regional climate model to compare future projections (2071 – 2100) to historical climate (1961 – 1990). They quantified changes in summer and fall daily maximum temperature of up to approximately 5 K (9 ºF or 5 ºC) for the California Region, and spring and winter maximum temperature changes of approximate 3 to 4 K (5.4 to 7.2 ºF or 3 to 4 ºC). Daily minimum temperature changes were also projected to increase by approximately 5 K (9 ºF or 5 ºC) for the summer and fall, and approximately 3.5 K (6.3 ºF or 3.5 ºC) for winter and spring in the California Region.

Daily maximum air temperature projections were investigated by Liu et al. (2013) using a single GCM and assuming an A2 greenhouse gas emissions scenario (worst case) in a national analysis. For the California Region, the results of their study show a projected increase in winter and spring maximum air temperature of 1.5 – 3.0 ºC (2.7 – 5.4 ºF) for a 2055 planning horizon compared to a baseline period of 1971 – 2000. The results of the study project increases in maximum air temperature from 2 to 4 ºC (3.6 – 7.2 ºF) for summer and fall temperatures.

Scherer and Diffenbaugh (2014) applied a multi-member ensemble GCM, assuming an A1B (middle of the road) emissions scenario, to the continental U.S. For the southwestern U.S., including the California Region, model projections indicate steadily increasing air temperatures throughout the 21st century for both daily maximum summer and winter minimum temperatures. By 2090, projections show an increase of 4.0 ºC (7.2 ºF) in the summer maximum air temperature and 3.4 ºC (6.1 ºF) in the winter minimum temperature, compared to a 1980 – 2009 baseline period. These results agree well with those described previously for Liu et al. (2013).

Projections of changes in temperature extremes have been the subject of several recent studies. A 2006 study by Tebaldi et al. applied nine GCMs at a global scale focused on extreme precipitation and temperature projections. Model projections of climate at the end of the century (2080 – 2099) were compared to historical data for the period 1980 – 1999. For the general California Region, using an A1B climate scenario, spatial variability in extreme temperature range (annual high minus annual low temperature) is illustrated, with some areas of slight increases and some areas of slight decreases. A statistically significant (indicated by concurrence of at least five out of nine models) increase in a heat wave duration index (increase of 3 to 4.5 days per year that temperatures continuously exceed the historical norm by at least 5 ºC or 9 ºF), and a statistically significant moderate increase in the number of warm nights (6 to 7.5 percent increase in the percentage of times in the year when minimum temperature is above the 90th percentile of the climatological distribution for the given calendar year), compared to the baseline period in the California Region. The number of frost days, (defined as the annual number of days with minimum temperatures below 0 ºC or 32 °F) is predicted to decrease, with statistical significance, by up to 5 days per year in the southwestern U.S., inclusive of the California Region.

In a study by Kunkel et al. (2010), two different downscaled GCMs were applied to the continental U.S., assuming high greenhouse gas emissions scenarios (A2 and A1F), with a focus on summer heat wave occurrence and intensity. For the California Region, projections indicate spatial variability, with up to a 7.5 ºC (13.5 ºF) increase in three-day heat wave temperatures and up to an 80-day increase in the annual number of heat wave days for a 2086 planning horizon compared to a recent historical baseline of 1976. A later study of the southwestern U.S. by Kunkel et al. (2013) showed a statistically significant decrease in the number of days with a minimum temperature less than 32 °F (0 ºC) for the 2041 – 2070 time period compared to the reference period of 1980 – 2000 based on the output from the eight North American Regional Climate Change Assessment Program (NARCCAP)'s Regional Climate Model simulations of the A2 emissions scenario. Similarly, the number of days with maximum temperatures exceeding 95 °F (35 ºC) is projected to increase by up to 30 days per year in 2041 – 2070 compared to the baseline period of 1980 – 2000.

Another regional study by Dettinger et al. (2012) evaluated trends in annual minimum temperature and annual mean precipitation for the southwestern U.S. using results from National Oceanic and Atmospheric Administration's (NOAA's) Geophysical Fluid Dynamics Laboratory (GFDL) coupled ocean atmospheric GCM model and National Center for Atmospheric Research's Parallel Climate Model (PCM1) simulating the A2 (middle of the road) and B1 (low) emissions scenarios over the 21st century. Results from this analysis show an increasing trend in annual average minimum temperature, up to 6 °C (10.8 °F), for all models and associated emissions scenarios.

Gershunov et al. (2012) studied trends in heat waves in California. The study used four GCMs and an A2 emissions scenario to evaluate heat waves, defined as a group of consecutive days in which maximum or minimum temperatures exceed the 95th percentile threshold. Projected heat wave trends were compared to a baseline period of 1950 – 1999. Heat waves were categorized into two types for the purposes of this study: Type 1 heat waves, which are dry daytime heat waves, and Type II heat waves, which are humid nighttime accentuated events. All four GCMs showed significant increases in heat wave activity of both types. Type II heat waves predicted to increase more intensely than the Type I events. The study predicts that desert heat waves will become less intense in the future, while coastal heat waves are projected to intensify.

The study of the California Region by Cayan et al. (2008), mentioned previously, also evaluated projected changes in the occurrence of extreme daily temperatures between June and September in northern and southern California. The study illustrates a projected increase in the occurrence of 99.9

percentile temperatures, in some cases increasing from 4 days per year during the period of 1961 – 1990 to over 200 occurrences by the end of the 21st century under the high emissions scenario. These projections of increased extreme temperatures are consistent with the projections from other studies.

According to a study by UC Los Angeles, southern California is likely to experience a 4.3 °F average rise in temperatures by the mid-21st century (i.e., 2041-2060), should greenhouse gas emissions continue to increase at comparable rates to those of the past decade. Coastal locations are projected to see roughly two to three times the number of extremely hot days. These temperature effects may be somewhat smaller if emissions begin to decline over the next few decades. By the end of the century, average temperatures across the region are most likely to be 8.2 °F warmer than they were in 1981-2000, if greenhouse gas emissions continue to increase at comparable rates to those of the past decade (UCLA and LARC 2012).

Strong consensus exists in the literature for the study area that the projected mean, minimum, maximum and extreme temperatures show an increasing trend over the next century (USACE 2015).

8.1.4 Observed Precipitation Trends

Multiple authors, evaluating precipitation trends on a national scale, have not identified significant trends in total annual precipitation in recent historical records for the study region. Grundstein (2009) found no statistically significant (95% C.I.) trend in soil moisture index, and no trend in annual precipitation in the California Region based on annual data from 1895 to 2006. Very slight increasing potential evaporation trends with statistical significance were identified in two locations within the California Region. Soil moisture is a function of both supply (precipitation) and demand (ET), and therefore is an effective proxy for both precipitation and ET.

A similar study by Wang et al. (2009) also focused on historical climate trends across the continental U.S. using gridded climate data and a shorter period of record (1950 – 2000). The authors identified generally positive significant trends in annual precipitation for most of the U.S. For the California Region, large spatial variability was found in historical precipitation trends. Increasing trends were seen throughout the region in the spring. However, winter, summer, and fall trends show areas of increasing precipitation trends and areas of decreasing trends. The authors do not provide information on statistical significance of the presented observed trends.

A 2011 study by McRoberts and Nielsen-Gammon used a new continuous and homogenous dataset to perform precipitation trend analyses for sub-basins across the United States. The extended data period used for the analysis was 1895 – 2009. Linear positive trends in annual precipitation were identified for most of the U.S. For the California Region, results indicate no change or slight increases (up to 10 percent change per century) for the majority of the region, with a small section of northeastern California displaying slight decreases (up to -5 percent change per century) in precipitation. The authors do not provide information on statistical significance of the presented observed trends.

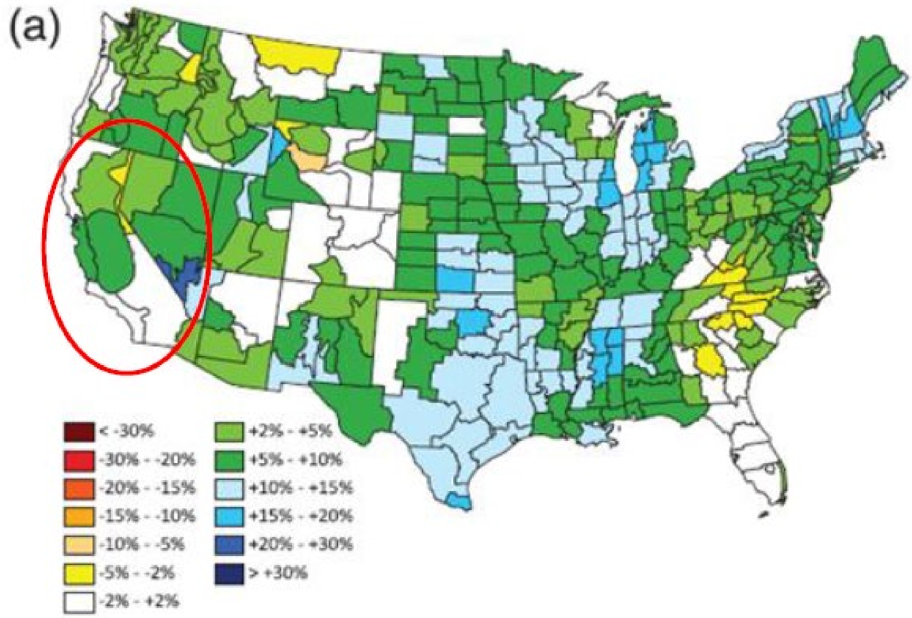

Figure 9. Linear trends in annual precipitation, 1895 – 2009, percent change per century. The California Region is within the red oval (McRoberts and Nielsen-Gammon, 2011).

Similarly, a study by MacDonald (2010) evaluated national precipitation from 2001 – 2009 standardized relative to data from 1895 – 2000. These results show a decrease in precipitation within the California Region.

Palecki et al. (2005) examined historical precipitation data from across the continental U.S. They quantified trends in precipitation for the period 1972 to 2002 using NCDC 15-minute rainfall data. A predominant decreasing trend in storm precipitation totals are projected for the California Region, with some areas showing statistically significant decreases (95% C.I.) in winter and fall precipitation storm totals, and statistically significant decreases (90% C.I.) in some areas during spring months. Across all seasons, storm durations have decreased and storm intensity has increased throughout the majority of the California Region.

According to the fourth NCA, Easterling et al. (2017) climate models project an increase in the frequency of heavy downpours, especially through atmospheric rivers, which are narrow bands of highly concentrated storms that move in from the Pacific Ocean. A series of strong atmospheric rivers caused extreme flooding in California in 2016 and 2017. Under the higher scenario (RCP8.5), models project increases in the frequency and intensity of atmospheric rivers. Climate models also project an increase in daily extreme summer precipitation in the Southwest region, based on projected increases in water vapor resulting from higher temperatures. Projections of summer total precipitation are uncertain, with average projected totals not differing substantially from what would be expected due to natural variations in climate.

A number of recent studies have focused more specifically on southwestern U.S., including the California Region. Kunkel et al. (2013) found no statistically significant trends in historical annual, seasonal, or extreme precipitation from 1895 – 2011 for the Southwest. No trends in the frequency of extreme precipitation events were found either.

Lavers et al. (2015) evaluated the contribution of atmospheric rivers to precipitation in Europe and the United States. Atmospheric rivers are concentrated near-surface water vapor that form about one mile up in the atmosphere and can extend for thousands of miles. (Dettinger et al., 2013). California's largest storms are generally fueled by landfalling atmospheric rivers and may contribute 20 to 50 percent of the precipitation and streamflow in California. (Dettinger et al., 2011). Lavers studied the percent of precipitation which was caused by atmospheric rivers from 1979 to 2012 using data from the European Centre for Medium-Range Weather Forecasts ERA- Interim reanalysis. These results illustrate that atmospheric rivers have the largest influence on precipitation from October to February in the California Region. Precipitation in the western U.S., and the California Region, in particular, is heavily influenced by atmospheric rivers due to the hills and mountains which cause orographic enhancement of precipitation. A zero-inflated beta regression model was used to examine changes in the contribution of atmospheric rivers to precipitation during the study period, and found an increasing trend in the probability of zero-atmospheric river contribution to cold season rainfall in the California Region and the southwestern U.S. (Lavers et al., 2015).

No consistent trend has been identified in the region's historic precipitation data, and there is little consensus across the literature (USACE, 2015).

8.1.5 Projected Precipitation Trends

In line with projections for the rest of the country, projections of future changes in precipitation in the California Region are variable with topography and latitudinal changes throughout the region. From a global analysis using three GCM projections, Hagemann et al. (2013) projects spatial variability in annual precipitation changes, with a range from -20 mm per year in south California to up to 200 mm per year in the northern parts of the region.

The Liu et al. (2013) study of the continental U.S., mentioned in Section 3.1, quantified spatial and seasonal variability in projected precipitation trends within the California Region. The study projects spatial variability in all seasons, with the largest increases and decreases in winter, with increases in southern California and decreases in northern California for a 2041 – 2070 planning horizon, relative to a recent historical baseline (1971 – 2000, centered around 1985) in the California Region. Decreasing precipitation trends for this time period are projected in summer and spring, with pockets of slight increases in southern California projected for summer, and areas of larger decreases projected in the mountainous areas of the region in spring. Fall precipitation trends are projected to primarily increase, with the largest increases occurring in southern California and the mountainous areas of northern California.

In a study of the western U.S. by Gutzler and Robbins (2010), the middle of the road (A1B) ensemble of projections show spatial variability in precipitation trends throughout the California Region. Areas of southern California exhibit decreasing trends or no change, while northern areas of the California Region exhibit no change or slight increasing trends in annual average precipitation for the last quarter of the 21st century compared to the last quarter of the 20th century. The authors also project an increase in future drought indices for the region, as a function of changing climate, that indicate reduced soil moisture and more drought-prone conditions.

Several regional studies have been performed on precipitation trends in the southwestern U.S., inclusive of the California Region. In support of the fourth NCA, Easterling et al. (20137) prepared a report that summarizes the most recent understanding of projected climates in the southwest United States. These authors calculated the median of sixteen downscaled simulations for three future time horizons: 2021 – 2050, 2041 – 2070, and 2070 – 2099. For the California Region, Cayan et al. (2013) found that under a high-emissions scenario, annual average precipitation is projected to be 80 – 100 percent of the historical average by the end of the 21st century, with decreases mainly in southern and central California.

A study by Seager and Vecchi (2010) projected seasonal climate trends in southwestern North America based on 24 climate models used as part of the Intergovernmental Panel on Climate Change (IPCC) Assessment Report Four (IPCC AR4). Results of the analysis indicate a drop in precipitation in the winter and summer seasons across the 21st century, and an increase in winter evaporation. In summer, evaporation decreases in parallel with precipitation, reflecting decreases in moisture available for evaporation.

A study by Dettinger (2012) simulated projected trends in annual mean precipitation over the 21st century based on two regionally downscaled model results with two emissions scenarios for the southwestern U.S. For the California Region specifically, the projections primarily indicate decreasing precipitation trends for the 21st century.

In addition to the study's evaluation of the southwestern U.S., Cayan et al. (2013) also evaluated future precipitation trends at a watershed scale for three regions, one of which was the California Region. The study noted large spatial and temporal variability in historical and projected precipitation trends. This study found, with medium-low confidence, a decrease in precipitation in the southern portion of the southwestern U.S. and no change or an increase in precipitation in the northern portions of the southwestern U.S. Little change in precipitation volume was projected for the California Region.

Wang and Zhang (2008) also used downscaled GCMs to look at potential future changes in extreme precipitation events across North America. The GCMs were forced with the IPCC high emissions scenario (A2) to quantify a significant increase in the recurrence (1 to 2 times) of the current 20-year 24-hour storm event for their future planning horizon (2050 – 2099) in the California Region. They found a greater increase in extreme precipitation event risk in southern California than in areas to the north.

Precipitation in the California Region is often related to landfalling atmospheric rivers. Atmospheric rivers are long streams of concentrated, near-surface water vapor above the Pacific Ocean which deliver masses of warm, moist air to the California Region. They were the focus of several studies related to precipitation and streamflow trends throughout the region. Understanding the behavior of atmospheric rivers can help in identifying precipitation trends in the California Region. Atmospheric rivers have been identified as being responsible for 20 – 50 percent of precipitation and streamflow in the California Region (Dettinger et al., 2011). Dettinger (2011) studied changes in the frequency of days from December through February when atmospheric rivers most likely occur using a seven model ensemble of historical climate and projected future climate simulations. Using an A2 emissions scenario, this study projected an increase in the number of atmospheric rivers and a lengthening of the peak season of atmospheric river occurrence. Dettinger (2013) reports that six out of the seven climate models predict that the average rain and snow delivered to California by future atmospheric rivers will increase by an average of about 10 percent by the year 2100. The historical average of nine atmospheric rivers that impact the California coast each year is projected to rise to 11 by the end of the century. Atmospheric river landfalls in the mountains and hills in California often cause heavy precipitation and extreme streamflow events (Kim, 2013).

A study by Warner et al. (2015) also investigated extreme precipitation events that occur along the west coast of North America associated with winter atmospheric river events. The study used phase 5 of the Coupled Model Intercomparison Project (CMIP5) to evaluate changes in precipitation trends from 2070 – 2099 compared to the baseline period of 1970 – 1999. The study found an increase of 11 – 18 percent in winter average precipitation along the west coast of the U.S. In addition, the frequency of days with vertically integrated water vapor transport is projected to increase as much as 290 percent by the end of the century.

Large variability exists, spatially, and across model projections, for future precipitation trends within the California Region. There is little consensus across the literature as to how precipitation trends will change, although many studies recognize this variability. Despite the low consensus in precipitation trends, extreme precipitation events are projected to increase in intensity and/or frequency with high consensus throughout the literature for the California Region (USACE, 2015).

8.1.6 Observed Hydrology Trends

In 2013, Xu et al. investigated trends in streamflow for approximately five stations in the California Region. This study used the Model Parameter Estimation Experiment (MOPEX) dataset for the period 1950 – 2000. Gages within the California Region primarily reported no statistically significant (at 95% C.I.) trend in streamflow.

A study by Sangarika et al. (2014) evaluated data from 240 unimpaired streamflow stations throughout the U.S. from 1951 – 2010. Similar to Xu et al., no statistically significant (90% C.I.) trend was found within the California Region.

Kalra et al. (2008) performed a study using recorded streamflow data from 639 unimpaired stations to assess trends and step changes in streamflow between 1951 and 2002. Kalra et al. reported no significant (95% C.I.) trend in streamflow within the California Region.

Hoerling et al. (2013) used observed climate records to analyze the last 100 years of climate variability in the southwestern U.S. The authors compared the basin-mean daily streamflow of 2001 – 2010 to 1931 – 2000 for the Sacramento-San Joaquin Rivers, located within the California Region, and found the rivers had 37 percent less mean flow from 2001 – 2010 compared to the 1931 – 2000 time period. In addition, these authors evaluated the timing of streamflow by comparing the date at which half of the annual streamflow had been discharged. For the California Region, spatial variability of streamflow timing was observed, with streamflow timing occurring earlier by up to 10 days in some areas, and with streamflow timing occurring later by about 10 days in other areas. Streamflow timing observations were reported with 90 to 95% confidence.

Literature on observed streamflow trends in the California Region have very low consensus. The majority of studies suggest that no statistically significant trends have been identified in the region's streamflow data for the latter half of the 20^{th} century.

8.1.7 Projected Hydrology Trends

A number of global and national scale studies have attempted to project future changes in hydrology, relying primarily on a combination of GCMs and macro-scale hydrologic models. The results presented by Thomson et al. (2005), described above, highlight the significant uncertainties associated with global climate modeling, particularly with respect to hydrologic parameters. Additional uncertainty is generated when these climate models are combined with hydrologic models that carry their own uncertainty. This comparison and quantification of uncertainty is the subject of a 2013 study by Hagemann et al. In this study, the authors apply three GCMs, across two emission scenarios to seed eight different hydrologic models for projecting precipitation, ET, and runoff on a global scale. Their findings, in agreement with CDM Smith (2012), indicate that the uncertainty associated with macro-scale hydrologic modeling is as great, or greater, than that associated with the selection of climate models. Study projections from Hagemann et al. (2013), for the California Region, show spatial variability, with some areas showing a decrease in runoff of up to 40 mm per year, and an increase of up to 20 mm per year for their future planning horizon (2071 – 2100) compared to the recent historical baseline (1971 – 2000), assuming an A2 emissions scenario. Changes in seasonal runoff are similar, showing a trend in runoff between -20 to +10 mm, with changes during the fall seasons showing a potential sight increase in runoff and other seasons primarily projecting a decrease in runoff.

A regional study by Cayan et al. (2013) evaluated projected changes in annual runoff based on sixteen simulations of a variable infiltration capacity (VIC) hydrologic model for the high emissions scenarios, comparing future conditions (2041 – 2070) to historical conditions (1971 – 2000). Projected annual median runoff is spatially and temporally variable within the California Region. In general, the mid and southwestern area of the California Region show a decreasing trend in annual median runoff, while increases in annual mean runoff are observed in the southeastern and northern portions of the California Region. The author did not provide specific information on confidence levels for the parameters in this study.

Because atmospheric rivers are responsible for almost all major historical floods in California, understanding how they are likely to change in the future is critical for flood risk mitigation, particularly for the Central Valley. Dettinger (2011) used a seven-model ensemble of historical- climate and projected future climate simulations to evaluate changes to the frequency and intensity of atmospheric rivers under climate change. Under the A2 scenario by 2100, there is an increase in the number of years with multiple atmospheric river events, an increase in the number of atmospheric rivers with higher-than-historical water-vapor transport rates, and an increase in atmospheric river storm temperatures. In addition, the study showed a lengthening of the peak season of atmospheric river occurrence, with the potential to lengthen the flood-hazard season.

Little consensus exists in the literature with regard to projected trends in streamflow and runoff in the California Region (USACE, 2015).

8.1.8 Observed Climate Findings

Evidence has been presented in the recent literature of increases in both annual average, and minimum and maximum temperature in the California Region over the past century. High consensus exists in the literature supporting these general observed temperature trends. However, seasonal variability and spatial variability exists in many temperature trends within the region.

Increases in annual average temperatures appear to be greatest along the coast and in southern California with less warming evident in the mountainous areas of the region. Seasonally, less consensus exists regarding the variability in temperature changes. Trends in maximum temperatures have generally illustrated the largest increases occurring in southern and central California. Minimum temperatures are also projected to decrease slightly in the mountainous areas of northern and central California with increases in minimum temperatures in the central and southern California at lower elevations within the California Region.

Trends in annual precipitation totals have been variable within the California Region in the 20th century. For the California Region as a whole, changes in annual precipitation totals are spatially variable. Observed precipitation trends may be influenced by the topographic diversity of the region or possibly the beginning and end dates over which each study was evaluated thus, making it difficult to develop general trends for the entire California Region.

Similarly, variability has been observed in historical streamflow trends and other hydrologic data for the California Region with relatively low consensus across the literature. The majority of the studies report no statistically significant trends in historical streamflows over the second half of the 20th century.

8.1.9 Future Climate Projection Summary

There is strong consensus in the literature that air temperatures will increase in the study basin, and throughout the country, over the next century. The studies reviewed here generally agree on an increase in mean annual air temperature of up to 8 ºF (4.5 ºC), with extreme temperature projections increasing by the latter half of the 21st century for the California Region. The largest increases are generally projected for the summer months with temperature increases generally projected to be higher in inland areas compared to the coast. High consensus is also seen in the literature with respect to projected increases in both frequency and severity of extreme high temperature events compared to the recent past. Decreases in frequency of extreme cold temperatures are projected, with largest frequency decreases in the mountainous areas of the California Region, including northern California.

Projections of precipitation in the study basin are less certain than those associated with air temperature. Results of some studies conflict with one another. In addition, they show seasonal and spatial variability in projected precipitation results throughout the California Region, which may be related to topographic or latitudinal variations. This variability may also be attributed to differences in time period over which the precipitation studies were conducted. The dominant trend appears to suggest an increase in precipitation in the northern areas of the region and a decrease in precipitation in the southern areas of the California Region. Moderate consensus among the reviewed studies was found regarding extreme precipitation events. Future storm events in the California Region are predicted to increase in frequency and intensity compared to the recent past.

Hydrologic projections, such as streamflow and runoff are harder to compare, with seasonal variabilities, model variabilities, and spatial variabilities in results. Hydrologic models are generally consistent with projections of future precipitation in that the northern areas are that runoff increases, if they occur, are primarily modeled for northern areas (and in the southeast, possibly related to an enhanced summer monsoon).

The trends and literary consensus of observed and projected as noted above are summarized for reference and comparison in Figure 10.

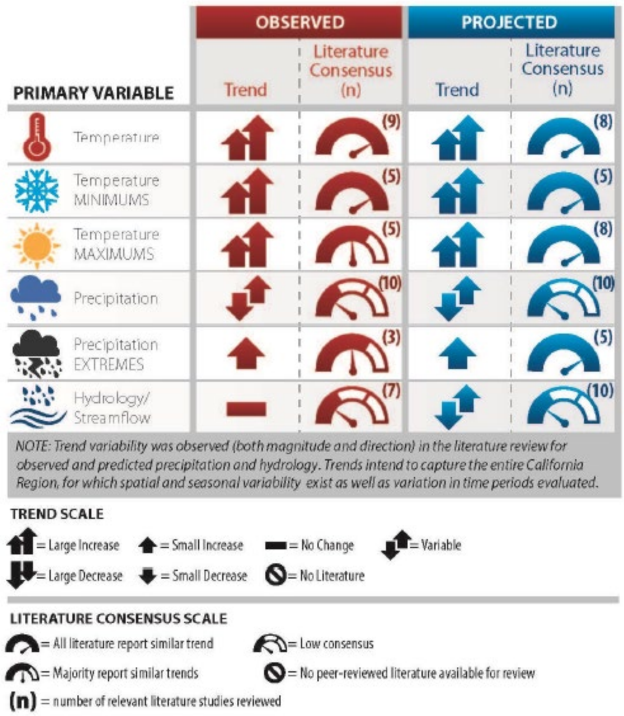

Figure 10: California Region 18 - Summary matrix of observed and projected climate trends and literary consensus. (USACE, 2015)

8.1.10 Project Specific Meteorological Trends

8.1.10.1 Temperature Trends

For this study, daily maximum high temperature data was accessed from the National Climate Data Center for a 59 year span (1960 – 2018) for a station located at the Santa Ana Fire Station. The station is located 5 miles west of the study area. A trend analysis was performed on the maximum daily high temperatures for the 59 years of record. The trend analysis shows a statistically significant ($p\text{-value} < 0.0001$) increase in temperature (Figure 11)

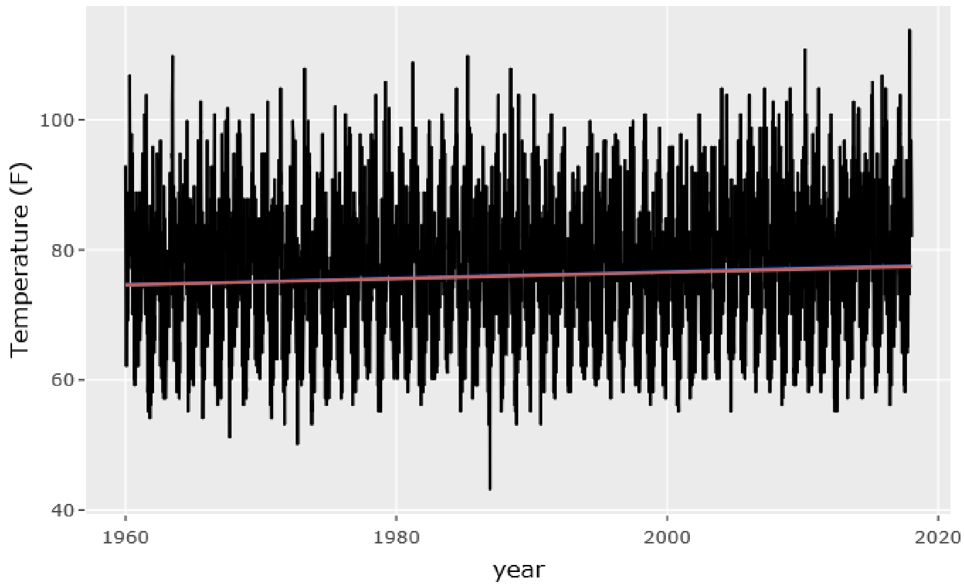

Figure 11. Increasing Maximum Daily Temperature Trend at the weather station located at Santa Ana Fire Station (NOAA ID GHCND:USC00047888)

8.1.10.2 Precipitation Trends

For this study, a trend analysis was performed on daily precipitation data from the National Climate Data Center for a 70 year span (1949 – 2018) for Station 1801034. The station is located 5 miles west of the study area. While it is not located specifically in the project area, it located at the same approximate elevation and provides a rainfall record representative of the project location. The trend analysis shows no statistically significant increase in precipitation. (Figure 12).

A nonstationarity analysis was completed for the same annual 24 hour peak rainfall events. Figure 13 reflects the results of applying 10 different nonstationarity detection methods on the data set. The results shows no nonstationarity detected on the four mean-based tests, two variance-based tests, or the four distribution-based tests.

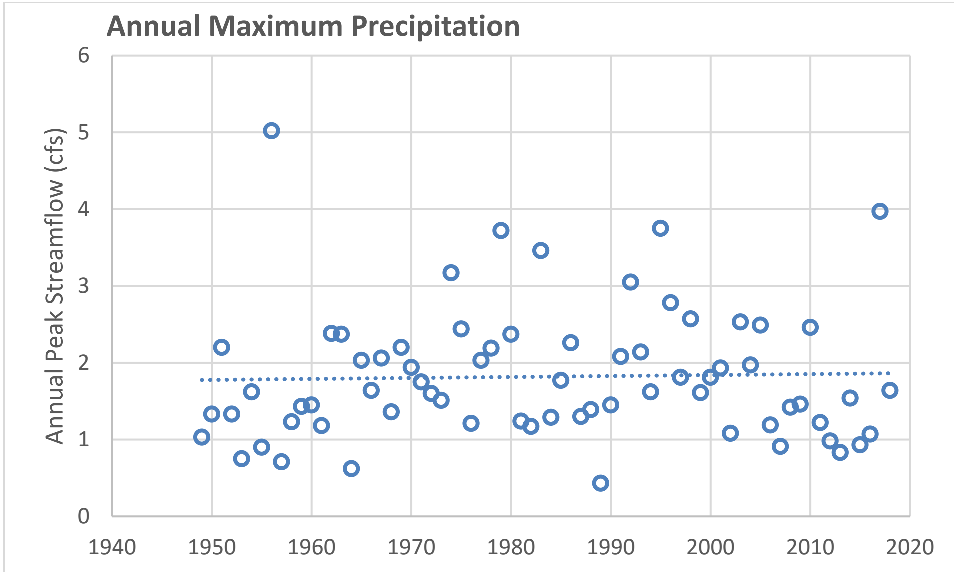

Figure 12. Trend Analysis, Station 1801034 (p value of 0.81)

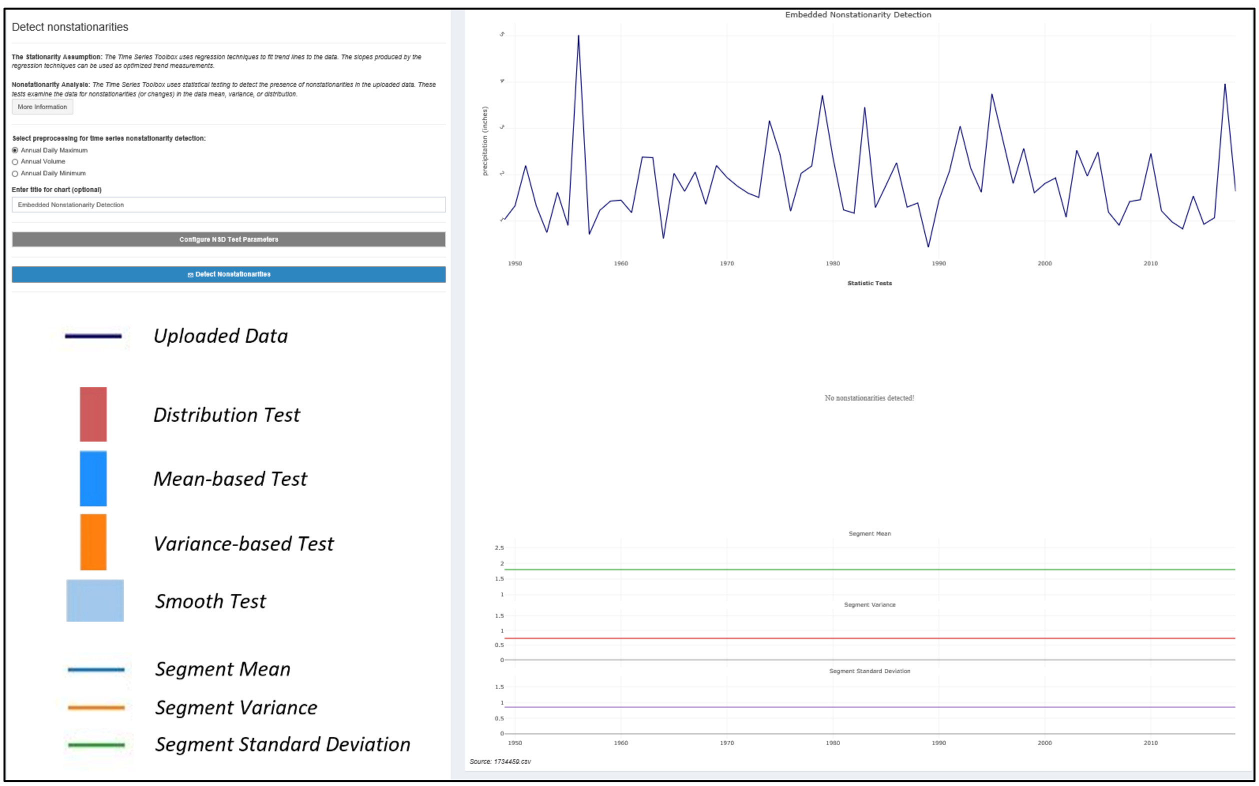

Figure 13. Nonstationarity Analysis, Station 1801034

Table 24 below includes a comparison between precipitation frequency from the Orange County Hydrology Manual and NOAA Atlas 14 precipitation. Despite 28 years of additional data, the precipitation data from Orange County Hydrology Manual compares favorably to the precipitation frequency relationship found in Atlas 14. This comparison supports the trend analysis, demonstrating that there has been no significant increased trend in precipitation over the past three decades.

Table 24. Comparison between Orange County Hydrology Manual precipitation and NOAA Atlas 14 precipitation (24 hour duration) for select frequencies.

Frequency (year)	**Orange County Hydrology Manual** **1987** (inches)	**NOAA Atlas 14 rainfall** ***Lat:33.719° Lon -118.013°*** **2014** (inches)
2	2.05	2.16
25	4.49	4.29
50	5.07	4.94
100	5.63	5.62

8.1.10.1 Streamflow Trends

Figure 14 displays the projected annual, maximum monthly trends from the USACE Climate Hydrology Assessment Tool (CMIP-5 data, downscaled to HUC-4 level via BCSD Method, based on 93 combinations of GCM/RCP model projections for HUC 1807-Southern California Coastal). As expected for this type of analysis, there is a considerable, but consistent spread in the projected annual maximum monthly flows. This spread is indicative of the uncertainty associated with climate changed hydrology. The trend, shown in Figure 15, found within the mean projected annual maximum monthly streamflow, indicates that there is no statistically significant increase in peakflows over time (p-value of 0.34).

The nearest USGS with a significant period of record is located on San Diego Creek near Irvine, California, approximately 8 miles east of the Anaheim Bay basin. The San Diego Creek basin is considered hydrologically similar to the study area, though the study area has been more intensely developed. The San Diego Creek watershed has been in a state of continual development since the 1950's. Measurements from the 1999 parcels and land use map show that about 55 percent of the drainage area is developed, with a mix of residential, commercial and industrial structures. The impervious coverage was estimated to be 15% in 1950, and slowly increased to 20% in 1970. After 1970, the impervious coverage increased rapidly to about 55% in 1999 due to increased urban development. Figure 16 displays the observed, annual instantaneous peak streamflow for San Diego Creek near Irvine, CA. The Mann-Kendall test shows a statistically significant increasing trend (p-value of 0.013).

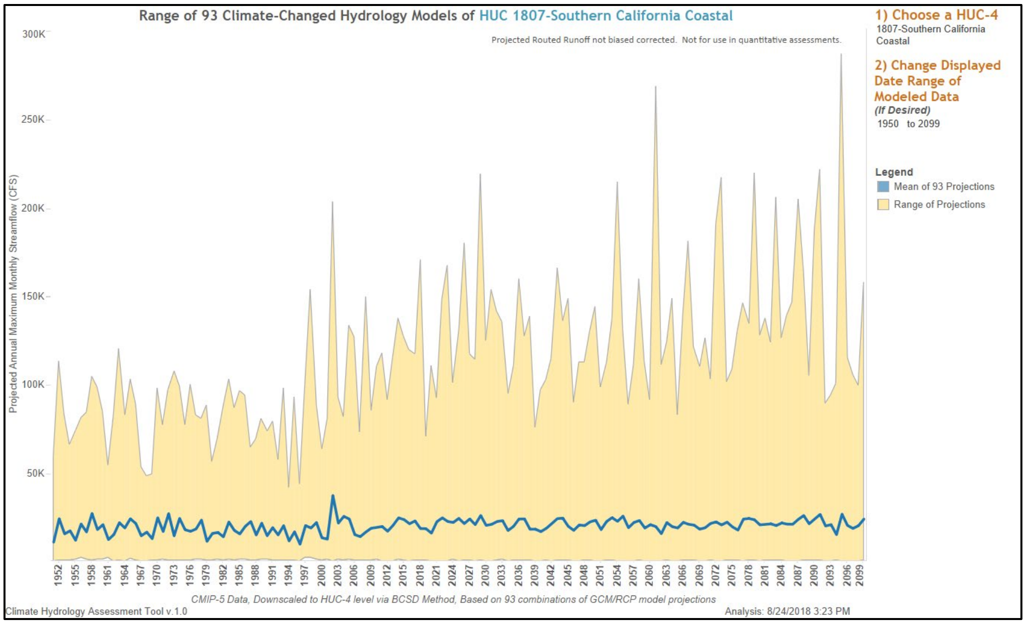

Figure 14. Project Annual Maximum Monthly Streamflow for HUC 1807 – Southern California Coastal

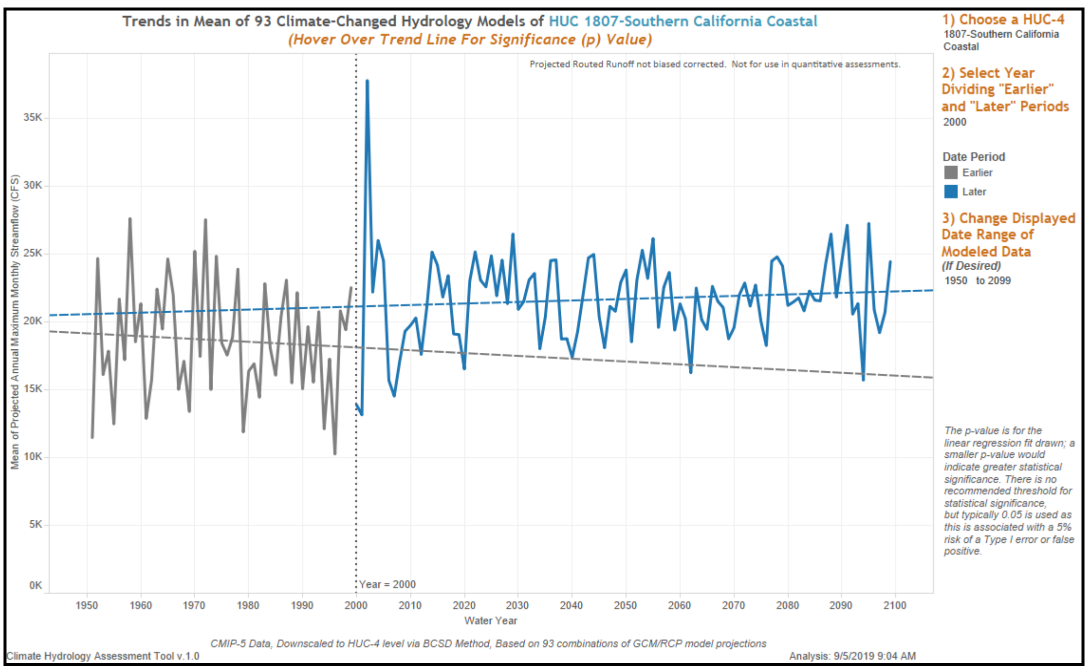

Figure 15. Mean Projected Annual Maximum Monthly Flow HUC 1807 – Southern California Coastal (p value of 0.34)

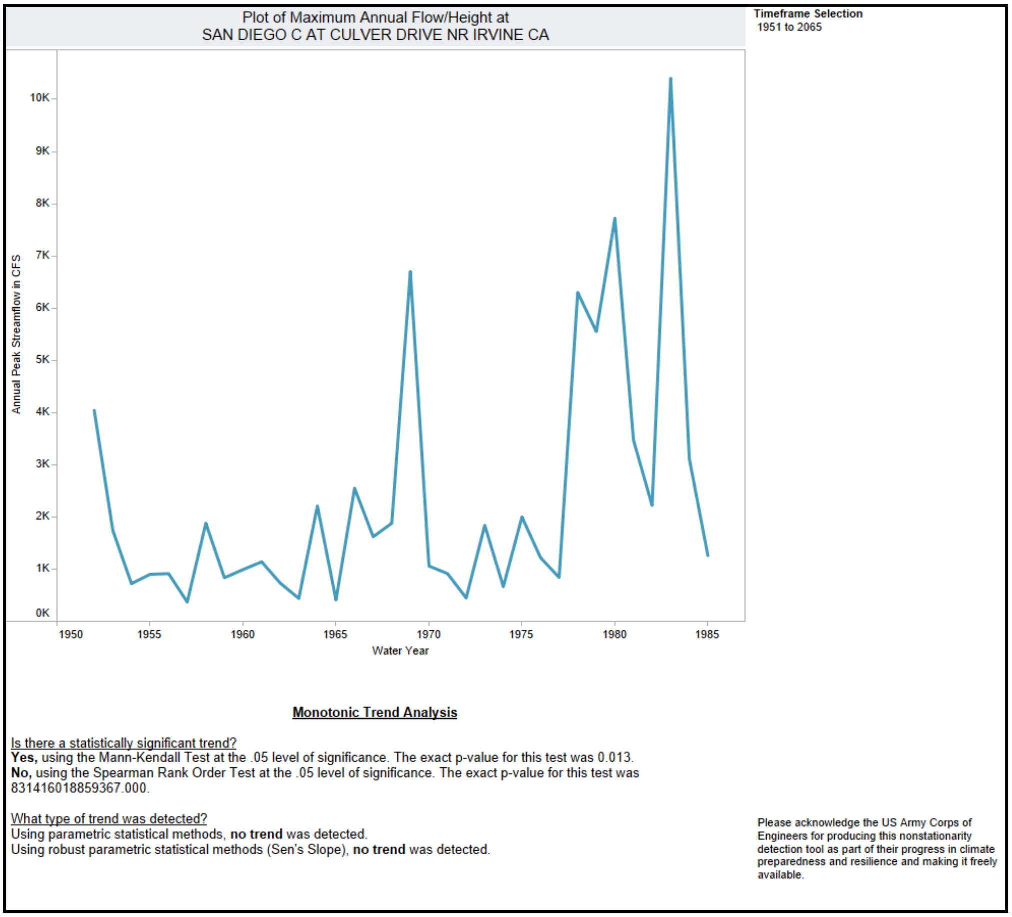

Figure 16. Annual Peak Streamflow – San Diego Creek at Culver Drive near Irvin, CA

In addition to the gage operated by the USGS on San Diego Creek, Orange County operates a local gage network. Some of these gages are located in the Anaheim Bay watershed, which encompasses the project location. Figures 17 and 18 display the maximum annual instantaneous streamflow for the Anaheim Barber Channel 232 and Westminster Channel 207.

The period of record for the Anaheim Barber and Westminster Channel gages begin in 1987 and 1958, respectively. The Anaheim Barber Channel gage does not show a statistically significant trend (p value of 0.95). Figure 18 depicts a statistically significant increase in annual peak discharges on the Westminster Channel.

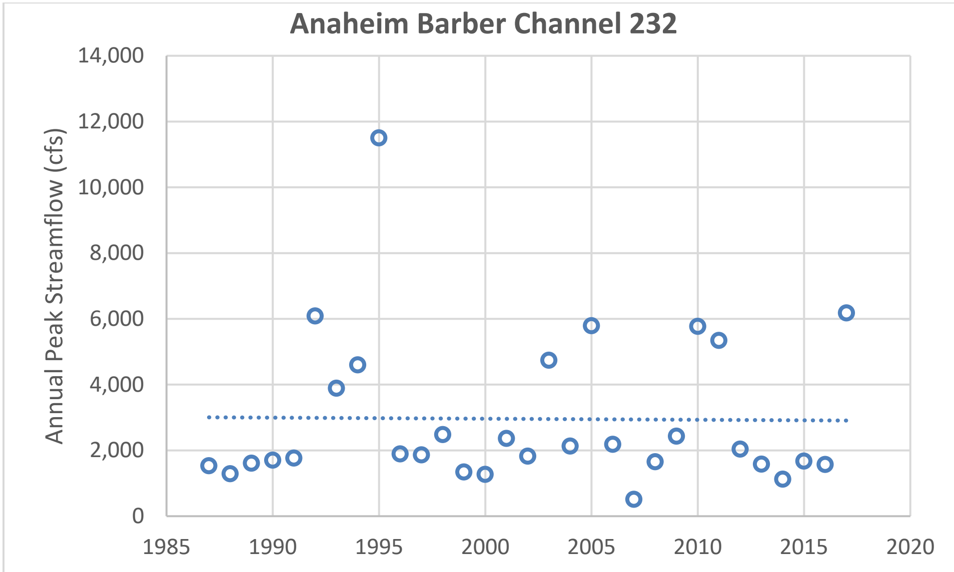

Figure 17. Annual Peak Streamflow – Anaheim Barber Channel 232 (p value of 0.95)

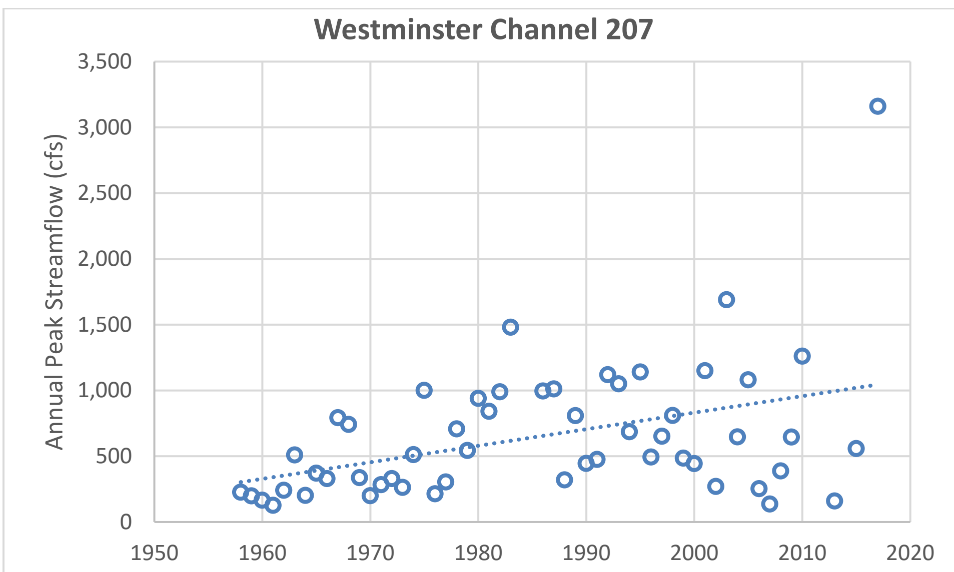

Figure 18. Annual Peak Streamflow – Westminster Channel 207 (p value of 0.0018)

8.1.11 Nonstationarity Detection Tool

Stationarity is the assumption that the statistical characteristics of hydrometerologic time series data are constant through time (USACE, April 2017). The stationarity assumption enables the use of well-accepted statistical methods in water resources planning and design in which the definition of future conditions relies primarily on the observed record. However, recent scientific evidence shows that in some locations climate change and human modifications of watersheds are undermining this fundamental assumption, resulting in nonstationarity (Milly et al., 2008, Friedman, et. al, 2016).

An assessment of historic steam gage records was performed in accordance to the Corps' Nonstationarity Detection guidance (ETL 1100-2-3, USACE, April 2017), to determine if nonstationarities exists within the streamflow records for gages located in and around the study area. This was accomplished by carrying out a nonstationarity detection analysis using the USACE's Nonstationarity Detection (NSD) Tool. The nonstationarity analysis conducted as part of this study was generated using the default settings in the NSD tool. The USACE NSD tool uses twelve nonparametric and parametric tests to identify abrupt or smooth changes in the distribution, mean, and variance of USGS annual peak flow time series data.

Using the web-based Nonstationarity Detection Tool, three stream gages within the watershed with a period of record of 30 years or more were investigated for nonstationarities. One of these gages is operated by the USGS. The other two gages are located operated by Orange County so these gage records are not automatically populated in USACE's Nonstationarity Detection Tool. Nonstationarity for these two gages was investigated using the Timeseries Tool Box. Of the three gages investigated, two showed strong evidence of nonstationarities in annual instantaneous peak streamflow datasets.

For USGS 11048500 San Diego Creek at Culver Drive, abrupt nonstationarities were detected as shown in Figure 19. Nonstationarities were detect at two points within the period of record: 1976 and 1977. Since they occur within a five year period, they could be considered as on nonstationarity, in 1977. For this changepoint there consensus between the Lombard Wilcoxon, Pettitt and Mann-Whitney tests. In addition, the nonstationarity detected in 1978 is indicated by statistical tests that target changes in mean and overall distribution. Therefore, the nonstationarity can be considered robust. On 1977, the nonstationarity detected corresponds to changes of about 3520 cfs in the mean of the annual instantaneous peak streamflow. Therefore, since the nonstationarity in 1977 demonstrates consensus, can be considered robust, and represents a significant change in the mean associated with the data, one can conclude that nonstationarities within the dataset exist. While the monotonic analysis detected a statistically significant trend using the Mann-Kendall Test, no trend was detected using parametric statistical methods.

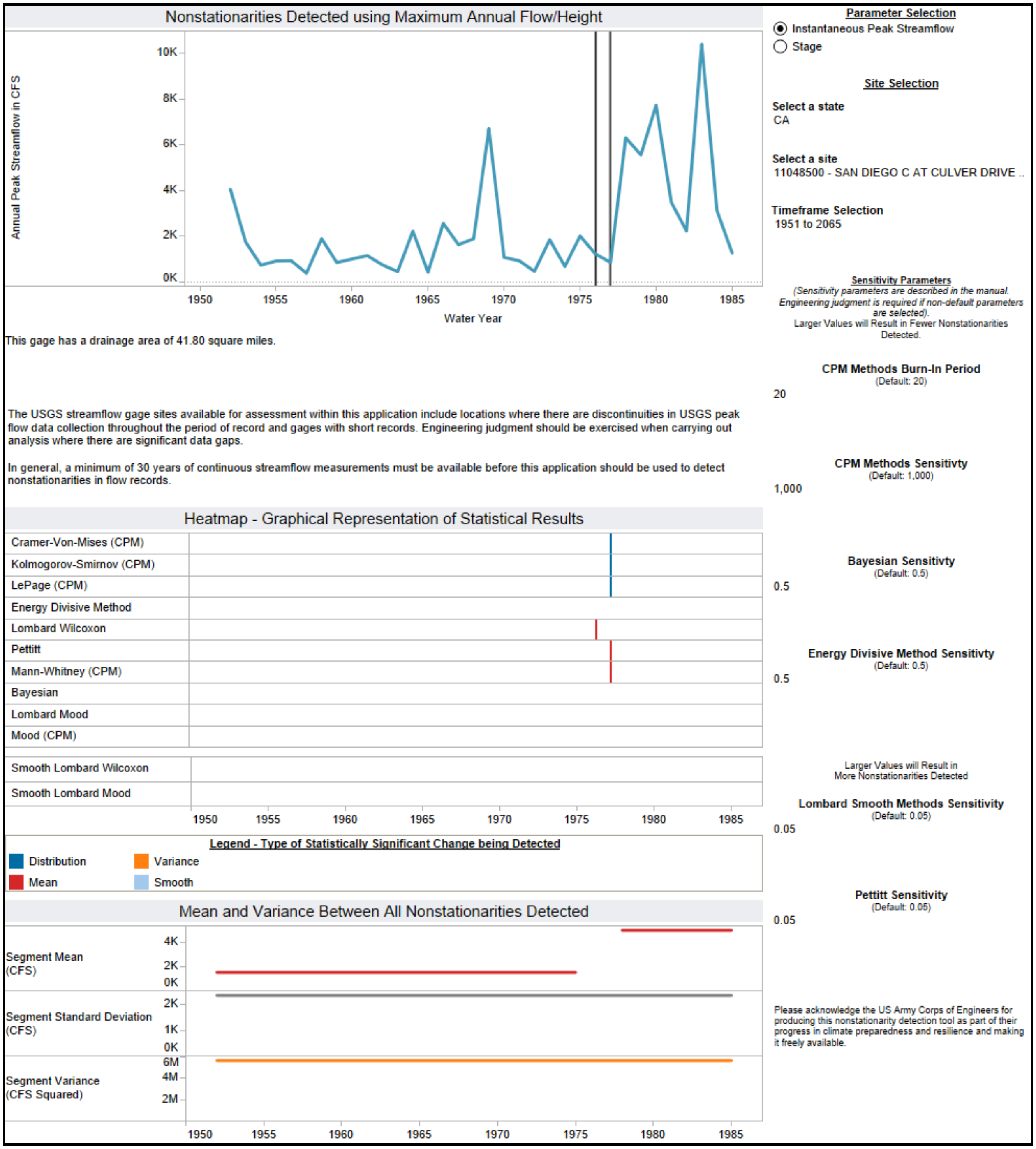

Figure 19. Nonstationarity Analysis, San Diego Creek in Irvine, CA

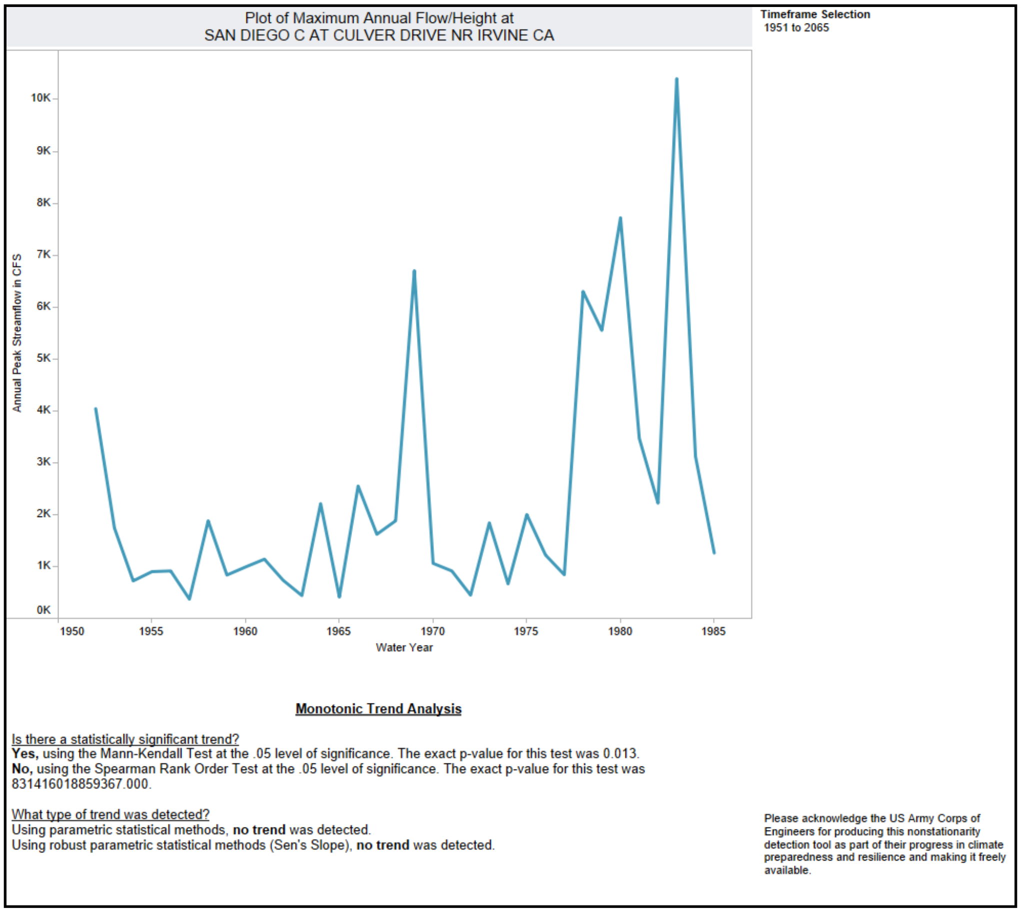

Figure 20. Annual Peak Streamflow – San Diego Creek at Culver Drive near Irvin, CA

8.1.12 Vulnerability Assessment Tool

The USACE Vulnerability Assessment Tool was applied for the 1807-Southern California Coastal HUC-4 to assess the project's vulnerability to climate change impacts relative to the other 201 HUC-4 Watersheds within the continental United States. The USACE Watershed Climate Vulnerability Assessment (VA) Tool facilitates a screening level, comparative assessment of the vulnerability of a given HUC 04 Watershed to the impacts of climate change relative to a maximum of 201 (depending on which business line is specified) HUC04 Watersheds within the continental United States (CONUS). Assessments using this tool identify and characterize specific climate threats and sensitivities or vulnerabilities, at least in a relative sense, across regions and business lines. Flood risk management is the primary business line being assessed as part of this Feasibility Study.

The Watershed Vulnerability tool uses the Weighted Order Weighted Average (WOWA) method to represent a composite index of how vulnerable (vulnerability score) a given HUC04 Watershed is to climate change specific to a given business line by using a set of specific indicator variables which relate to a particular business line. The HUC04 Watersheds with the top 20% of WOWA scores are flagged as vulnerable. All vulnerability assessment analyses were performed using the National Standard Settings.

Indicators considered within the WOWA score for Flood Risk Reduction include: the acres of urban area within the floodplain, the coefficient of variation in cumulative annual flow, runoff elasticity (ratio of streamflow runoff to precipitation), and two indicators of flood magnification factor (indicator of how much high flows are projected to change over time). Additional information about each of these indicator variables and how they are used to determine a WOWA score is described in the Vulnerability Assessment Tool User Manual.

The USACE Climate Vulnerability Assessment Tool makes an assessment for two 30-year epochs centered at 2050 and 2085 to judge future risk due to climate change. These two epochs are selected to be consistent with many other national and international analyses related to climate. The Vulnerability tool assesses climate change vulnerability for a given business line using climate changed hydrology based on a combination of projected climate outputs from the general circulation models (GCM) and representative concentration pathway (RCPs) of greenhouse gas emissions resulting in 100 traces per watershed per time period. The top 50% of the traces is called "wet" and the bottom 50% of traces is called "dry." Meteorological data projected by the GCMs is translated into runoff using the Variable Infiltration Capacity (VIC) macroscale hydrologic model. The VIC model applied to generate the results used by the Vulnerability Assessment Tool was developed by the U.S. Bureau of Reclamation and is configured to model unregulated basin conditions.

While there is a great deal of uncertainty with the climate changed hydrology given by the vulnerability assessment tool, it does allow a qualitative analysis of watershed-scale vulnerability for USACE business lines and for individual contributing indicator variables. Each of the inputs to the vulnerability assessment tool has uncertainty associated with it. The vulnerability tool relies on projected, climate changed hydrology. The uncertainty associated with projected hydrologic data includes error in temporal downscaling, error in spatial downscaling, errors in the hydrologic modeling, errors associated with emissions scenarios, and errors associated with GCMs. Some of the uncertainty associated with the tool can be visualized because the tool separates results for each of the scenarios (wet versus dry) and epochs (2050 versus 2085) combinations rather than presenting a single, aggregate result (USACE, 2016b). The analysis also incorporates uncertainty inherent in the level of risk aversion selected (ORness factor) and the importance weights applied. Some users may elect to use a higher level of risk aversion while others may not.

For the Flood Risk Reduction business line, the project was determined to be relatively vulnerable to climate change for the Dry and Wet scenarios within the Southern California Coastal HUC-4 region as shown in Figure 21 below, with increasing vulnerability over time for both wetter and dryer future conditions. The main indicator variables contributing to the WOWA score include Flood Magnification Factor as well as the total number acreage included in the 500-year floodplain, particularly for the dry traces. In addition, for the dry scenario there was a +15.2% change and the wet scenario a +19.31% change in the WOWA scores computed for 2050 and 2085 for the HUC-1807 Region with a Flood Risk Reduction business line as shown in Figure 22 and Figure 23.

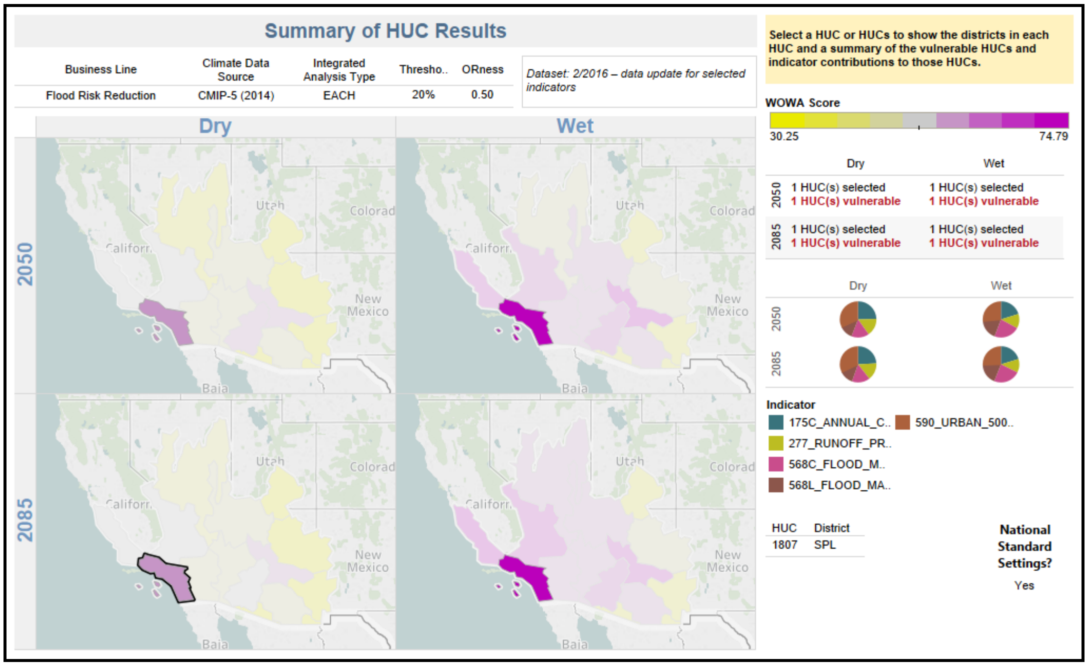

Figure 21. Vulnerability Assessment Tool HUC-4:1807 – Southern California Coastal

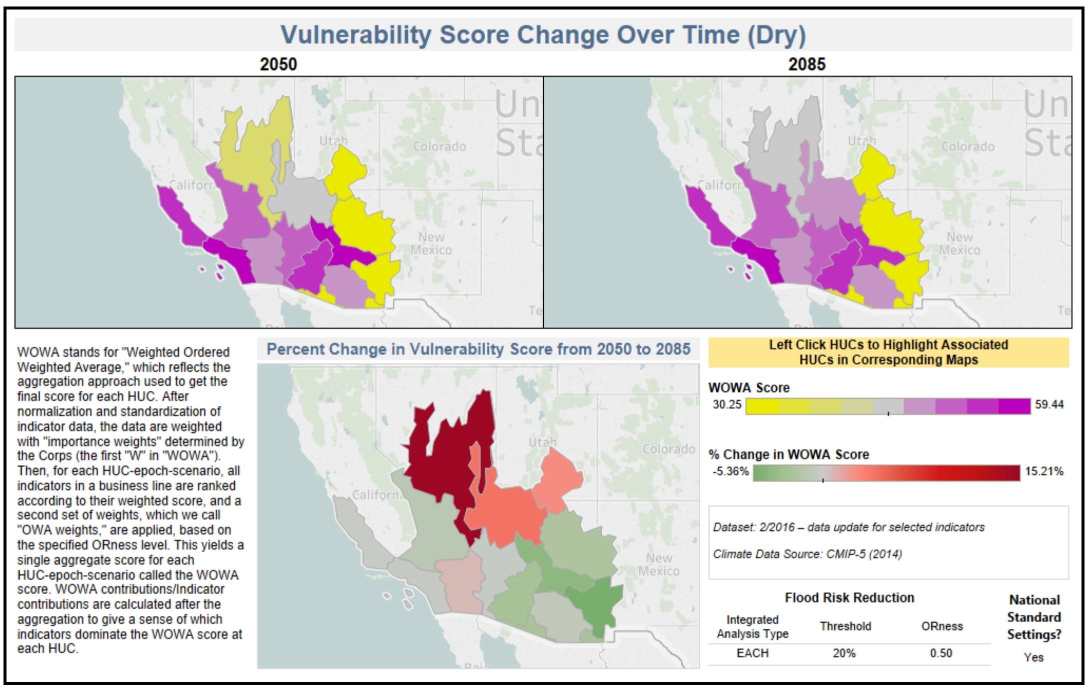

Figure 22. Vulnerability Score, Dry Scenario HUC-4:1807 – Southern California Coastal

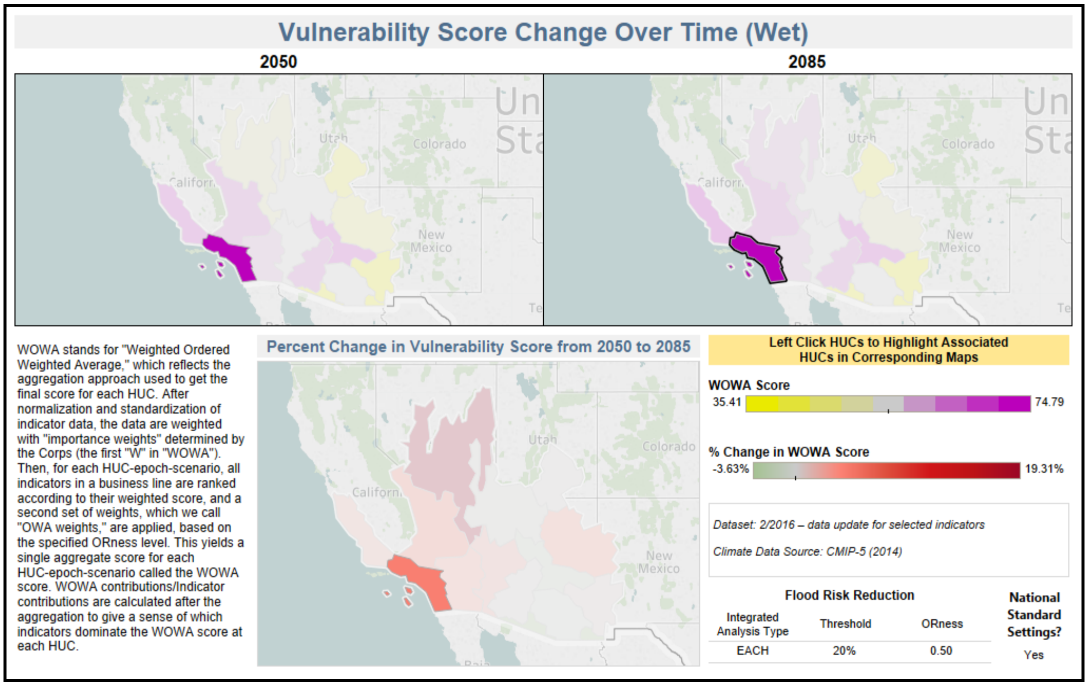

Figure 23. Vulnerability Score, Wet Scenario HUC-4:1807 – Southern California Coastal

8.2 Relative Sea Level Change

Relative Sea Level Change (RSLC) is an important variable in the flood risk management projects impacted by sea level outlet conditions, because sea level change can potentially affect the project and system performance. Therefore, projects need to consider how sensitive and adaptable engineered systems are to climate change and sea level change.

ER 1100-2-8162 requires that planning studies and engineering designs over the project lift cycle, for both existing and proposed conditions, consider a range of possible future rates of SLC when formulating and evaluating alternatives. This includes both structural and non-structural solutions.

This study uses current USACE guidance to assess relative sea level change. Current USACE guidance (ER 1100-2-8162 and ETL 1100-2-1) specifies the procedures for incorporating RSLC into planning studies and engineering design projects. Projects must consider alternatives that formulated and evaluated for the entire range of possible rates of RSLC for both existing and proposed projects. USACE guidance specifies evaluating alternatives using "low, "intermediate", and "high" rates of future sea level change.

- Low – Uses the historic rate of local mean sea-level change
- Intermediate - Estimate the "intermediate" rate of local mean sea-level change using the modified NRC Curve I. It is corrected for the local rate of vertical land movement.
- High - Estimate the "high" rate of local mean sea-level change using the modified NRC Curve III. It is corrected for the local rate of vertical land movement.

USACE (ETL 1100-2-1, 2014) recommends an expansive approach to considering and incorporating RSLC into civil works projects. It is important to understand the difference between the period of analysis (POA) and planning horizon. Initially, USACE projects are justified over a period of analysis, typically 50 years. However, USACE projects can remain in service much longer than the POA. The climate for which the project was designed can change over the full lifetime of a project to the extent that stability, maintenance, and operations may be impacted, possibly with serious consequences, but also potentially with beneficial consequences. Given these factors, the project planning horizon (not to be confused with the economic period of analysis) should be 100 years, consistent with ER 1110-2-8159. Current guidance considers both short- and long-term planning horizons and helps to better quantify RSLC. RSLC must be included in plan formulation and the economic analysis, along with USACE expectations of climate change and RSLC, and their impacts. Some key expectations include:

- At minimum 20-, 50-, and 100-year planning horizons should be considered in the analysis.
- Reinforces the concept that a thorough physical understanding of the project area and purpose is required to effectively assess the projects sensitivity to RSLC.
- Sea level changes should be incorporated into models at the mean and extreme events.
- Identification of thresholds by the project delivery team and tipping points within the impacted project area will inform both the selection of anticipatory, adaptive, and reactive options selected and the decision/timing strategies.

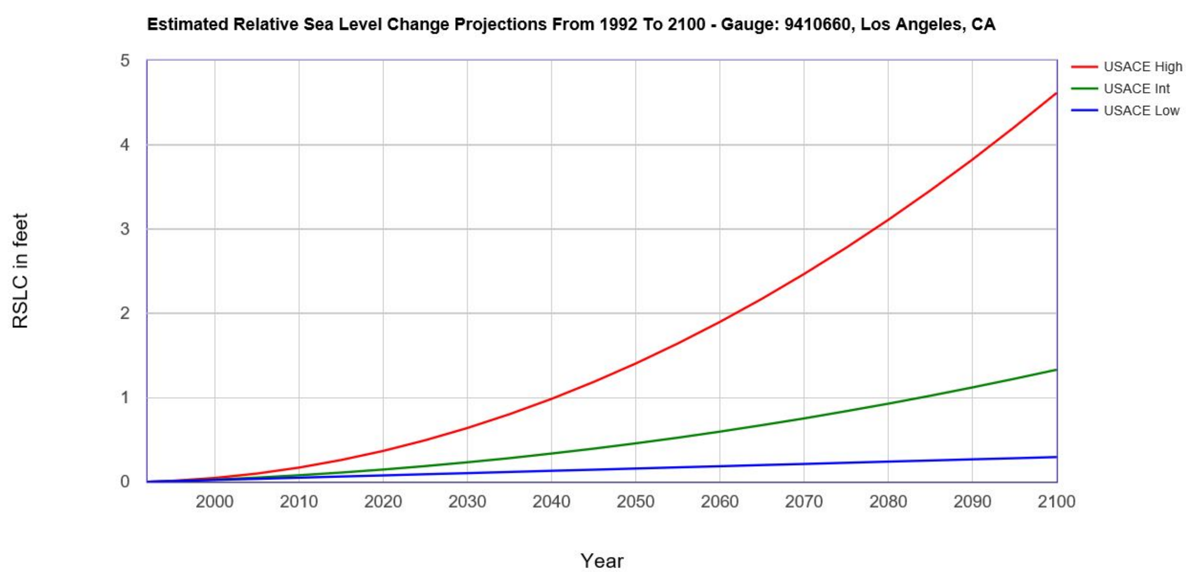

Figure 24. RSLC for Gage 9410660, Los Angeles, CA; NOAA's published rate: 0.83 mm/yr

Table 25: Relative Sea Level Change for Gage 9410660, Los Angeles, CA through 2100

Year	Low (ft)	Intermediate (ft)	High (ft)
2020	0.08	0.15	0.37
2030	0.10	0.23	0.64
2040	0.13	0.34	0.99
2050	0.16	0.46	1.41
2055	0.17	0.52	1.64
2060	0.19	0.60	1.90
2070	0.21	0.75	2.47
2080	0.24	0.93	3.11
2090	0.27	1.12	3.83
2100	0.29	1.33	4.62

An Environmental Assessment was recently completed for Ammunition Pier and Turning Basin at Naval Weapons Station Seal Beach (September 2018). The Coastal Engineering Report included an evaluation of three difference sea level rise scenarios for the 75 year design life recommended for the project (2094). The analysis included sea level rise scenarios of 0.0 ft, 3.3 ft and 5.5 ft. Sea level change projected by the University Sea Grant Program is comparable to the Intermediate and High values in Table 25 (Grifman 2013).

Sensitivity analysis on the downstream boundary conditions is described later in Sections 9.0 and 10.0, Hydraulic Analysis and Results, respectively. This analysis demonstrates that the future without project will become increasingly more vulnerable over time due to sea level change. On the downstream most leveed reaches of C02 and C05, maximum water surface elevations are limited because of overtopping of the levees on the upstream end of these reaches. Under the ‘High’ scenario for the year 2100, rainfall-storm frequency induced overtopping on C05 is increased from the 10% AEP to the 20% to 50% AEP event. On the C02, this frequency is increased from the 2% AEP to the 20% to 50% AEP event. Instead of overtopping on the upstream end from rainfall events, the greater risk of overtopping is on the downstream end, where even relatively frequent storm events (20% to 50% AEP) would be able to induce overtopping.

Both the NED and the LPP are affected similarly by sea level change because the levees/floodwalls are improved with both plans. Under the ‘Intermediate’ and ‘High’ RSLC scenerios, the lower end of C02 and C05 systems would be affected by a higher tailwater condition. Upstream of these reaches, the backwater affects from a higher tailwater conditions dissipates. An evaluation of the ‘High’ scenario for the year 2100 with the LPP plan shows a water surface profile elevate to near the levee crest for the 1% AEP event. As an example, at Graham St. the 1% AEP water surface elevation is 11.3 ft. NAVD 88, but under the ‘High’ scenario this increases to 13.3 ft NAVD, which exceeds the 0.2% AEP event (existing hydrology).

Midway through the life of the project (2055), sea level change should be evaluated to determine if the changes are tracking closer to the ‘Intermediate’ or ‘High’ scenario. If rates are tracking closer to the ‘High’ scenario, there may be a need to increase the life of the project to maintain the project benefits. Sea Level change rates do not have any impact on the formulated alternatives, because leveeing these areas is the only alternative considered for reducing flood damages, but during PED, floodwall heights should be further evaluated for final elevations.

8.3 Alternatives and Climate Change Considerations

The Locally Preferred Plan is expected to reduce losses due to flooding however residual risks, including those resulting from changes climate conditions, exist within the watershed. While climate changes were considered during the plan formulation process, uncertainty with those projections exist and risk still remains. Table 26 summarizes residual risk associated with the tentatively selected plan specifically due to the potential for a changing climate.

Table 26. Climate Risk Register

Feature or Measure	Trigger	Hazard	Consequence	Qualitative Likelihood
Levee/Floodwall Heights	Increased water surface elevations in levee/floodwall areas due to sea level change	Reduced assurance on levee/floodwalls; increased probability of overtopping	Flooding of protected area, economic damages and transportation delays	Likely – SLC projects increases in the future.
Levee/Floodwall Heights	Increased water surface elevations in levee/floodwall areas due to higher intensity rainfall	Reduced assurance on levee/floodwalls; increased probability of overtopping	Flooding of protected area, economic damages and transportation delays	Possible to Likely – While there is less consensus on future rainfall projections, some climate models project an increase in the frequency of heavy downpours, especially through atmospheric rivers
Channel Widening	Increased water surface elevations in the widened channels due to higher intensity rainfall	Reduced assurance of channel containment; increase probability of overbank flooding	Flooding of protected area, economic damages and transportation delays	Possible to Likely – While there is less consensus on future rainfall projections, some climate models project an increase in the frequency of heavy downpours, especially through atmospheric rivers
Diversion Channel	Increased water surface elevations in the diversion channel due to higher intensity rainfall	Reduced assurance of channel containment; increase probability of overbank flooding	Flooding of protected area, economic damages and transportation delays	Possible to Likely – While there is less consensus on future rainfall projections, some climate models project an increase in the frequency of heavy downpours, especially through atmospheric rivers

Table 27. Climate Risk Register (continued)

Feature or Measure	Trigger	Hazard	Consequence	Qualitative Likelihood
Gravity Drainage	More runoff from due to higher intensity rainfall	More overbank flooding in the levee/floodwall interior areas	Flooding of protected area, economic damages and transportation delays	Possible to Likely – While there is less consensus on future rainfall projections, some climate models project an increase in the frequency of heavy downpours, especially through atmospheric rivers

The NED Plan and the LPP Plan reduce flood damages in the same manner. Both plans increase the hydraulic efficiency of the existing channels, but the LPP goes further by expanding the cross-sectional area of the channel to maximize the Local Sponsor's available real estate. By replacing road crossings, it also decreases head losses, reduces water surface elevations, and reduces overbank flooding. This approach is applied on the downstream reaches of C02 and C05, but due to the low lying topography adjacent and surrounding the channel flood walls are required. Channel cross-sections throughout the system have been modified by over time to accommodate increased flow conditions due to development. The approach is adaptable, and this adaption can continue in the future if future peak discharges result from increased rainfall depths or intensity, though real estate constrains could present a challenge.

Early in the project formulation reservoirs were considered, but were eliminated due to the lack of open space and the need to preserve the limited open space available in the region. Reservoirs would present the same limitation if future peak stream flows increase, because real estate constraints would make it difficult to expand storage areas to accommodate increased storm intensities.

A tunnel was also considered as an alternative to reduce flood damages, but this alternative was eliminated because of the high cost. It also had appeared to have limited effectiveness on the lower leveed end of the C02 and C05 systems, where backwater from the ocean outlet limited hydraulic capacity. This limitation will likely increase over time with increased sea level change. However, if the storm intensity increase in the future, the tunnel option could potentially be complementary to the LPP Plan to offset increased discharges.

In summary, increases in future climate change effects in increase peak discharges in the future adaptive management strategies may be required to maintain the same storm damage reduction, but the recommended plan would remain unchanged and would be adaptable in the future. This could include increasing the channel cross-section or increasing floodwall heights in the downstream reach to maintain comparable benefits with high sea level conditions.

9.0 Hydraulic Analysis

9.1.1 Existing Conditions

HEC-RAS 1-D models were developed to match channel sections shown on the most current as-built drawings or 2016 surveyed data (from C06 PS&E Project). Using the steady state models as a base, Tetra Tech also developed 1-D unsteady HEC-RAS models for the channel component of the system.

Since little gage data existing for the study area, no hydraulic model calibration was not performed for historic flood events. Instead, model results and inundation mapping was coordinated with Orange County to determine that the results reasonably reflected the existing flood risk based on their flood surveillance and response to locations within the study area. Photographs from significant storm events were compared to the inundation mapping for the less frequent events and adjustments were made to model parameter to better match observed flooding.

The downstream leveed reaches on C02 and C05 were modeling using lateral structures. Due to the regular nature of the channel cross-sections and the relatively uniform composition of the channel lining material and roughness, one of the greatest source of uncertainty in the hydraulic model is expected to be the bridges and the culverts. Bridge and culvert debris is expected to have a significant impact on the stage-discharge relationship in many channel reaches. Fences, walls, and other hydraulic obstructions parallel to the channel and in the overbank areas also are expected to affect flooding limits, but a detailed evaluation of all of these obstructions is beyond the scope of the modeling performed for the study.

9.1.2 Model Elevation Data

Digital topographic data were obtained from Orange County. The topographic data were collected during December 17, 2011 to February 9, 2012 by USGS and processed through the Digital Elevation Model (DEM) unto digital topographic data set. The DEM data set has horizontal datum in the CCS83, Zone VI (US Feet) and has vertical datum in NAVD 88 (US Feet).

9.1.3 Vertical Datum Adjustment

Most of the C05 and C06 channels as-built drawings are based on NGVD 29 datum except as-built drawing C05- 501-1A in the vicinity of Garden Grove Freeway which is based on NAVD 88 datum. All of the C02 and C04 channels as-built drawings are based on NGVD 29 datum. Many of the drawings were dated earlier than 1980 and associated benchmarks are no longer in existence, therefore, current Orange County benchmarks are used in computing an average vertical datum adjustment. There are total of 35 benchmarks used (8 in the vicinity of C06, 9 in the vicinity of C05 below C06, and 18 in the vicinity of C05 above C06) and results in an average vertical datum adjustment value of 2.42 feet (i.e., NAVD 88 elevation = NGVD 29 elevation + 2.42’).

The stream centerline shape file was provided by OCPW. The cross-section layer was developed based on the as-built drawings by locating cross-sections where changes in channel invert slope, shape, dimensions, and/or materials occur.

9.1.4 HEC-RAS GeoRAS Layer Setup

Using HEC-GeoRAS, a GeoRAS export file was generated that contained river, reach, and station identifiers; cross-sectional cut lines; cross-sectional surface lines; cross-sectional bank stations; downstream reach lengths for the left over bank, main channel, and right over bank.

9.1.5 Lateral Structures

Lateral structures were placed on both sides of the open channel segments to compute channel overflow when the computed water surface elevation is higher than the lateral weir elevation. Lateral structure were also used to represent the levee/floodwalls. The lateral weir structures were delineated in ArcGIS with the aid of aerial photography and DEM data and imported into HEC-RAS. The lateral weir elevation profiles were further filtered to remove distorted DEM data points (due to trees, fences, buildings, overhang wires, etc.) and adjusted to match the as-built sections as needed (e.g., top of sheet pile or top of concrete channel, etc.).

In general, lateral structure weir coefficient should be in the range of 0.1 to 0.5 for an overland flow interface between the channel and adjacent floodplain (e.g., non-elevated overbank terrain). In this analysis, a weir coefficient of 0.5 was used for most of the channel reach to emulate the overland flow escaping the channel with block walls, fences, and/or buildings that restrict the overland flow within the channel right-of-way.

9.1.6 Manning's n Values

Table 27 lists the Manning's n-values adopted per Orange County Flood Control Design Manual (OCPW 2000) and used in the hydraulic model.

Table 28: Manning's n Values used in the cross-sections

Description	Value
Reinforced Concrete Pipe	0.013
Rectangular Concrete Lined Channel	0.014
Trapezoidal Concrete Lined Channel	0.015
Trapezoidal Earthen Channel with Riprap	0.035
Soft-bottom Channel	0.03
Sheet Piles Soft-bottom Channel	0.022

9.1.7 Debris Loading

Debris loading is applicable to the baseline conditions only. Two feet of debris loading was added to each side of all bridge piers that measure 6 feet or less in width (transverse dimension) for the full depth of flow and 6 feet of floating depth for piers without and with debris walls (USACE 2004), respectively. Debris loading is not used at any bridges in either of the alternatives. The proposed improvements will replace the earthen or rock lined channels with concrete; therefore, the future with-project conditions are expected to significantly reduce or completely eliminate the primary source of in-channel vegetation.

Concurrence on this approach was obtain from in a letter to the OCPW dated September 09, 2016. Per paragraph 21.2 of the USACE Hydrology and Hydraulics Policy Memorandum No. 4 Debris Loading on Bridges and Culverts (CESPL-ED-H 335-2-5c).

9.1.8 Two-dimensional Flow Areas

Lateral structures connect the one-dimensional channel to two-dimensional flow areas. Five two-dimensional flow areas were created and incorporated in the HEC-RAS model. Flow Area 1 is connected to the left overbank of C05 and C06. Flow Area 2 is connected to the right overbank of C06 and the left overbank of C05. Flow Area 3 is connected to the left overbank of C05 and the right overbank of C04. Flow Area 4 is connected to the right overbank of C04. Flow Area 5 is downstream of C05 and C04 and represents Outer Bolsa Bay, Huntington Harbour and Pacific Coast Highway.

The two-dimensional flow areas have a cell spacing of 50 feet, but breaklines were used to add additional detail to topographic features and changes in roughness (Manning's n values). Table 25 shows the Manning's n values used in the two-dimensional flow areas.

Table 29. Manning's n Values used in the two-dimensional flow areas

Description	Value
Residential	0.12
Commercial	0.12
Open Space	0.05
Soft-bottom Channel	0.03
Streets	0.012

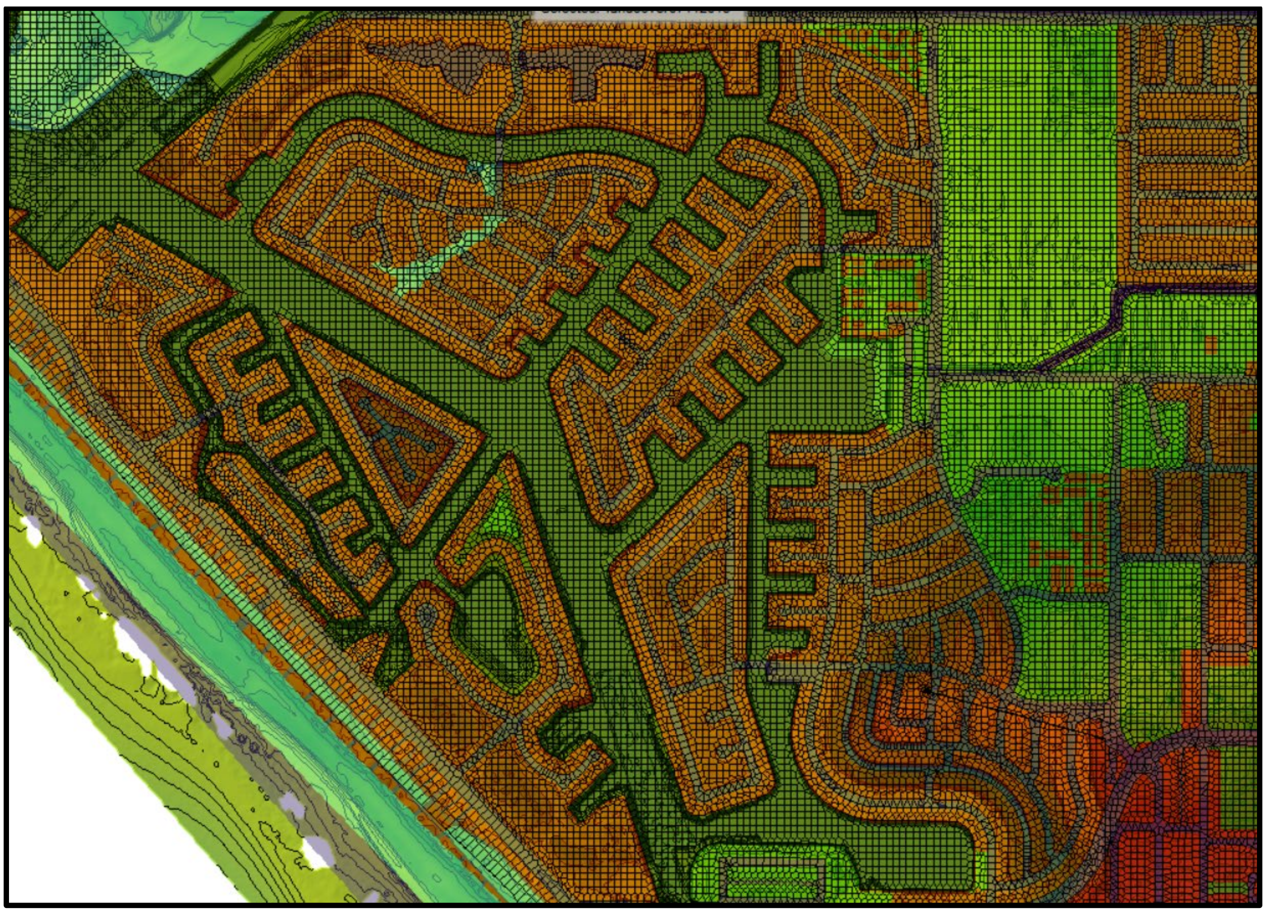

Figure 25: Two dimensional flow area in the Huntington Harbour area.

9.1.9 Storage Areas

Upstream of C05, flow enters the channel downstream of Haster Basin, which was designed to contain the 100 year event. Haster Basin is represented as a storage area with a pump station, so the maximum discharge during events less than or equal to the 100 year event are limited to the pump station capacity of 459 cfs. The storage area connects to the downstream two-dimensional flow area to simulate overbank flooding for events exceeding the 100 year event. Seal Beach National Wildlife Refuge on the downstream reach of C02 is also represented as a storage area.

9.1.10 Downstream Boundary Conditions

The downstream boundary of the hydraulic model is located where Huntington Harbour opens up into Anaheim Bay. Previous hydraulic analysis performed by Orange County and the Los Angeles District used separate boundary conditions for C04 and C05. Losses through Huntington Harbour, the Warner Avenue Bridge and Outer Bolsa Bay were accounted for in the downstream boundary condition by using assumed losses determined from previous studies. For this study, a two-dimensional flow area was used on the downstream end of the model domain so only one boundary condition represents the ocean water level. A constant elevation boundary condition was used, but sensitivity analysis demonstrated that using an unsteady water surface elevation produced similar inundation extents and depths.

The downstream boundary condition for the hydraulic model used a stage hydrograph based on the closes tidal gage: Los Angeles NOAA Gage. A Mean High High Water (MHHW) was used as the base water surface elevation for the hydraulic analysis (5.28 ft NAVD 88). EM 1110-2-1416 states that when the profile computation begins at the outlet of a stream influenced by tidal fluctuations, the maximum predicted tide, including wind setup, is taken as the starting elevation.

Non-tidal residual was added to MHHW to account for regional effects of wind, waves and atmospheric pressure. The frequency analysis for the non-tidal residual presented in Section 4.1.2 was used as a basis for the non-tidal residual contribution to the downstream boundary condition. Model runs were performed on the non-tidal residual frequencies ranging between the 50% AEP (0.7 ft) up to the 4% AEP event (1.7 ft). The sensitivity analysis demonstrated that the difference in water surface elevations is limited to the downstream leveed reaches on C02 and C05, and diminishes upstream. Based on this sensitivity analysis, model runs were performed for the economic analysis used a 10% AEP non-tidual residual of 1.5 feet.

Consistent with ER 1100-2-8162, sea level change was incorporated into the downstream boundary condition. The difference between the year the project is expected to provide benefits (2030) and the 50 year economic period of analysis is 0.7 ft. for the intermediate scenario. Sensitivity analysis was performed on the downstream boundary to evaluate differences in the relative sea level change between 2030 and 2080. The sensitivity analysis demonstrated that the difference in water surface elevations is limited to the downstream leveed reaches, and diminishes near the upstream end of the leveed reaches for the Without Project, LPP and the NED Plan. Depth grids were reviewed for the Without Project scenario, and flood depths and extents were nearly the same. Compiling GeoFDA model data for the FDA economic analysis was complicated by to the expansive and densely populated study area, making the compiling process time consuming. Based on the sensitivity analysis of sea level change values representing the base and future year and considering the time constraints of compiling GeoFDA data, model runs performed for the economic analysis used the middle year (2055) sea level change value of +0.52 ft. Additional sensitivity analysis on the “low” and “high” sea level change were performed and are discussed in Section 9.0 Model Results.

Table 28 presents the factors contributing to the total water level used for the downstream boundary condition.

Table 30. Summary of factors contributing to the downstream boundary condition

Factor	Value (ft.)
Mean Higher High Water	5.3 ft. (NAVD 88)
Non-Tidal Residual	+1.5 ft.
Sea Level Change	+0.5 ft.
Total Water Level	7.3 ft. (NAVD 88)

9.1.11 Risk and Uncertainty

In accordance with EM 1110-2-1619 "Risk-Based Analysis for Flood Damage Reduction Studies", a risk analysis was performed for this study using HEC-FDA. This program incorporates a Monte Carlo simulation to sample the interaction among the various hydrologic, hydraulic, and economic uncertainties. Uncertainties in the hydrology and hydraulics include the uncertainties associated with the discharge-frequency curve and the stage-discharge curve. Both of these relationships have statistical confidence bands that define the uncertainty of the relationships at various target frequencies. The Monte Carlo simulation routine randomly samples within these confidence bands over a range of frequencies until a representative sample is developed. Reliability statistics are based on the results of the Monte Carlo random sampling.

Based on Table 4-5 in EM 1110-2-1619, equivalent record length was represented graphically using an equivalent record length of 30 years. While there are several gages located in and around the study area, the period of record for these gages is relatively short and the study area has been subject to development and other sources of hydrologic changes that lead to nonstationarity.

Hydraulic analysis was performed within the hydraulic model to evaluate the sensitivity of the stage-discharge relationship. The uncertainty of the stage-discharge relationship is expected to be reduced for the minimum and maximum channel improvements because the channel will uniformly concrete with less variability in roughness. Based on this sensitivity analysis, the following standard deviation parameters are currently used to define the uncertainty in the stage-discharge relationship. This uncertainty in the stage-discharge relationship reflects the lack of calibration information available for the hydraulic model.

<u>Without / Existing Project Condition</u>
Normal Distribution with a standard deviation of 1 foot, becoming constant at the 5 year profile.

<u>NED</u>
Normal Distribution with a standard deviation of 0.75 feet, becoming constant at the 10 year profile.

<u>LPP</u>
Normal Distribution with a standard deviation of 0.75 feet, becoming constant at the 50 year profile.

Additional discussion on the risk and reliability analyses can be found in the Economics Appendix.

10.0 Model Results

10.1 Existing Conditions

Plates 2-16 contain the water surface profiles, and Plates 47-51 contain the inundation maps for Existing Conditions. Overtopping and breaching of the levees on the downstream end of C05 results in significant inundation for events exceeding the 10 Year event (10% AEP). For events exceeding the 50 Year event (2% AEP), overtopping and breaching of the levees on the downstream end of C02 result in additional flooding on the downstream end of C02.

10.1.1 Low Sea Level Change Scenario

Under the low sea level change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). Since the protected areas are currently at risk from levee overtopping and breach, this risk will increase over time.

10.1.2 Moderate Sea Level Change Scenario

Under the moderate change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). Since the protected areas are currently at risk from levee overtopping and breach, this risk will increase over time, but at a rate greater than the low sea level change scenario. Plate 62 shows that there will be a modest increase in the protected area by the year 2100 under this scenario.

10.1.3 High Sea Level Change Scenario

Under the high change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). Since the protected areas are currently at risk from levee overtopping and breach, this risk will increase over time, but at a rate greater than the low sea level change scenario. Plate 62 shows that there will be a significant increase in the protected area by the year 2100 under this scenario.

10.2 NED Plan

Plates 17-31 contain the water surface profiles, and Plates 52-56 contain the inundation maps for the NED Plan. Since the levees on the downstream end of C05 and C02 are fully improved, they contain events up to 200 Year event (0.5% AEP). Due to limited conveyance improvements upstream of the leveed sections, some overbank flooding remains for events greater including and greater than the 10 Year event (10% AEP), though flooding is reduced compared to existing conditions.

10.2.1 Low Sea Level Change Scenario

Under the low sea level change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). Since the rate of rise is modest, the conditional non-exceedance probability of overtopping of the levees would be expected to be at a level that would allow them to be recognized as protecting against the base flood elevation under current NFIP regulations through the 20 year project milestone, the future year (2080) and for the full period of analysis (2100).

10.2.2 Moderate Level Change Scenario

Under the moderate sea level change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). The conditional non-exceedance probability of overtopping of the levees would be expected to be at a level that would allow them to be recognized as protecting against the base flood elevation under current NFIP regulations through the 20 year project milestone, through the future year (2080). Approaching the full period of analysis (2100), the conditional non-exceedance probability of overtopping of the levees may reach a level that requires adaptive management strategies to maintain an acceptable level.

10.2.3 High Sea Level Change Scenario

Under the high sea level change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). The conditional non-exceedance probability of overtopping of the levees would be expected to be at a level that would allow them to be recognized as protecting against the base flood elevation under current NFIP regulations through the 20 year project milestone. As the project reaches midway through is economic analysis period (2055), conditional non-exceedance probability of overtopping of the levees may reach a point where it may where it is no longer able to be recognized as protecting against the base flood elevation based on current NFIP regulations without adaptive management. At the full period of analysis (2100), Plate 62 and 63 demonstrate that since the protected area is connected to Huntington Harbour and Anaheim Bay, the landward side of C02 will also be exposed to flooding from high tide conditions.

10.3 LPP Plan

Plates 32-46 contain the water surface profiles, and Plates 57-61 contain the inundation maps for the LPP Plan. Since the levees on the downstream end of C05 and C02 are fully improved, they contain events up to 200 Year event (0.5% AEP). Due to limited conveyance improvements upstream of the leveed sections, some overbank flooding remains for events greater including and greater than the 10 Year event (10% AEP), though flooding is reduced compared to existing conditions.

10.3.1 Low Sea Level Change Scenario

Under the low sea level change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). Since the rate of rise is modest, the conditional non-exceedance probability of overtopping of the levees would be expected to be at a level that would allow them to be recognized as protecting against the base flood elevation under current NFIP regulations through the 20 year project milestone, the future year (2080) and for the full period of analysis (2100).

10.3.2 Moderate Level Change Scenario

Under the moderate sea level change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). The conditional non-exceedance probability of overtopping of the levees would be expected to be at a level that would allow them to be recognized as protecting against the base flood elevation under current NFIP regulations through the 20 year project milestone, through the future year (2080). Approaching the full period of analysis (2100), the conditional non-exceedance probability of overtopping of the levees may reach a level that requires adaptive management strategies to maintain an acceptable level.

10.3.3 High Sea Level Change Scenario

Under the high sea level change scenario, affected reaches are limited to the downstream leveed reaches of C02 and C05. Model results demonstrate that the conditional non-exceedance probability of overtopping of the levees would increase under this scenario for future year and through the full period of analysis (2100). The conditional non-exceedance probability of overtopping of the levees would be expected to be at a level that would allow them to be recognized as protecting against the base flood elevation under current NFIP regulations through the 20 year project milestone. As the project reaches midway through is economic analysis period (2055), conditional non-exceedance probability of overtopping of the levees may reach a point where it may where it is no longer able to be recognized as protecting against the base flood elevation based on current NFIP regulations without adaptive management. At the full period of analysis (2100), Plate 62 and 63 demonstrate that since the protected area is connected to Huntington Harbour and Anaheim Bay, the landward side of C02 will also be exposed to flooding from high tide conditions.

10.3.4 Flow Uncertainty

Since there is considerable uncertainty in the flow frequency due to a limited gage records and significant changes in land cover, and because some climate projects show that there could be increases in intense rainfall in the future, the performance of the LPP was evaluated by increasing the 1% AEP (100 YR) flow by 26%. This 26% increase represents the upper confidence limit of the flow frequency analysis for San Diego Creek. The results of this analysis show that overbank flooding would be similar to results for the 0.2% AEP event. Floodwall overtopping is expected on the upstream end of the leveed reach of C05, with overbank flooding along the I-405 corridor on C02, C05 and C06.

10.3.5 Huntington Harbor Impacts

Model results for the two dimension flow area representing Huntington Harbor were used to evaluate the potential for impacts both on Eelgrass locations and for the potential to make existing bulkheads more vulnerable to erosion. Results for select locations are included on Plates 64-72. After construction of the NED Plan, flow rates will increase downstream of the C02 and C05 system due to reduced overbank flooding and attenuation. Eelgrass locations are expected to experience increased velocities. The largest observed velocity increase is downstream of the C02 system, where the flow is confined to a relatively narrow channel. Existing bulkheads along the main channel of Huntington Harbor are expected to have the greatest exposure to velocity increases, through with the LPP velocities are expected to remain below 2 ft/s. Since bulkhead erosion has been a problem in the past, costs were included to mitigate increased velocities due to the increased flow rates. Protection of the bulkheads will be investigated in PED.

10.3.6 Consequences

In accordance with ER 1105-2-101, potential life loss was evaluated using HEC-FIA 3.0. Gridded data output data from HEC-RAS (with terrain, arrival time and depth grids) were used in the analysis. The results of the life loss analysis can be found in the Economic Appendix.

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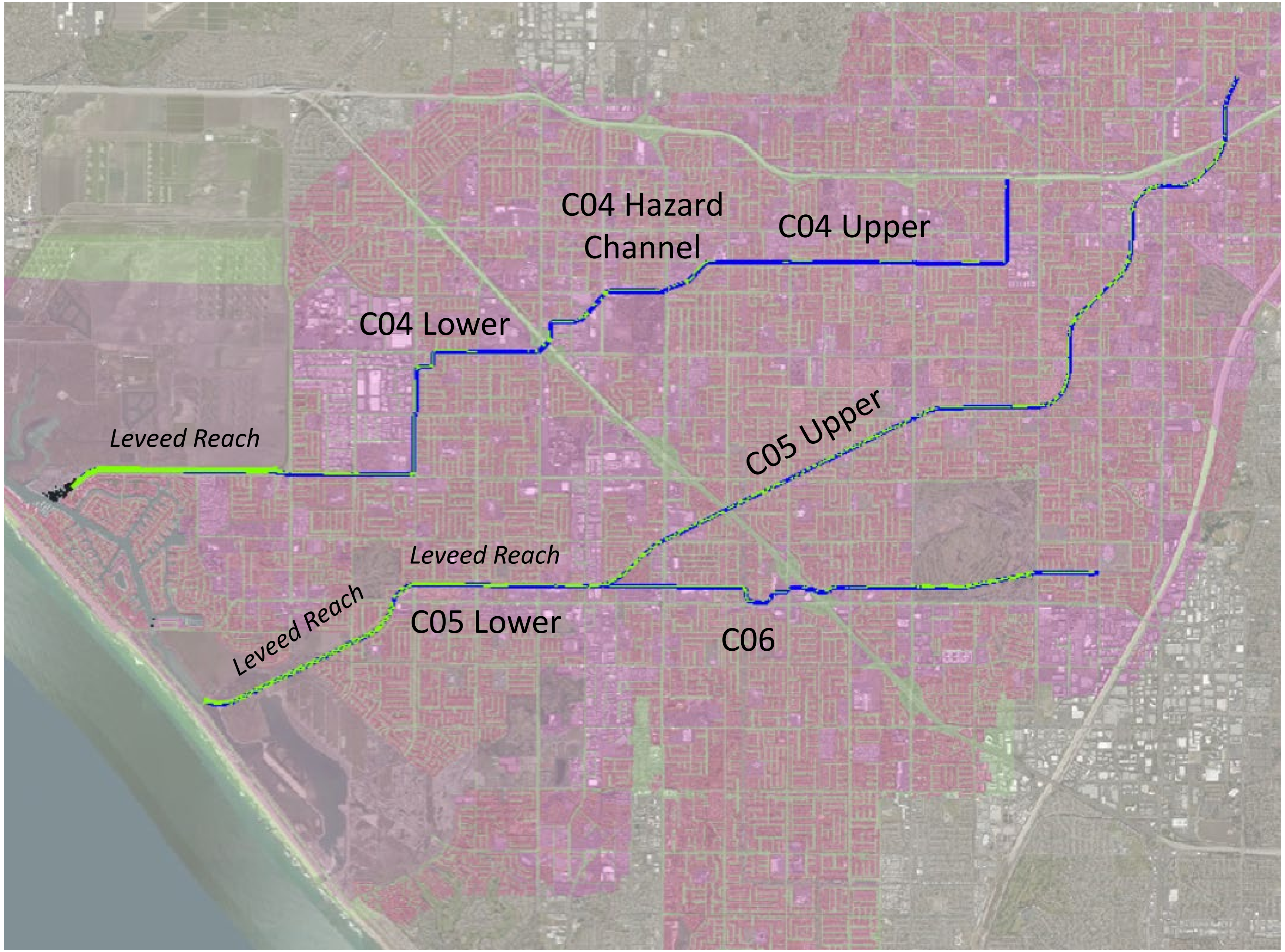
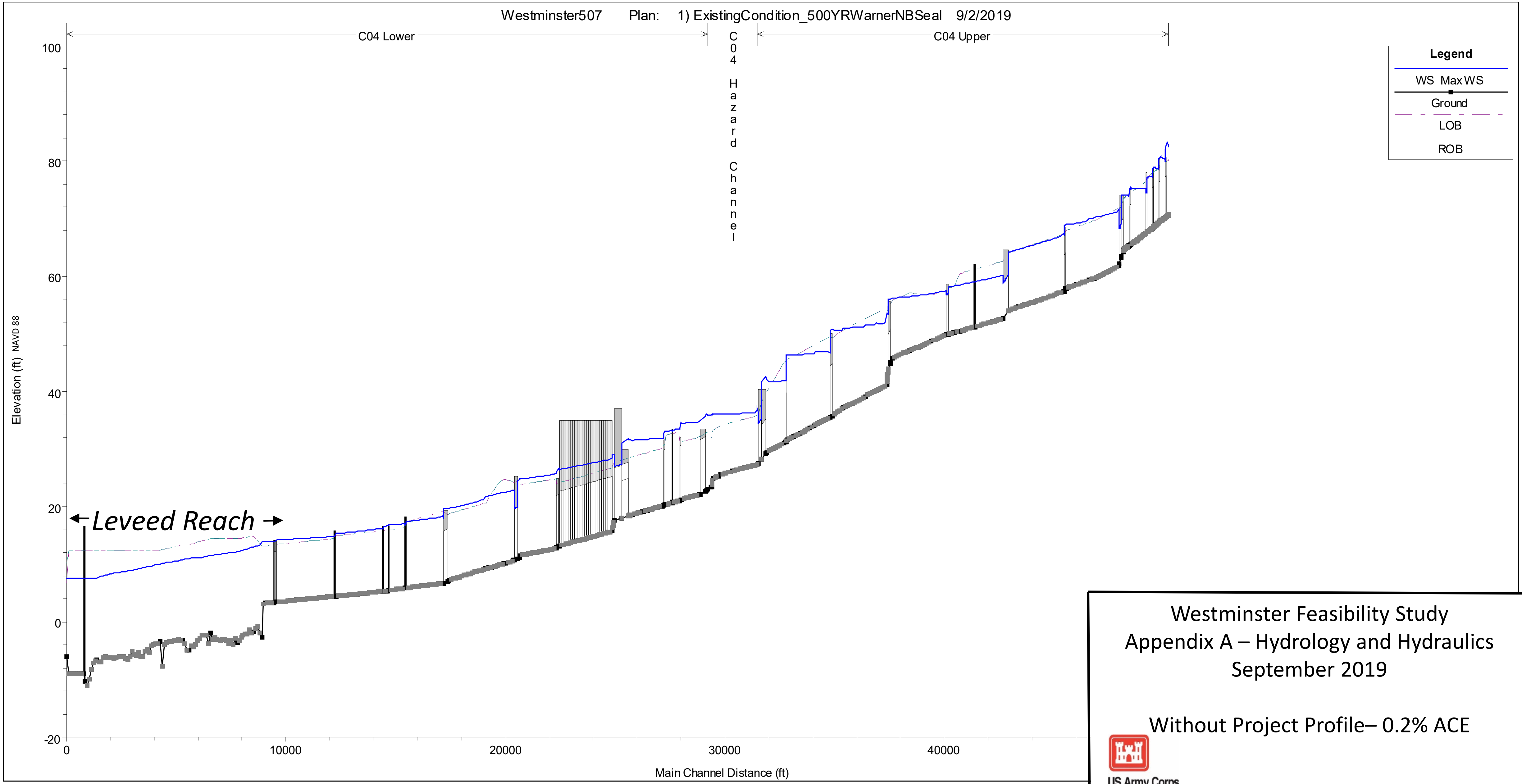


Westminster Feasibility Study
Appendix A – Hydrology and Hydraulics
September 2019

HEC-RAS Schematic

US Army Corps of Engineers
Chicago District

Plate A-1

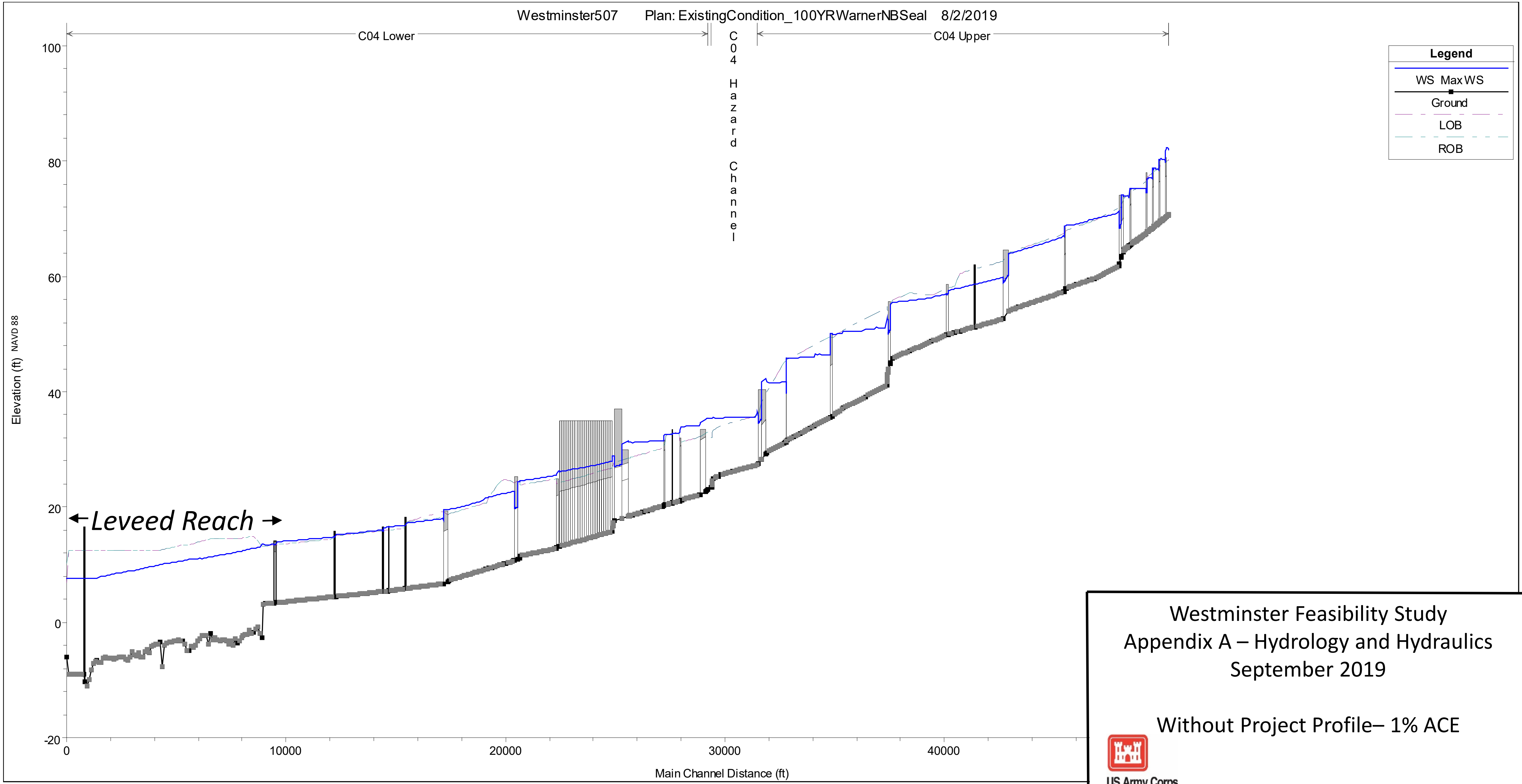


Westminster Feasibility Study
Appendix A – Hydrology and Hydraulics
September 2019

Without Project Profile– 0.2% ACE

US Army Corps of Engineers
Chicago District

Plate A-2



Westminster Feasibility Study
Appendix A – Hydrology and Hydraulics
September 2019

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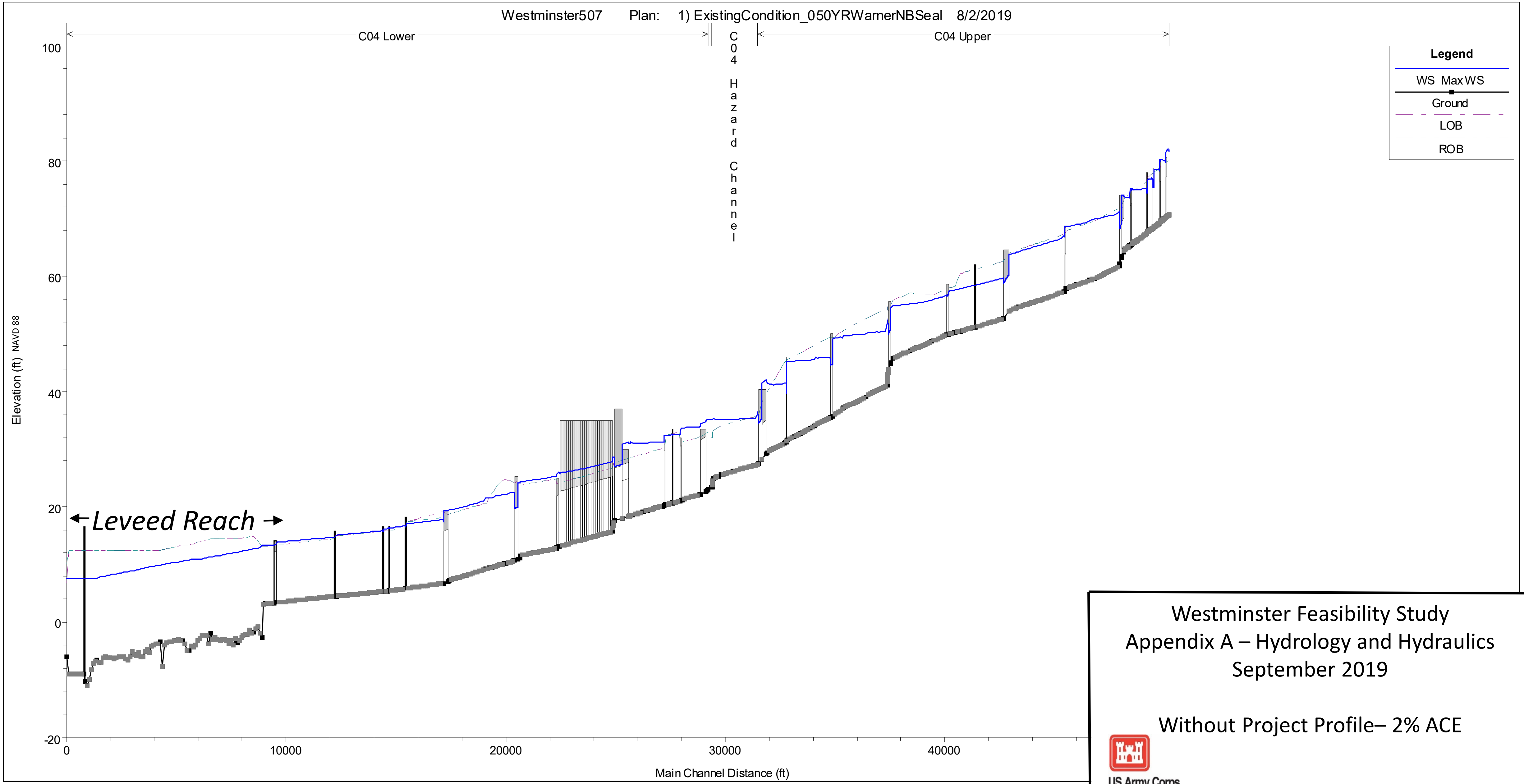
US Army Corps of Engineers
Chicago District



Westminster Feasibility Study
Appendix A – Hydrology and Hydraulics
September 2019

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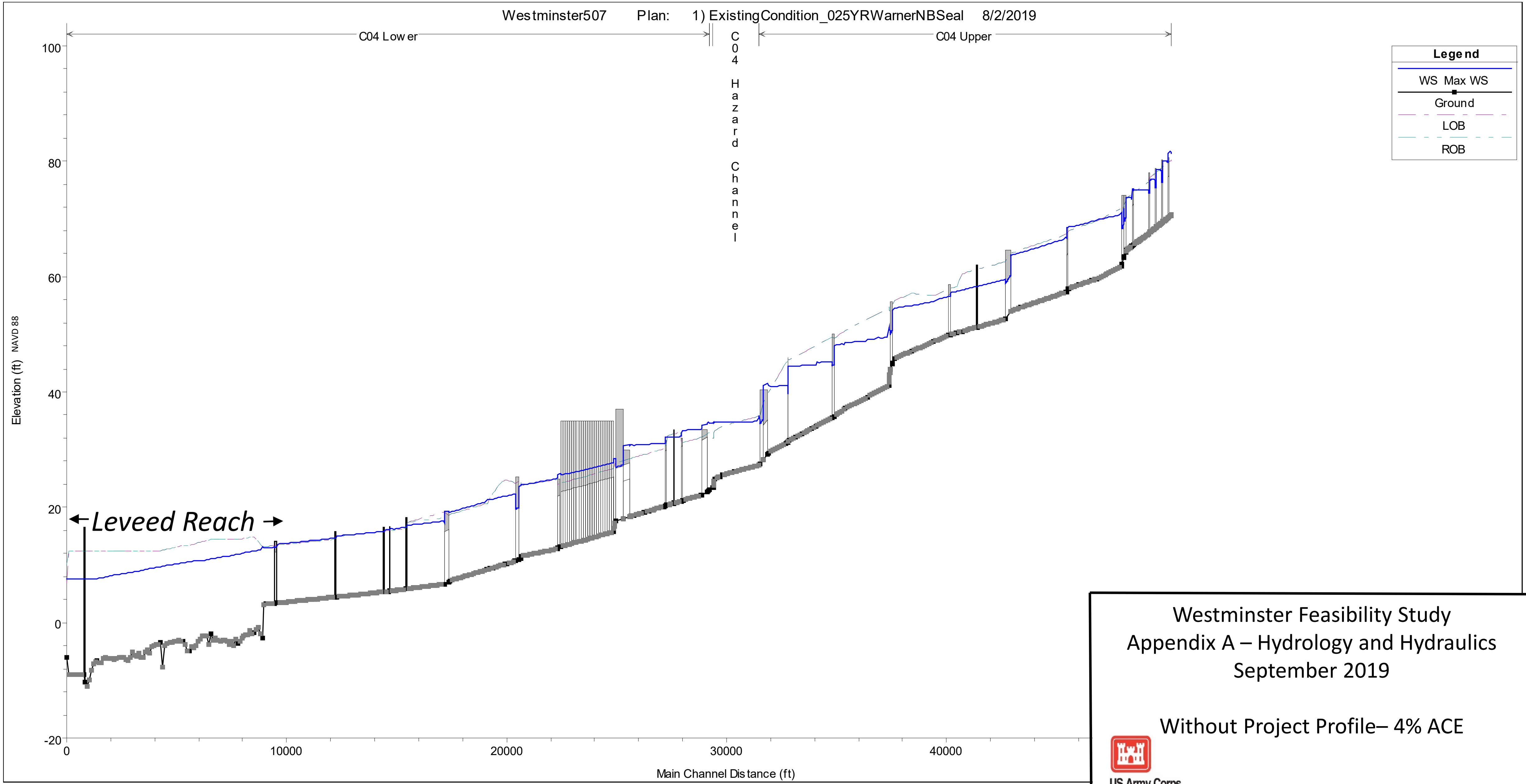
Chicago District

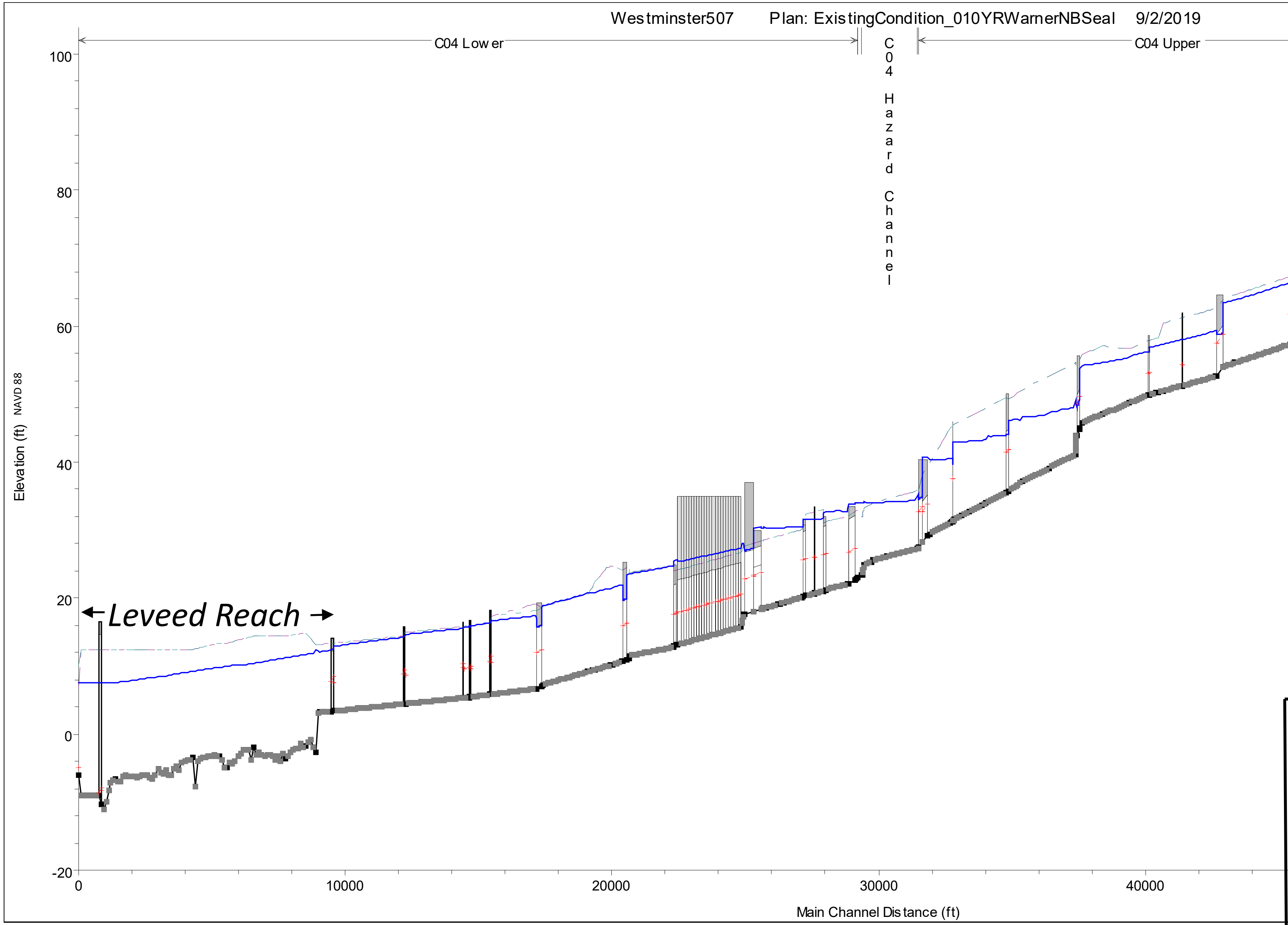


Westminster Feasibility Study
Appendix A – Hydrology and Hydraulics
September 2019

Without Project Profile– 4% ACE

US Army Corps of Engineers
Chicago District

Plate A-5



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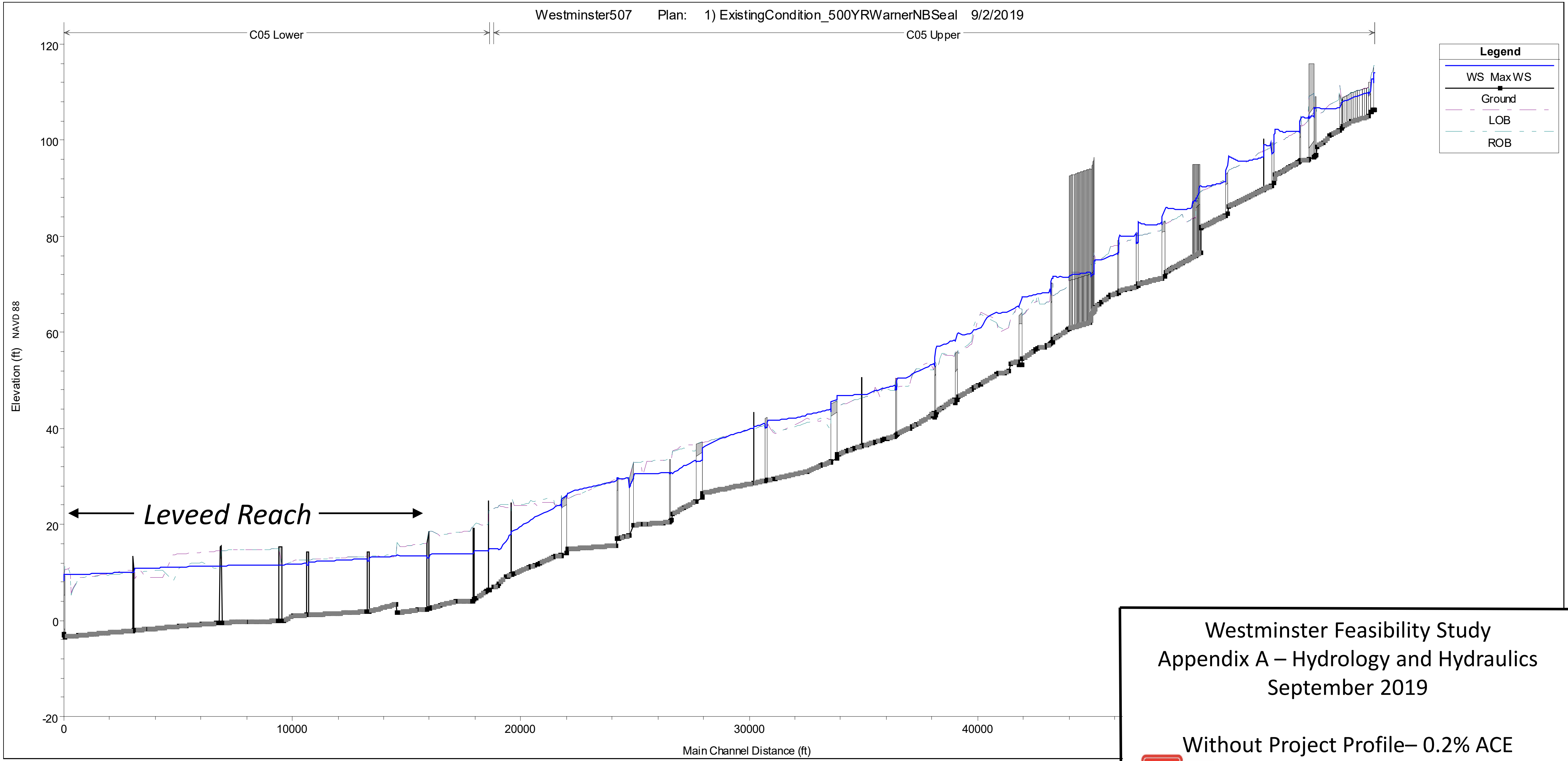
September 2019

Without Project Profile– 10% ACE

US Army Corps of Engineers
Chicago District

Plate A-6



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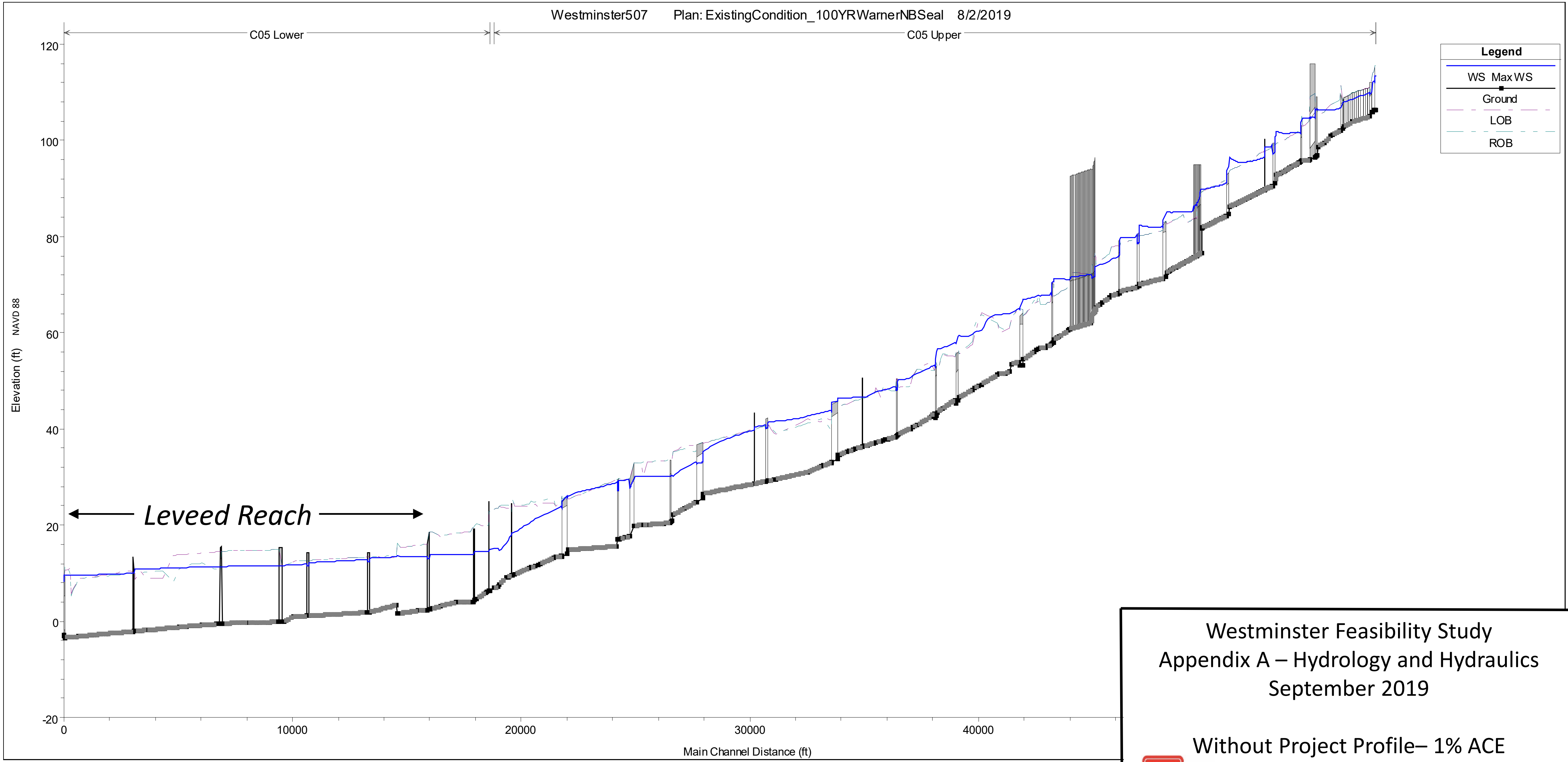
Appendix A – Hydrology and Hydraulics
September 2019

Without Project Profile– 0.2% ACE

US Army Corps of Engineers
Chicago District

Plate A-7



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September 2019

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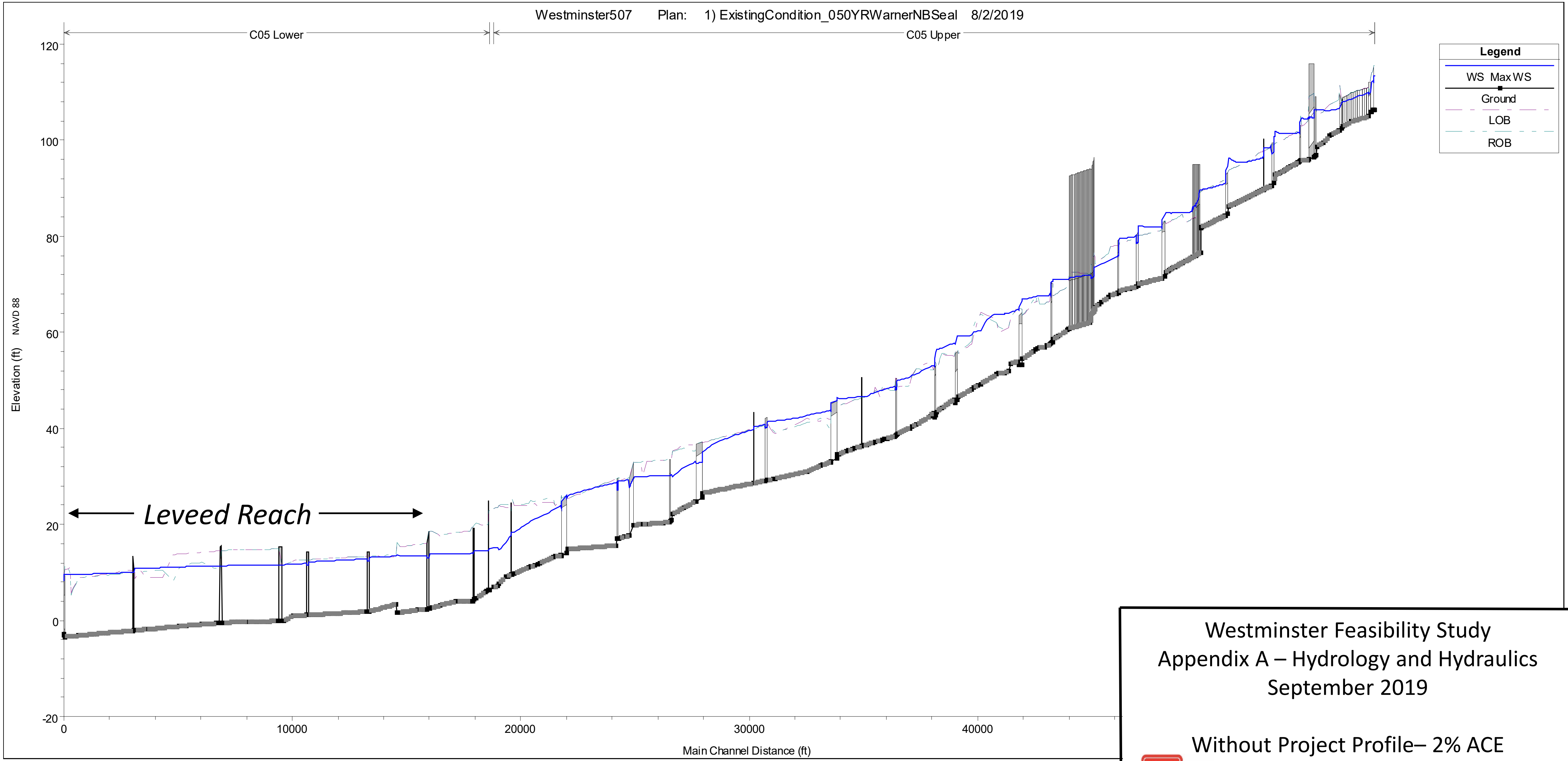
US Army Corps of Engineers
Chicago District



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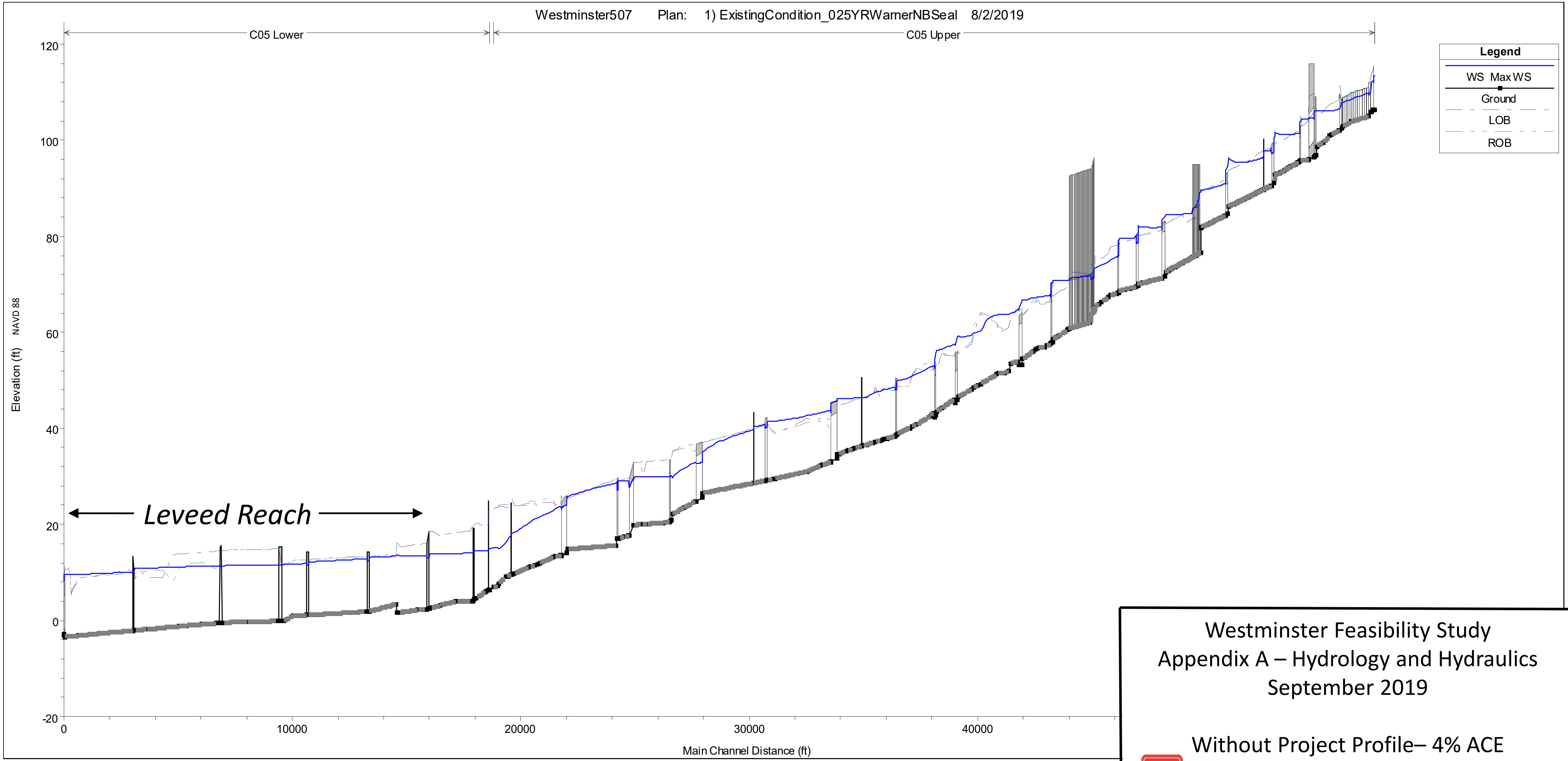
September 2019

Without Project Profile– 2% ACE

US Army Corps of Engineers
Chicago District

Plate A-9



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Appendix A – Hydrology and Hydraulics
September 2019

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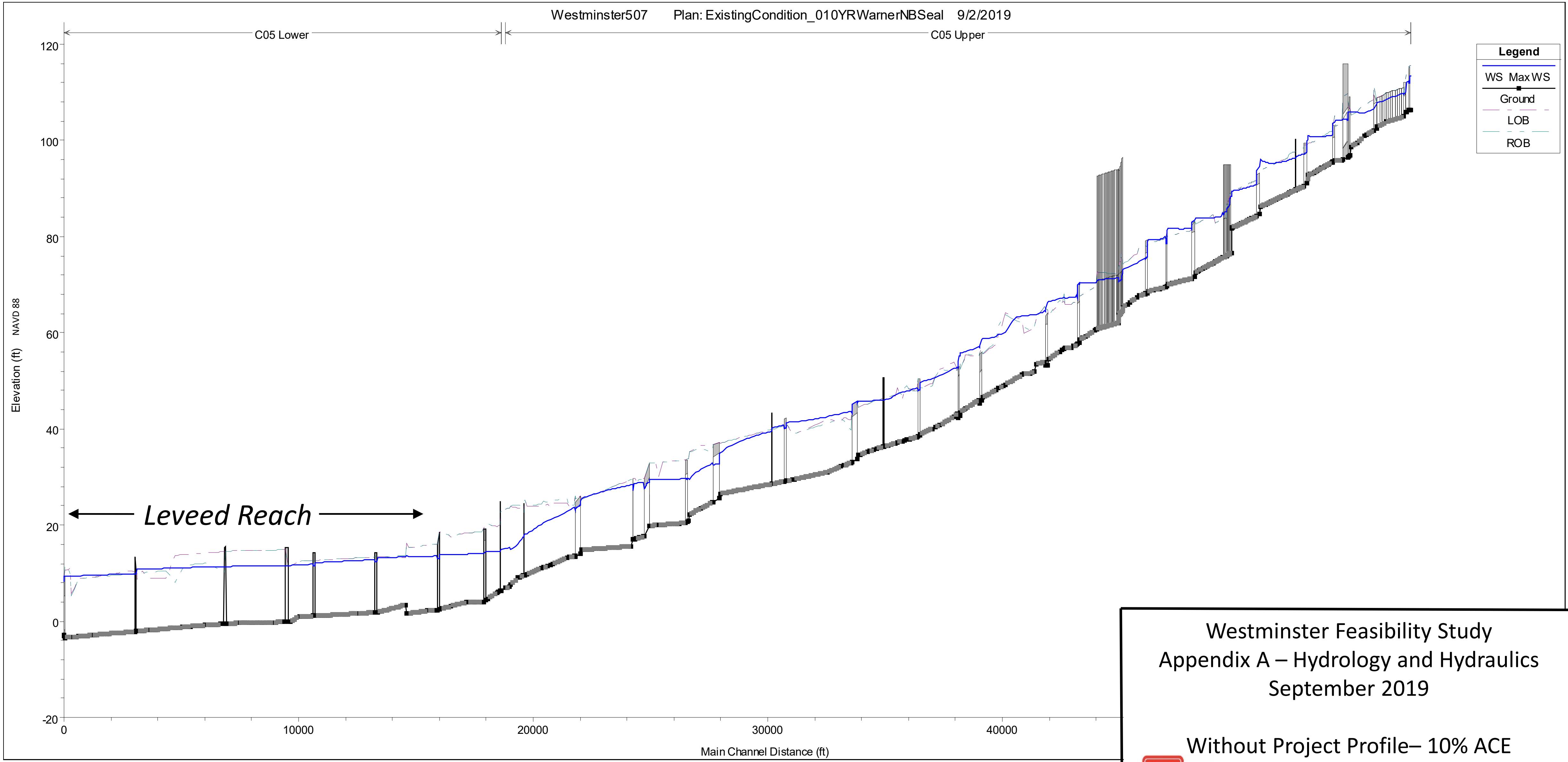
US Army Corps of Engineers
Chicago District

Plate A-10



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Appendix A – Hydrology and Hydraulics
September 2019

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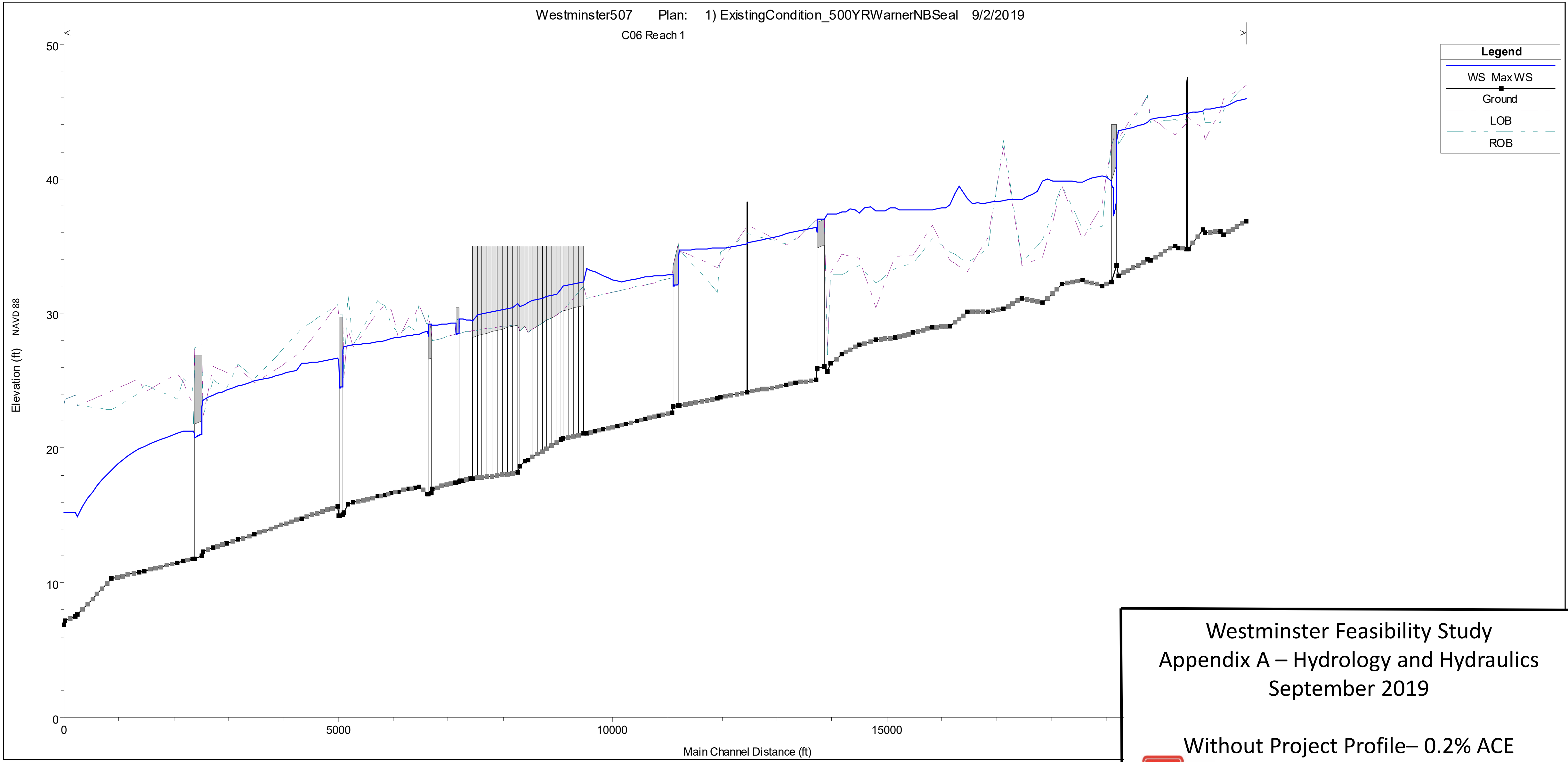
US Army Corps of Engineers
Chicago District

Plate A-11



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Appendix A – Hydrology and Hydraulics
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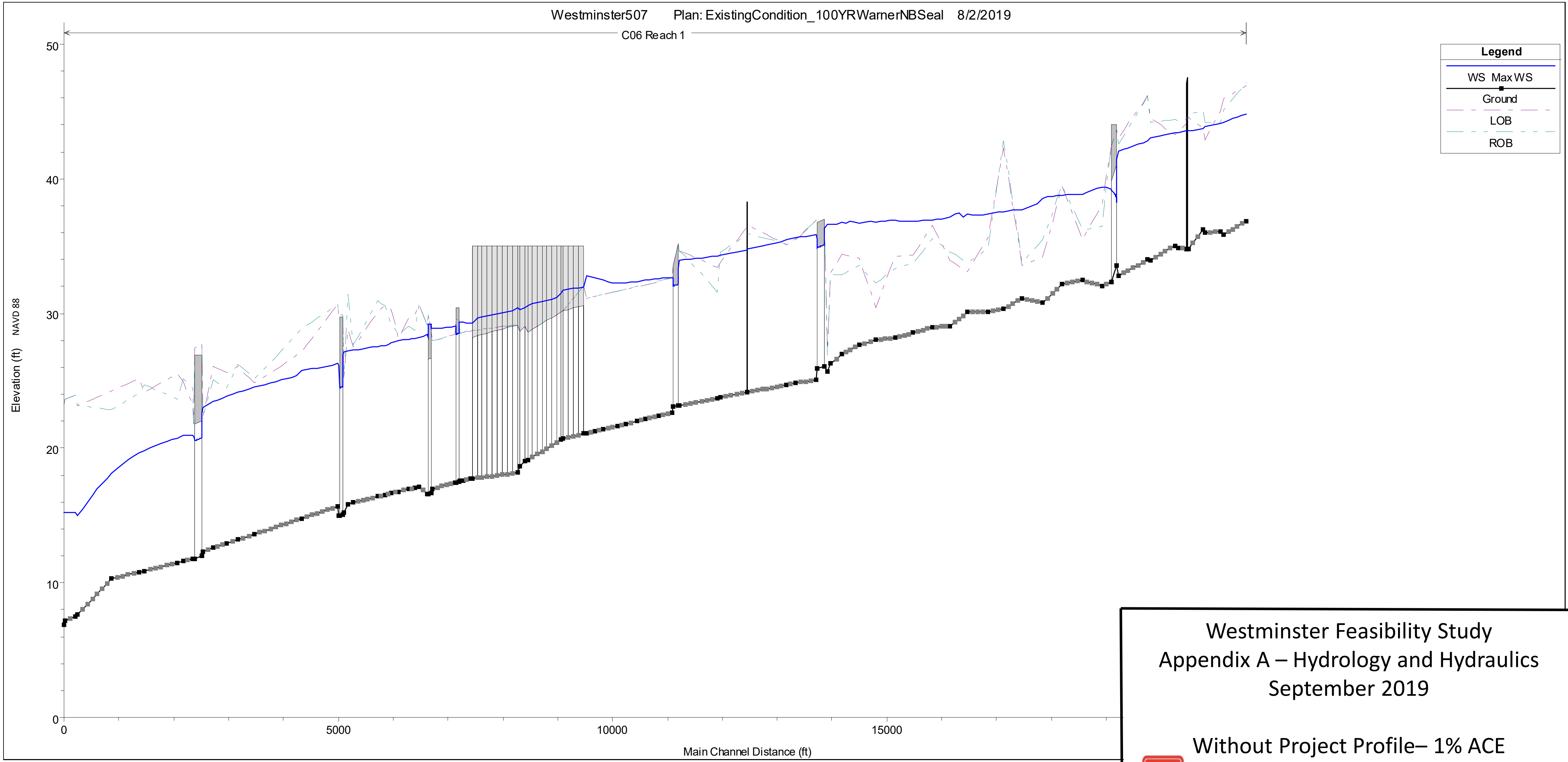
US Army Corps of Engineers
Chicago District

Plate A-12



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Appendix A – Hydrology and Hydraulics
September 2019

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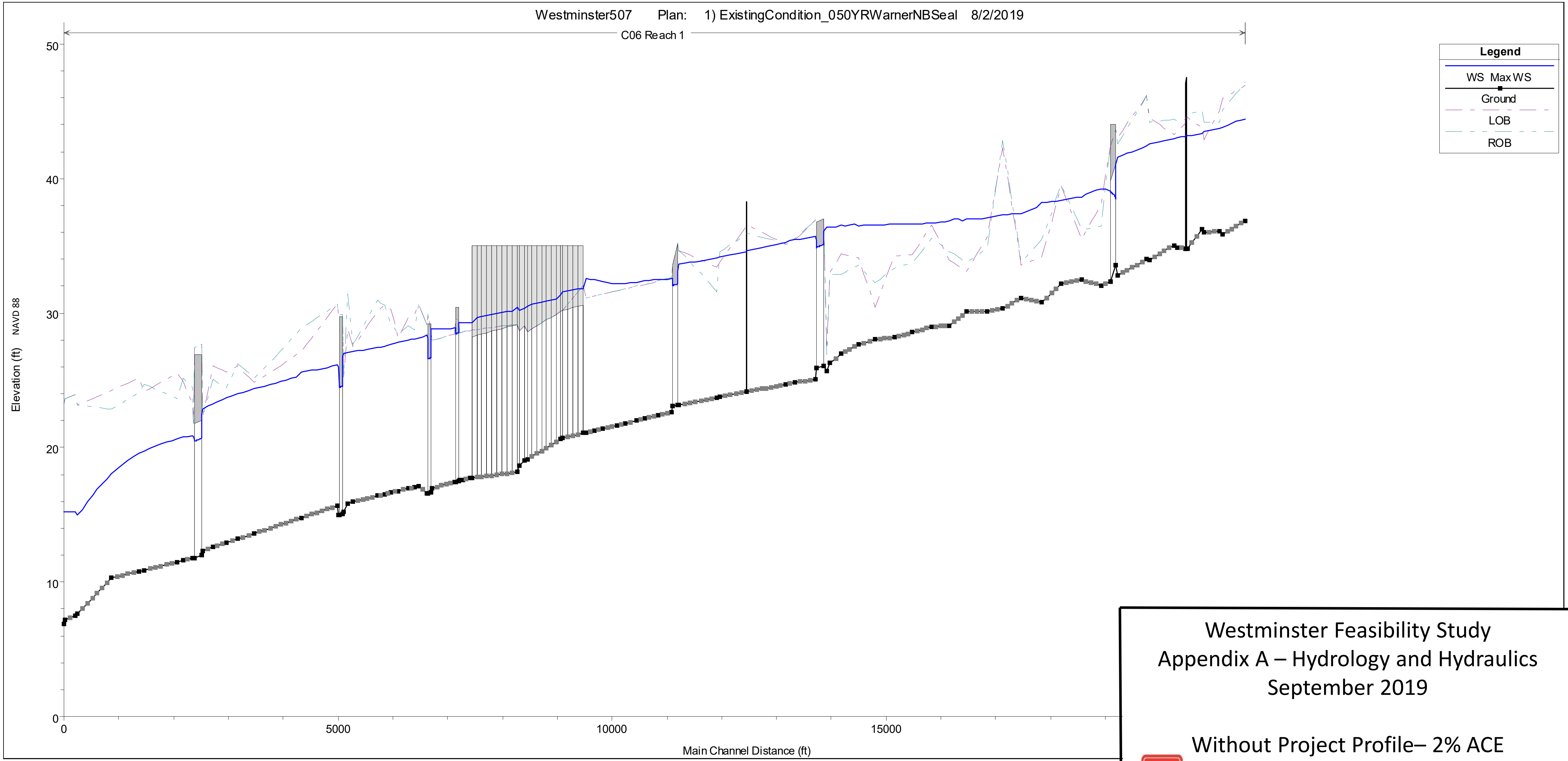
US Army Corps of Engineers
Chicago District

Plate A-13



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September 2019

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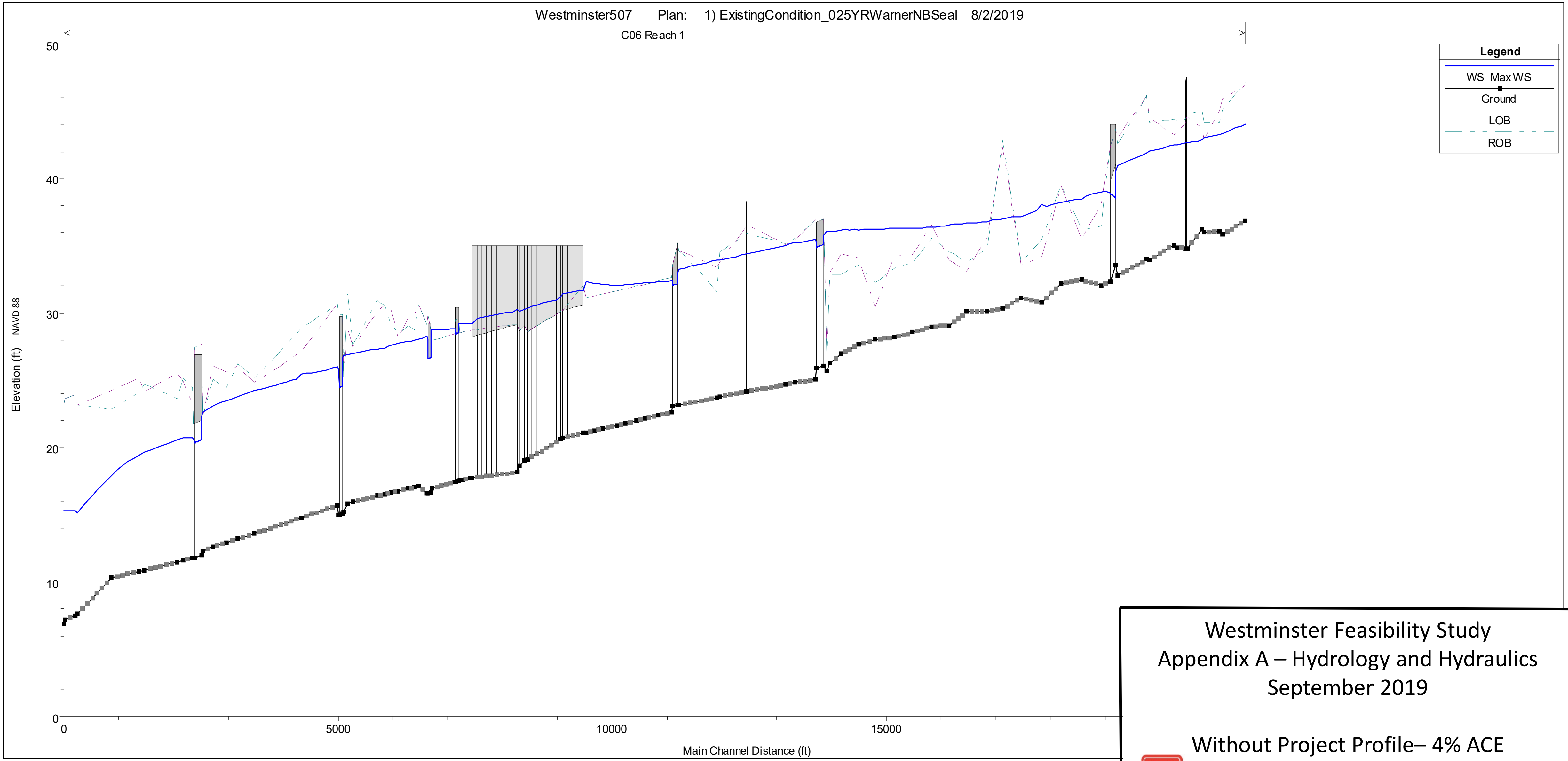
US Army Corps of Engineers
Chicago District

Plate A-14



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Appendix A – Hydrology and Hydraulics
September 2019

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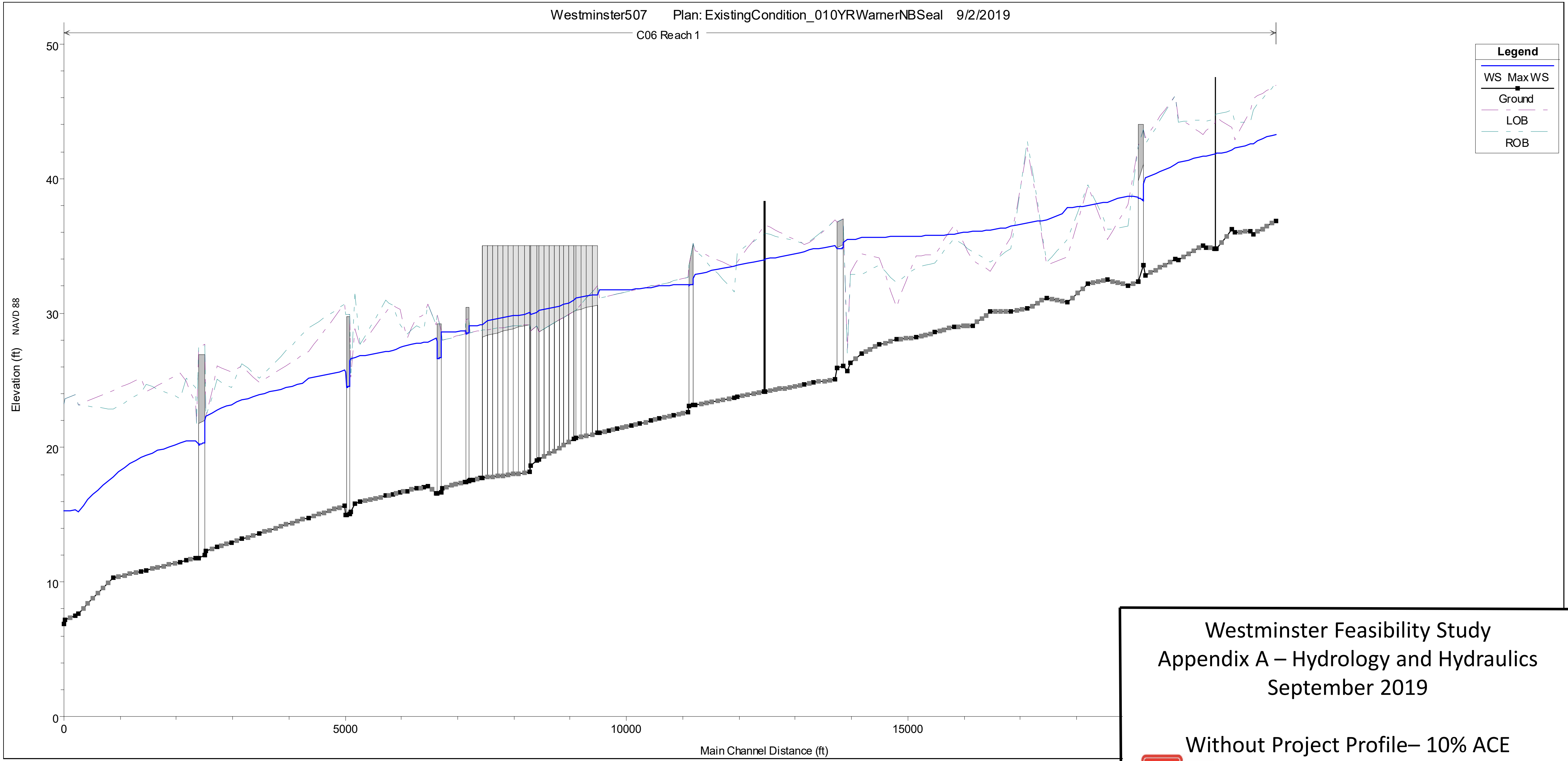
US Army Corps of Engineers® Chicago District

Plate A-15



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Appendix A – Hydrology and Hydraulics
September 2019

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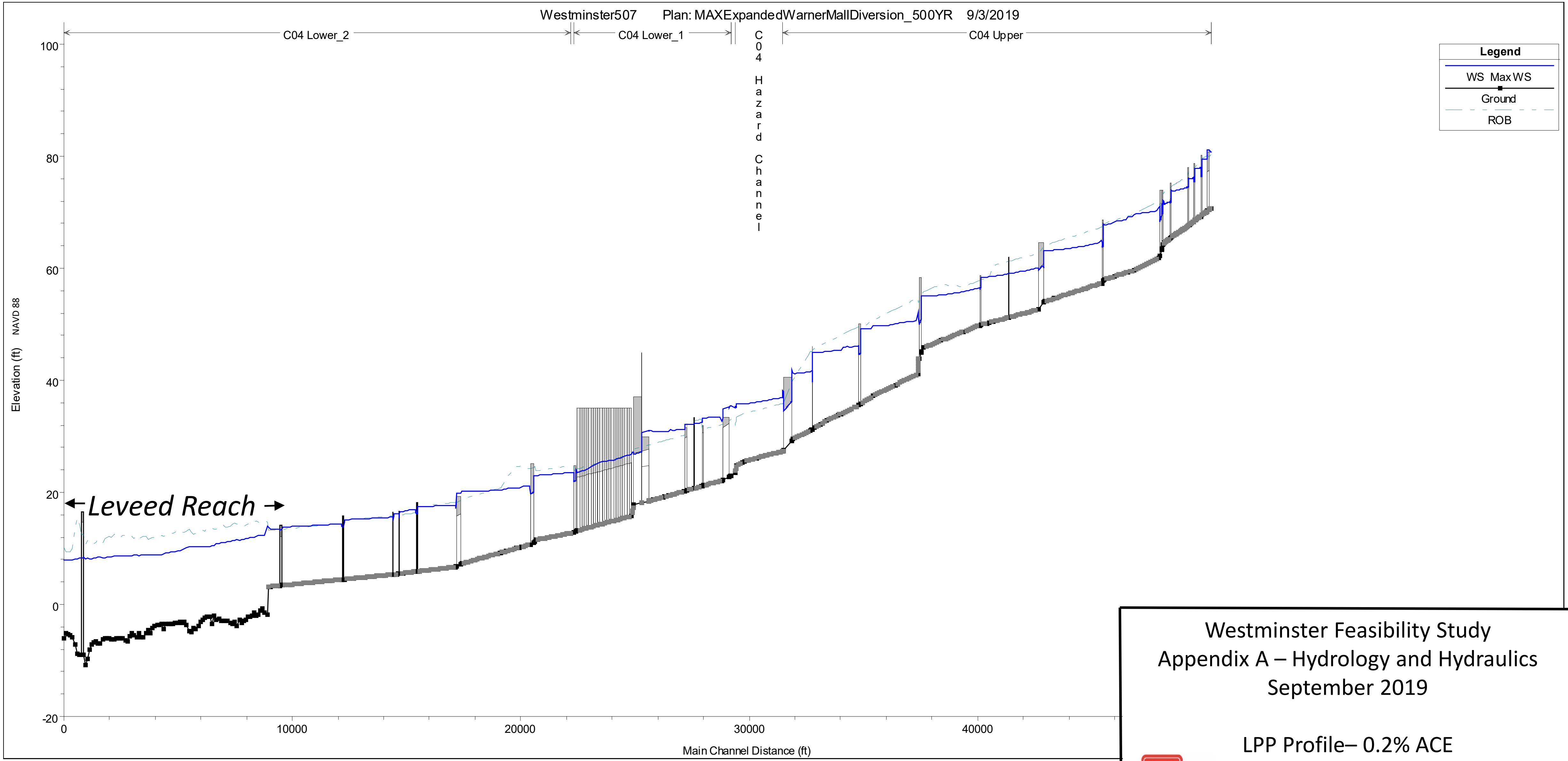
US Army Corps of Engineers
Chicago District

Plate A-16



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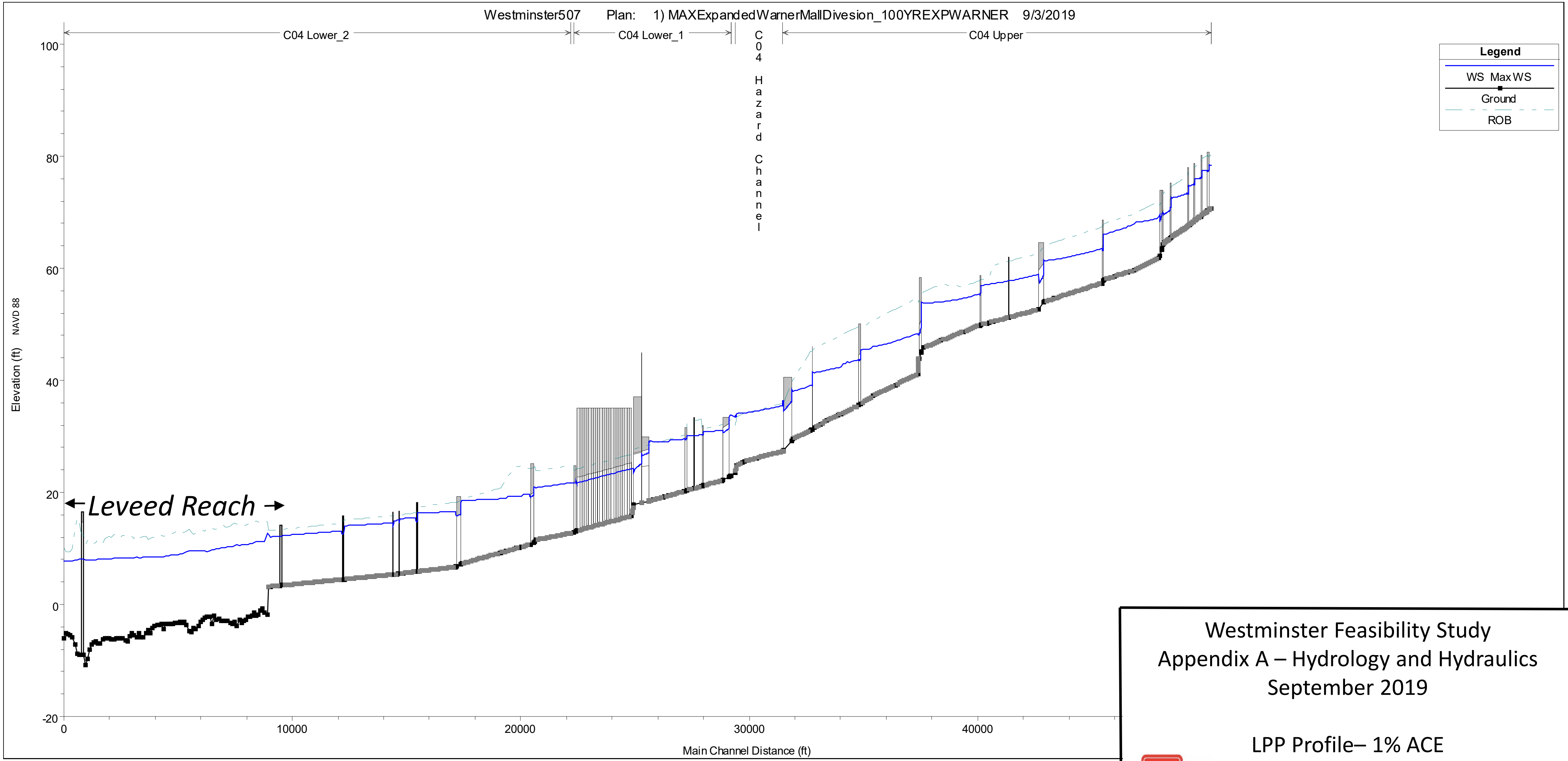
Appendix A – Hydrology and Hydraulics
September 2019

LPP Profile– 0.2% ACE

US Army Corps of Engineers
Chicago District

Plate A-17



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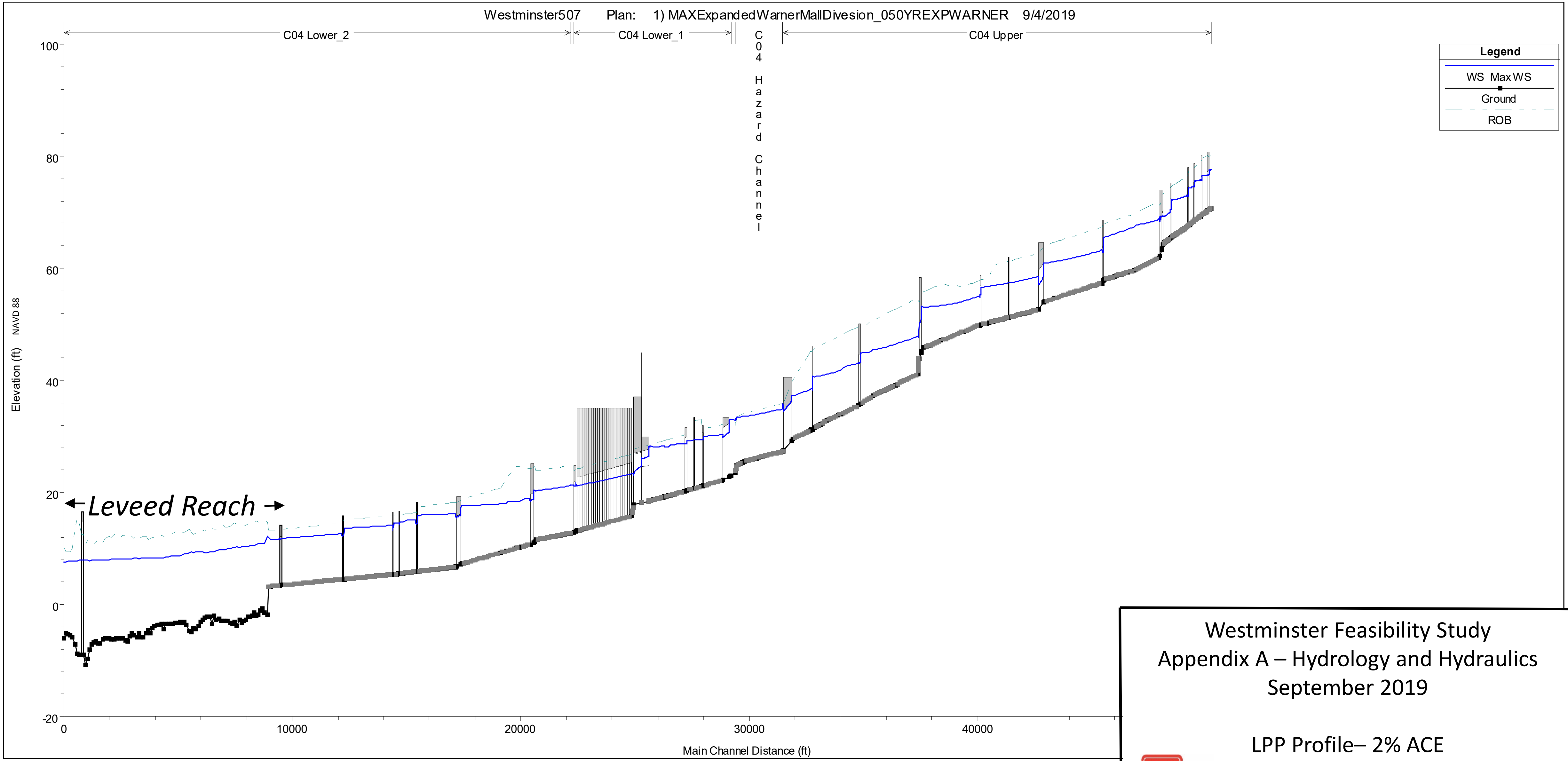
Appendix A – Hydrology and Hydraulics
September 2019

LPP Profile– 1% ACE

US Army Corps of Engineers
Chicago District



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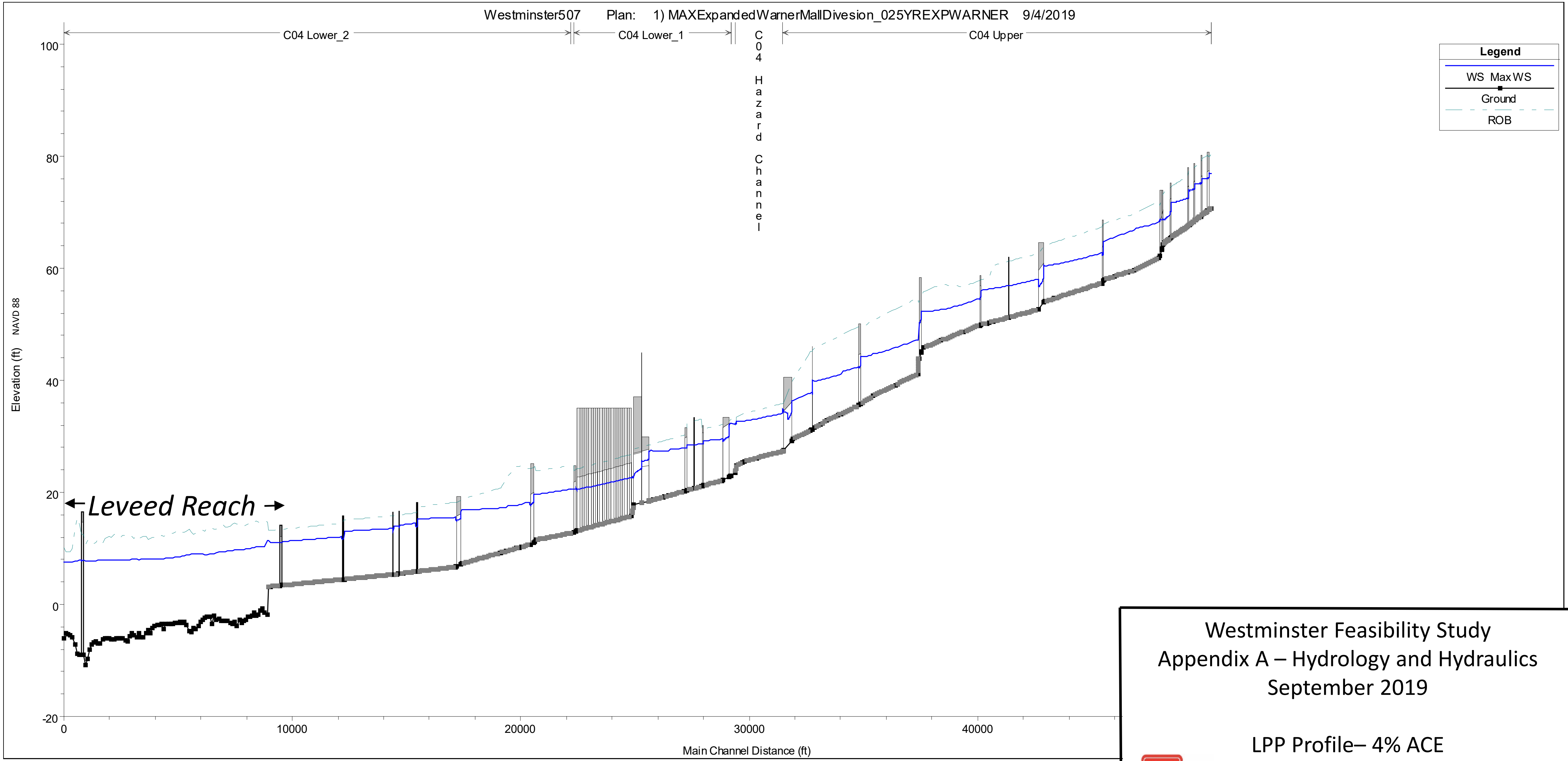
Appendix A – Hydrology and Hydraulics
September 2019

LPP Profile– 2% ACE

US Army Corps of Engineers
Chicago District

Plate A-19



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Appendix A – Hydrology and Hydraulics
September 2019

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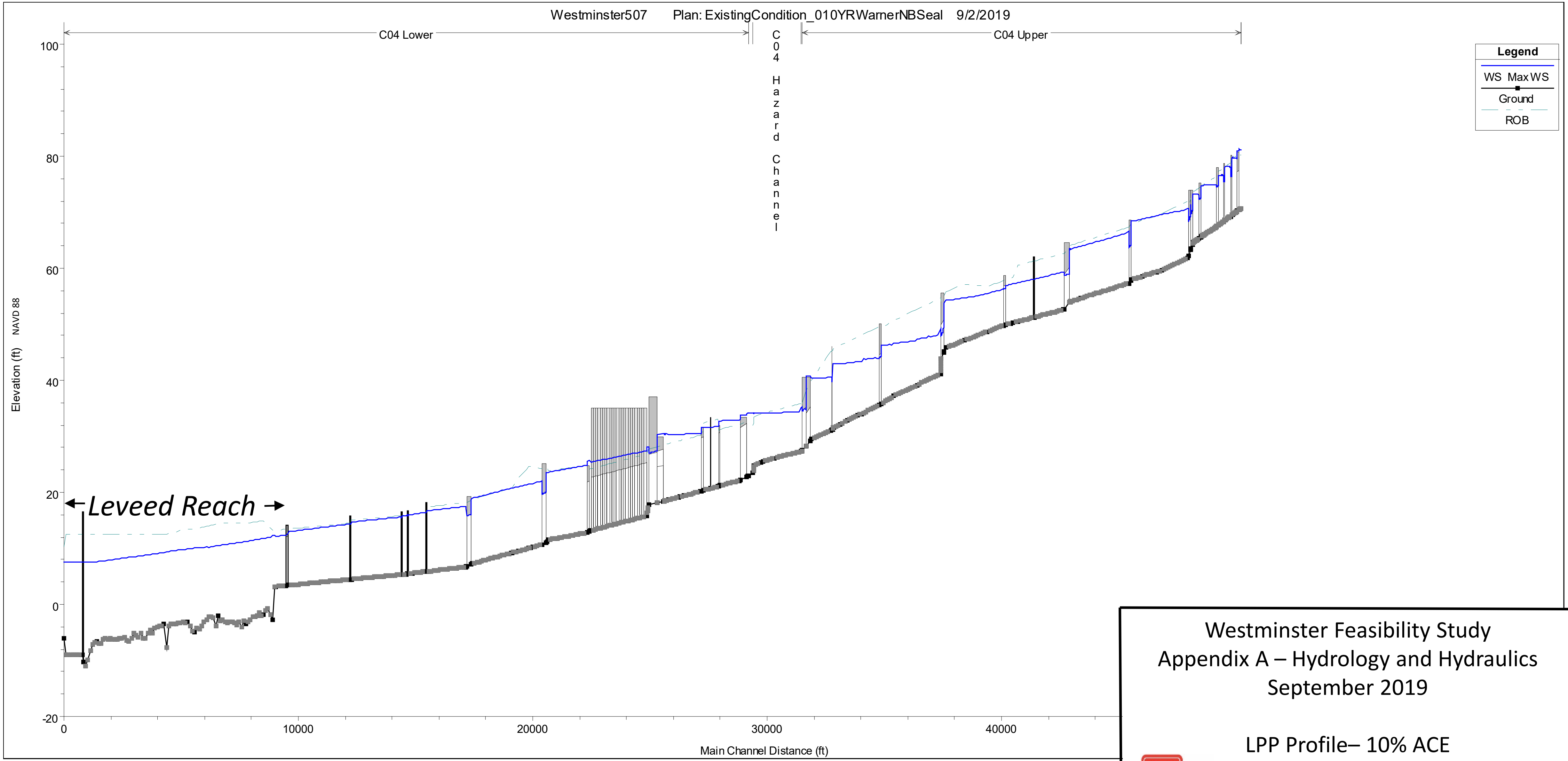
US Army Corps of Engineers
Chicago District

Plate A-20



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September 2019

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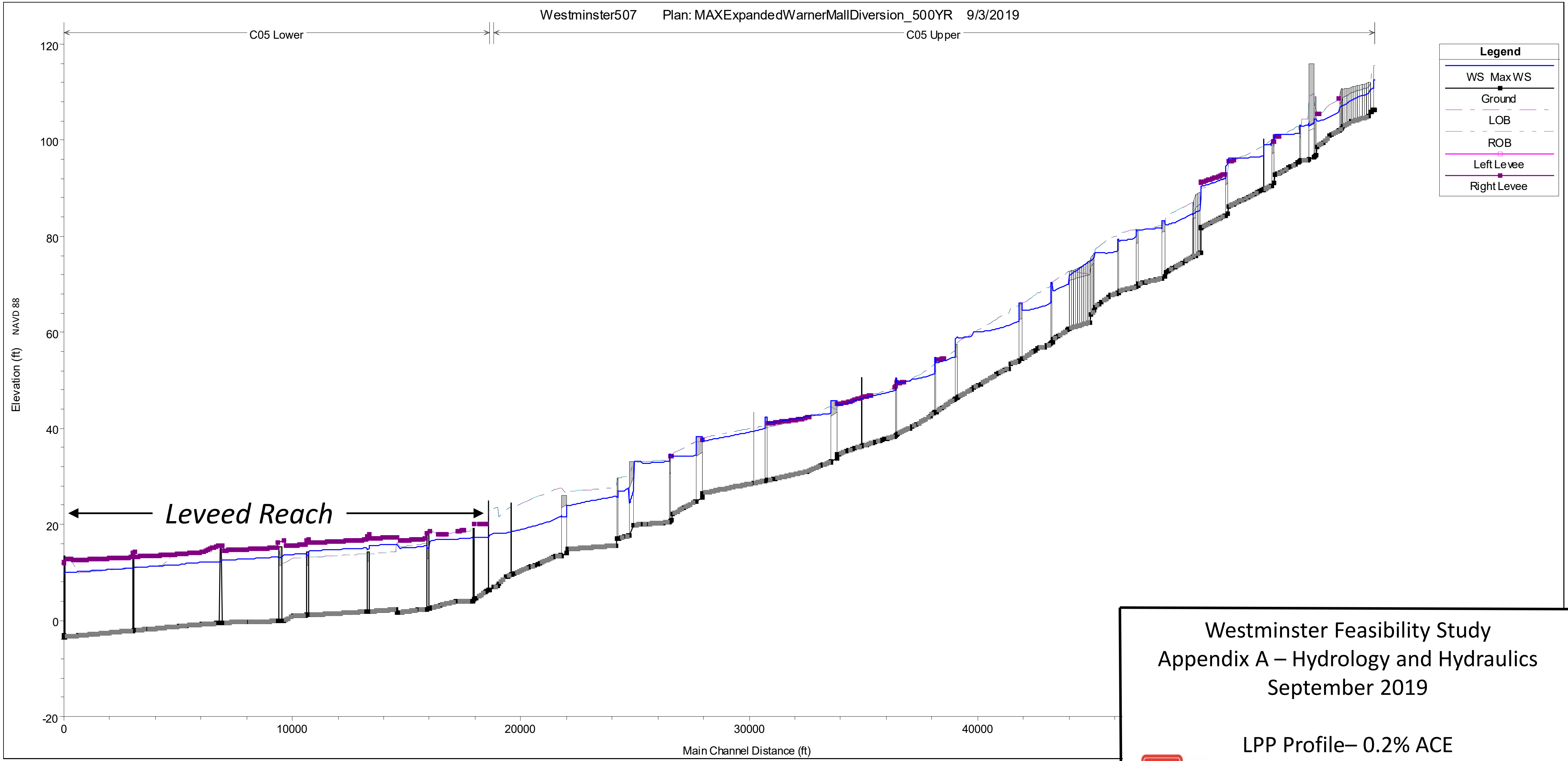
US Army Corps of Engineers
Chicago District

Plate A-21



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September 2019

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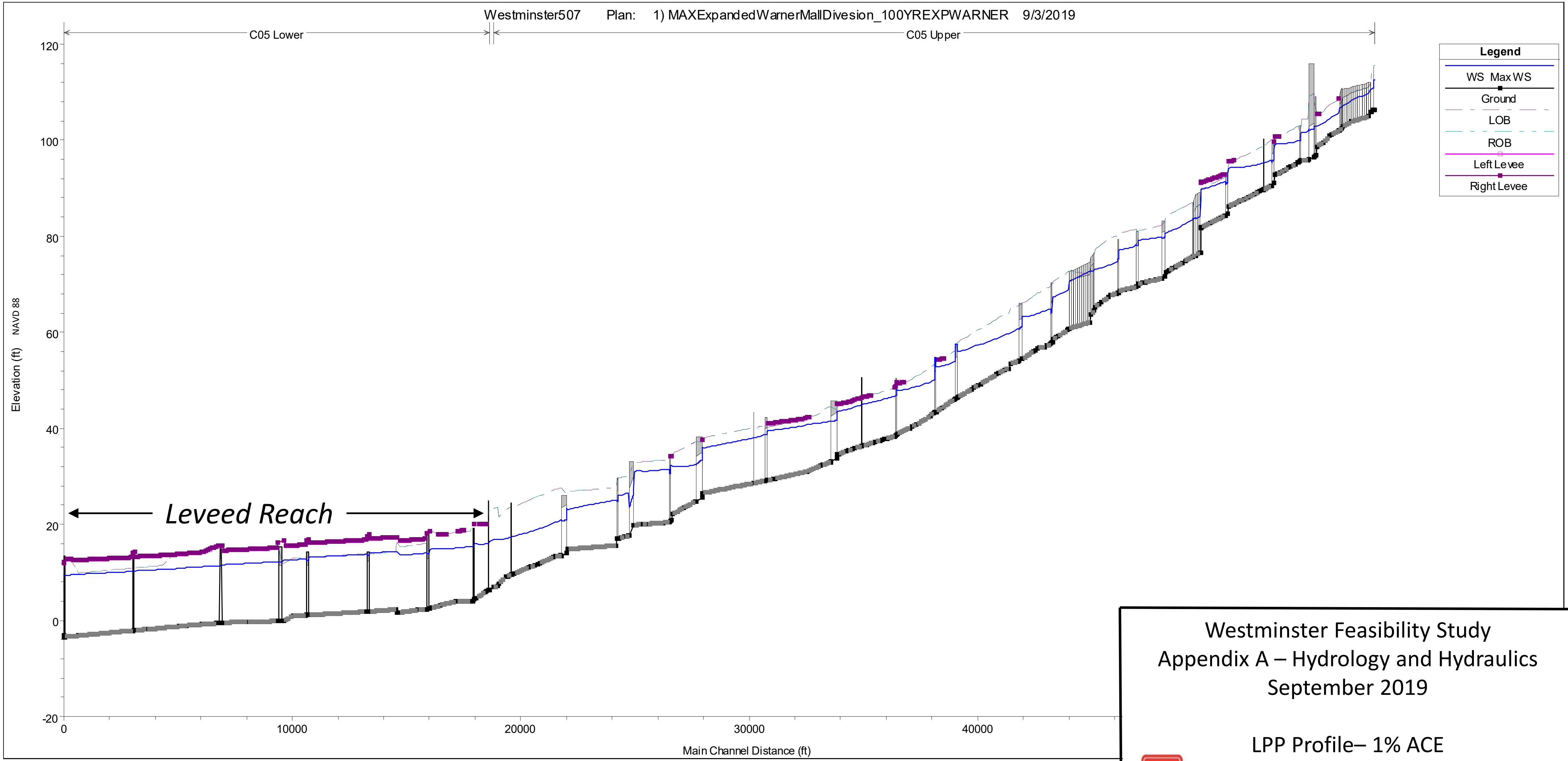
Chicago District



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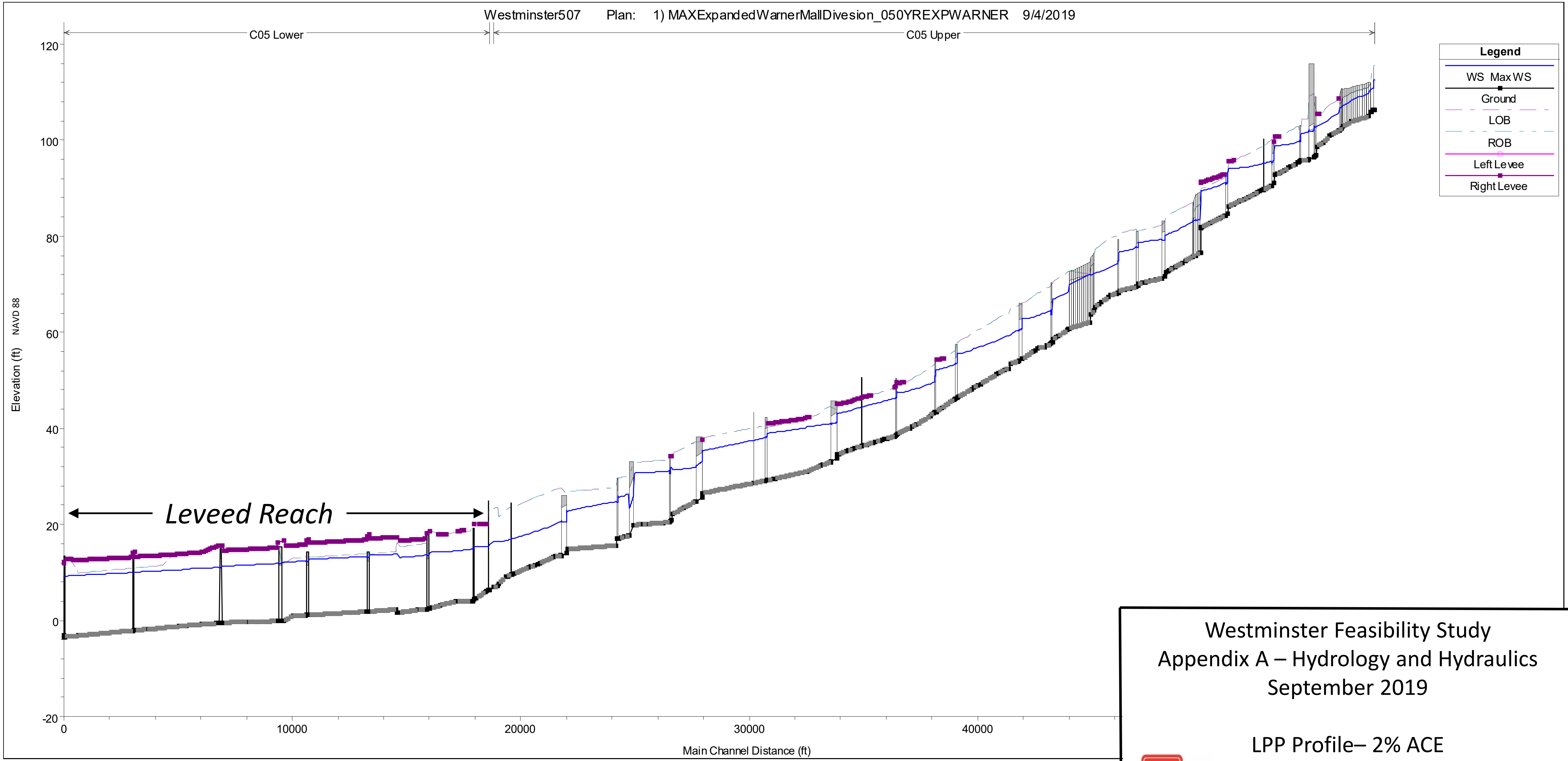
September 2019

LPP Profile– 1% ACE

US Army Corps of Engineers
Chicago District

Plate A-23



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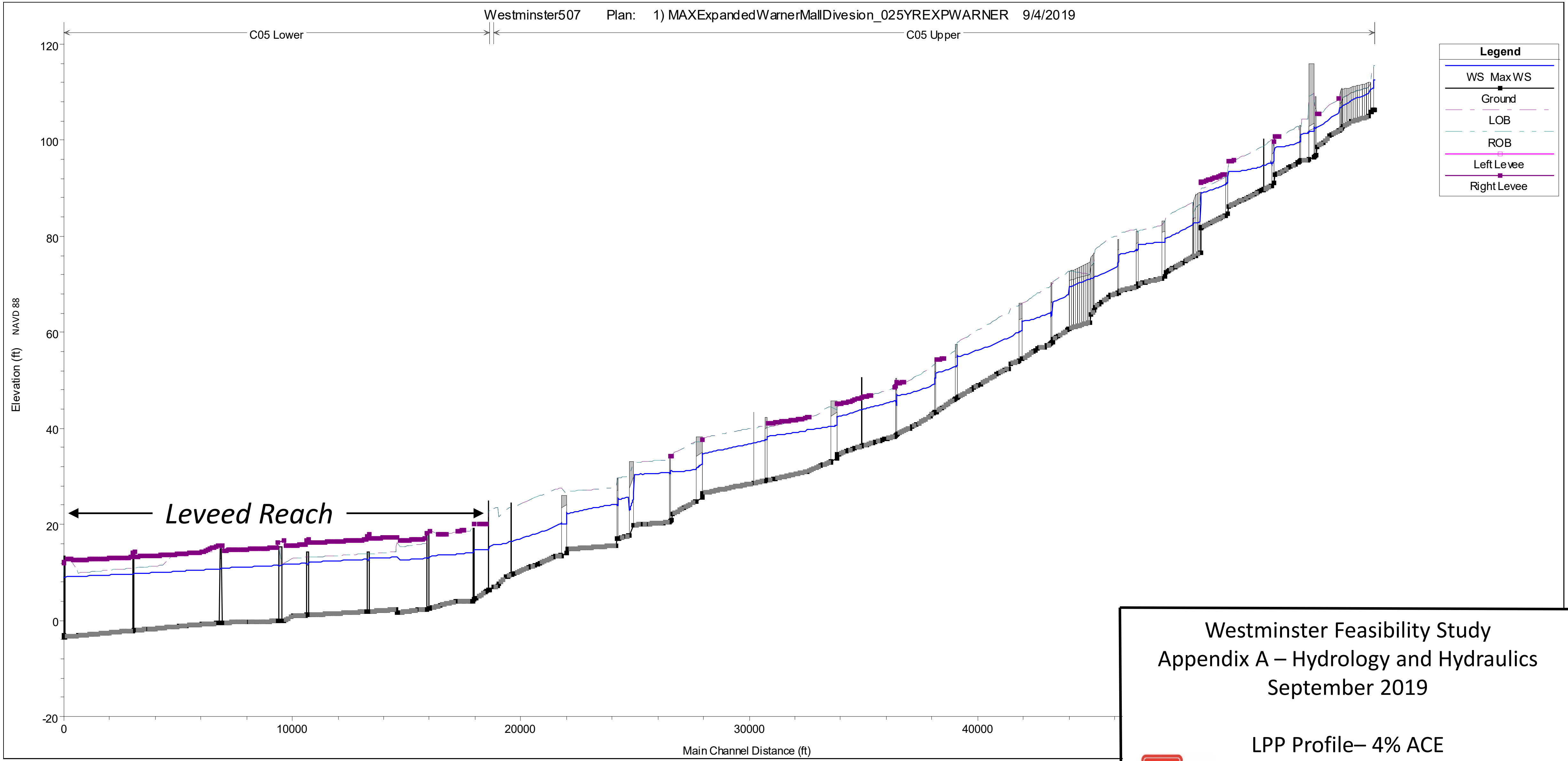
September 2019

LPP Profile– 2% ACE

US Army Corps of Engineers
Chicago District

Plate A-24



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September 2019

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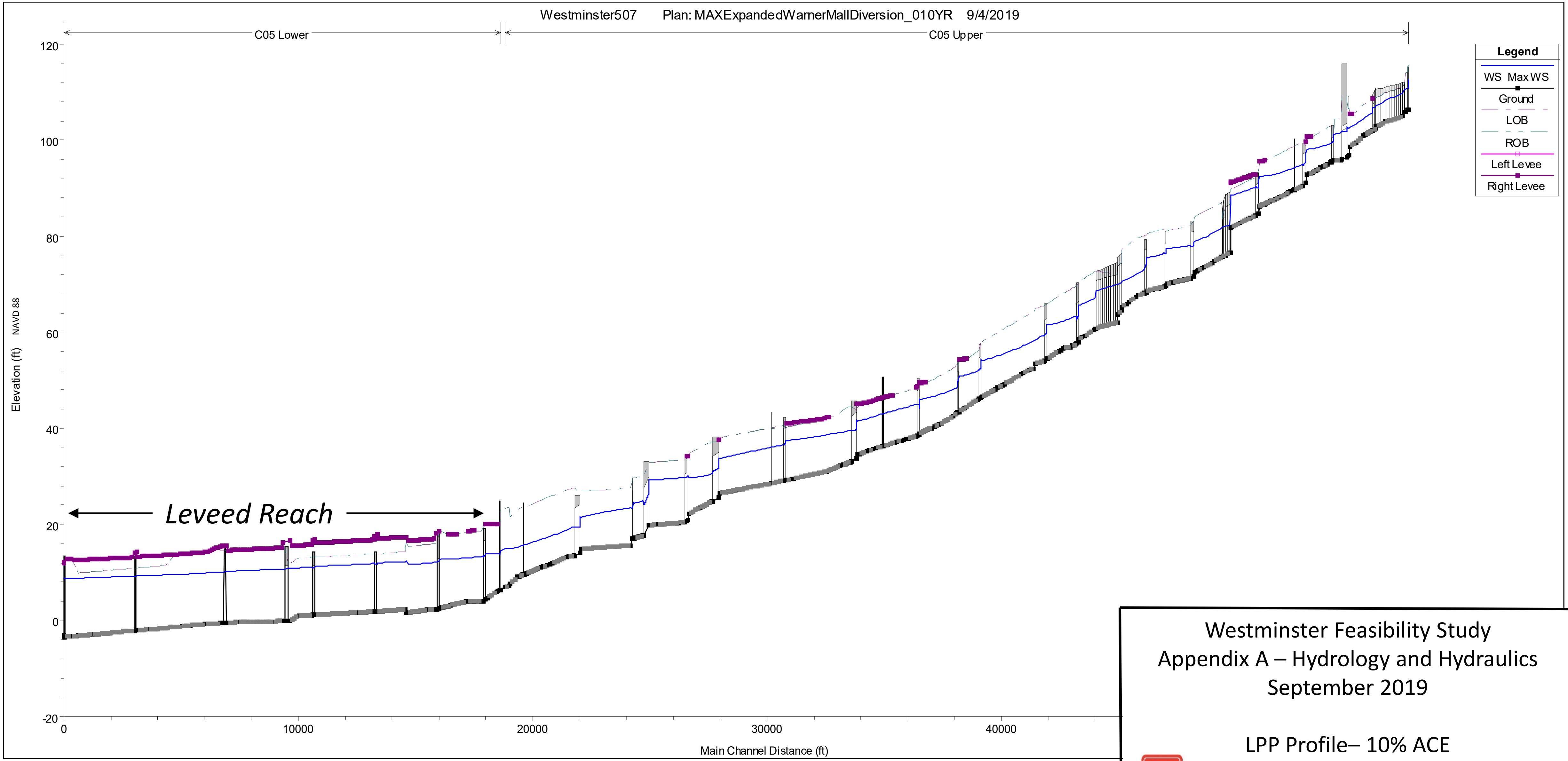
Chicago District



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Appendix A – Hydrology and Hydraulics
September 2019

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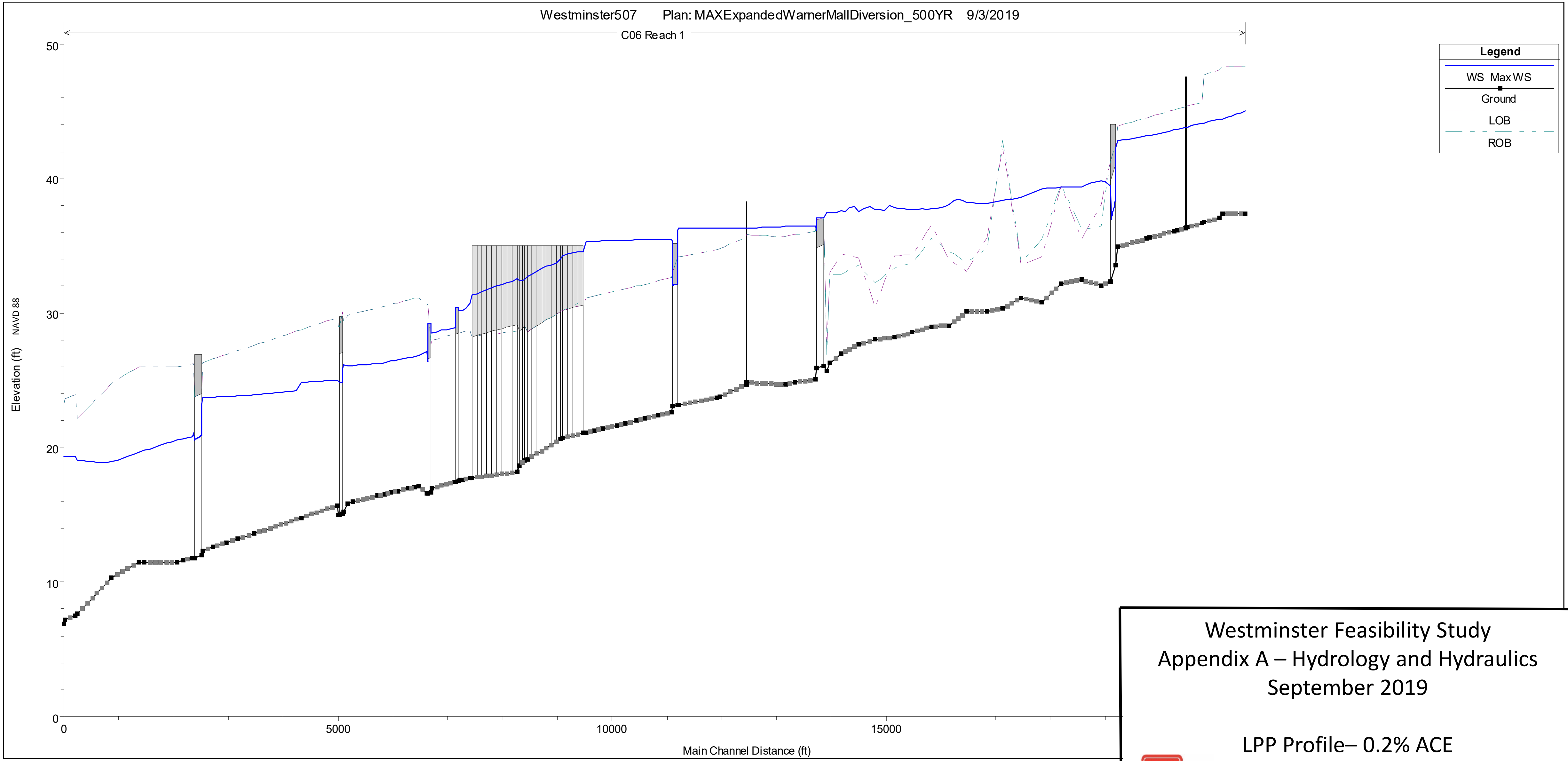
Chicago District



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Appendix A – Hydrology and Hydraulics
September 2019

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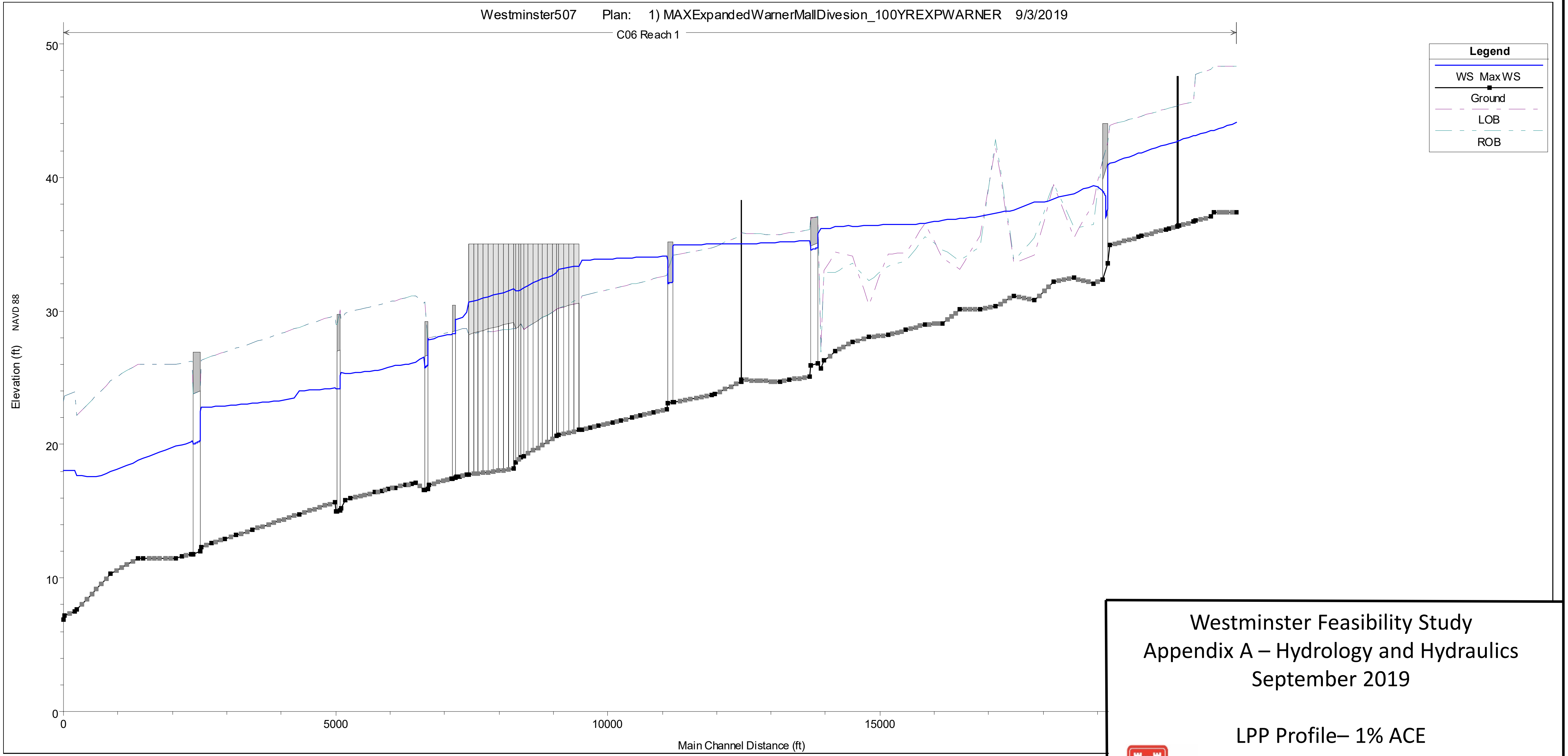
Chicago District

Plate A-27



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September 2019

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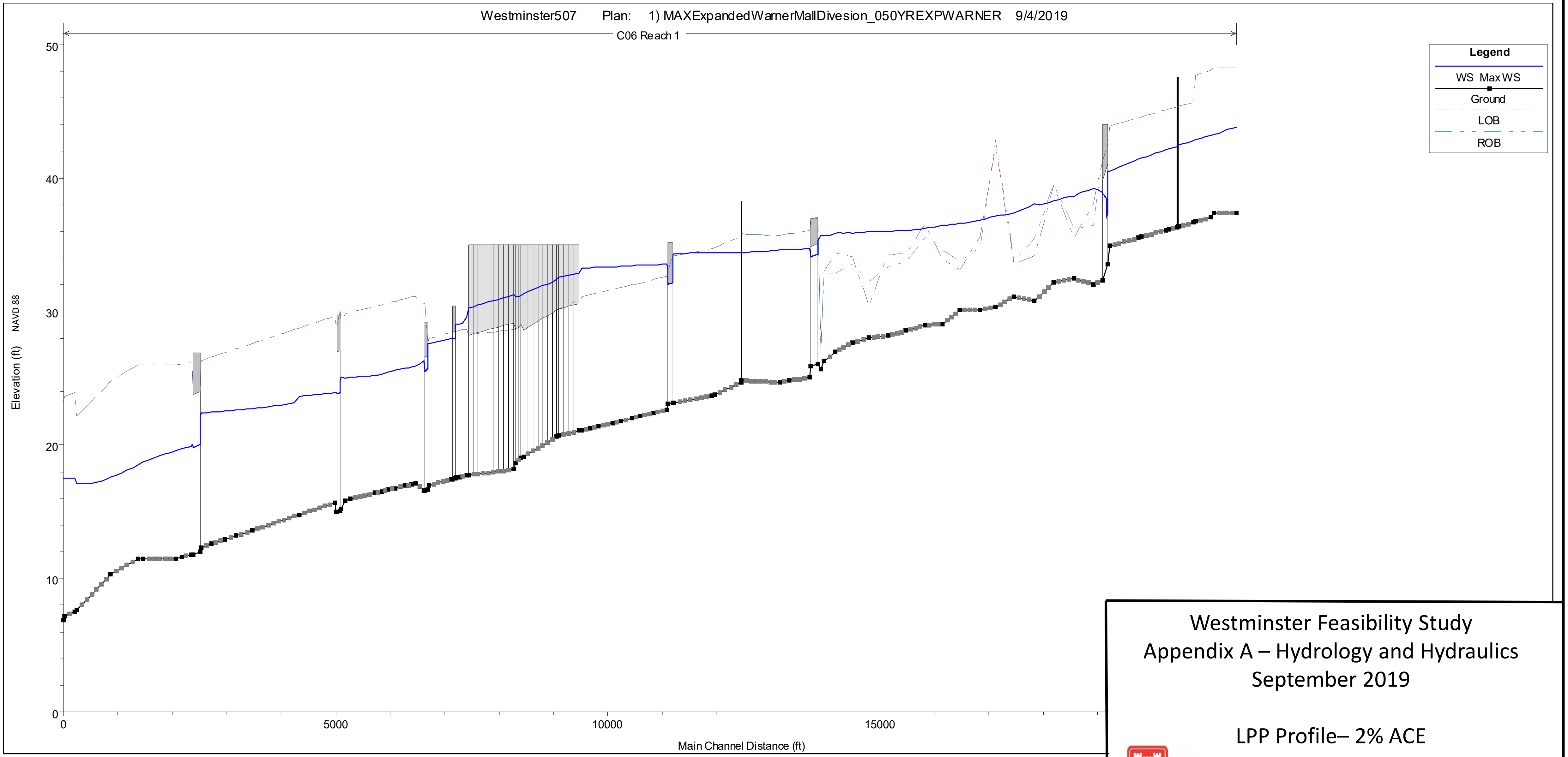

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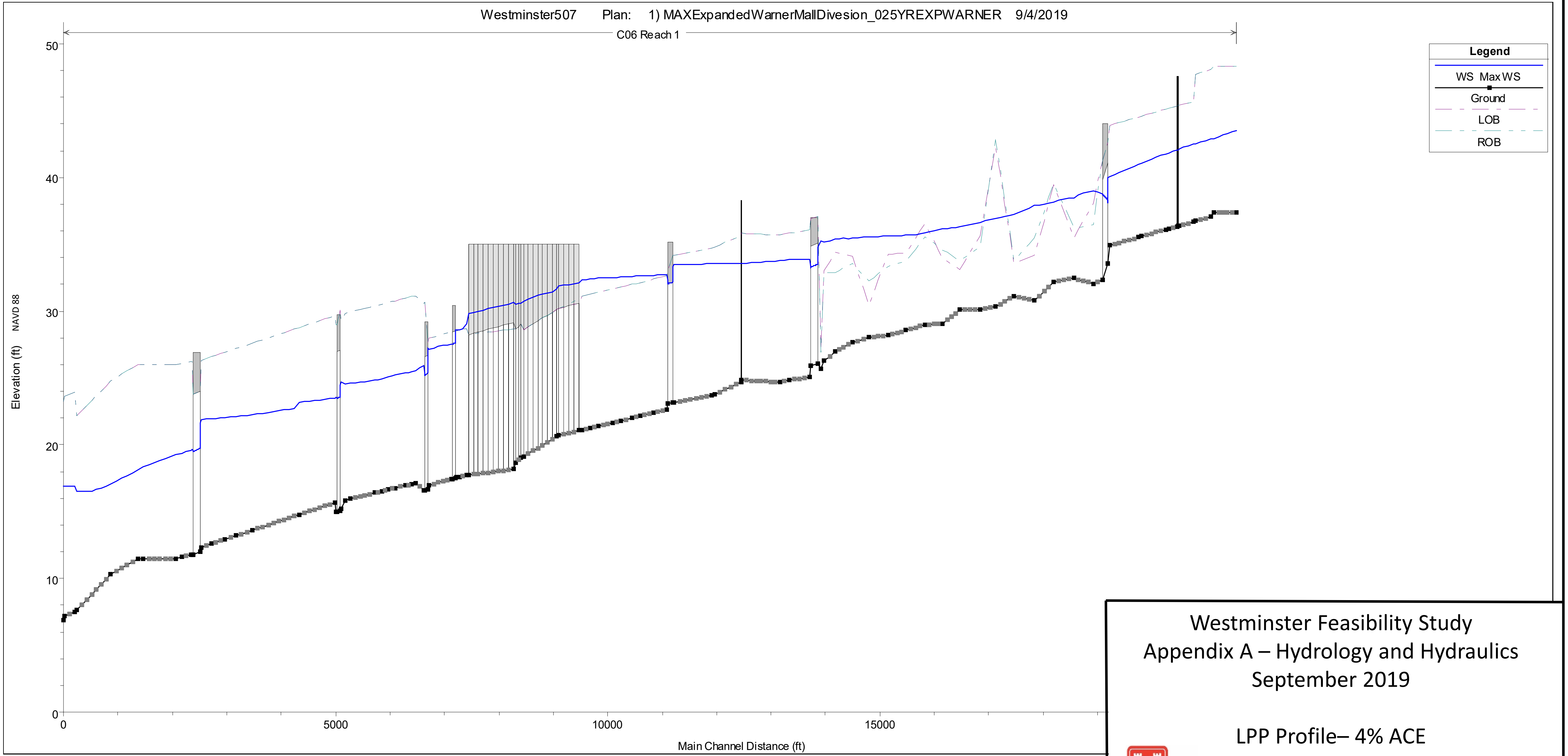
Chicago District



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September 2019

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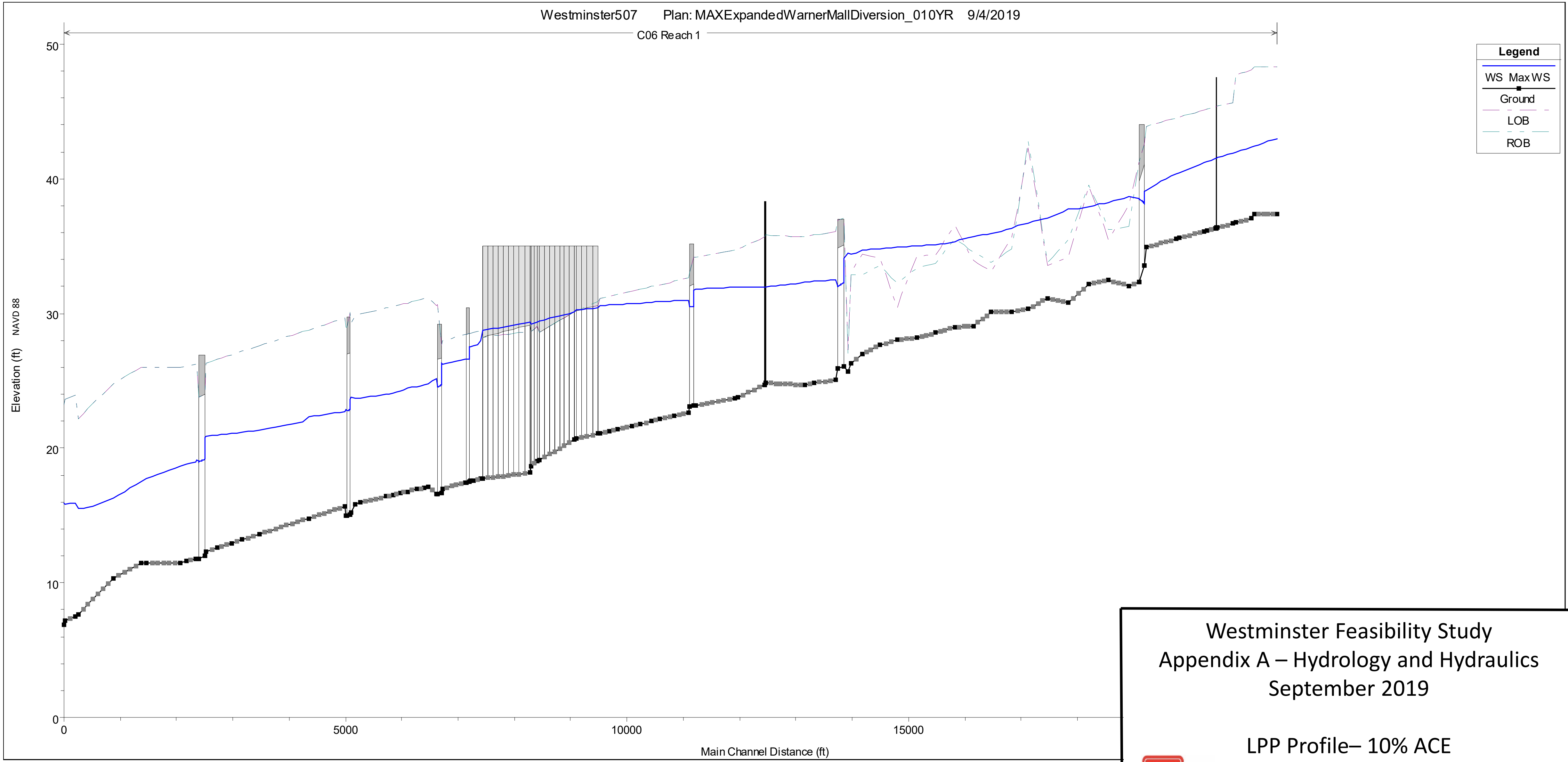
US Army Corps of Engineers
Chicago District

Plate A-30



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September 2019

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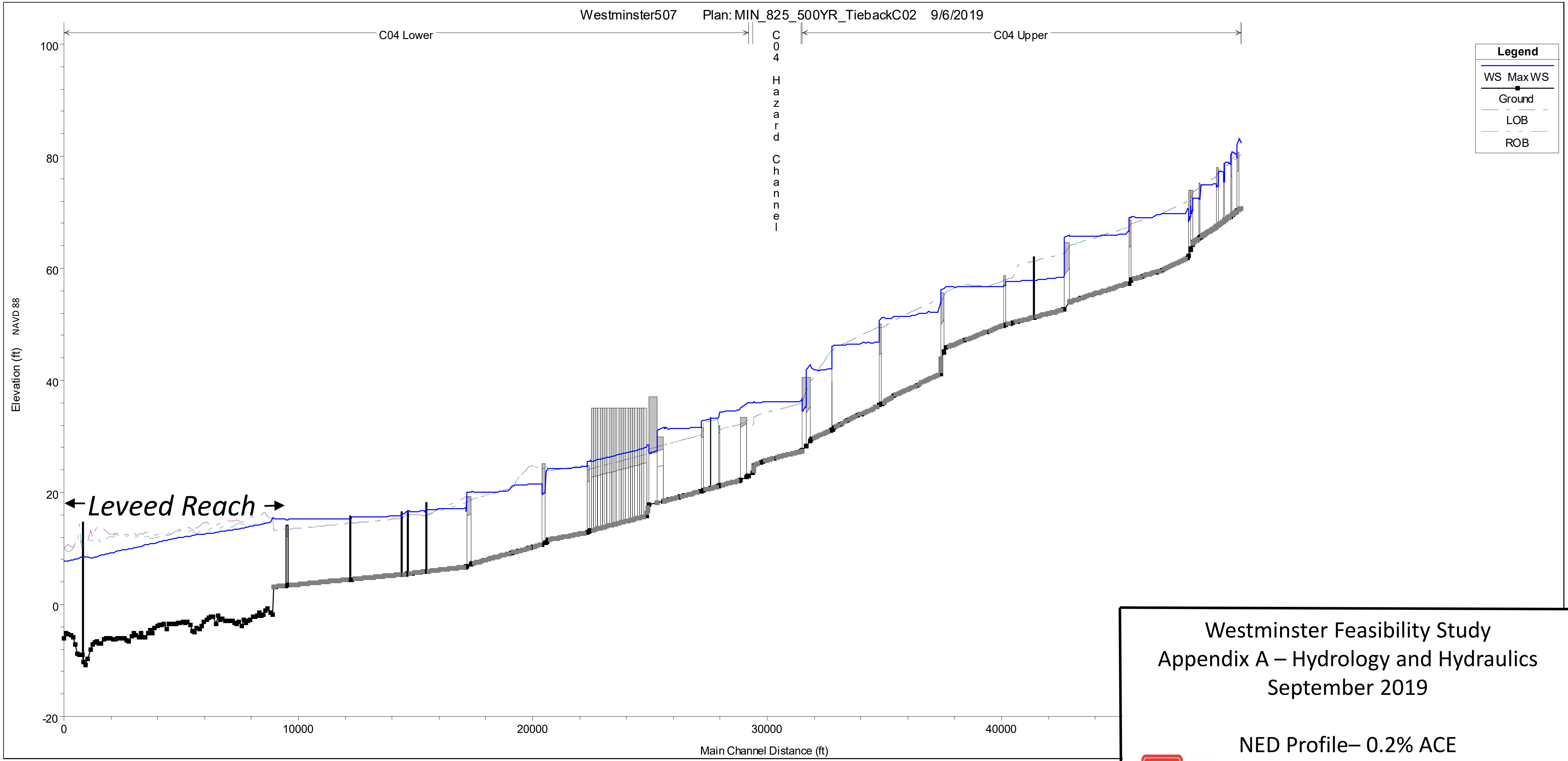
US Army Corps of Engineers
Chicago District



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September 2019

NED Profile– 0.2% ACE

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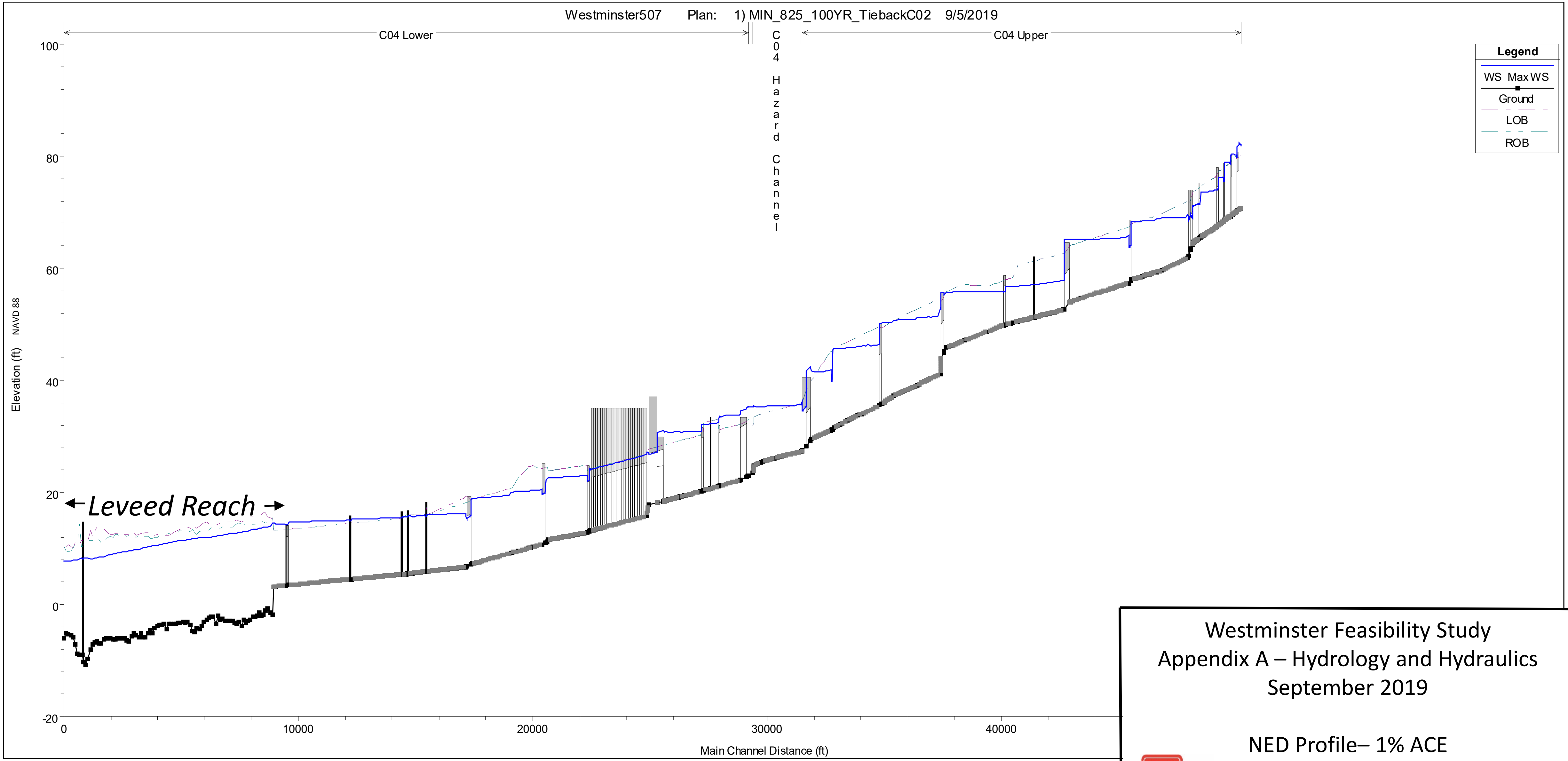

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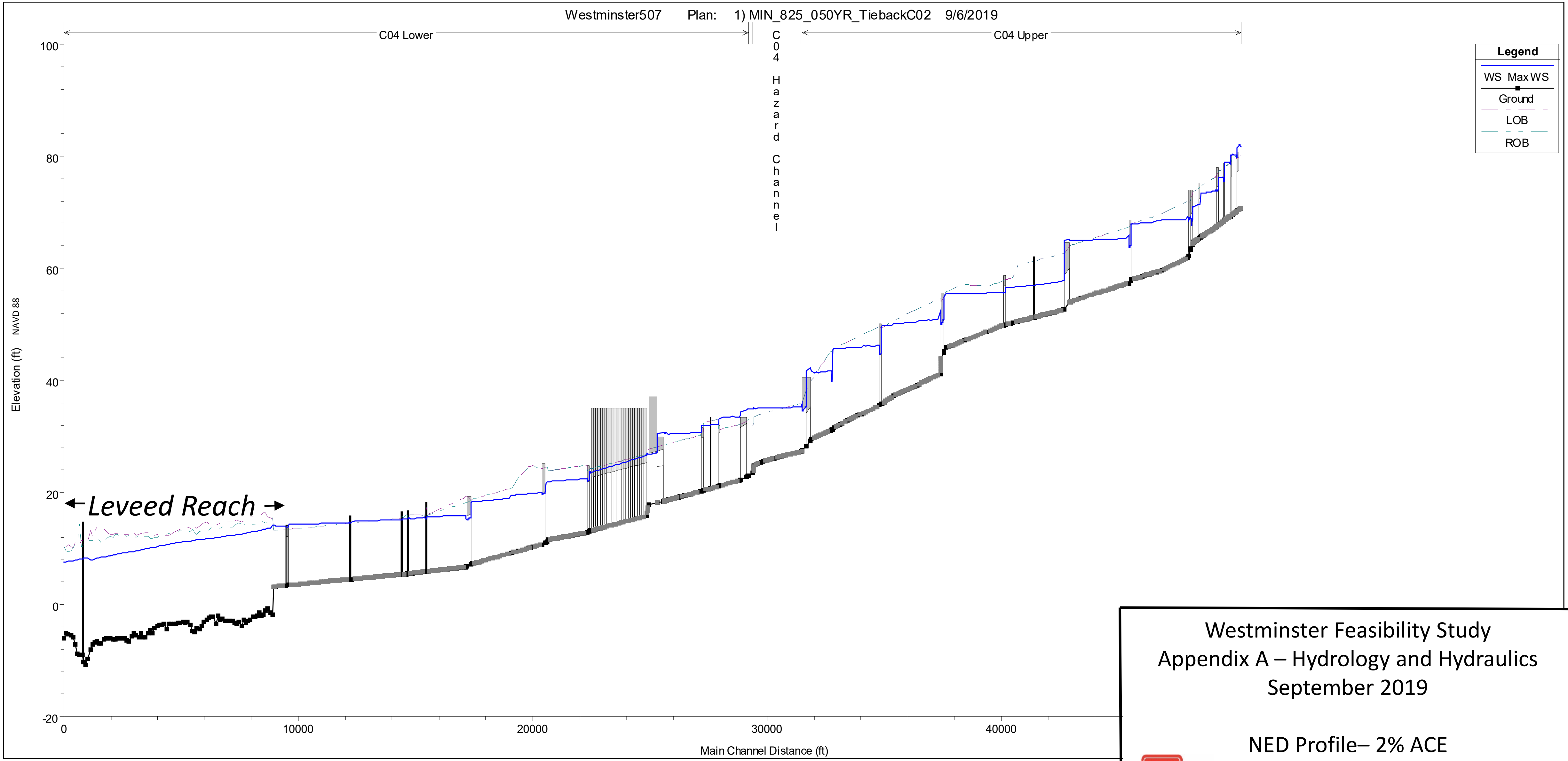
NED Profile– 1% ACE

US Army Corps of Engineers
Chicago District

Plate A-33



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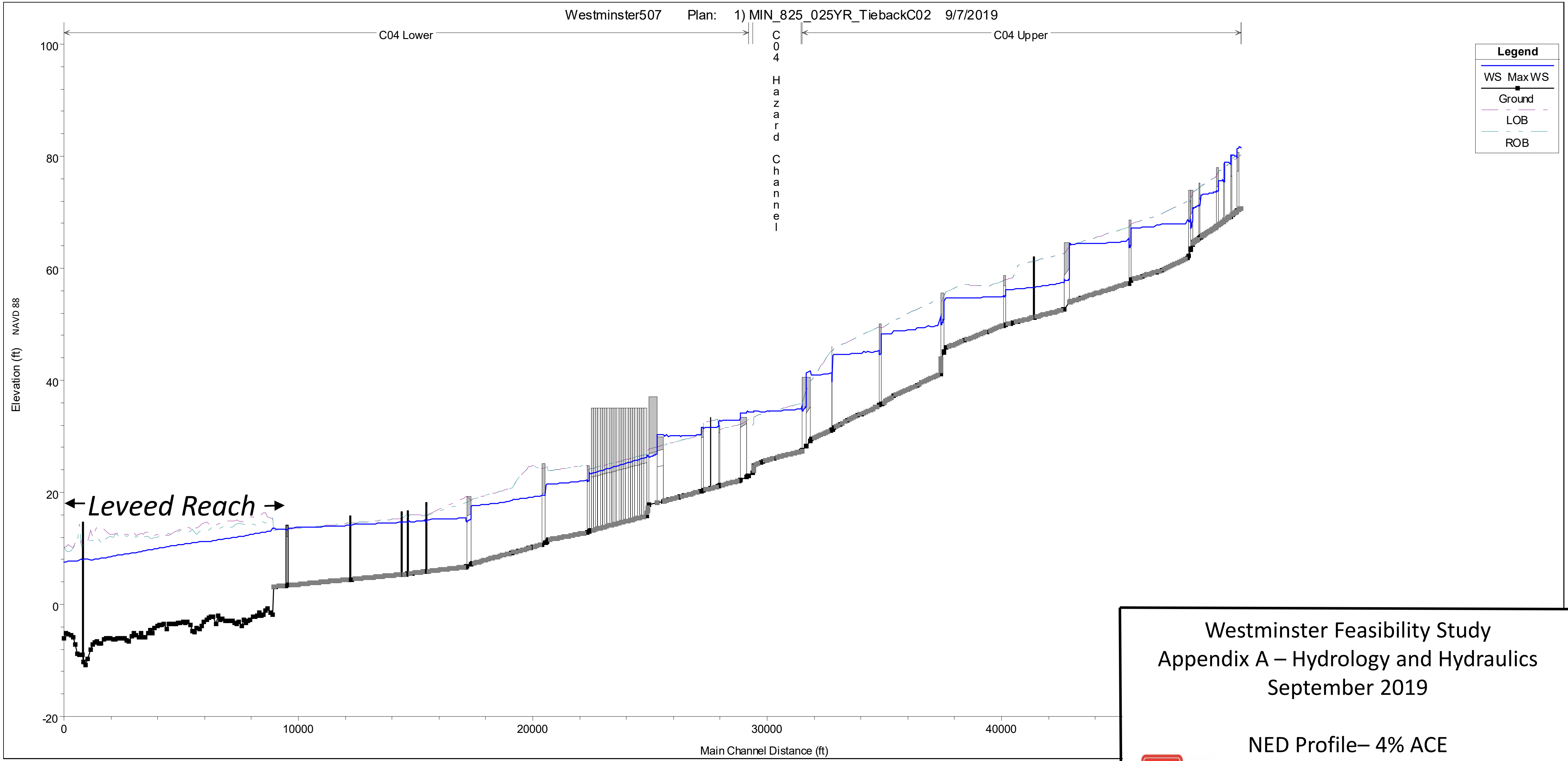
NED Profile– 2% ACE

US Army Corps of Engineers
Chicago District

Plate A-34



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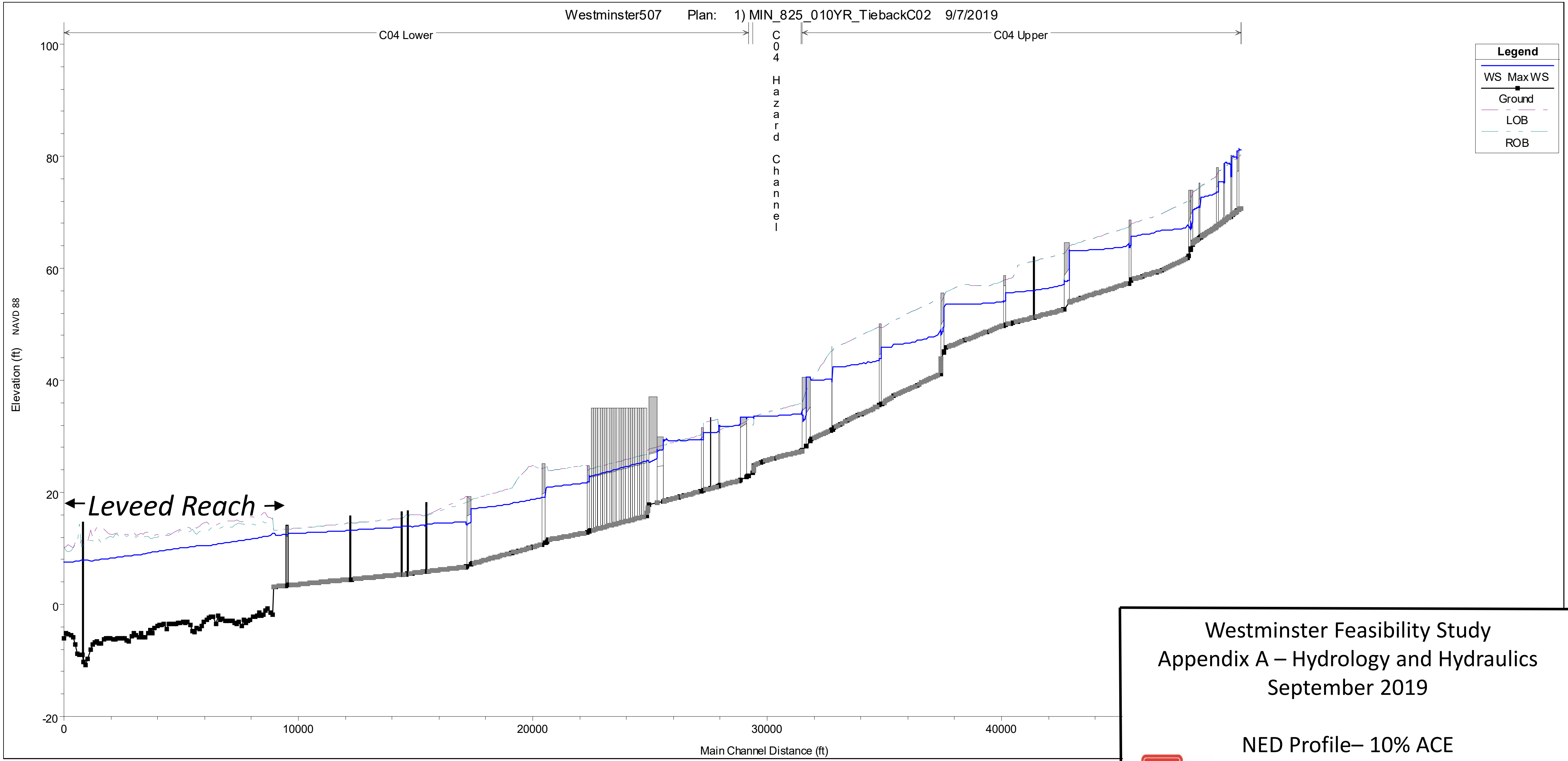
September 2019

NED Profile– 4% ACE

US Army Corps of Engineers
Chicago District

Plate A-35



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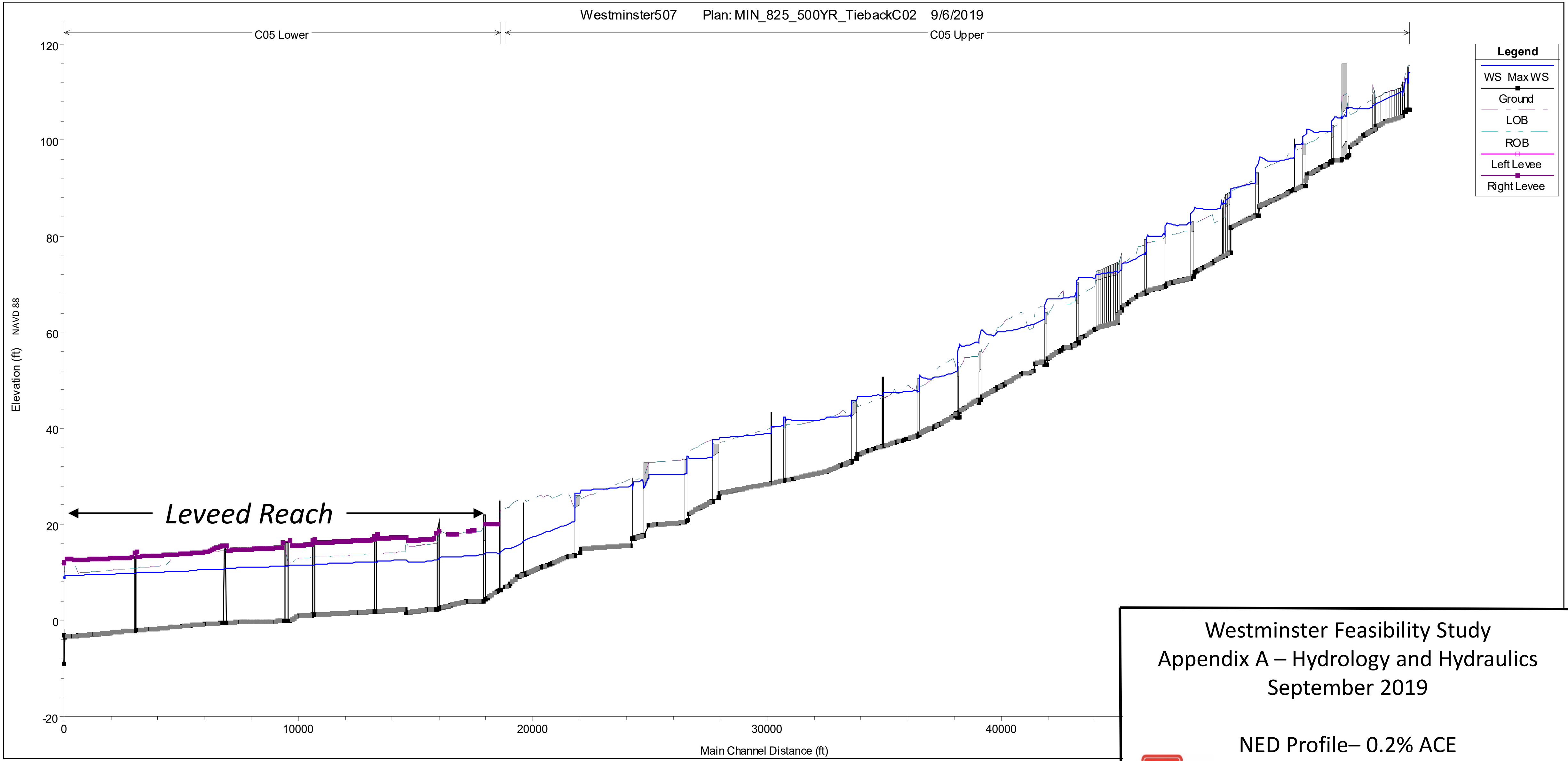
September 2019

NED Profile– 10% ACE

US Army Corps of Engineers
Chicago District



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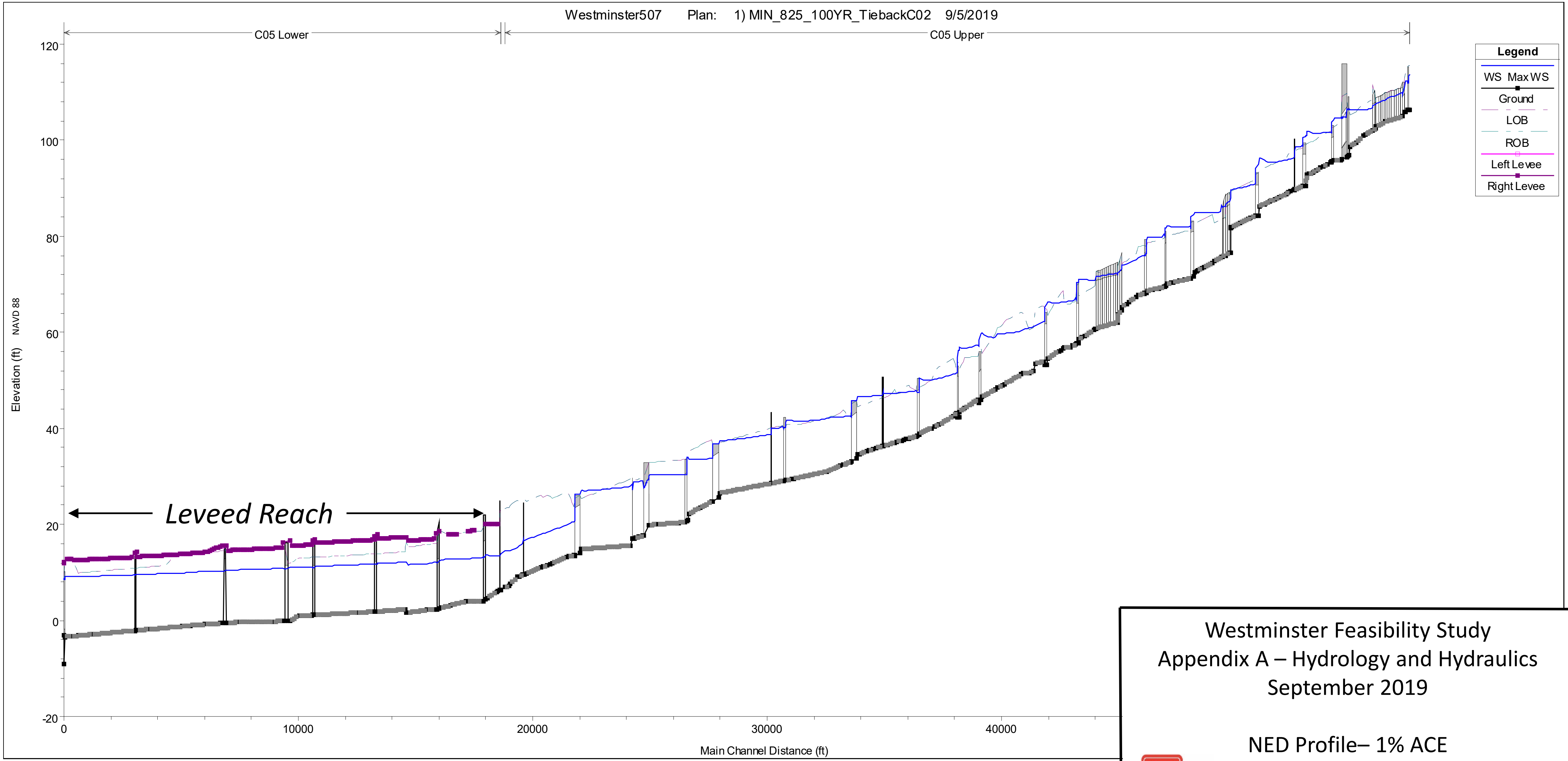
September 2019

NED Profile– 0.2% ACE

US Army Corps of Engineers
Chicago District

Plate A-37



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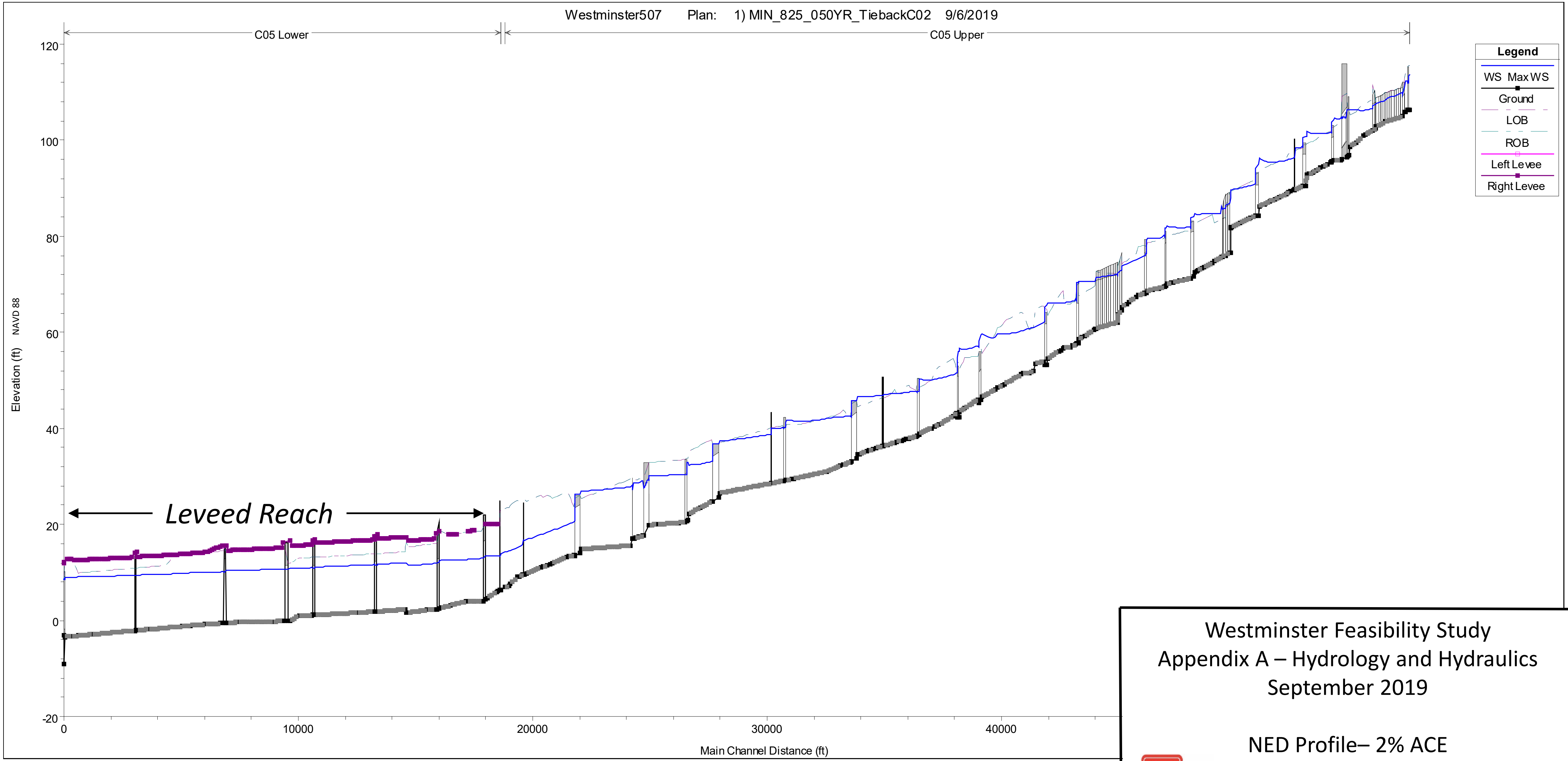
NED Profile– 1% ACE

US Army Corps of Engineers
Chicago District

Plate A-38



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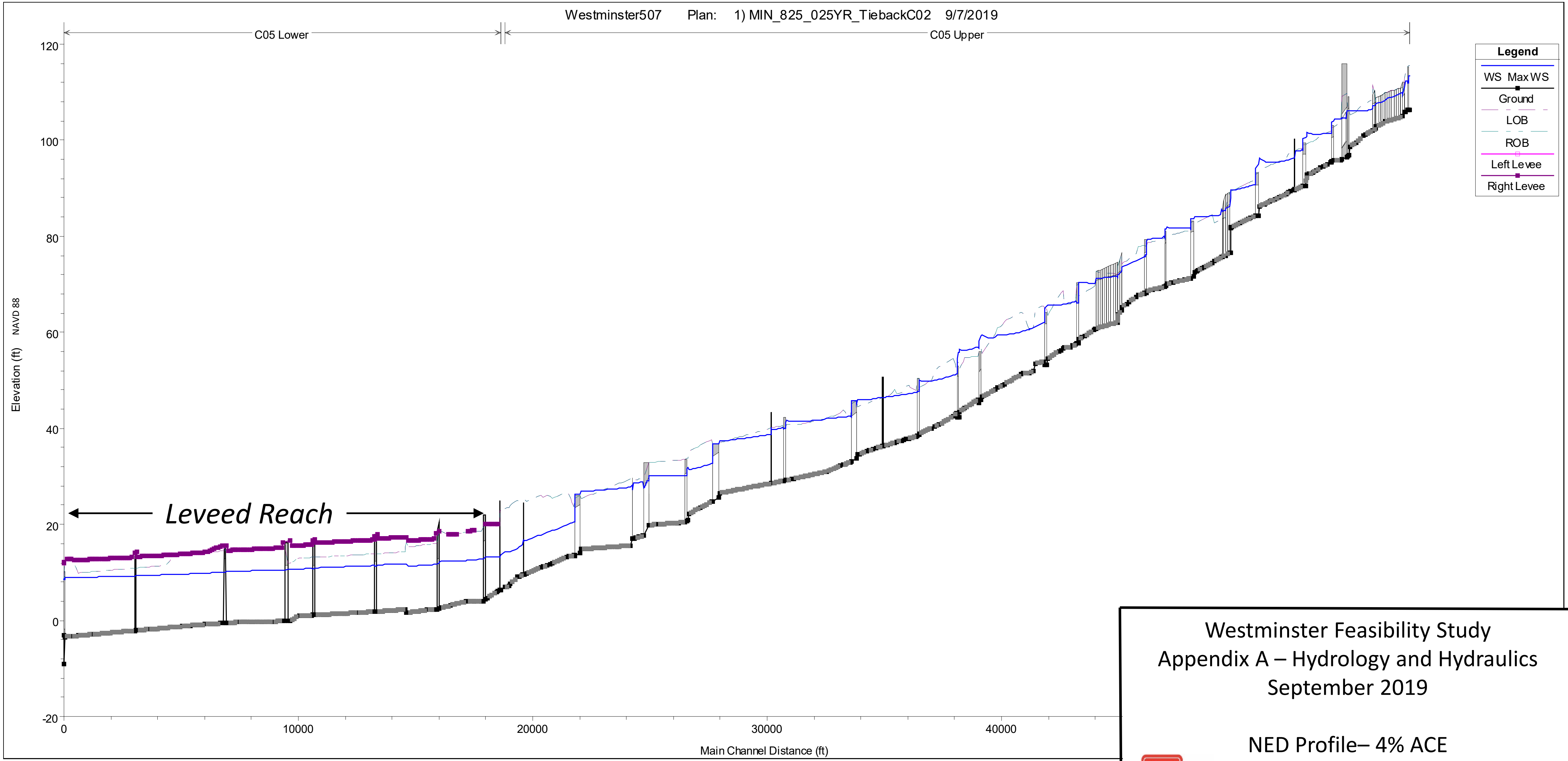
September 2019

NED Profile– 2% ACE

US Army Corps of Engineers
Chicago District

Plate A-24



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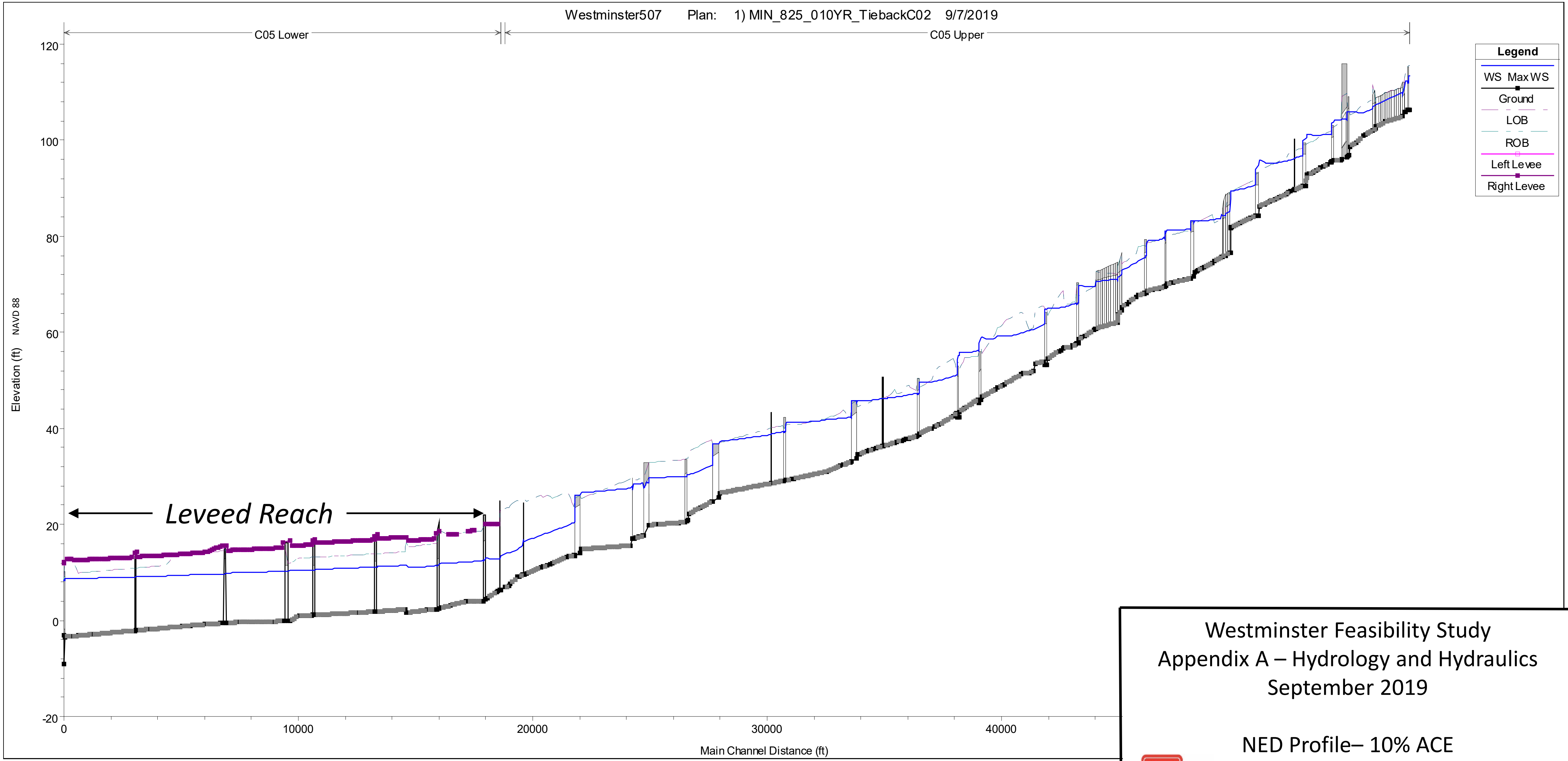
September 2019

NED Profile– 4% ACE

US Army Corps of Engineers
Chicago District

Plate A-40



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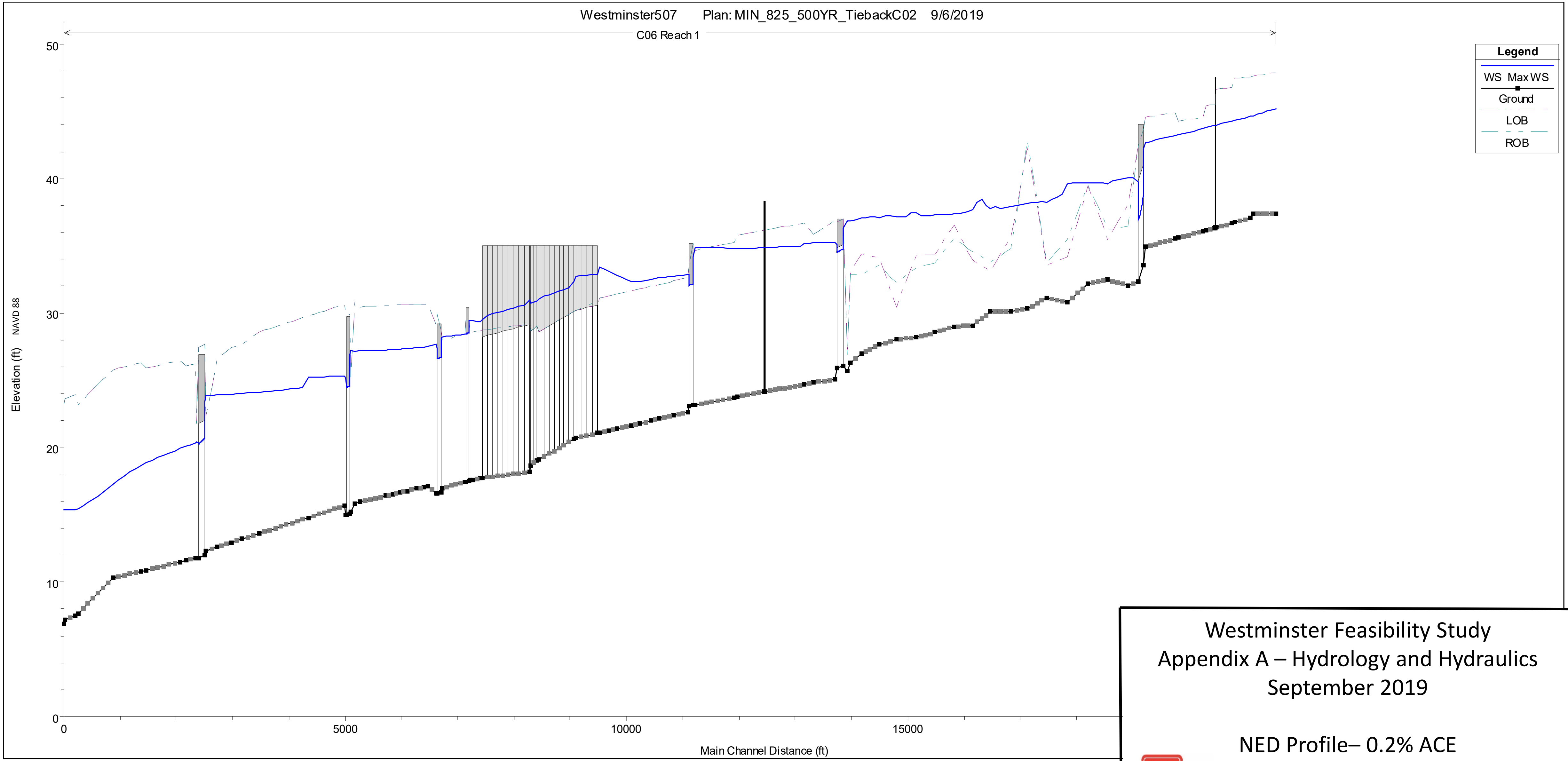
NED Profile– 10% ACE

US Army Corps of Engineers
Chicago District

Plate A-41



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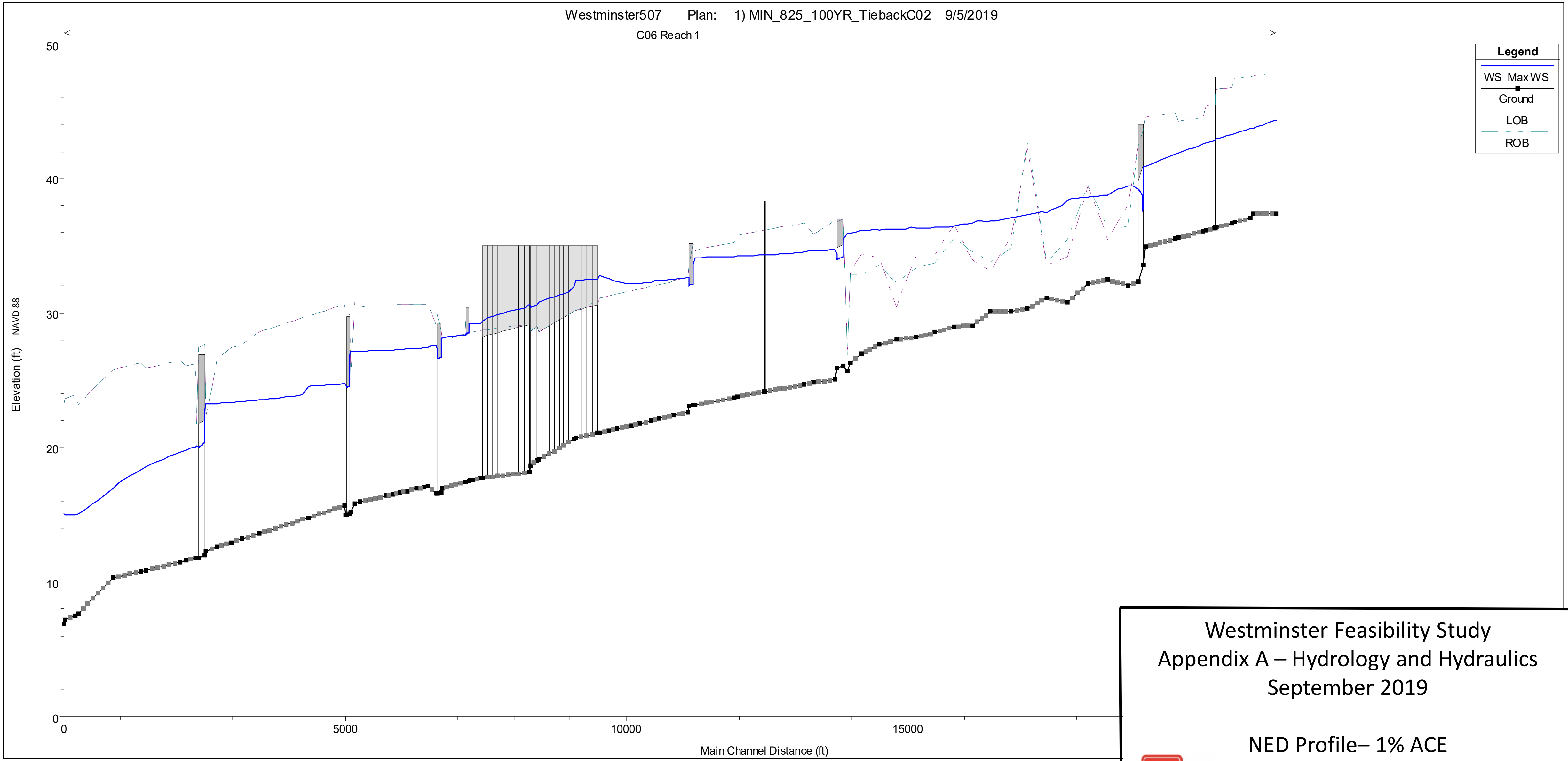
NED Profile– 0.2% ACE

US Army Corps of Engineers
Chicago District



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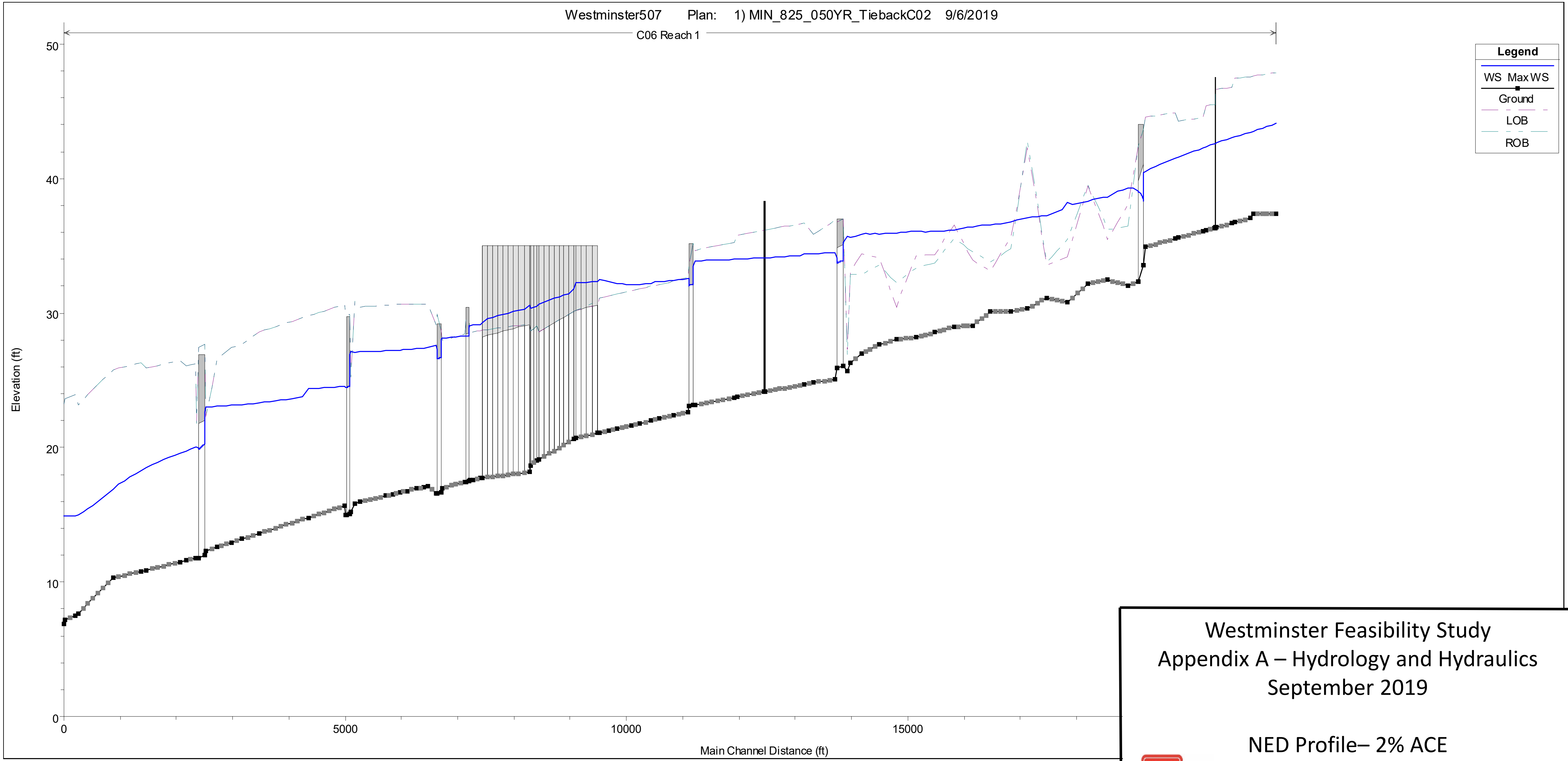
NED Profile– 1% ACE

US Army Corps of Engineers
Chicago District

Plate A-43



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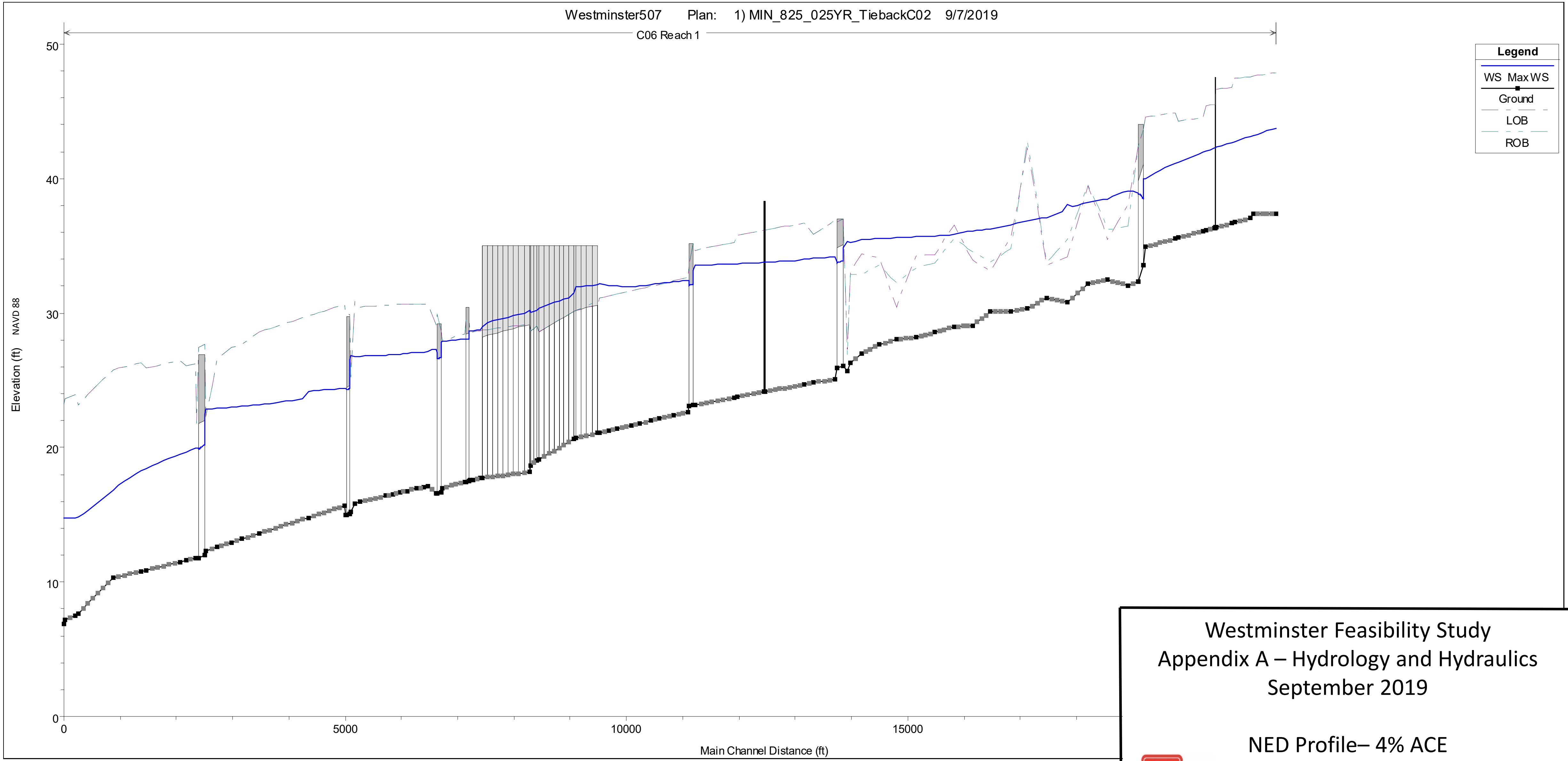
NED Profile– 2% ACE

US Army Corps of Engineers
Chicago District



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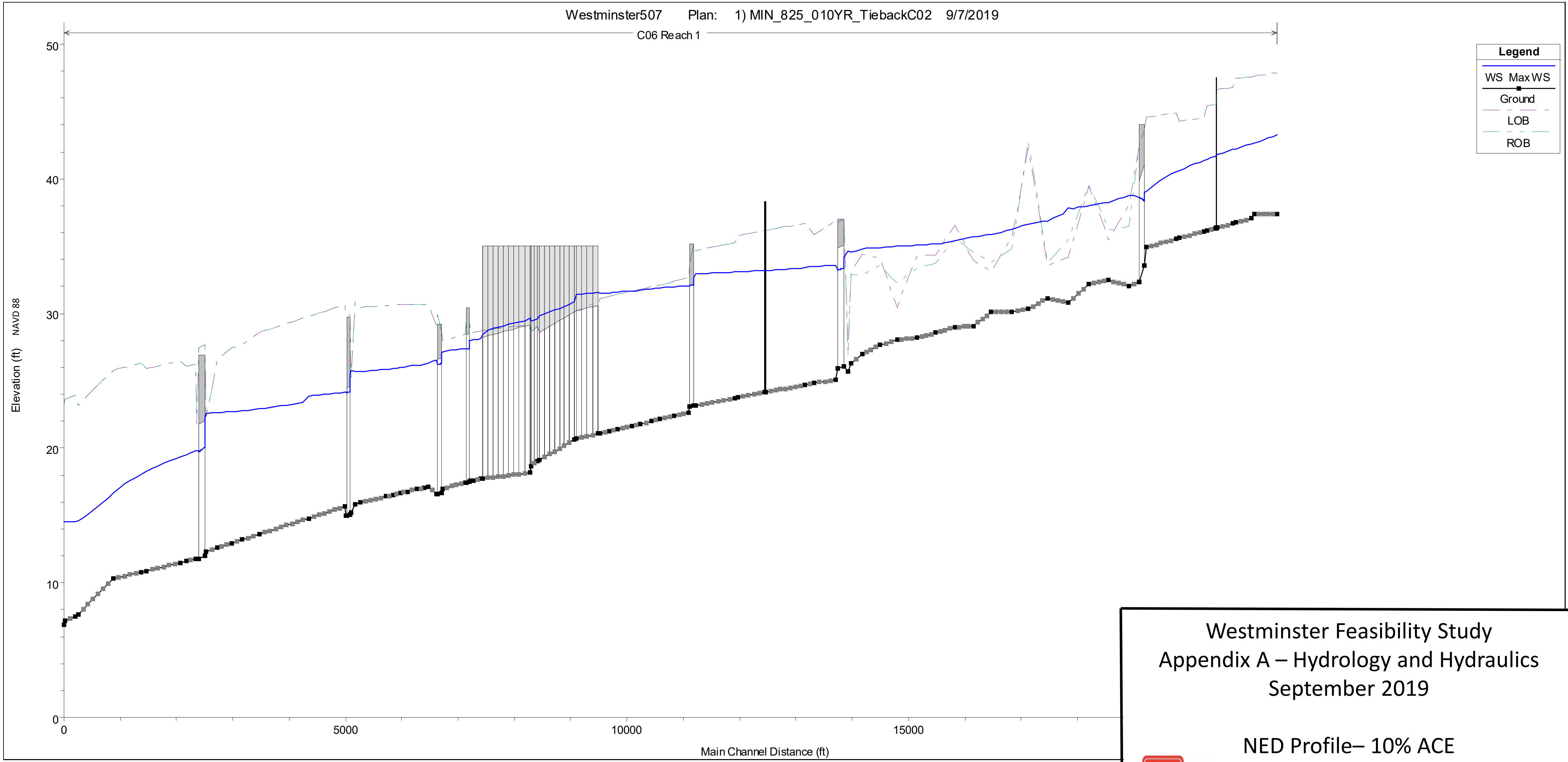
NED Profile– 4% ACE

US Army Corps of Engineers
Chicago District



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NED Profile– 10% ACE

US Army Corps of Engineers
Chicago District

Plate A-46

River	Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
C06	Reach 1	21784.51	Max WS	712.11	37.35	44.1		44.86	0.000941	6.98	102.05	25.25	0.61
C06	Reach 1	21779		Lat Struct									
C06	Reach 1	21769		Lat Struct									
C06	Reach 1	21374	Max WS	712.04	37.35	43.51		44.54	0.001408	8.11	87.78	23.49	0.74
C06	Reach 1	21321	Max WS	712.03	37.06	43.48		44.37	0.001176	7.58	93.89	24.26	0.68
C06	Reach 1	21040	Max WS	711.97	36.74	43.14		44.04	0.001188	7.61	93.53	24.21	0.68
C06	Reach 1	20990	Max WS	711.9	36.68	43.08		43.98	0.001187	7.61	93.55	24.21	0.68
C06	Reach 1	20725	Max WS	711.42	36.38	42.76	41.7	43.67	0.001203	7.65	93.03	24.15	0.69
C06	Reach 1	20710		Bridge									
C06	Reach 1	20690	Max WS	711.42	36.34	42.69		43.62	0.001229	7.71	92.27	24.05	0.69
C06	Reach 1	20685		Lat Struct									
C06	Reach 1	20684		Lat Struct									
C06	Reach 1	20540	Max WS	711.17	36.16	42.51		43.43	0.001234	7.72	92.12	24.04	0.7
C06	Reach 1	20490	Max WS	710.85	36.11	42.44		43.37	0.001246	7.75	91.75	23.99	0.7
C06	Reach 1	20040	Max WS	707.53	35.59	41.85		42.81	0.001294	7.85	90.15	23.79	0.71
C06	Reach 1	19990	Max WS	706.68	35.53	41.79		42.74	0.001297	7.85	90	23.77	0.71
C06	Reach 1	19456	Max WS	697.05	34.92	41.04		42.04	0.00139	8.03	86.81	23.36	0.73
C06	Reach 1	19426	Max WS	920.75	33.57	40.93		41.77	0.000772	7.36	125.1	17	0.48
C06	Reach 1	19375		Culvert									
C06	Reach 1	19325.2	Max WS	917.56	32.32	39.03		40.03	0.000986	8.05	114.05	17	0.55
C06	Reach 1	19150.4	Max WS	918.51	32.05	39.37		39.58	0.00155	3.72	255.29	72.04	0.32
C06	Reach 1	19144		Lat Struct									
C06	Reach 1	19133		Lat Struct									
C06	Reach 1	18791.14	Max WS	914.72	32.48	38.74		39.05	0.002038	4.57	249.95	78.99	0.38
C06	Reach 1	18428.7	Max WS	885.79	32.17	38.37		38.5	0.001394	2.89	306.74	100.86	0.29
C06	Reach 1	18076.6	Max WS	436.99	30.8	38.16		38.19	0.000253	1.72	510.83	170.3	0.13
C06	Reach 1	17702.84	Max WS	789.38	31.12	37.57		37.79	0.001275	3.9	307.37	102.11	0.3
C06	Reach 1	17363.24	Max WS	782.65	30.34	37.32		37.43	0.000886	2.59	302.57	82.77	0.24
C06	Reach 1	17065.84	Max WS	781.29	30.15	37.09		37.18	0.000986	2.55	343.8	115.01	0.25
C06	Reach 1	16702.77	Max WS	675.72	30.1	36.89		36.98	0.000483	2.38	370.75	124.3	0.19
C06	Reach 1	16387.3	Max WS	784.25	29.08	36.76		36.83	0.000407	2.05	405.88	102.57	0.17
C06	Reach 1	16058.48	Max WS	777.39	28.97	36.56		36.64	0.000734	2.28	344.52	104.81	0.22
C06	Reach 1	15711.28	Max WS	734.47	28.56	36.47		36.51	0.000188	1.5	556.1	134.15	0.12
C06	Reach 1	15388.89	Max WS	607.56	28.21	36.46		36.48	0.000101	1.1	697.02	157.14	0.09

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C06	Reach 1	15027.15	Max WS	768.42	28.02	36.37		36.4	0.000119	1.3	682.55	128.75	0.1
C06	Reach 1	14729.11	Max WS	751.81	27.66	36.3		36.35	0.000255	1.82	419.15	79.56	0.14
C06	Reach 1	14409.75	Max WS	696.42	26.96	36.29		36.31	0.000104	1.19	683.89	178	0.09
C06	Reach 1	14211.21	Max WS	1265.82	26.3	36.14		36.22	0.00034	2.22	588.81	104.97	0.16
C06	Reach 1	14157.44	Max WS	1295.72	25.71	36.17		36.21	0.000094	1.64	891.42	95.89	0.09
C06	Reach 1	14088.87	Max WS	1268.27	26.09	35.76		36.5	0.000523	6.9	183.75	19	0.39
C06	Reach 1	14028.03		Culvert									
C06	Reach 1	13967.16	Max WS	1072.4	25.89	34.77		35.39	0.000471	6.36	168.64	19	0.38
C06	Reach 1	13937.16	Max WS	1264.61	25.09	35.23		35.5	0.00015	4.14	305.79	40.29	0.26
C06	Reach 1	13935		Lat Struct									
C06	Reach 1	13932		Lat Struct									
C06	Reach 1	13560	Max WS	1262.96	24.82	35.19		35.44	0.000138	4.01	315.02	40.74	0.25
C06	Reach 1	13400	Max WS	1262.94	24.7	35.18		35.42	0.000133	3.96	319.27	40.95	0.25
C06	Reach 1	12695	Max WS	1323.08	24.82	34.99	29.55	35.28	0.000163	4.31	306.99	40.35	0.28
C06	Reach 1	12690		Bridge									
C06	Reach 1	12685	Max WS	1323.61	24.7	35		35.28	0.000156	4.24	312.05	40.6	0.27
C06	Reach 1	12682		Lat Struct									
C06	Reach 1	12680		Lat Struct									
C06	Reach 1	12200	Max WS	1322.49	23.76	34.99		35.21	0.000113	3.77	350.64	42	0.23
C06	Reach 1	12150	Max WS	1322.49	23.72	34.99		35.2	0.000111	3.76	352.15	42	0.23
C06	Reach 1	11455.52	Max WS	1320.62	23.17	34.93		35.13	0.000094	3.54	373.12	42	0.21
C06	Reach 1	11425.52	Max WS	1455.51	23.15	34.85		35.09	0.000116	3.93	370.22	42	0.23
C06	Reach 1	11384		Culvert									
C06	Reach 1	11343.86	Max WS	1273.75	23.06	33.8		34.29	0.000306	5.65	225.52	21	0.3
C06	Reach 1	11323.86	Max WS	1449.23	22.62	34.07		34.35	0.00013	4.22	343.46	30	0.22
C06	Reach 1	11321		Lat Struct									
C06	Reach 1	11318		Lat Struct									
C06	Reach 1	11072.67	Max WS	1449.24	22.38	34.05		34.31	0.000124	4.14	349.98	30	0.21
C06	Reach 1	10822.67	Max WS	1449.22	22.14	34.02		34.28	0.000118	4.06	356.52	30	0.21
C06	Reach 1	10672.67	Max WS	1295.18	22	33.97		34.17	0.000092	3.61	359.07	30	0.18
C06	Reach 1	10472.67	Max WS	1291.85	21.81	33.93		34.12	0.000089	3.55	363.52	30	0.18
C06	Reach 1	10322.67	Max WS	1291.8	21.66	33.9		34.09	0.000086	3.52	367.17	30	0.18
C06	Reach 1	10062.67	Max WS	1288.09	21.42	33.86		34.05	0.000082	3.45	373.27	30	0.17
C06	Reach 1	9912.67	Max WS	1284.25	21.27	33.83		34.01	0.000079	3.41	376.8	30	0.17

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C06	Reach 1	9762.67	Max WS	1280.35	21.13	33.79		33.97	0.000077	3.37	379.86	30	0.17
C06	Reach 1	9713.67	Max WS	1638.52	21.07	33.37	25.11	33.73	0.000665	4.85	337.98		0.24
C06	Reach 1	9325.64	Max WS	1638.52	20.72	33.09	24.76	33.46	0.000665	4.85	338.13		0.24
C06	Reach 1	9295.64	Max WS	1638.52	20.62	32.86	25.3	33.43	0.001026	6.05	270.75		0.3
C06	Reach 1	8681	Max WS	1747.02	19.12	31.74	24.01	32.39	0.001166	6.45	270.75		0.32
C06	Reach 1	8639.8	Max WS	1747.02	19.04	31.59	24.11	32.24	0.001177	6.47	270		0.32
C06	Reach 1	8530.93	Max WS	1746.96	18.68	31.47	23.75	32.12	0.001177	6.47	270		0.32
C06	Reach 1	8500.93	Max WS	1746.96	18.16	31.65	22.88	32.09	0.000682	5.29	330.22		0.25
C06	Reach 1	7667.26	Max WS	1860.57	17.73	30.62	22.66	31.16	0.000884	5.91	315		0.29
C06	Reach 1	7665		Lat Struct									
C06	Reach 1	7663		Lat Struct									
C06	Reach 1	7637.26	Max WS	1860.52	17.7	29.89		30.89	0.000614	8.03	231.62	19	0.41
C06	Reach 1	7506.72	Max WS	1860.48	17.59	29.4		30.47	0.000666	8.29	224.48	19	0.43
C06	Reach 1	7456.72	Max WS	1860.52	17.55	29.37		30.44	0.000664	8.28	224.63	19	0.42
C06	Reach 1	7436.72	Max WS	1860.48	17.52	29.36		30.43	0.000662	8.27	225.01	19	0.42
C06	Reach 1	7408		Culvert									
C06	Reach 1	7381.06	Max WS	1860.35	17.46	28.26		29.54	0.000841	9.06	205.24	19	0.49
C06	Reach 1	7372		Lat Struct									
C06	Reach 1	7367		Lat Struct									
C06	Reach 1	7361.06	Max WS	1860.35	17.44	28.25		29.52	0.00084	9.06	205.31	19	0.49
C06	Reach 1	6951.81	Max WS	1860.35	16.99	27.85		29.11	0.000829	9.02	206.3	19	0.48
C06	Reach 1	6931.81	Max WS	1860.35	16.67	27.9		29.08	0.000759	8.72	213.45	19	0.46
C06	Reach 1	6898		Culvert									
C06	Reach 1	6865.33	Max WS	1853.52	16.62	25.84		27.58	0.001268	10.58	175.26	19	0.61
C06	Reach 1	6845.33	Max WS	1853.29	16.6	26.52		27.13	0.000379	6.26	296.29	44.75	0.43
C06	Reach 1	6843		Lat Struct									
C06	Reach 1	6839		Lat Struct									
C06	Reach 1	6700	Max WS	1852.32	17.15	26.18		26.98	0.000553	7.19	257.68	42.08	0.51
C06	Reach 1	6630	Max WS	1852.06	17.08	26.09		26.9	0.000556	7.2	257.11	42.04	0.51
C06	Reach 1	6505	Max WS	1851.8	16.95	25.98		26.79	0.000551	7.18	257.95	42.1	0.51
C06	Reach 1	6325	Max WS	1851.29	16.77	25.88		26.66	0.000532	7.09	261.25	42.34	0.5
C06	Reach 1	6200	Max WS	1850.52	16.65	25.73		26.52	0.000539	7.12	260.07	42.25	0.51
C06	Reach 1	6075	Max WS	1850	16.52	25.59		26.38	0.000542	7.13	259.37	42.2	0.51
C06	Reach 1	5950	Max WS	1849.47	16.4	25.51		26.29	0.000533	7.09	260.95	42.32	0.5

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C06	Reach 1	5500	Max WS	1848.95	15.95	25.34		26.05	0.000471	6.77	273.06	43.17	0.47
C06	Reach 1	5400	Max WS	1848.7	15.85	25.31		26	0.000458	6.7	275.95	43.37	0.47
C06	Reach 1	5330.27	Max WS	1849.16	15.25	25.39		25.96	0.000344	6.03	306.53	45.43	0.41
C06	Reach 1	5310.27	Max WS	1848.24	15.08	25.13		25.97	0.000486	7.35	251.29	25	0.41
C06	Reach 1	5277		Culvert									
C06	Reach 1	5244.61	Max WS	1826.83	14.95	24.19		25.16	0.000599	7.91	231.05	25	0.46
C06	Reach 1	5224.61	Max WS	1827.31	15.67	24.22		25.14	0.000668	7.68	237.98	40.66	0.56
C06	Reach 1	5221		Lat Struct									
C06	Reach 1	5214		Lat Struct									
C06	Reach 1	4570	Max WS	1828.91	14.78	23.99		24.73	0.000498	6.89	265.35	42.63	0.49
C06	Reach 1	3700	Max WS	2157.94	13.6	23.05		24	0.000625	7.83	275.75	43.35	0.55
C06	Reach 1	3400	Max WS	2157.57	13.19	22.94		23.81	0.00055	7.46	289.03	44.26	0.52
C06	Reach 1	3200	Max WS	2157.85	12.92	22.88		23.7	0.000505	7.23	298.37	44.89	0.49
C06	Reach 1	2950	Max WS	2158.04	12.58	22.82		23.57	0.000452	6.94	310.9	45.72	0.47
C06	Reach 1	2757.86	Max WS	2158.07	12.32	22.78		23.48	0.000414	6.72	320.93	46.37	0.45
C06	Reach 1	2737.86	Max WS	2158.07	12.03	22.44		23.51	0.000602	8.29	260.35	25	0.45
C06	Reach 1	2677		Culvert									
C06	Reach 1	2615.52	Max WS	2158.06	11.79	20.1		21.78	0.001121	10.38	207.85	25	0.63
C06	Reach 1	2595.52	Max WS	2158.01	11.76	20.28		21.57	0.000944	9.11	236.84	40.57	0.66
C06	Reach 1	2570	Max WS	2257.13	11.76	20.15		21.63	0.001102	9.76	231.27	40.16	0.72
C06	Reach 1	2566		Lat Struct									
C06	Reach 1	2565		Lat Struct									
C06	Reach 1	2400	Max WS	2256.31	11.59	19.95		21.44	0.001113	9.79	230.39	40.09	0.72
C06	Reach 1	2300	Max WS	2256.3	11.49	19.84		21.34	0.00112	9.82	229.84	40.05	0.72
C06	Reach 1	1700	Max WS	2255.23	11.49	18.98		21.03	0.001716	11.48	196.47	37.47	0.88
C06	Reach 1	1600	Max WS	2254.54	11.49	18.8		20.99	0.001886	11.88	189.77	36.93	0.92
C06	Reach 1	1100	Max WS	2245.54	10.29	17.93		19.85	0.001575	11.11	202.11	37.92	0.85
C06	Reach 1	482.28	Max WS	2238	7.67	17.68		18.54	0.000533	7.45	300.45	45.03	0.51
C06	Reach 1	433.07	Max WS	2403.92	7.5	18.04		18.34	0.000114	4.34	553.51	52.5	0.24
C06	Reach 1	244.42	Max WS	2403.35	7.2	18.02		18.3	0.000105	4.23	568.08	52.5	0.23
C06	Reach 1	229.66	Max WS	2403.34	6.87	18.03		18.3	0.000096	4.1	586.13	52.5	0.22
C05	Upper	57849	Max WS	459	106.34	112.41		113.3	0.001325	7.57	60.66	10	0.54
C05	Upper	57848	Max WS	459	106.34	112.4		113.29	0.001326	7.57	60.64	10	0.54
C05	Upper	57845		Culvert									

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C05	Upper	57813	Max WS	459	106.26	110.85		112.4	0.00278	10.01	45.86	10	0.82
C05	Upper	57803	Max WS	459	106.22	110.82		112.37	0.002759	9.98	45.98	10	0.82
C05	Upper	57800		Lat Struct									
C05	Upper	57798		Lat Struct									
C05	Upper	57725	Max WS	459	105.93	110.61		112.1	0.002635	9.81	46.78	10	0.8
C05	Upper	57677.82	Max WS	459	105.83	110.5	109.61	111.74	0.002063	8.94	51.34	11	0.73
C05	Upper	57607.48	Max WS	459	105.01	109.78	108.8	110.97	0.001949	8.75	52.44	11	0.71
C05	Upper	57592.48	Max WS	459	104.97	109.75	108.75	110.93	0.001934	8.73	52.58	11	0.7
C05	Upper	56841.04	Max WS	459	103.84	108.16	107.62	109.61	0.002553	9.66	47.5	11	0.82
C05	Upper	56467.97	Max WS	459	102.77	107.08	106.55	108.54	0.002561	9.67	47.45	11	0.82
C05	Upper	56437.97	Max WS	459	102.43	106.98	106.46	108.56	0.002839	10.09	45.5	10	0.83
C05	Upper	56335.69	Max WS	458.99	102.09	106.66	106.12	108.23	0.002808	10.05	45.69	10	0.83
C05	Upper	56305.69	Max WS	458.99	102.02	105.75		107.38	0.003067	10.25	44.8	12	0.93
C05	Upper	56302		Lat Struct									
C05	Upper	56301		Lat Struct									
C05	Upper	56000	Max WS	458.98	101.16	104.78	104.72	106.51	0.003358	10.58	43.38	12	0.98
C05	Upper	55900	Max WS	458.98	100.91	104.43	104.47	106.27	0.003635	10.88	42.19	12	1.02
C05	Upper	55600	Max WS	458.97	99.42	103.53		104.87	0.002345	9.31	49.29	12	0.81
C05	Upper	55329.11	Max WS	458.93	98.69	102.92		104.19	0.002165	9.05	50.72	12	0.78
C05	Upper	55296.3	Max WS	458.73	96.82	102.98		103.18	0.000187	3.57	128.35	20.84	0.25
C05	Upper	55270		Culvert									
C05	Upper	55244.67	Max WS	458.79	96.61	102.86		103.05	0.000179	3.52	130.16	20.84	0.25
C05	Upper	55228.2	Max WS	458.83	96.54	102.98		103.03	0.000036	1.82	252.71	39.24	0.13
C05	Upper	55211.86	Max WS	811.71	96.48	102.88		102.96	0.000047	2.2	369.21	57.65	0.15
C05	Upper	55100		Culvert									
C05	Upper	54992	Max WS	811.59	95.96	102.21		102.27	0.000035	1.91	425.14	68	0.13
C05	Upper	54960	Max WS	811.59	95.89	101.81		102.54	0.000724	6.86	118.38	20	0.5
C05	Upper	54927	Max WS	811.59	95.88	101.77		102.51	0.000734	6.89	117.86	20	0.5
C05	Upper	54922		Lat Struct									
C05	Upper	54920		Lat Struct									
C05	Upper	54675.18	Max WS	811.63	95.82	101.53		102.31	0.000804	7.11	114.1	20	0.53
C05	Upper	54645.18	Max WS	811.63	95.81	101.42		102.32	0.000908	7.62	107.1	20.74	0.57
C06	Reach 1	19144		Lat Struct									
C06	Reach 1	19133		Lat Struct									

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C05	Upper	54547.02	Max WS	809.46	95.48	99.9		101.2	0.001668	9.15	88.47	20	0.77
C05	Upper	54540		Lat Struct									
C05	Upper	54519		Lat Struct									
C05	Upper	54500	Max WS	809.33	95.35	99.82		101.09	0.001621	9.06	89.32	20	0.76
C05	Upper	54400	Max WS	809.03	95.06	99.66		100.86	0.001484	8.79	92.05	20	0.72
C05	Upper	54200	Max WS	808.65	94.5	99.43		100.47	0.001215	8.2	98.58	20	0.65
C05	Upper	54100	Max WS	808.2	94.22	99.35		100.31	0.001083	7.88	102.56	20	0.61
C05	Upper	53900	Max WS	807.45	93.65	99.25		100.06	0.00084	7.21	112	20	0.54
C05	Upper	53750	Max WS	806.93	93.22	99.21		99.91	0.000694	6.74	119.71	20	0.49
C05	Upper	53650	Max WS	806.34	92.94	99.15		99.8	0.000624	6.49	124.19	20	0.46
C05	Upper	53584.9	Max WS	805.97	92.75	99.12		99.74	0.000581	6.33	127.39	20	0.44
C05	Upper	53554.9	Max WS	1284.4	91.01	98.06		99.35	0.001108	9.1	141.1	20	0.6
C05	Upper	53493.59		Culvert									
C05	Upper	53428.3	Max WS	1279.98	90.52	95.79		98.08	0.002515	12.15	105.33	20	0.93
C05	Upper	53398.3	Max WS	1279.98	90.45	95.73		97.19	0.001455	9.7	131.93	25	0.74
C05	Upper	53393		Lat Struct									
C05	Upper	53392		Lat Struct									
C05	Upper	53087	Max WS	1351.01	89.73	95.24	94.22	96.74	0.001425	9.8	137.83	25	0.74
C05	Upper	53077		Bridge									
C05	Upper	53067	Max WS	1350.72	89.69	95.22		96.7	0.001412	9.77	138.24	25	0.73
C05	Upper	53063		Lat Struct									
C05	Upper	53062		Lat Struct									
C05	Upper	53000	Max WS	1350.71	89.53	95.14		96.58	0.001355	9.63	140.23	25	0.72
C05	Upper	52900	Max WS	1350.36	89.3	95		96.4	0.001291	9.47	142.52	25	0.7
C05	Upper	52815.67	Max WS	1349.51	89.11	94.89		96.25	0.001239	9.34	144.52	25	0.68
C05	Upper	52700	Max WS	1349.01	88.84	94.76		96.05	0.001156	9.12	147.96	25	0.66
C05	Upper	52421.24	Max WS	1325.75	88.2	94.5		95.6	0.000932	8.42	157.5	25	0.59
C05	Upper	52221.24	Max WS	1321.07	87.73	94.37		95.36	0.000794	7.96	166.06	25	0.54
C05	Upper	52001.24	Max WS	1312.65	87.22	94.28		95.14	0.00066	7.44	176.39	25	0.49
C05	Upper	51781.24	Max WS	1305.1	86.71	94.23		94.98	0.000544	6.94	187.99	25	0.45
C05	Upper	51561.24	Max WS	1300.38	86.2	94.2		94.85	0.000454	6.51	199.9	25	0.41
C05	Upper	51531.24	Max WS	1959.77	84.67	92.97		94.35	0.00093	9.45	207.45	25	0.58
C05	Upper	51470		Culvert									
C05	Upper	51409.01	Max WS	2086.45	84.24	91.38		93.5	0.001613	11.69	178.44	25	0.77

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C05	Upper	51379.01	Max WS	2086.38	84.17	91.33		93.44	0.001598	11.65	179.04	25	0.77
C05	Upper	51373		Lat Struct									
C05	Upper	51369		Lat Struct									
C05	Upper	51200	Max WS	2085.76	83.76	91		93.06	0.001548	11.52	181	25	0.76
C05	Upper	51090	Max WS	2085.71	83.51	90.8		92.84	0.001517	11.44	182.26	25	0.75
C05	Upper	50750	Max WS	2085.2	82.73	90.22		92.15	0.001403	11.13	187.35	25	0.72
C05	Upper	50400	Max WS	2084.83	81.93	89.71		91.5	0.00126	10.72	194.55	25	0.68
C05	Upper	50350	Max WS	2084.82	81.81	89.64		91.4	0.00124	10.66	195.66	25	0.67
C05	Upper	50330.15	Max WS	2084.81	81.77	89.84	87.34	91.16	0.000858	9.23	225.85	28	0.57
C05	Upper	50320		Inl Struct									
C05	Upper	50300.15	Max WS	2084.5	76.64	83.93	81.96	85.34	0.00189	9.53	218.82	30	0.62
C05	Upper	50114.33	Max WS	2084.13	75.94	83.7	81.26	84.94	0.001616	8.95	232.76	30	0.57
C05	Upper	50104.33	Max WS	2084.13	75.9	83.82	80.99	84.87	0.001632	8.23	253.36	32	0.52
C05	Upper	50000.11	Max WS	2082.65	75.71	83.52	80.8	84.6	0.001685	8.33	249.9	32	0.53
C05	Upper	49970.11	Max WS	2082.25	75.63	83.32		84.59	0.000826	9.02	230.82	30	0.57
C05	Upper	49964		Lat Struct									
C05	Upper	49961		Lat Struct									
C05	Upper	49650	Max WS	3198.9	74.78	82.53		85.47	0.001913	13.77	232.35	30	0.87
C05	Upper	49550	Max WS	3198.89	74.51	82.24		85.2	0.001922	13.79	231.95	30	0.87
C05	Upper	49200	Max WS	3198.7	73.58	81.39		84.29	0.001868	13.65	234.26	30	0.86
C05	Upper	49100	Max WS	3198.69	73.32	81.2		84.05	0.001817	13.52	236.53	30	0.85
C05	Upper	48950	Max WS	3239.96	72.92	80.93		83.76	0.00178	13.48	240.39	30	0.84
C05	Upper	48900	Max WS	3239.96	72.79	80.84		83.64	0.001753	13.41	241.64	30	0.83
C05	Upper	48800.14	Max WS	3239.7	72.52	80.67		83.4	0.001693	13.25	244.58	30	0.82
C05	Upper	48770.14	Max WS	3239.7	71.59	80.64		82.02	0.000703	9.42	343.77	38	0.55
C05	Upper	48719.31		Culvert									
C05	Upper	48652.65	Max WS	3236.72	71.27	79.65		81.26	0.000877	10.16	318.45	38	0.62
C05	Upper	48622.65	Max WS	3236.71	71.23	79.76		81.16	0.000736	9.49	341.14	40	0.57
C05	Upper	48619		Lat Struct									
C05	Upper	48615		Lat Struct									
C05	Upper	48380	Max WS	3235.54	70.94	79.62		80.97	0.000698	9.32	347.33	40	0.56
C05	Upper	48140	Max WS	3235.53	70.66	79.49		80.79	0.000665	9.16	353.09	40	0.54
C05	Upper	47900	Max WS	3234.58	70.38	79.32		80.59	0.00064	9.04	357.78	40	0.53
C05	Upper	47800	Max WS	3235.28	70.26	79.26		80.52	0.000628	8.99	360.02	40	0.53

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C05	Upper	47621.98	Max WS	3234.64	70.05	79.16		80.39	0.000606	8.87	364.57	40	0.52
C05	Upper	47591.98	Max WS	3234.63	69.64	79.12		80.37	0.000611	8.98	360.33	38	0.51
C05	Upper	47560.95		Culvert									
C05	Upper	47529.92	Max WS	3230.23	69.48	78.08		79.6	0.000809	9.88	326.88	38	0.59
C05	Upper	47499.92	Max WS	3230.23	69.44	78.2		79.52	0.000679	9.22	350.24	40	0.55
C05	Upper	47497		Lat Struct									
C05	Upper	47495		Lat Struct									
C05	Upper	47253.69	Max WS	3510.26	69.15	77.57		79.26	0.0009	10.42	336.75	40	0.63
C05	Upper	47013.69	Max WS	3510.11	68.86	77.32		78.99	0.000887	10.37	338.38	40	0.63
C05	Upper	46773.69	Max WS	3510.01	68.58	77.09		78.74	0.000871	10.31	340.44	40	0.62
C05	Upper	46743.69	Max WS	3510	68.23	77.03		78.74	0.000896	10.5	334.23	38	0.62
C05	Upper	46711.49		Culvert									
C05	Upper	46679.52	Max WS	3505.79	68.1	74.67	74.52	77.73	0.002109	14.03	249.84	38	0.96
C05	Upper	46649.52	Max WS	3504.74	68.06	74.61		77.39	0.001887	13.37	262.19	40	0.92
C05	Upper	46644		Lat Struct									
C05	Upper	46639		Lat Struct									
C05	Upper	46400	Max WS	3503.72	67.76	74.08	73.96	77.07	0.002103	13.86	252.86	40	0.97
C05	Upper	46300	Max WS	3503.69	67.38	73.88		76.7	0.001934	13.48	259.99	40	0.93
C05	Upper	46000	Max WS	3502.83	66.27	73.37		75.73	0.001485	12.34	283.93	40	0.82
C05	Upper	45900	Max WS	3502.78	65.9	73.23		75.45	0.001351	11.95	293.05	40	0.78
C05	Upper	45709.62	Max WS	3502.63	65.2	73.05		74.98	0.001103	11.16	313.8	40	0.7
C05	Upper	45679.62	Max WS	3502.61	64.47	72.94	71.67	75.53	0.00225	12.92	271	32	0.78
C05	Upper	45532.03	Max WS	3502.55	63.74	72.62	70.93	74.98	0.001984	12.32	284.2	32	0.73
C05	Upper	45507.03	Max WS	3502.54	62.07	72.72	69.27	74.58	0.002376	10.95	320		0.59
C05	Upper	44600	Max WS	3501.63	60.78	70.48	67.97	72.46	0.001573	11.28	310.53	32	0.64
C05	Upper	44596		Lat Struct									
C05	Upper	44592		Lat Struct									
C05	Upper	44550	Max WS	3501.35	60.63	68.78		71.97	0.001978	14.32	244.58	30	0.88
C05	Upper	44491.56	Max WS	3501.32	60.44	68.62		71.78	0.001957	14.26	245.5	30	0.88
C05	Upper	44100	Max WS	3500.98	59.21	67.73		70.64	0.001745	13.7	255.51	30	0.83
C05	Upper	44000	Max WS	3500.96	58.89	67.53		70.37	0.001675	13.51	259.22	30	0.81
C05	Upper	43874.65	Max WS	3500.92	58.5	67.3		70.03	0.00159	13.26	264.02	30	0.79
C05	Upper	43844.65	Max WS	3500.91	58.02	67.34		68.86	0.000754	9.89	353.97	38	0.57
C05	Upper	43808.16		Culvert									

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C05	Upper	43771.66	Max WS	3496.39	57.65	64.88		67.4	0.001583	12.73	274.63	38	0.83
C05	Upper	43741.66	Max WS	3496.38	57.56	64.83		67.08	0.001376	12.02	290.9	40	0.79
C05	Upper	43737		Lat Struct									
C05	Upper	43735		Lat Struct									
C05	Upper	43600	Max WS	3733.37	57.18	64.56		67.05	0.001502	12.65	295.19	40	0.82
C05	Upper	43500	Max WS	3733.36	56.91	64.38		66.81	0.001447	12.49	298.93	40	0.81
C05	Upper	43262.27	Max WS	3733	56.8	63.95		66.6	0.001647	13.04	286.17	40	0.86
C05	Upper	43200	Max WS	3733	56.61	63.85		66.43	0.001588	12.88	289.74	40	0.84
C05	Upper	43100	Max WS	3732.99	56.29	63.7		66.17	0.001484	12.59	296.4	40	0.82
C05	Upper	43000	Max WS	3732.97	55.97	63.56		65.91	0.001384	12.3	303.47	40	0.79
C05	Upper	42537.35	Max WS	3732.77	54.51	63.18		64.98	0.000932	10.76	346.9	40	0.64
C05	Upper	42507.35	Max WS	3732.77	54.42	63.32		64.84	0.000746	9.86	378.4	42.5	0.58
C05	Upper	42449.3		Culvert									
C05	Upper	42385.67	Max WS	3730.73	54.03	60.81		63.41	0.00168	12.95	287.99	42.5	0.88
C05	Upper	42355.67	Max WS	3730.15	53.94	60.75		63.66	0.001904	13.69	272.5	40	0.92
C05	Upper	42351		Lat Struct									
C05	Upper	42347		Lat Struct									
C05	Upper	42000	Max WS	3933.96	53.43	59.92	60.11	63.46	0.002417	15.09	260.64	40.36	1.05
C05	Upper	41925	Max WS	3933.21	52.45	59.73		62.56	0.001738	13.51	291.08	40	0.88
C05	Upper	41740	Max WS	3931.65	52.15	59.37		62.25	0.001775	13.61	288.97	40	0.89
C05	Upper	41500	Max WS	3930.85	51.52	58.87		61.65	0.001688	13.38	293.85	40	0.87
C05	Upper	41400	Max WS	3930.05	51.23	58.67		61.38	0.001628	13.21	297.4	40	0.85
C05	Upper	40700	Max WS	3925.08	49.25	57.45		59.67	0.001216	11.97	327.94	40	0.74
C05	Upper	40600	Max WS	3925.05	48.97	57.32		59.46	0.001154	11.76	333.81	40	0.72
C05	Upper	40400	Max WS	3923.38	48.4	57.1		59.07	0.001022	11.28	347.81	40	0.67
C05	Upper	40300	Max WS	4301.91	48.12	56.75		59.16	0.001258	12.47	345.05	40	0.75
C05	Upper	39727.04	Max WS	4427.22	46.5	55.96		58.09	0.001019	11.7	378.25	40	0.67
C05	Upper	39697.04	Max WS	4427.21	46.41	56.1		57.89	0.000821	10.76	411.64	42.5	0.61
C05	Upper	39647.4		Culvert									
C05	Upper	39591.36	Max WS	4425.72	46.12	53.82		56.66	0.001612	13.52	327.29	42.5	0.86
C05	Upper	39561.36	Max WS	4425.72	46.03	53.77		56.95	0.001833	14.3	309.57	40	0.91
C05	Upper	39558		Lat Struct									
C05	Upper	39555		Lat Struct									
C05	Upper	39000	Max WS	4425.26	44.16	52.91		55.39	0.001277	12.64	350.03	40	0.75

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C05	Upper	38774.85	Max WS	4425.19	43.45	52.73		54.94	0.001076	11.93	371.07	40	0.69
C05	Upper	38744.85	Max WS	4497.6	43.39	52.77		54.75	0.00093	11.28	398.64	42.5	0.65
C05	Upper	38717.6		Culvert									
C05	Upper	38683.16	Max WS	4495.08	43.26	50.01	50.29	53.83	0.002465	15.66	286.97	42.5	1.06
C05	Upper	38653.16	Max WS	4495.07	43.2	49.94	49.96	53.35	0.002169	14.81	303.43	45	1.01
C05	Upper	38648		Lat Struct									
C05	Upper	38645		Lat Struct									
C05	Upper	38500	Max WS	4494.32	42.52	49.64		52.7	0.001843	14.04	320.22	45	0.93
C05	Upper	37900	Max WS	4492.03	40.82	48.67		51.18	0.00137	12.71	353.36	45	0.8
C05	Upper	37700	Max WS	4490.54	40.28	48.42		50.76	0.001229	12.26	366.38	45	0.76
C05	Upper	37600	Max WS	4638.95	40.02	48.26		50.69	0.001266	12.51	370.78	45	0.77
C05	Upper	37072.77	Max WS	4357.37	38.97	47.8		49.67	0.00091	10.97	397.25	45	0.65
C05	Upper	37042.77	Max WS	4434.84	38.65	48.01		49.4	0.000618	9.48	467.87	50	0.55
C05	Upper	37005.5		Culvert									
C05	Upper	36961.11	Max WS	4708.13	38.36	46.69		48.68	0.000985	11.3	416.6	50	0.69
C05	Upper	36931.11	Max WS	4709.76	38.32	46.6		49.08	0.001287	12.64	372.51	45	0.77
C05	Upper	36926		Lat Struct									
C05	Upper	36923		Lat Struct									
C05	Upper	36600	Max WS	4709.09	37.85	46.18		48.63	0.001262	12.56	374.87	45	0.77
C05	Upper	36500	Max WS	4709.08	37.7	46.06		48.49	0.00125	12.52	376.08	45	0.76
C05	Upper	36400	Max WS	4708.44	37.56	45.93		48.36	0.001243	12.49	376.85	45	0.76
C05	Upper	36300	Max WS	4708.43	37.42	45.81		48.23	0.001235	12.47	377.66	45	0.76
C05	Upper	36100	Max WS	4708.38	37.13	45.57		47.96	0.001213	12.39	379.96	45	0.75
C05	Upper	36000	Max WS	4707.85	36.99	45.46		47.83	0.001203	12.36	380.95	45	0.75
C05	Upper	35716.82	Max WS	4707.85	36.59	45.13		47.46	0.001172	12.25	384.28	45	0.74
C05	Upper	35600	Max WS	4707.83	36.42	44.97		47.3	0.001166	12.23	384.93	45	0.74
C05	Upper	35511	Max WS	4707.82	36.3	44.87	43.28	47.19	0.001158	12.2	385.81	45	0.73
C05	Upper	35509.7		Bridge									
C05	Upper	35483	Max WS	4707.5	36.26	44.83		47.14	0.00116	12.21	385.57	45	0.74
C05	Upper	35479		Lat Struct									
C05	Upper	35478		Lat Struct									
C05	Upper	35200	Max WS	4706.58	35.86	44.44		46.75	0.001157	12.2	385.94	45	0.73
C05	Upper	35100	Max WS	4705.02	35.72	44.28		46.6	0.001161	12.21	385.39	45	0.74
C05	Upper	34900	Max WS	4809.93	35.36	43.94		46.35	0.001205	12.45	386.31	45	0.75

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C05	Upper	34800	Max WS	4809.11	35.18	43.83		46.2	0.001176	12.35	389.47	45	0.74
C05	Upper	34500	Max WS	4808.26	34.65	43.53		45.78	0.001088	12.03	399.69	45	0.71
C05	Upper	34422.44	Max WS	4808.24	34.51	43.46		45.68	0.001063	11.94	402.84	45	0.7
C05	Upper	34392.44	Max WS	5127.27	33.76	43.54		45.25	0.000725	10.49	488.85	50	0.59
C05	Upper	34276		Culvert									
C05	Upper	34152.46	Max WS	5121.47	33.04	41.49		43.77	0.001118	12.12	422.45	50	0.74
C05	Upper	34122.46	Max WS	5120.39	32.98	41.46		43.73	0.001105	12.08	424.03	50	0.73
C05	Upper	34116		Lat Struct									
C05	Upper	34089		Lat Struct									
C05	Upper	33800	Max WS	5119.31	32.37	41.19		43.28	0.000984	11.61	440.77	50	0.69
C05	Upper	33700	Max WS	5119.29	32.18	41.11		43.16	0.000945	11.46	446.7	50	0.68
C05	Upper	33100	Max WS	5110.98	31.05	40.81		42.51	0.000724	10.47	488	50	0.59
C05	Upper	31700	Max WS	5328.04	29.49	39.66		41.36	0.000698	10.48	508.27	50	0.58
C05	Upper	31600	Max WS	5328.03	29.39	39.6		41.29	0.00069	10.44	510.32	50	0.58
C05	Upper	31400.95	Max WS	5327.97	29.19	39.48		41.15	0.000673	10.35	514.62	50	0.57
C05	Upper	31370.95	Max WS	5415.67	29.19	39.35		41.12	0.000722	10.66	508.09	50	0.59
C05	Upper	31321.64		Culvert									
C05	Upper	31266.75	Max WS	5405.9	29.03	38.59		40.58	0.000863	11.31	477.78	50	0.65
C05	Upper	31236.75	Max WS	5405.89	29.03	38.55		40.56	0.000872	11.35	476.09	50	0.65
C05	Upper	31221		Lat Struct									
C05	Upper	31219		Lat Struct									
C05	Upper	30760	Max WS	5537.62	28.58	37.98	35.83	40.13	0.000952	11.79	469.76	50	0.68
C05	Upper	30750	Max WS	5537.61	28.57	37.96	35.82	40.12	0.000952	11.79	469.73	50	0.68
C05	Upper	30748		Lat Struct									
C05	Upper	30746		Lat Struct									
C05	Upper	28532.89	Max WS	5534.89	26.49	35.82		38.01	0.000971	11.86	466.52	50	0.68
C05	Upper	28502.89	Max WS	5534.89	25.62	35.99		37.76	0.000711	10.68	518.36	50	0.58
C05	Upper	28364.14		Culvert									
C05	Upper	28225.6	Max WS	5527.15	24.76	32.4		35.65	0.001763	14.47	381.98	50	0.92
C05	Upper	28195.6	Max WS	5527.15	24.67	32.36		34.59	0.001139	11.99	461.16	60	0.76
C05	Upper	28190		Lat Struct									
C05	Upper	28145		Lat Struct									
C05	Upper	27700	Max WS	5564.33	23.43	32		33.82	0.000827	10.82	514.44	60	0.65
C05	Upper	27225	Max WS	5564.22	22.17	31.97		33.36	0.000553	9.47	587.72	60	0.53

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C05	Upper	27175	Max WS	5564.74	20.78	32.24		33.26	0.000346	8.09	687.76	60	0.42
C05	Upper	27128.93	Max WS	5604.89	20.63	32.22		33.23	0.00034	8.06	695.45	60	0.42
C05	Upper	27106.07		Culvert									
C05	Upper	27075.93	Max WS	5603.32	20.47	31.42		32.55	0.000402	8.53	657.14	60	0.45
C05	Upper	27050		Lat Struct									
C05	Upper	27049		Lat Struct									
C05	Upper	26800	Max WS	5603.32	20.35	31.31		32.44	0.000401	8.52	657.87	60	0.45
C05	Upper	26100	Max WS	5602.9	20.08	31.03		32.16	0.000402	8.53	657.16	60	0.45
C05	Upper	25900	Max WS	5602.82	20	30.95		32.08	0.000402	8.53	657.15	60	0.45
C05	Upper	25800	Max WS	5354.23	19.96	31.12		32.12	0.000347	7.99	669.83	60	0.42
C05	Upper	25581.28	Max WS	5354.12	19.88	31.05		32.04	0.000346	7.99	670.16	60	0.42
C05	Upper	25531.28	Max WS	5354.1	19.88	31.03		32.02	0.000348	8	668.91	60	0.42
C05	Upper	25429.99		Culvert									
C05	Upper	25275	Max WS	5350.39	17.58	26.55		28.09	0.000666	9.94	538.42	60	0.58
C05	Upper	25271		Lat Struct									
C05	Upper	25265	Max WS	5350.39	17.57	26.55		28.08	0.000665	9.93	538.69	60	0.58
C05	Upper	25264		Lat Struct									
C05	Upper	25163.75	Max WS	5350.37	17.45	26.5		28.01	0.00065	9.85	542.94	60	0.58
C05	Upper	25100	Max WS	5676.64	17.38	26.17		27.97	0.0008	10.77	527.17	60	0.64
C05	Upper	24941.18	Max WS	5676.64	17.19	26.06		27.83	0.000776	10.66	532.31	60	0.63
C05	Upper	24891.18	Max WS	5676.66	17.14	26.03		27.79	0.000773	10.65	533.2	60	0.63
C05	Upper	24841.18	Max WS	5676.65	17.08	26.13		27.67	0.000654	9.96	569.91	63	0.58
C05	Upper	24824.69		Culvert									
C05	Upper	24801.18	Max WS	5673.67	17.03	24.91		26.94	0.000996	11.43	496.38	63	0.72
C05	Upper	24763		Lat Struct									
C05	Upper	24762		Lat Struct									
C05	Upper	24751.18	Max WS	5673.05	15.57	25.04		26.59	0.000638	9.99	567.97	60	0.57
C05	Upper	22652.97	Max WS	5705.69	14.86	23.07		25.16	0.000992	11.58	492.78	60	0.71
C05	Upper	22617.97	Max WS	5739.96	14.85	23.01		25.15	0.001023	11.72	489.74	60	0.72
C05	Upper	22587.97	Max WS	5739.95	14.12	23.15		24.79	0.000697	10.25	560.01	62	0.6
C05	Upper	22471.63		Culvert									
C05	Upper	22348.4	Max WS	5737.17	13.42	20.86		23.26	0.001258	12.43	461.45	62	0.8
C05	Upper	22318.4	Max WS	5737.17	13.58	20.82		23.53	0.001474	13.2	434.51	60	0.87
C05	Upper	22310		Lat Struct									

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C05	Upper	22285		Lat Struct									
C05	Upper	22100	Max WS	5769.98	13.29	20.36		23.24	0.001604	13.6	424.27	60	0.9
C05	Upper	22000	Max WS	5769.08	13.09	20.15		23.03	0.001613	13.62	423.51	60	0.9
C05	Upper	21400	Max WS	5762.76	11.93	19.07		21.88	0.001554	13.45	428.32	60	0.89
C05	Upper	21300	Max WS	5761.63	11.73	18.91		21.69	0.001523	13.37	431.1	60	0.88
C05	Upper	21200	Max WS	5760.49	11.54	18.76		21.51	0.001497	13.29	433.44	60	0.87
C05	Upper	21000	Max WS	5743.78	11.15	18.47		21.13	0.001428	13.07	439.32	60	0.85
C05	Upper	20900	Max WS	5778.72	10.96	18.33		20.98	0.001417	13.07	442.19	60	0.85
C05	Upper	20300	Max WS	5773.98	9.79	17.49		19.92	0.001239	12.5	461.76	60	0.79
C05	Upper	20200	Max WS	5809.82	9.6	17.36		19.78	0.001221	12.47	465.76	60	0.79
C05	Upper	20164	Max WS	5809.01	9.53	17.32	16.16	19.72	0.001208	12.43	467.39	60	0.79
C05	Upper	20160.15		Bridge									
C05	Upper	20148	Max WS	5808.18	9.5	17.32		19.7	0.001195	12.38	469.01	60	0.78
C05	Upper	20142		Lat Struct									
C05	Upper	20138		Lat Struct									
C05	Upper	20000	Max WS	5798.61	9.21	17.12		19.44	0.001149	12.22	474.6	60	0.77
C05	Upper	19900	Max WS	5794.47	9.02	16.98		19.27	0.001125	12.13	477.69	60	0.76
C05	Upper	19602.78	Max WS	5781.46	7.51	16.91		18.54	0.000676	10.25	563.93	60	0.59
C05	Upper	19553.57	Max WS	5776.46	7.16	16.91		18.47	0.000628	10.03	575.72	59.06	0.57
C05	Upper	19396.42	Max WS	5770.59	6.87	16.81		18.31	0.000591	9.83	587.1	59.06	0.55
C05	Lower	19222.95	Max WS	8148.71	6.38	16.34		18.17	0.000665	10.84	751.64	75.46	0.61
C05	Lower	19212.95	Max WS	8151.4	6.38	16.33	13.51	18.16	0.000668	10.85	750.98	75.46	0.61
C05	Lower	19167.47		Bridge									
C05	Lower	19158.85	Max WS	8110.22	6.27	15.92		17.85	0.000727	11.14	728.03	75.46	0.63
C05	Lower	19144		Lat Struct									
C05	Lower	19140		Lat Struct									
C05	Lower	19093.7	Max WS	8107.09	6.07	15.92		17.77	0.000681	10.91	743.32	75.46	0.61
C05	Lower	19028.64	Max WS	8080.51	5.88	15.87		17.66	0.000648	10.72	753.87	75.46	0.6
C05	Lower	18640.91	Max WS	8057.14	4.72	15.87		17.3	0.000461	9.57	841.51	75.46	0.51
C05	Lower	18542.48	Max WS	8057.12	4.42	15.9	11.49	17.24	0.000423	9.3	865.95	75.46	0.48
C05	Lower	18503.88		Bridge									
C05	Lower	18466.48	Max WS	8054.55	4.07	15.39		16.77	0.00044	9.43	854.37	75.46	0.49
C05	Lower	18445		Lat Struct									
C05	Lower	18444		Lat Struct									

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C05	Lower	18372.48	Max WS	8051.89	4.05	15.35		16.73	0.000443	9.45	852.39	75.46	0.5
C05	Lower	18368.06	Max WS	8051.89	4.05	15.34		16.73	0.000443	9.45	852.21	75.46	0.5
C05	Lower	18080.49	Max WS	8049.21	4	15.2		16.61	0.000455	9.53	844.86	75.46	0.5
C05	Lower	18067.06	Max WS	8049.21	3.99	15.19		16.6	0.000454	9.52	845.25	75.46	0.5
C05	Lower	17806.6	Max WS	8040.84	3.96	15.05		16.48	0.000467	9.61	836.82	75.46	0.51
C05	Lower	17763.45	Max WS	8040.83	3.94	15.03		16.46	0.000467	9.61	836.84	75.46	0.51
C05	Lower	17716.32	Max WS	8037.92	3.93	15.01		16.44	0.000469	9.62	835.72	75.46	0.51
C05	Lower	17060.16	Max WS	8028.83	3.13	14.86		16.14	0.000393	9.07	885.42	75.46	0.47
C05	Lower	16669.61	Max WS	8031.37	2.64	14.8		15.99	0.000353	8.75	917.6	75.46	0.44
C05	Lower	16600.78	Max WS	8300.58	2.55	14.61	9.77	15.91	0.000386	9.12	910.31	75.46	0.46
C05	Lower	16522.57		Bridge									
C05	Lower	16443.57	Max WS	8282.58	2.31	14.09		15.44	0.000413	9.32	888.92	75.46	0.48
C05	Lower	16438		Lat Struct									
C05	Lower	16434		Lat Struct									
C05	Lower	16374.67	Max WS	8282.55	2.29	14.06		15.41	0.000414	9.33	888.18	75.46	0.48
C05	Lower	16075.92	Max WS	8437.29	2.19	13.81		15.25	0.000447	9.62	876.65	75.46	0.5
C05	Lower	15272.12	Max WS	8413.33	1.6	13.54		14.89	0.00041	9.34	900.75	75.46	0.48
C05	Lower	15173.7	Max WS	8432.8	1.53	14.31		14.63	0.000075	4.52	1866.34	146	0.22
C05	Lower	15124.49	Max WS	8429.91	2.26	14.27		14.63	0.000091	4.81	1753.08	146	0.24
C05	Lower	15123.4	Max WS	8429.91	2.26	14.27		14.63	0.000226	4.81	1753.05	146	0.24
C05	Lower	13960.9	Max WS	8425.02	1.85	14.02		14.37	0.000216	4.74	1777.53	146	0.24
C05	Lower	13930.92	Max WS	8420.97	1.84	13.82	7.25	14.37	0.000363	5.96	1413.68	118	0.3
C05	Lower	13880.92		Bridge									
C05	Lower	13830.92	Max WS	8416.5	1.81	13.53		14.11	0.000388	6.08	1383.37	118	0.31
C05	Lower	13825		Lat Struct									
C05	Lower	13823		Lat Struct									
C05	Lower	13800.9	Max WS	8418.77	1.81	13.73		14.09	0.000231	4.84	1740.08	146	0.25
C05	Lower	13739.5	Max WS	8418.76	1.81	13.71		14.08	0.000231	4.84	1737.91	146	0.25
C05	Lower	13100	Max WS	8551.05	1.61	13.54		13.92	0.000237	4.91	1742.03	146	0.25
C05	Lower	12200	Max WS	8543.24	1.36	13.34		13.71	0.000234	4.89	1748.43	146	0.25
C05	Lower	11327	Max WS	8605.86	1.13	13.12		13.5	0.000236	4.92	1750.58	146	0.25
C05	Lower	11297.04	Max WS	8602.74	1.12	12.9	6.61	13.49	0.000399	6.19	1389.92	118	0.32
C05	Lower	11239.01		Bridge									
C05	Lower	11187	Max WS	8597.27	1.09	12.55		13.17	0.000435	6.36	1351.7	118	0.33

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C05	Lower	11174		Lat Struct									
C05	Lower	11164		Lat Struct									
C05	Lower	11157	Max WS	8600.97	1.08	12.76		13.15	0.000257	5.04	1705.07	146	0.26
C05	Lower	10600	Max WS	8595.9	0.92	12.57		12.97	0.000258	5.05	1701.23	146	0.26
C05	Lower	10202	Max WS	8616.69	-0.07	12.52	4.7	12.86	0.000203	4.69	1838.26	146	0.23
C05	Lower	10056.87		Bridge									
C05	Lower	9921	Max WS	8608.07	-0.14	12.16		12.52	0.000218	4.79	1796.5	146	0.24
C05	Lower	9910		Lat Struct									
C05	Lower	9906		Lat Struct									
C05	Lower	9871	Max WS	8608.07	-0.15	12.15		12.51	0.000218	4.79	1796.39	146	0.24
C05	Lower	9500	Max WS	8606.25	-0.24	12.06		12.42	0.000218	4.79	1795.7	146	0.24
C05	Lower	9000	Max WS	8601.13	-0.3	11.93		12.29	0.000222	4.82	1785.09	146	0.24
C05	Lower	8600	Max WS	8597.77	-0.34	11.82		12.18	0.000226	4.84	1775.1	146	0.24
C05	Lower	8000	Max WS	8592.93	-0.4	11.66		12.03	0.000231	4.88	1761.37	146	0.25
C05	Lower	7593	Max WS	8589.87	-0.44	11.57		11.94	0.000235	4.9	1753.03	146	0.25
C05	Lower	7525	Max WS	8589.86	-0.45	11.55	4.3	11.92	0.000235	4.9	1752.13	146	0.25
C05	Lower	7424.94		Bridge									
C05	Lower	7325	Max WS	8585.36	-0.6	11.3		11.68	0.000241	4.94	1737.22	146	0.25
C05	Lower	7316		Lat Struct									
C05	Lower	7315		Lat Struct									
C05	Lower	7257	Max WS	8585.35	-0.62	11.28		11.66	0.000241	4.94	1737.81	146	0.25
C05	Lower	6600	Max WS	8577.7	-0.84	11.13		11.51	0.000236	4.91	1747.95	146	0.25
C05	Lower	6139	Max WS	8573.16	-1	11.03		11.4	0.000232	4.88	1756.25	146	0.25
C05	Lower	5953	Max WS	8570.21	-1.08	10.99		11.36	0.00023	4.86	1762.08	146	0.25
C05	Lower	5600	Max WS	9324.63	-1.24	10.75		11.19	0.000277	5.32	1751.16	146	0.27
C05	Lower	5328	Max WS	9325.78	-1.36	10.68		11.12	0.000274	5.3	1758.23	146	0.27
C05	Lower	4900	Max WS	9327.79	-1.55	10.57		11	0.000268	5.27	1769.83	146	0.27
C05	Lower	4740	Max WS	9329.81	-1.62	10.53		10.96	0.000266	5.26	1774.09	146	0.27
C05	Lower	4200	Max WS	9332.36	-1.86	10.4		10.82	0.00026	5.22	1789.42	146	0.26
C05	Lower	3900	Max WS	9334.04	-1.99	10.32		10.74	0.000256	5.19	1797.65	146	0.26
C05	Lower	3700	Max WS	9335.52	-2.08	10.27		10.69	0.000253	5.18	1803.75	146	0.26
C05	Lower	3687	Max WS	9335.68	-2.08	10.27	2.95	10.69	0.000253	5.18	1803.23	146	0.26
C05	Lower	3635.91		Bridge									
C05	Lower	3581	Max WS	9332.72	-2.13	10.15		10.57	0.000258	5.21	1792.99	146	0.26

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C05	Lower	3570		Lat Struct									
C05	Lower	3566		Lat Struct									
C05	Lower	3400	Max WS	9333.98	-2.21	10.11		10.53	0.000256	5.19	1798.23	146	0.26
C05	Lower	1800	Max WS	9336.78	-2.89	9.72		10.12	0.000238	5.07	1840.65	146	0.25
C05	Lower	1775	Max WS	9335.86	-2.9	9.7		10.1	0.000238	5.07	1840.29	146	0.25
C05	Lower	1200	Max WS	9336.44	-3.16	9.54		9.93	0.000232	5.04	1853.73	146	0.25
C05	Lower	900	Max WS	9335.95	-3.31	9.45		9.84	0.000229	5.01	1862.33	146	0.25
C05	Lower	850	Max WS	9335.11	-3.33	9.43		9.82	0.000229	5.01	1862.5	146	0.25
C05	Lower	634	Max WS	9332.1	-3.41	9.37	1.62	9.76	0.000227	5	1866.57	146	0.25
C05	Lower	615.72		Bridge									
C05	Lower	580.41	Max WS	9328.92	-3.41	9.33		9.72	0.00023	5.02	1859.45	146	0.25
C05	Lower	575	Max WS	9327.25	-3.19	9.28	3.87	9.72	0.000379	5.28	1767.27	215.85	0.33
C04	Upper	50219.64	Max WS	1111.18	70.72	78.37		79.38	0.000868	8.06	137.84	18.02	0.51
C04	Upper	50219.63		Lat Struct									
C04	Upper	50219.62		Lat Struct									
C04	Upper	50138.63	Max WS	1111.16	70.5	78.35		79.31	0.000811	7.86	141.34	18.02	0.49
C04	Upper	50113.59	Max WS	1111.15	70.4	78.48		79.27	0.000629	7.14	155.55	19.27	0.44
C04	Upper	50085.25 Mallard St		Culvert									
C04	Upper	50053.15	Max WS	1110.78	70.19	77.51		78.53	0.000882	8.09	137.31	18.77	0.53
C04	Upper	50028.14	Max WS	1110.76	70.09	77.42		78.52	0.000976	8.41	132.03	18.02	0.55
C04	Upper	49840	Max WS	1110.92	69.58	77.35		78.33	0.000833	7.94	139.94	18.02	0.5
C04	Upper	49815	Max WS	1110.92	69.48	77.48		78.29	0.000646	7.21	154.08	19.27	0.45
C04	Upper	49784.9 Teal St		Culvert									
C04	Upper	49754.53	Max WS	1110.79	69.26	76.17		77.25	0.000968	8.35	133.01	19.26	0.56
C04	Upper	49729.52	Max WS	1110.79	69.16	76.02		77.28	0.001172	8.99	123.51	18.01	0.61
C04	Upper	49540.11	Max WS	1110.82	68.65	75.91		77.03	0.001002	8.5	130.74	18.02	0.56
C04	Upper	49515.11	Max WS	1110.82	68.55	76.05		76.97	0.000771	7.69	144.43	19.27	0.5
C04	Upper	49485.41 Woodbury S		Culvert									
C04	Upper	49453.64	Max WS	1108.82	68.34	75.04		76.19	0.001051	8.6	128.96	19.25	0.59
C04	Upper	49428.64	Max WS	1108.5	68.24	74.89		76.22	0.001269	9.25	119.81	18.01	0.63
C04	Upper	49264.54	Max WS	1126.86	67.79	74.71		75.98	0.001179	9.05	124.53	18.01	0.61
C04	Upper	49239.47	Max WS	1126.86	67.69	74.85		75.89	0.000903	8.18	137.81	19.27	0.54
C04	Upper	49211.87 Blake St		Culvert									
C04	Upper	49177.99	Max WS	1126.58	67.47	73.4		74.93	0.001545	9.92	113.62	19.16	0.72

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C04	Upper	49152.98	Max WS	1126.71	67.37	73.31		75.04	0.001796	10.53	107.02	18.01	0.76
C04	Upper	48503.87	Max WS	1126.46	65.62	72.55		73.81	0.001173	9.03	124.74	18.02	0.61
C04	Upper	48478.84	Max WS	1126.46	65.52	72.67		73.71	0.000903	8.18	137.78	19.27	0.54
C04	Upper	48446.8	Ranney St	Culvert									
C04	Upper	48414.96	Max WS	1108.67	65.3	70.3		72.36	0.002408	11.52	96.22	19.26	0.91
C04	Upper	48389.95	Max WS	1107.57	65.2	70.23	70.1	72.55	0.00278	12.22	90.61	18.01	0.96
C04	Upper	48153.55	Max WS	1098.24	64.56	69.58	69.43	71.87	0.002755	12.16	90.35	18.01	0.96
C04	Upper	48128.48	Max WS	1119.78	64.26	69.96		70.44	0.00039	5.55	201.71	35.38	0.41
C04	Upper	48100.04	Westminste	Culvert									
C04	Upper	48063.49	Max WS	1117.34	63.47	69.75		70.15	0.000298	5.08	219.74	35.02	0.36
C04	Upper	48063.48		Lat Struct									
C04	Upper	48063.47		Lat Struct									
C04	Upper	48047.75	Max WS	1117.33	63.28	69.77		70.14	0.000263	4.86	229.72	35.38	0.34
C04	Upper	48008.02	Westminste	Culvert									
C04	Upper	47962.03	Max WS	1114.6	62.25	69.58		69.87	0.000182	4.3	259.49	35.39	0.28
C04	Upper	47928.15	Max WS	1113.11	61.84	69.22		70.01	0.000761	7.16	155.37	32.13	0.57
C04	Upper	46827.13	Max WS	1406.73	59.64	67.87		68.78	0.00077	7.64	184.06	34.7	0.59
C04	Upper	46594.06	Max WS	1501.51	59.34	67.5		68.56	0.00091	8.27	181.52	34.48	0.64
C04	Upper	45994	Max WS	1661.88	58.56	66.64		67.99	0.00116	9.29	178.9	34.25	0.72
C04	Upper	45538.54	Max WS	1750.86	57.97	65.99		67.52	0.001328	9.9	176.82	34.07	0.77
C04	Upper	45516.07	Max WS	1750.85	57.83	66.06		67.01	0.000615	7.83	223.72	27.19	0.48
C04	Upper	45479.91	Ward St	Culvert									
C04	Upper	45433.98	Max WS	1748.85	57.33	63.46		65.17	0.001432	10.5	166.62	27.18	0.75
C04	Upper	45410.68	Max WS	1746.82	57.3	63.57		64.7	0.000818	8.52	205.14	37.41	0.64
C04	Upper	43359.6	Max WS	2003.02	54.63	61.54		62.73	0.000778	8.73	229.42	38.37	0.63
C04	Upper	42918.6	Max WS	2003.15	54.06	61.31		62.37	0.000664	8.27	242.32	38.87	0.58
C04	Upper	42893.64	Max WS	2003.14	53.91	61.4		62.31	0.000568	7.64	262.33	35.01	0.49
C04	Upper	42793.37	Brookhurst	Culvert									
C04	Upper	42678.99	Max WS	1995.66	52.65	58.85		60.16	0.000988	9.2	216.98	35.01	0.65
C04	Upper	42678.98		Lat Struct									
C04	Upper	42678.97		Lat Struct									
C04	Upper	42641.94	Max WS	1994.47	52.61	58.81		60.12	0.000984	9.18	217.15	35.01	0.65
C04	Upper	41375.07	Max WS	1988.93	51.24	57.72	55.87	58.91	0.000862	8.77	226.67	35.01	0.61
C04	Upper	41369.91	Ped Bridge	Bridge									

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C04	Upper	41359.91	Max WS	1988.13	51.22	57.71		58.9	0.000856	8.75	227.11	35.01	0.61
C04	Upper	40686.2	Max WS	1987.88	50.49	57.22		58.33	0.000766	8.43	235.77	35.01	0.57
C04	Upper	40486.2	Max WS	1987.78	50.28	57.09		58.17	0.00074	8.33	238.55	35.02	0.56
C04	Upper	40391.62	Max WS	1987.73	50.18	57.03		58.1	0.000727	8.28	239.96	35.02	0.56
C04	Upper	40161.66	Max WS	1987.67	49.93	56.9		57.93	0.000692	8.15	243.95	35.02	0.54
C04	Upper	40125.21	Bushard St	Culvert									
C04	Upper	40078.95	Max WS	1969.11	49.81	55.38		56.97	0.001324	10.1	195.03	35.01	0.75
C04	Upper	39392.79	Max WS	1951.76	48.7	54.61		55.99	0.001088	9.43	207.01	35.01	0.68
C04	Upper	38396.56	Max WS	1944.66	47.09	53.97		54.98	0.000687	8.07	240.93	35.01	0.54
C04	Upper	37639.84	Max WS	1945.84	45.86	53.76		54.53	0.00046	7.04	276.4	35.02	0.44
C04	Upper	37544.92	Max WS	1945.9	45.05	53.85		54.47	0.000335	6.31	308.22	35.02	0.38
C04	Upper	37527.21	Max WS	1945.89	44.9	53.56		54.51	0.000571	7.81	249.01	28.77	0.47
C04	Upper	37474.7	Magnolia St	Culvert									
C04	Upper	37409.55	Max WS	1933.92	43.9	48.07	49.01	51.91	0.004562	15.73	122.96	29.51	1.36
C04	Upper	37409.54		Lat Struct									
C04	Upper	37409.53		Lat Struct									
C04	Upper	37384.29	Max WS	1818.91	41.13	48.28		49.1	0.000537	7.27	250.31	35.02	0.48
C04	Upper	36385.86	Max WS	3109.46	39.15	47		48.99	0.001192	11.31	274.97	35.02	0.71
C04	Upper	35394.36	Max WS	3230.52	37.19	46.01		47.71	0.000918	10.46	308.83	35.02	0.62
C04	Upper	34884.2	Max WS	3516.58	35.81	45.41		47.1	0.000869	10.45	336.5	36.81	0.61
C04	Upper	34874.27	Max WS	3516.57	35.78	45.5		47.05	0.000756	9.98	352.3	36.26	0.56
C04	Upper	34826.08	Newland St	Culvert									
C04	Upper	34781.48	Max WS	3513.65	35.53	43.69		45.88	0.001253	11.88	295.69	36.26	0.73
C04	Upper	34771.4	Max WS	3514.26	35.51	43.64		46.01	0.001375	12.34	284.73	35.02	0.76
C04	Upper	34028.57	Max WS	3512.24	34.02	42.38		44.62	0.001269	12	292.57	35.02	0.73
C04	Upper	33871.95	Max WS	3511.66	33.7	42.21		44.37	0.001205	11.79	297.88	35.04	0.71
C04	Upper	33402.87	Max WS	3511.57	32.76	41.79		43.7	0.001031	11.09	316.61	36.61	0.66
C04	Upper	33117.8	Max WS	3571.12	32.19	41.5		43.35	0.000983	10.93	326.77	37.44	0.65
C04	Upper	32829.45	Max WS	3571.1	31.61	41.33		43.02	0.000872	10.43	342.37	38.67	0.62
C04	Upper	32799.44	Max WS	3571.11	31.25	41.4		42.91	0.000712	9.84	363.01	35.75	0.54
C04	Upper	32792.51	Mobile Hon	Culvert									
C04	Upper	32785.65	Max WS	3568.56	31.21	39.13		41.6	0.001457	12.61	283.1	35.75	0.79
C04	Upper	32756.19	Max WS	3568.56	31.15	39.09		41.65	0.001523	12.85	277.8	35.02	0.8
C04	Upper	32711.89	Max WS	3568.56	31.06	39.02		41.57	0.00151	12.81	278.6	35.02	0.8

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C04	Upper	31916.8	Max WS	3567.9	29.46	37.97		40.2	0.001244	11.98	297.85	35.04	0.72
C04	Upper	31867.74	Max WS	3567.9	29.21	38.3		39.34	0.00048	8.18	436.2	48.01	0.48
C04	Upper	31779.18	Hazard/Bea	Culvert									
C04	Upper	31522.47	Max WS	3567.86	27.49	36.01		37.19	0.000583	8.73	408.73	48.01	0.53
C04	Upper	31522.46		Lat Struct									
C04	Upper	31522.45		Lat Struct									
C04	Hazard Ch:	31472.3	Max WS	3046.88	27.32	35.41		37	0.000904	10.11	301.26	37.24	0.63
C04	Hazard Ch:	31472.2		Lat Struct									
C04	Hazard Ch:	31472.19		Lat Struct									
C04	Hazard Ch:	30339.9	Max WS	3044.58	26.14	34.49		35.98	0.000825	9.8	310.7	37.22	0.6
C04	Hazard Ch:	29820.6	Max WS	3041.51	25.56	34.12		35.54	0.000765	9.55	318.51	37.2	0.58
C04	Hazard Ch:	29728.7	Max WS	3040.31	25.36	34.09		35.46	0.000723	9.36	324.77	37.19	0.56
C04	Hazard Ch:	29461.1	Max WS	3036.36	24.84	34.01		35.24	0.000625	8.9	341.12	37.2	0.52
C04	Hazard Ch:	29411.1	Max WS	3481.3	23.49	33.71		35.01	0.000602	9.16	380.09	37.2	0.51
C04	Hazard Ch:	29385.19	Max WS	3481.05	23.42	33.38		34.75	0.000648	9.4	370.4	37.21	0.53
C04	Hazard Cul	31472.3	Max WS	520.96	27.32	35.41	29.77	35.62	0.00046	3.62	144.1		0.22
C04	Hazard Cul	30339.9	Max WS	521	26.14	34.89	28.59	35.09	0.00046	3.62	144.1		0.22
C04	Hazard Cul	29820.6	Max WS	521.03	25.56	34.65	28.01	34.85	0.000461	3.62	144.04		0.21
C04	Hazard Cul	29728.7	Max WS	521.03	25.36	34.61	27.81	34.81	0.00046	3.62	144.1		0.21
C04	Hazard Cul	29461.1	Max WS	521.03	24.84	34.48	27.29	34.69	0.00046	3.62	144.1		0.21
C04	Hazard Cul	29411.1	Max WS	521.03	23.49	34.46	25.94	34.67	0.00046	3.62	144.1		0.19
C04	Hazard Cul	29385.19	Max WS	521.03	23.42	34.41	25.87	34.61	0.00046	3.62	144.1		0.19