TOWN OF DUCK NORTH CAROLINA
SHORELINE & VOLUME CHANGE
MONITORING REPORT

Submitted to:

TOWN OF DUCK

Submitted By:

Aptim Coastal Planning & Engineering of north Carolina, Inc.

May 2018

2017 TOWN OF DUCK
SHORELINE & VOLUME MONITORING REPORT

EXECUTIVE SUMMARY

The Town of Duck is located on the Outer Banks of North Carolina roughly 27 miles south-southeast of the North Carolina and Virginia border. The Town extends along 5.9 miles of Atlantic Ocean shoreline from the Dare County and Currituck County line south to the Town of Southern Shores.

Data collected in December 2017 was used to update shoreline and volume change analyses that have been conducted since 2013 including the feasibility study (CPE-NC, 2013), the design analysis associated with the beach nourishment project (CPE-NC, 2015), and the 2015 Town-wide monitoring (CPE-NC, 2016).

In addition to providing information on the general condition and behavior of the Duck shoreline, the monitoring program is also designed to track the performance of the beach fill project constructed between May and June 2017. The beach fill project placed a total of 1,263,181 cubic yards along 1.6 miles of the Town's shoreline between profile stations D-10 and D-19. For purposes of monitoring the performance of the beach fill, the December 2017 survey was adopted as the starting point to which future changes will be referenced. Based on a comparison of the Pre-construction survey obtained in April 2017 and the December 2017 monitoring survey, the volume of beach fill material on the active profile in December 2017 was 966,300 cubic yards.

The following summarizes shoreline changes between October 1996, September 2013, May 2015, and December 2017 and volumetric changes measured between September 2013, May 2015, and December 2017.

Average Mean High Water (+1.2' NAVD) Shoreline Changes (feet/year)

	Sept. 2013 to May 2015	May 2015 to Dec. 2017	Oct 1996 to Dec. 2017
Project Area (D-10 to D-19)	2.2	44.0	4.4
Monitoring Area (PI-17 to SS-02)	-2.6	13.5	1.2

Volumetric Changes above -24' NAVD (cubic yards/ft./year)

	May 2015 to Dec. 2017	Sept. 2013 to Dec. 2017
Project Area (D-10 to D-19)	46.2	26.7
Monitoring Area (PI-17 to SS-02)	14.7	6.6

Volumetric Changes above -24' NAVD (cubic yards)

	May 2015 to Dec. 2017	Sept. 2013 to Dec. 2017
Project Area (D-10 to D-19)	1,039,200	1,027,100
Monitoring Area (PI-17 to SS-02)	1,343,100	947,400

In general, the shoreline change analysis showed the monitoring area (PI-17 to SS-02) experienced a net positive change in the position of the MHW shoreline from May 2015 to December 2017. As delineated in the table above, the monitoring area advanced seaward at an average shoreline change rate of 13.5 ft./yr., while the shoreline within the project area (D-10 to D-19) experienced an advance of 44.0 ft./yr., primarily as a result of the beach nourishment project that was completed in June 2017.

The total volumetric change measured between May 2015 and December 2017 above the -24.0 ft. NAVD contour within the monitoring area (Stations PI-17 to SS-02) was a gain of 1,343,100 cubic yards, or 519,800 cubic yards per year. This translates into an average volume change rate of 14.7 cy/ft./yr. (accretion) throughout the monitoring area. The volume change within the project area (Stations D-10 to D-19) was a gain of approximately 1,039,200 cubic yards in the 2.6 year span.

The long-term volumetric change measured over the 4.3-year period between September 2013 and December 2017 within the monitoring area (PI-17 to SS-02) was a gain of 947,000 cubic yards, or 222,900 cubic yards per year above the -24.0 ft. NAVD contour. This translates into an average volume change rate of 6.6 cy/ft./yr. (accretion) throughout the monitoring area. Again, this gain is largely influenced by the beach nourishment project completed in June 2017. The long-term changes within the project area (D-10 to D-19) over the 4.3-year period was a volumetric gain of approximately 1,027,100 cubic yards.

The previous Town-wide monitoring report (CPE-NC, 2016) updated the SBEACH storm vulnerability analysis based on the May 2015 beach profile survey data. The updated analysis identified the beach areas between Stations D-9 to D-11 (Pelican Way to Ocean Pines Dr.) and D-25 to D-29 (Sea Colony Dr. to Ocean Front Dr.) as having experienced an increase in the number of vulnerable structures. The recent changes computed between May 2015 and December 2017 show the D-9 to D-11 shoreline advanced seaward at 18.5 ft./yr. and gained approximately 197,500 cubic yards. The recent changes are a reversal from the changes measured between September 2013 and May 2015 in which the area was experiencing a shoreline recession rate of -0.9 ft./yr. and a volume loss rate of -29.8 cy/ft./yr. This reversal is primarily driven by the construction of the beach fill project, completed in June 2017. The beach from D-25 to D-29 experienced shoreline advance at 1.4 ft./yr. and an approximate gain of 189,900 cubic yards between May 2015 and December 2017. These recent changes between Stations D-25 to D-29, which are not likely related to the beach fill project, are a reversal from the -11.3 ft./yr. average shoreline recession rate and -25.2 cy/ft./yr. average volume change rate measured between September 2013 and May 2015. The SBEACH vulnerability analysis was not updated for this report, however, the recent positive trends in the two areas has likely reduced the number of vulnerable structures previously identified.

2017 TOWN OF DUCK
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I. INTRODUCTION

The Town of Duck is focused on a long-term shoreline management program that will serve to sustain the beaches that support a significant portion of their local economy, maintains the tax base of the Town, retains existing recreational resources, and protects existing natural resources. In order to accomplish these stated goals, the Town is taking steps to maintain and monitor its oceanfront beach and dune to a configuration that provides a reasonable level of storm damage reduction to public and private development and mitigates long-term erosion impacts.

This monitoring report is an update to the previous monitoring report prepared for the Town (CPE-NC, 2016) and describes the analysis of beach profile data for shoreline changes measured in October 1996, September 2013, May 2015, and the recent data collected in December 2017. The report also evaluates volume change trends measured between September 2013, May 2015, and December 2017 along the Town's shoreline. The data and analysis in this report will be utilized as a basis of comparison for future physical monitoring of the Town of Duck.

Future monitoring reports will also track the performance of the beach fill project constructed between May and June 2017. The beach fill project covered 1.6 miles of the Town's shoreline between profile stations D-10 and D-19.

II. PROJECT LOCATION

The Town of Duck is located on the Outer Banks of North Carolina roughly 27 miles south-southeast of the North Carolina and Virginia border. The Town encompasses 5.5 square miles extending along 5.9 miles of Atlantic Ocean shoreline from the Dare County and Currituck County line south-southeast to the Town of Southern Shores. The USACE Field Research Facility (FRF) is located within the Town limits, approximately 2.3 miles north of the southern limit and 3.6 miles south of the northern limit. A Location Map is provided in Figure 1. This location map highlights the limits of the nourishment project built along a 1.6-mile section of the Town's oceanfront shoreline between May 23 and June 29, 2017, and the two Outer Continental Shelf (OCS) borrow areas located in Federal waters offshore of Dare County.

While only 1.6 miles of the Town's shoreline was directly impacted by the beach nourishment project, the beach monitoring program includes the entire 5.9 miles of the Town's shoreline as well as small segments of the Pine Island and Southern Shores shorelines north and south of the Duck town limits, respectively. The extent of the survey coverage is intended to provide the Town with information on shoreline behavior that will be used to determine how well the beach nourishment project performs and if other segments of the Town's shoreline should be included in future beach nourishment efforts.

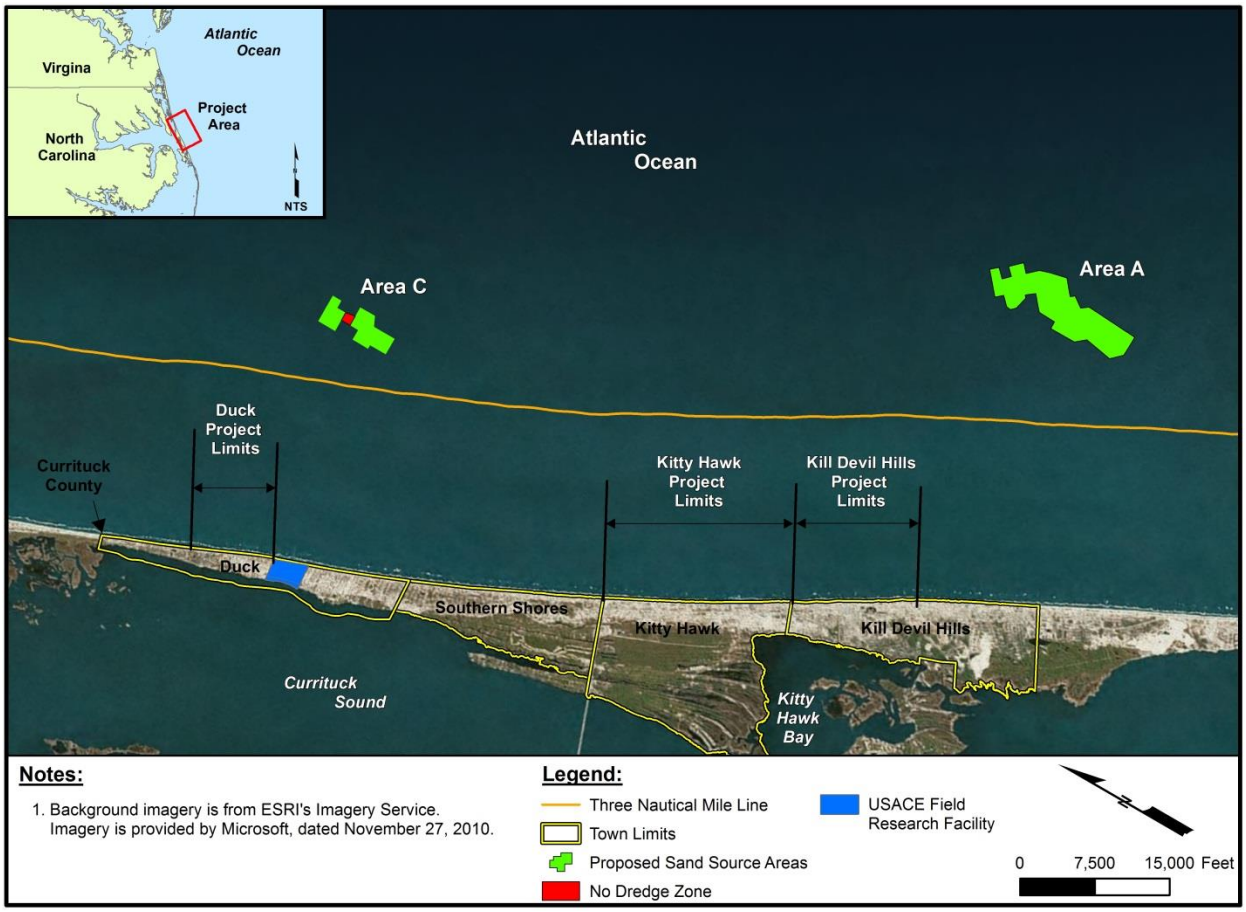


Figure 1. Project Location Map.

III. SURVEY DATA COLLECTION

Beach profile surveys were conducted along the Town's approximately 5.9 mile ocean shoreline in November 2011, September 2013, May 2015, and December 2017. These surveys were conducted to monitor the condition of the beach, analyze the vulnerability of existing development and infrastructure with respect to potential damages associated with long-term shoreline recession and impacts from coastal storms, and evaluate the performance of a beach fill completed in June 2017 along a portion of the Town's shoreline. Additionally, the database of beach profiles is used to calculate short and long-term volume and shoreline change rates and will assist in identifying patterns of volumetric and shoreline change along the Town's shoreline. The surveys consist of a total of 34 profiles with a spacing of roughly 1,000 feet. In addition, two profiles were surveyed both north and south of the Town limits to evaluate adjacent trends that might impact project formulation should these areas be included in future erosion mitigation plans. In all, a total of 38 profiles, encompassing 35,000 feet of shoreline, were surveyed as part of this project. Survey data were collected along transects listed in Table 1. Coordinates shown in Table 1 are referenced to the North Carolina State Plane coordinate system in feet NAD83 and the profile azimuth refers to degrees referenced to true north. Transects listed in Table 1 are shown graphically in Figure 2 through Figure 5. The 2017 Town of Duck Beach Profile Survey Report is provided as Appendix A.

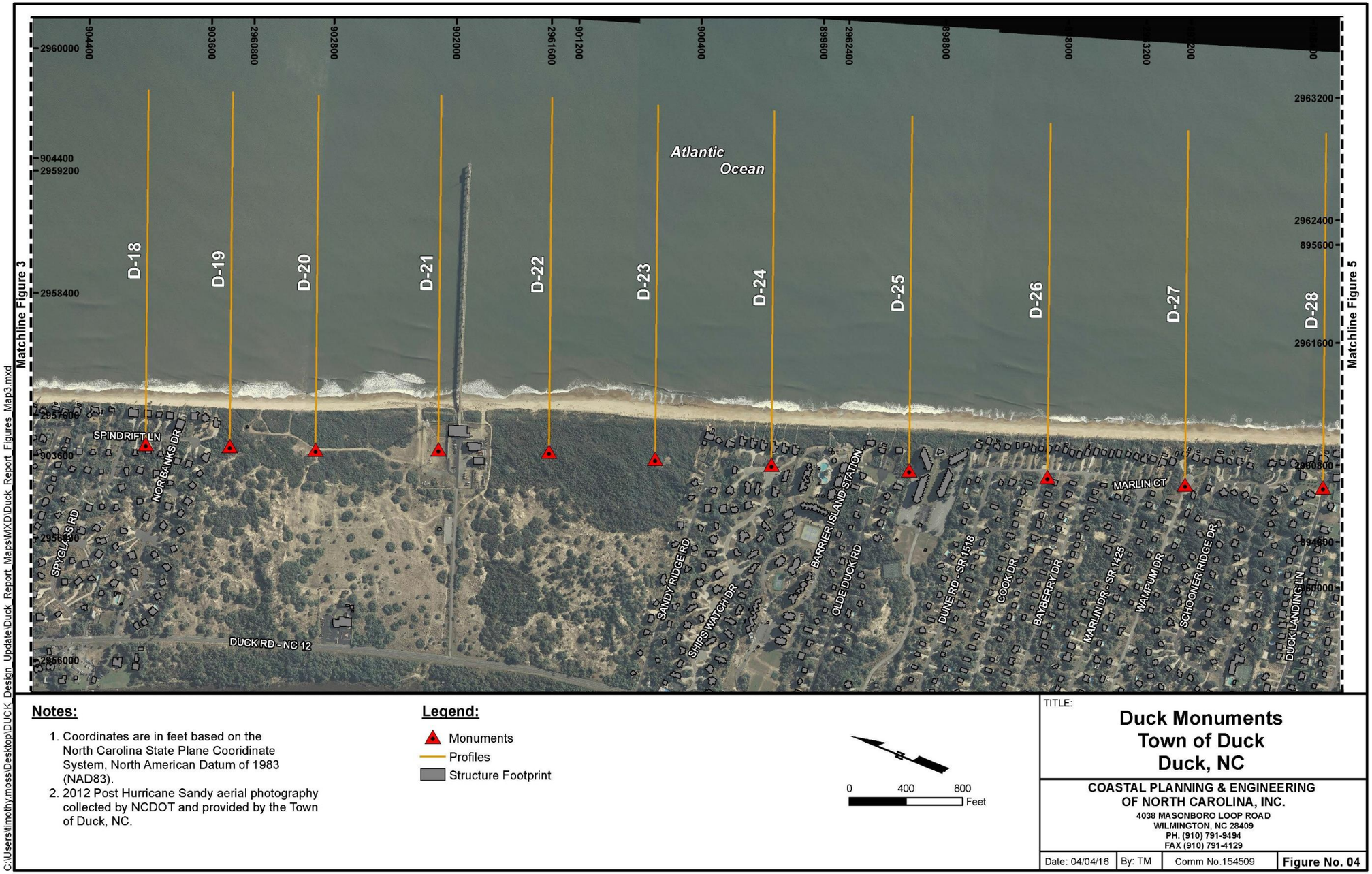
Table 1. Profile Survey Baseline and Azimuth

Profile[(1)]	Easting	Northing	Azimuth
PI-17	2950657.3	920098.9	70
PI-18	2951026.0	919175.4	70
D-01	2951387.5	918267.7	70
D-02	2951733.8	917384.4	70
D-03	2952103.0	916429.4	70
D-04	2952464.0	915495.3	70
D-05	2952849.3	914598.0	70
D-06	2953224.4	913696.9	70
D-07	2953607.3	912798.8	70
D-08	2953983.0	911897.9	70
D-09	2954356.7	910994.8	70
D-10	2954759.1	910066.7	70
D-11	2955158.1	909133.1	70
D-12	2955461.4	908412.5	70
D-13	2955874.3	907478.4	70
D-14	2956252.1	906578.3	70
D-15	2956628.6	905677.8	70
D-16	2956978.7	904767.7	70
D-17	2957333.7	903863.9	70
D-18	2957718.8	902886.5	70
D-19	2957932.5	902331.0	70
D-20	2958139.7	901760.7	70
D-21	2958472.1	900958.7	70
D-22	2958754.0	900228.8	70
D-23	2958992.7	899515.6	70
D-24	2959267.2	898739.8	70
D-25	2959601.7	897824.3	70
D-26	2959928.6	896902.3	70
D-27	2960250.6	895981.9	70
D-28	2960604.1	895073.0	70
D-29	2960963.6	894166.2	70
D-30	2961317.7	893257.6	70
D-31	2961676.7	892350.7	70
D-32	2962078.1	891379.4	70
D-33	2962439.4	890553.2	70
D-34/-197+12	2962839.6	889616.1	70
SS-01/-187+14	2963230.4	888697.7	70
SS-02/-177+13	2963619.0	887775.8	70

[(1)]PI-Pine Island transects; D-Duck transects; SS-Southern Shores transects

Figure 2. Profile Survey Baseline and Azimuth PI-17 to D-7

Figure 3. Profile Survey Baseline and Azimuth D-8 to D-17



Notes:

1. Coordinates are in feet based on the North Carolina State Plane Cooridinate System, North American Datum of 1983 (NAD83).
2. 2012 Post Hurricane Sandy aerial photography collected by NCDOT and provided by the Town of Duck, NC.

Legend:

- Monuments
- Profiles
- Structure Footprint

TITLE:

Duck Monuments
Town of Duck
Duck, NC

COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA, INC.
4038 MASONBORO LOOP ROAD
WILMINGTON, NC 28409
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Date: 04/04/16	By: TM	Comm No.154509	Figure No. 04

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Figure 4. Profile Survey Baseline and Azimuth D-18 to D-28

Notes:

1. Coordinates are in feet based on the North Carolina State Plane Cooridinate System, North American Datum of 1983 (NAD83).
2. 2012 Post Hurricane Sandy aerial photography collected by NCDOT and provided by the Town of Duck, NC.

Legend:

- Monuments
- Profiles
- Structure Footprint

0 400 800 Feet

TITLE:

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Date: 04/04/16	By: TM	Comm No.154509	Figure No. 05

Figure 5. Profile Survey Baseline and Azimuth D-29 to SS-02

The profile surveys conducted by Aptim Coastal Planning & Engineering of North Carolina, Inc. (APTIM – formerly CPE-NC) in September 2013, May 2015, and December 2017, extended landward until a structure was encountered or to a range 50 feet beyond the landward toe of dune, whichever was more seaward. Elevation measurements were also taken seaward along the profile to at least the -30-foot NAVD contour. Upland data collection included all grade breaks and changes in topography to provide a representative description of the conditions at the time of the work. The maximum spacing between data records along individual profiles was 25 feet. The upland survey extended into wading depths sufficiently to allow the offshore portion to overlap the upland portion by a minimum of 50 feet.

IV. SHORELINE CHANGES

A shoreline change analysis was completed to assess shoreline advance and recession along the study area. The shoreline is typically defined as a specified elevation contour. For this study, the shoreline was defined as the Mean High Water (MHW) contour, which represents the +1.2-foot NAVD elevation (CPE-NC, 2015). Shoreline change is calculated by comparing shoreline position along shore perpendicular transects. Typically, shoreline change is then annualized to describe recession and advance rates. Regardless of whether total or annual shoreline changes are described, positive shoreline change denotes seaward advance while negative shoreline change indicates landward recession.

The analysis discussed in this report evaluated the MHW positions for the following surveys: October 1996 (LiDAR), and profile surveys obtained in September 2013, May 2015, and December 2017. The MHW position for each survey was identified along shore perpendicular transects spaced at approximately 1,000-foot intervals at the profiles identified in Table 1 along the monitoring area.

The linear changes in the shoreline position represented by the MHW contour can vary considerably along the monitoring area and can sometimes differ from volume change trends along sections of a beach. This difference is often due to changes in the slope of the foreshore along the beach from one end of the monitoring area to the other. As shown in Figure 6, the position of the MHW location on the profile can vary greatly depending on the shape of the profile at the time of the survey.

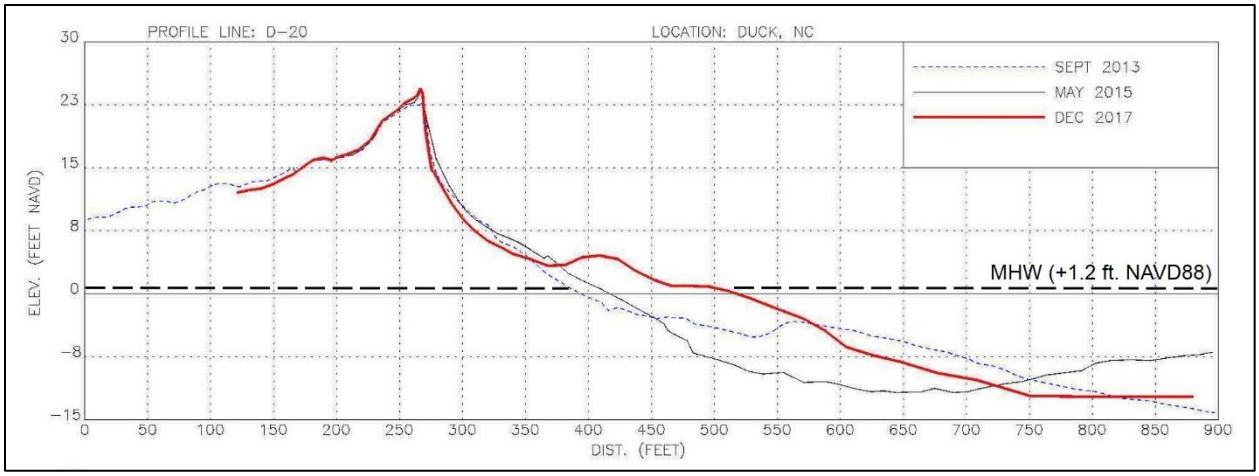

Figure 6. MHW Shoreline Change Variations

Shoreline change is provided as a rate in an annualized form by dividing the shoreline change by the time period (number of years) between survey events (i.e. feet per year). These rates are described in terms of positive ("+") or advance (shoreline moving seaward) and negative ("-") or recession (shoreline moving landward).

May 2015 to December 2017

The average shoreline change within the monitoring area (PI-17 to SS-02) between May 2015 and December 2017, a time period that included the Duck beach fill project, was 34.8 feet (shoreline advanced seaward) and represents an equivalent average annual shoreline change rate of +13.5 feet per year. This is a significant change in the shoreline behavior observed during the previous monitoring period (September 2013 to May 2015) which did not include the effects of the beach fill project. Prior to the construction of the 2017 beach fill project, the average shoreline change within the monitoring area was a recession rate of -2.6 ft./yr.

The average shoreline change rate was also calculated at +44.0 ft./yr. for the project area (D-10 to D-19) in which fill was placed as part of the 2017 beach nourishment project. This is a significant increase from the +2.2 ft./yr. change rate that was measured in the same area between September 2013 and May 2015. Long-term changes over the 21 year period from October 1996 to December 2017 within the monitoring area (PI-17 to SS-02) and the project area (D-10 to D-19) show average shoreline change rates of +1.2 ft./yr. and +4.4 ft./yr., respectively. Table 2 shows the measured change rates at each profile location. Figure 7 graphically displays the variability of changes along the Town's shoreline between the short-term change rates measured from September 2013 to May 2015 and May 2015 to December 2017 and the long-term rates calculated between October 1996 and December 2017.

Although the average shoreline change rates calculated between May 2015 and December 2017 were positive for the monitoring and project areas, a profile-by-profile comparison shows a wide range in the rate of change along the shoreline outside of the project area. The shoreline changes within the monitoring area ranged from an advance of 12.8 ft./yr. between Stations D-05 and D-

08 (south end of Station Bay Dr. to Waxwing Ct.) to a recession of -19.6 ft./yr. between Stations D-23 and D-24 (the southern portion of the USACE Field Research Facility and Ship Watch Dr.). The highest recession rates were measured at Stations D-09 (-17.0 ft./yr.), D-23 (-27.7 ft./yr.) and D-30 (-20.2 ft./yr.).

The 2015 monitoring report (CPE-NC, 2016), identified two (2) main areas of erosion based on the shoreline changes that occurred between the September 2013 and May 2015 monitoring surveys. The first area was located in the northern portion of the monitoring area between PI-17 and D-11 (Pine Island to Ocean Pines Dr.) which experienced an erosion rate of -6.4 ft./yr. The second area was along the southern portion of the monitoring area between D-25 and SS-01 (Sea Colony Dr. to Southern Shores) which was eroding at a rate of -4.7 ft./yr. The recent changes from May 2015 to December 2017 show the shoreline along the northern area advanced an average of 26.2 ft. seaward while the second or southern area advanced at an average rate of 1.0 ft./yr. There was one exception in the southern area located in the vicinity of D-30 (Lala Ct.) where the shoreline migrated landward a distance of 52.1 ft., or a rate of -20.1 ft./yr., when annualized from May 2015 to December 2017. A discussion of the changes observed at D-30 is provided later in this report.

The previous Town-wide monitoring report (CPE-NC, 2016) also updated the SBEACH storm vulnerability analysis which was initially presented in the May 2013 feasibility report (CPE-NC, May 2013). The updated analysis, which was based on the May 2015 beach profile survey data, identified the beach areas between Stations D-09 to D-11 (Pelican Way to Ocean Pines Dr.) and D-25 to D-29 (Sea Colony Dr. to Ocean Front Dr.) as having experienced an increase in the number of vulnerable structures relative to those identified in the feasibility report (CPE-NC, 2013). However, the recent changes measured between May 2015 and December 2017 show the shoreline between D-09 to D-11 advanced seaward an average distance of 48 ft. This reversal is attributed primarily to the construction of the beach fill project, completed in June 2017. The average shoreline change for the area between Station D-25 to D-29 advanced seaward 3.7 ft. between May 2015 and December 2017. These changes are not likely related to the beach fill project. Given the recent shoreline changes, some of the structures identified as being vulnerable in the SBEACH analysis (CPE-NC, 2016) may now be outside the storm impact area.

In general, the average shoreline change rates within both the monitoring area and project area experienced shoreline advance during the short-term period from May 2015 to December 2017. Furthermore, due to the shoreline advance that occurred as a result of the 2017 beach nourishment project between Stations D-10 and D-19, the long-term shoreline change between October 1996 and December 2017 measured an advance of the shoreline at a rate of 1.2 feet per year within the monitoring area. This rate is a reversal from the previous long-term rates measured by comparing the long-term rates from 1996 to 2011, 2012, 2013, and 2015, which were -0.6 ft./yr., -1.4 ft./yr., -0.3 ft./yr., and -0.5 ft./yr., respectively.

Over the long-term period from 1996 to 2017, the rates of change within specific segments of the monitoring area ranged from an advance of 3.5 ft./yr. between Stations D-07 and D-20 (Waxwing Ln. to the USACE Field Research Facility) to a recession of -1.7 ft./yr. between Stations D-25 and D-27 (Sea Colony Dr. to Wampum Dr.).

Table 2. MHW Shoreline Changes

PROFILE	EFFECTIVE DISTANCE (FT)	MHW SHORELINE CHANGES (FT/YR)		
		SEPT. 2013 TO MAY 2015	MAY 2015 TO DEC. 2017	OCT. 1996 TO DEC. 2017
PI-17	497	-3.2	20.9	2.8
PI-18	985	-21.9	-5.9	0.3
D-01	963	-4.3	6.2	1.5
D-02	986	4.5	-3.0	0.7
D-03	1,012	-25.0	13.4	1.1
D-04	988	13.7	-6.6	-1.7
D-05	975	-32.3	20.3	-1.2
D-06	975	-9.9	7.7	-0.6
D-07	975	-2.3	10.3	0.9
D-08	976	-0.3	12.7	2.1
D-09	993	21.8	-17.0	1.2
D-10	1,012	-19.4	28.2	4.0
D-11	897	-5.1	44.3	7.1
D-12	900	21.3	33.4	7.5
D-13	997	20.1	41.8	6.4
D-14	975	-4.1	66.3	6.3
D-15	975	14.5	47.7	5.3
D-16	973	-15.0	63.0	2.7
D-17	1,010	-1.5	44.9	0.6
D-18	823	0.5	39.7	2.2
D-19	601	10.3	30.9	1.9
D-20	737	12.4	23.3	0.8
D-21	825	-27.6	15.8	-1.3
D-22	767	-23.2	1.8	-1.0
D-23	787	10.8	-27.6	-0.1
D-24	899	14.5	-11.6	0.5
D-25	976	-6.5	2.2	-1.3
D-26	977	-23.7	12.3	-2.2
D-27	975	-23.3	0.8	-1.7
D-28	975	-3.2	-4.2	0.3
D-29	975	0.4	-4.0	1.2
D-30	975	39.0	-20.1	1.7
D-31	1,013	-17.0	8.9	0.5
D-32	975	-6.3	4.0	-1.4
D-33	959	-4.9	1.7	-1.0
D-34	1,007	-12.6	12.2	0.8
SS-01	998	6.6	-2.6	-0.8
SS-02	500	1.9	-0.9	0.0
PROJECT AREA (D-10 TO D-19)	8,358	2.2	44.0	4.4
MONITORING AREA (PI-17 TO SS-02)	34,808	-2.6	13.5	1.2

Project Area

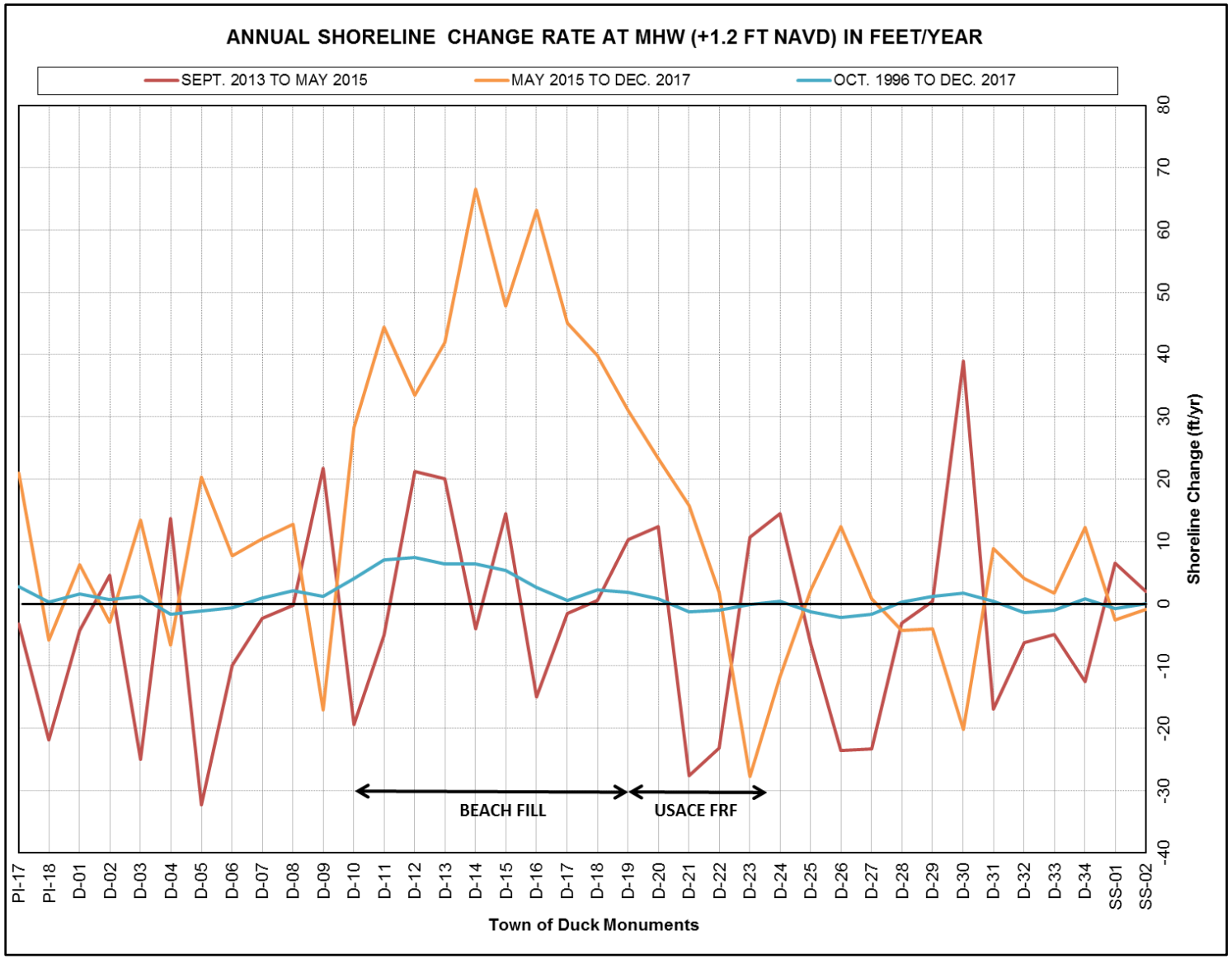

Figure 7. Comparative graph of historical MHW (+1.2 FT NAVD) shoreline change rates in Feet/Year.

V. VOLUMETRIC CHANGES

Volumetric changes discussed in this report represent the change in the quantity of sediment measured through comparison of the September 2013, May 2015, and December 2017 beach profile monitoring surveys. The volumetric changes for this monitoring period were evaluated between the May 2015 and December 2017 surveys, a span of 2.6 years; whereas the long-term changes were calculated over the 4.3 year period between September 2013 and December 2017. All volumetric changes are given in cubic yards and volumetric change rates have been normalized to an annual rate and are given in cubic yards per linear foot of shoreline per year. Volumetric changes are calculated between the dunes (upland) and the -24.0 foot NAVD contour. The volumetric changes for the Town of Duck are listed in **Error! Reference source not found.** and illustrated in **Error! Reference source not found.**.

Volumetric changes provided in this report include the impact of the Town of Duck beach fill project, constructed between May and June 2017 with the placement of 1,263,181 cubic yards of sand in the project area (Stations D-10 to D-19).

May 2015 to December 2017 (2.6 years)

The total volumetric change in the monitoring area (PI-17 to SS-02) calculated above the -24 ft. contour between May 2015 and December 2017 was a gain of approximately 1,343,100 cubic yards, or an annual rate of 519,800 cy/yr. This is equivalent to an average volume change rate of 14.7 cy/ft./yr. (accretion) throughout the monitoring area over the 2.6 year period. The individual rates of volume change along the monitoring area (excluding the beach fill project area) were predominantly positive, but varied from a gain of 14.6 cy/ft./yr. between Stations D-03 and D-08 (S. Baum Trl. to Waxwing Ct.) to a loss of -50.2 cy/ft./yr. at Station D-30 (LaLa Ct.). The highest erosion rates were measured at Stations D-09 (-19.3 cy/ft./yr.), D-23 (-41.3 cy/ft./yr.), D-24 (-24.8 cy/ft./yr.) and D-30 (-50.2 ft./yr.), as shown in Table 3.

The profile at D-30 exhibited the highest rate of erosion between May 2015 and December 2017. During the previous monitoring period (September 2013 to May 2015) this profile saw a positive volume change rate of +80.4 cy/ft./yr, which was the highest positive volume change measured. The profile to the north (D-29) experienced a negative rate of -55 cy/ft./yr. during that same period. The recent results show a reversal of volume change at these two profiles where D-29 experienced a positive volume change rate of -27.6 cy/ft./yr. between May 2015 and December 2017 and D-30 experienced a negative volume change rate of -50.2 cy/ft./yr. during the same period. Inspections of the beach profile cross sections indicate the erosion at profile D-30 is a result of the berm eroding and a lowering of the nearshore profile between May 2015 and December 2017. In May 2015, the width of the berm at D-30 was significantly larger than on the adjacent profiles, due to the significant accretion that took place between September 2013 and May 2015. The December 2017 profiles generally appear more uniform. This may be due to seasonal changes or the natural redistribution of the accreted material to adjacent portions of the beach.

Table 3. Volumetric Changes above -24 FT NAVD

PROFILE	EFFECTIVE DISTANCE (FT)	VOLUMETRIC CHANGES (CY/FT/YR)	
		MAY 2015 TO DEC. 2017	SEPT. 2013 TO DEC. 2017
PI-17	497	12.6	3.3
PI-18	985	-5.6	-16.4
D-01	963	2.3	-3.1
D-02	986	-8.7	-5.2
D-03	1,012	24.4	1.8
D-04	988	2.1	-5.0
D-05	975	28.1	-4.3
D-06	975	-2.9	-9.0
D-07	975	15.3	-1.9
D-08	976	20.3	-2.2
D-09	993	-19.3	-1.9
D-10	1,012	30.6	1.7
D-11	897	78.7	20.4
D-12	900	18.9	23.4
D-13	997	33.0	33.0
D-14	975	69.5	42.9
D-15	975	52.2	36.6
D-16	973	69.4	34.6
D-17	1,010	33.1	27.8
D-18	823	45.1	29.4
D-19	601	31.8	17.1
D-20	737	22.4	15.0
D-21	825	0.2	10.8
D-22	767	15.0	5.1
D-23	787	-41.3	1.2
D-24	899	-24.8	-0.2
D-25	976	7.0	3.9
D-26	977	27.5	6.1
D-27	975	16.1	-2.3
D-28	975	-6.6	-8.3
D-29	975	27.6	-4.9
D-30	975	-50.2	0.9
D-31	1,013	11.5	4.3
D-32	975	6.7	3.0
D-33	959	0.0	-5.2
D-34	1,007	23.5	0.5
SS-01	998	-0.9	-2.5
SS-02	500	-7.8	-1.4
PROJECT AREA (D-10 TO D-19)	8,357	46.2	26.7
MONITORING AREA (PI-17 TO SS-02)	34,808	14.7	6.6

Project Area

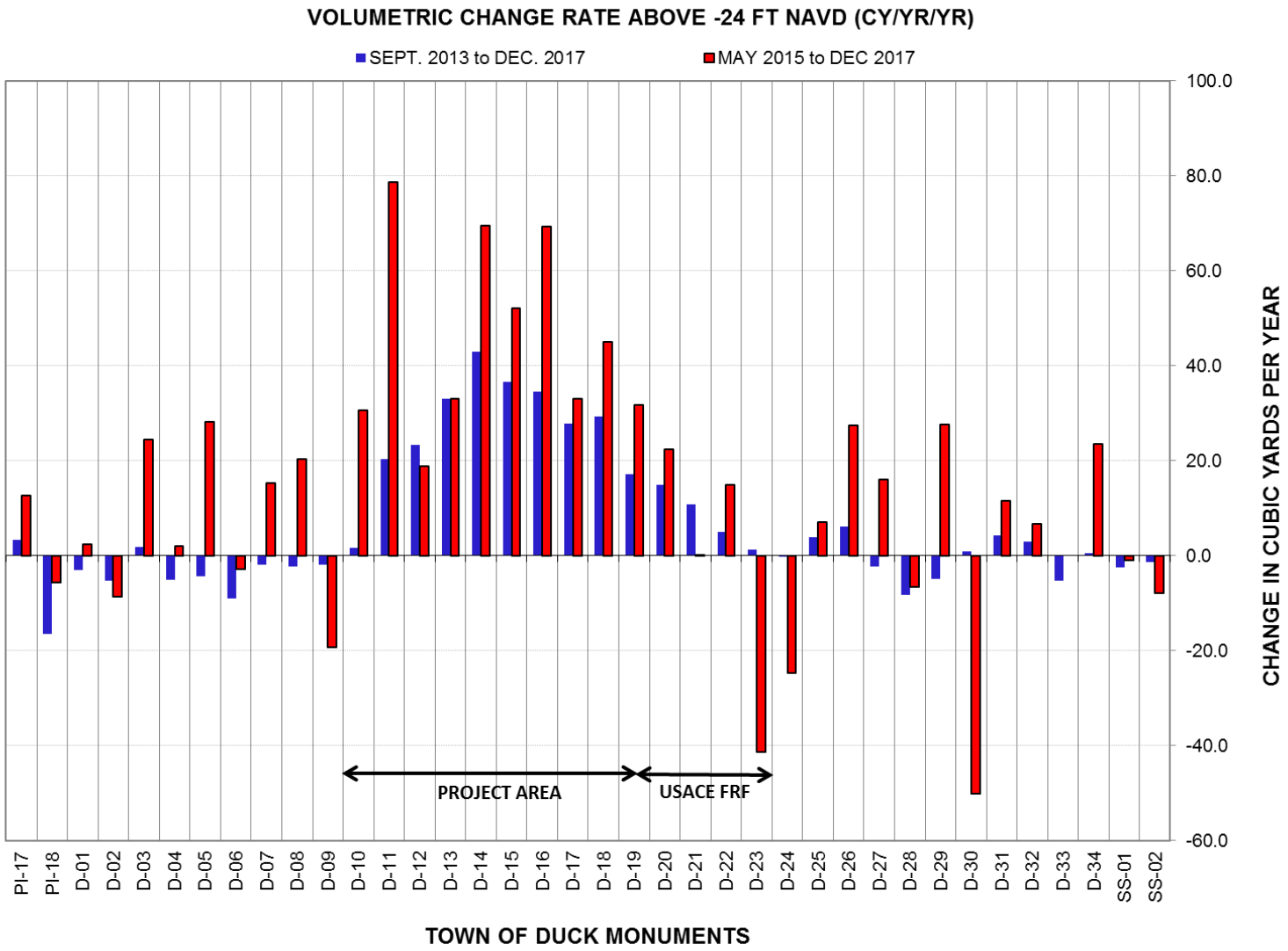

Figure 8. Annual Volumetric Change Rates Above -24 FT NAVD (CY/FT/YR).

Recent investigations performed by APTIM of the offshore areas adjacent to the Towns of Kitty Hawk and Kill Devil Hills suggest that topographic features (shoals and depressions) located offshore of the depth of closure may be influencing local areas of beach erosion and accretion. At present, it is unclear if such features are present in this particular location offshore of the Town of Duck; however, such features could be contributing to the changes observed in the vicinity of profiles D-29 and D-30.

Within the project area (D-10 to D-19), which as noted above received 1,263,181 cubic yards of beach fill between May and June 2017, there was a volumetric gain of approximately 1,039,200 cubic yards in the 2.6 year span. **Error! Reference source not found.** includes the individual rates calculated along each profile. A profile-by-profile comparison of the volume change rate in cy/ft./yr. is provided in **Error! Reference source not found.**. **Error! Reference source not found.** also includes volume change rates measured between September 2013 and December 2017, which are discussed later in this report.

The 2016 monitoring report (CPE-NC, 2016) identified two (2) main areas of erosion within the monitoring area. One area was in the northern portion between PI-17 and D-11 (-25.6 cy/ft./yr.) and the second along the southern portion between D-25 and SS-01 (-9.9 cy/ft./yr.). Based on the volume changes computed between the May 2015 and December 2017 monitoring surveys, the volume change trends in these two areas reversed. For the area between PI-17 and D-11 (Pine Island to Ocean Pines Dr.) and the area from D-25 to SS-01 (Sea Colony Dr. to Southern Shores) volumetric changes were accretionary at rates of 13.7 cy/ft./yr. and 5.7 cy/ft./yr., respectively.

The previous Town-wide monitoring report (CPE-NC, 2016) updated the SBEACH storm vulnerability analysis based on the May 2015 beach profile survey data. The updated analysis identified the beach areas between Stations D-9 to D-11 (Pelican Way to Ocean Pines Dr.) and D-25 to D-29 (Sea Colony Dr. to Ocean Front Dr.) as having experienced an increase in the number of vulnerable structures compared to the analysis performed during the feasibility study (CPE-NC, 2013. The recent changes computed between May 2015 and December 2017 show a gain of approximately 212,700 cubic yards between Stations D-9 and D-11, equivalent to an average volume change rate of 30 cy/ft./yr. (accretion). The recent changes are a reversal from the -29.8 cy/ft./yr. average volume change rate measured between September 2013 and May 2015, which is attributed primarily to the construction of the beach fill project completed in June 2017. The area between Stations D-25 to D-29 experienced an approximate gain of 180,300 cubic yards, equivalent to an average volume change rate of 14.3 cy/ft./yr. (accretion) between May 2015 and December 2017. These recent changes between Stations D-25 to D-29 are a reversal from the average -25.2 cy/ft./yr. erosion rate calculated between September 2013 and May 2015; however, these changes are not directly attributed to the beach fill project completed in June 2017.

While the SBEACH analysis was not updated for this report, the positive volumetric changes observed between Pelican Way and Ocean Pines Dr. (D-9 to D-11) and between Sea Colony Dr. and Ocean Front Dr. (D-25 to D-29), has likely reduced the number of vulnerable structures previously identified.

September 2013 to December 2017 (4.3 years)

The total volumetric change in the monitoring area (PI-17 to SS-02) between September 2013 and December 2017 was calculated to be a gain of approximately 947,400 cubic yards, or 222,900 cubic yards per year. This translates into an average volume change rate of 6.6 cy/ft./yr. (accretion) throughout the monitoring area. The changes within the project area (D-10 to D-19) also measured a volumetric gain of approximately 1,027,100 cubic yards in the 4.3 year span, or 241,600 cubic yards per year. This translates into an average volume change rate of 26.7 cy/ft./yr. (accretion) throughout the project area. These volumetric changes are illustrated in Figure 8. Table 3 includes the individual rates calculated along each profile.

Although the average volume changes calculated between September 2013 and December 2017 were positive for the monitoring and project areas, a review of the changes at each profile shows the rate of change along the shoreline outside of the 2017 project area (Stations D-10 to D-19) varied between September 2013 and December 2017. The volume change rates within the monitoring area (Stations PI-17 to SS-02) range from 4.5 cy/ft./yr. (accretion) between Stations D-21 and D-26 (the USACE Field Research Facility Pier to Cook Dr.) to -8.2 cy/ft./yr. (erosion) between Stations PI-18 and D-02 (Pine Island and N Baum Trl.). The highest erosion rates were measured at Stations PI-18 (-16.4 cy/ft./yr.), D-06 (-9.0 cy/ft./yr.) and D-28 (-8.3 cy/ft./yr.).

As previously mentioned, two (2) main areas of erosion were identified within the monitoring area in the previous monitoring report (CPE-NC, 2016). These areas were between Stations PI-17 and D-11 (Pine Island to Ocean Pines Dr.) and D-25 and SS-01 (Sea Colony Dr. to Southern Shores). Annualized erosion rates between September 2013 to May 2015 were -25.6 cy/ft./yr. and -9.9 cy/ft./yr., respectively. The volumetric changes calculated for the 4.3-year period form September 2013 to December 2017 show a significantly lower erosion rate. For the area between PI-17 and D-11, the long-term rate between September 2013 and December 2017 was -1.7 cy/ft./yr. while the long-term volume change rate between Stations D-25 and SS-01 was-0.4 cy/ft./yr.

Beach Fill Performance

The performance of the 2017 beach fill project along the Town of Duck will be based on changes that occur relative to the conditions depicted by the December 2017 monitoring survey. While the beach fill project was completed in June 2017, beach fill projects typically undergo an initial period of profile adjustment in which material placed on the upper portion of the profile is redistributed to lower portions of the profile in response to tide and wave conditions. In addition to the onshore-offshore profile adjustments, some of the beach fill material is removed from the ends of the fill and distributed to the adjacent shorelines. Once these initial adjustments occur, the performance of the beach fill typically begins to mimic the behavior of a natural beach. Therefore, for purposes of monitoring the performance of the beach fill, the volume of the beach fill material on the active profile determined from comparison of the Pre-Construction survey obtained in April 2017 with the December 2017 monitoring survey will be used to represent the initial volume of material in the beach fill project. In this regard, the volume of beach fill material remaining on the active beach profile as of December 2017 was 966,300 cubic yards.

VI. SUMMARY AND RECOMMENDATIONS

This monitoring report evaluated shoreline and volume changes along the 5.9 mile shoreline of the Town of Duck and the adjacent shorelines north and south. Data collected in December 2017 was used to update shoreline and volume change analyses conducted during the feasibility study (CPE-NC 2013) and the design analysis associated with the beach nourishment project (CPE-NC 2015). Both the shoreline and volume change results were influenced by the beach fill project constructed in June 2017, which placed 1,263,181 cy of material along the beach between station D-10 and D-19.

Shoreline Change Analysis: Shoreline change analysis examined the change in the MHW line (+1.2 ft. NAVD contour) between May 2015 and December 2017 and compared those changes with those measured between September 2013 and May 2015 and October 1996 and December 2017. In general, the average shoreline change rates were positive from May 2015 to December 2017 and are primarily attributed to the beach nourishment project completed in June 2017. The average shoreline change rate measured within the monitoring area (Stations PI-17 to SS-02) between 2015 and 2017 was an advance at 13.5 feet per year. Within the project area (D-10 to D-19) the advance of the shoreline was equivalent to 44.0 feet per year. The shoreline changes within the monitoring area range from an advance of 12.8 ft./yr. between Stations D-05 and D-08 (south end of Station Bay Dr. to Waxwing Ct.) to a recession of -19.6 ft./yr. between Stations D-23 and D-24 which lies between the southern portion of the USACE Field Research Facility and Ship Watch Drive.

A review of the long-term changes show the average shoreline change rate measured within the monitoring area between 1996 and 2017 was +1.2 feet per year. This advance rate measured between 1996 and 2017 is a deviation from the trend of recession observed when comparing the measured long-term rates from 1996 to 2011, 1996 to 2012, 1996 to 2013, and 1996 to 2015, which were -0.6 ft./yr., -1.4 ft./yr., -0.3 ft./yr., and -0.5 ft./yr. respectively. This reversal is driven by the construction of the beach fill project between Stations D-10 and D-19 in June 2017.

Volume Change Analysis: Volumetric changes discussed in this report represent the change in the quantity of sediment measured through comparison of the beach profile survey data between the recent changes computed between May 2015 and December 2017 and the long-term changes measured between September 2013 and December 2017.

The total volumetric change measured between May 2015 and December 2017 above the -24.0 ft. NAVD contour within the monitoring area (Stations PI-17 to SS-02) was a gain of 1,343,100 cubic yards. This translates into an average volume change rate of 14.7 cy/ft./yr. (accretion) throughout the monitoring area. The volume change within the project area (Stations D-10 to D-19) over the same 2.6-year period, was a gain of approximately 1,039,200 cubic yards. Although the overall average rates were predominantly positive throughout the monitoring area, the analysis identified

several profiles with high rates of erosion. The highest erosion rates were measured at Stations D-09 (-19.3 cy/ft./yr.), D-23 (-41.3 cy/ft./yr.), D-24 (-24.8 cy/ft./yr.) and D-30 (-50.2 ft./yr.).

The long-term volumetric change measured between September 2013 and December 2017 within the monitoring area (PI-17 to SS-02) was a gain of 947,000 cubic yards, or 222,900 cubic yards per year above the -24.0 ft. NAVD contour. The long-term changes over the 4.3-year period within the project area (D-10 to D-19) measured a volumetric gain of approximately 1,027,100 cubic yards, which is equivalent to 241,600 cubic yards per year.

In 2015, the analysis of the beach profile monitoring data identified two (2) primary areas of erosion between Stations PI-17 and D-11 (-25.6 cy/ft./yr.) and Stations D-25 and SS-01 (-9.9 cy/ft./yr.). The recent changes showed those areas experienced volumetric gains from May 2015 to December 2017 with measured average annual change rates of 13.7 cy/ft./yr. (accretion) from Station PI-17 to D-11 and 5.7 cy/ft./yr. (accretion) from D-25 to SS-01. The area in the vicinity of Profile D-30 (Lala Ct.) was an exception to the accretion that occurred between D-25 and SS-01. Volume change analysis showed a rate of erosion of -50.2 cy/ft./yr. for profile D-30. This anomaly is most likely temporary and may have resulted from a natural redistribution of the accreted material to adjacent portions of the beach or possibly due to the influence of offshore topographic features.

The previous Town-wide monitoring report (CPE-NC, 2016) updated the SBEACH storm vulnerability analysis based on the May 2015 beach profile survey data. The 2015 analysis identified the beach areas between Stations D-9 to D-11 (Pelican Way to Ocean Pines Dr.) and D-25 to D-29 (Sea Colony Dr. to Ocean Front Dr.) as having experienced an increase in the number of vulnerable structures. The recent changes computed between May 2015 and December 2017 show the D-9 to D-11 shoreline advanced seaward at 18.6 ft./yr. and gained approximately 212,700 cubic yards, equivalent to an average volume change rate of 30 cy/ft./yr. (accretion). The recent changes are a reversal from the -0.9 ft./yr. average shoreline recession rate and -29.8 cy/ft./yr. average volume change rate measured between 2013 and 2015. These changes are primarily attributed to the recent beach fill project. For the area between D-25 and D-29, recent changes show a seaward advance of the shoreline at a rate of 1.4 ft./yr. and experienced an approximate gain of 180,300 cubic yards, equivalent to an average volume change rate of 14.3 cy/ft./yr. (accretion) between May 2015 and December 2017. These positive changes are not directly attributed to the recent beach fill project. While the SBEACH vulnerability analysis was not updated for this report, the positive changes observed in these two areas has likely reduced the number of vulnerable structures previously identified.

The two areas north and south of the project area described above as having the highest erosion rates in 2015 (Stations PI-17 to D-11 and D-25 to SS-01), should continue to be monitored to determine if the recent accretion measured in those areas between May 2015 and December 2017 continues to persist. The volume changes and overall accretion measured within the monitoring area (14.7 cy/ft./yr.) and the project area (46.2 cy/ft./yr.) between May 2015 and December 2017 are primarily attributed to the construction of the beach nourishment project that was completed in June 2017. The recent high rates of accretion are expected to moderate over time as the beach continues to adjust to a more equilibrated state. Changes within the project area are anticipated to

continue to slow (or maintain the long-term trend) as the equilibrium is achieved and the changes begin to align with historic change rates. The long-term volume changes for the monitoring area (6.6 cy/ft./yr.) and project area (26.7 cy/ft./yr.) computed from September 2013 to December 2017 are higher than the rate of change factored into the design of the beach fill project (-2.5 cy/ft./yr.). Variations of this magnitude are to be expected as the project design change rate was measured over the longer term of approximately 15 years (1996 and 2011) while the volume changes in this analysis were measured over spans of 2.6 and 4.3 years.

APTIM recommends the Town continue to monitor the entire Town oceanfront shoreline in order to assess if the trends measured in the volume change analysis persist in those regions identified. This monitoring will be instrumental for the Town to evaluate future areas of concerns and to develop successful shoreline management strategies to deal with issues as they arise. The monitoring program will also provide valuable information on the performance of the 2017 beach fill project and aid in the determination as to when additional nourishment is needed in the project area. The measured performance of the beach fill will also serve as a valuable tool to aid in the development and design of future beach nourishment projects the Town may consider.

VII. REFERENCES

Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC, 2016), *Town of Duck North Carolina Shoreline & Volume Change Monitoring Report*, Wilmington, NC.

Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC, 2015), *Town of Duck North Carolina Erosion & Shoreline Management Design Report*, Wilmington, NC.

Coastal Planning & Engineering of North Carolina, Inc. (CPE-NC, 2013), *Erosion and Shoreline Management Feasibility Study*, Wilmington, NC.

APPENDIX A

2017 TOWN OF DUCK, NORTH CAROLINA
BEACH PROFILE SURVEY REPORT

2017 Town of Duck, North Carolina
Beach Profile Survey Report

Prepared for:

Town of Duck, North Carolina

Prepared by:

Aptim Coastal Planning and Engineering of NC, Inc.
4038 Masonboro Loop Road
Wilmington, NC 28409

April 2018

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ABSTRACT

Aptim Coastal Planning and Engineering of North Carolina, Inc. (APTIM) was contracted by Dare County, North Carolina to provide a topographic and hydrographic survey for the Post Construction Monitoring Survey within the project area of the 2017 beach nourishment project. Furthermore, APTIM was contracted by the Town of Duck to conduct beach profile surveys for the remaining portions of the Town outside of the project area. The survey of the Town of Duck consisted of thirty-six (36) profile, including all of Duck and two profiles north of the Town limit. APTIM surveyors conducted the beach and hydrographic surveys November 30, 2017 through December 05, 2017.

The physical monitoring of the Town of Duck included topographic and hydrographic surveys of the beach and offshore areas. The monitoring data is necessary to observe and assess beach conditions for future construction. Monitoring surveys are further needed to continually observe the performance of the nourishment project as well as assess effects of said project on adjacent shorelines.

The scientific monitoring processes provide information necessary to plan, design, and optimize subsequent follow up projects. The information gathered may potentially reduce the need for, and cost of, unnecessary work as well as potentially reducing any environmental impacts that may have occurred or are to be expected.

SURVEY METHODOLOGIES

The surveys were conducted in accordance with the Minimum Performance Standards for the U.S. Army Corps of Engineers (USACE), Engineering and Design Hydrographic Surveying Manual. All hydrographic surveying was conducted under the direct supervision of an American Congress of Surveying and Mapping (ACSM) Certified Hydrographer (CH). Included in this Hydrographic and Topographic Survey Report are thirty-eight (38) profile stations, one (1) project location map, and seven (7) plan view maps. The plan view maps show reduced true position elevation data collected during the survey. The location of all published control, as well as control found and used for survey purposes, is presented in the Monument Information Report provided in **Appendix 1.**

Vertical data was collected in the North American Vertical Datum of 1988 (NAVD88). All Horizontal data is provided in the North Carolina State Plane Coordinate System, North American Datum of 1983/2011 (NAD 83/2011) zone 3200. Profile data is presented in xyz format relative to The North American Vertical Datum of 1988 (NAVD88) in **Appendix 2** (digital format only). Profile plots are provided in **Appendix 3.** Ground digital photography obtained during the survey is provided in **Appendix 4.** Copies of all field book pages are provided in **Appendix 5** (digital format only).

The field survey and data collection activities encompassed four (4) phases. Brief descriptions of each survey phase, including methodologies and quality control/quality assurance procedures, are described below.

Phase One: Control Reconnaissance/Establishment/Verification

Prior to the start of the survey, reconnaissance of the monuments was conducted to confirm that survey control was in place and undisturbed. Real Time Kinematic Global Positioning System (RTK GPS) was used to locate and confirm survey control for this project. The horizontal and vertical accuracy of control data meets the accuracy requirements as set forth in the Engineering and Design Hydrographic Surveying Manual (EM 1110-2-1003). In order to achieve required accuracy, the topographic and hydrographic surveys were controlled using 2nd order monuments, specifically CAFFEY, ARCH, C255, TIDAL C, TIDAL D, KITTY from the National Geodetic Survey (NGS). Horizontal and vertical positioning checks were conducted at the beginning and end of each day using at least two 2nd order monuments in the project area. The RTK GPS utilizes statistical methods to ensure accuracy of RTK GPS data remains within the 95% confidence interval. The control check shots were acquired using a minimum of five (5) epochs which results in a high accuracy location. Results from 2nd order control checks are displayed showing northing, easting, monument elevation, inverses, horizontal and vertical root mean square error, location description and photographs as indicated in the Monument Information Report (**Appendix 1**).

Phase Two: Beach Profiles

Upon completion of the control reconnaissance survey, beach/upland and nearshore operations were initiated. Cross-sections of the beach in the project area were surveyed using extended rod RTK GPS rovers, and standard RTK GPS rovers. Extended rod RTK GPS rovers were used to augment RTK GPS survey capability into the nearshore. The current systems allow surveyors from APTIM to collect the entire beach profile with RTK GPS technology. Incorporation of RTK GPS into monitoring surveys greatly reduces the potential for human error during data collection and reduction. Furthermore, RTK GPS provides accuracies of two (2) centimeters ± one (1) part per million with true horizontal positioning to the survey data point regardless of sea state.

Profiles commenced from the onshore control point and extend seaward overlapping the offshore data. Nearshore portions of the profiles were surveyed by two (2) surveyors with an Extended Rod Trimble R8 RTK GPS rover who entered the water wearing Personal Floatation Devices (PFD). Trimble TSC3 data collectors are equipped with Bluetooth technology allowing wireless communication with the GPS receiver at a data exchange speed of 2.1 megabits per second. The rover system allows surveyors from APTIM to reach a maximum water depth of eleven (11) feet. The nearshore survey extended seaward to a point overlapping the offshore portion of the profiles by at least fifty (50) feet.

The upland portion of the survey commenced at the waterline and extended 25 feet landward of the dune or until an obstacle was encountered. The upland portions of the profiles were surveyed using an RTK GPS. Elevations were taken at approximately twenty-five (25) foot intervals along each profile line and at all grade breaks. To maintain online accuracy surveyors utilized the RTK GPS feature *stakeout point.* S*takeout point* allows surveyors to maintain the profile azimuth without relying on survey lathe or conventional compass bearings.

Phase Three: Nearshore/Offshore Profiles

The Nearshore/Offshore profiles were conducted at each required profile station. The profiles were obtained 2,500 feet beyond the shoreline or to the -30 NAVD88 contour, whichever is more landward. The landward limits of the nearshore profiles were based on a minimum overlap of fifty (50) feet beyond the seaward extent of beach profiles. Soundings were collected at a maximum of twenty-five (25) foot intervals with an Odom Hydrotrac, sufficient to provide an accurate depiction of the seafloor.

Nearshore/offshore profiles were collected using an Odom Hydrotrac single frequency sounder with digitizer on APTIM's twenty-eight (28) foot Parker survey vessel with a centrally located hull-mounted transducer. Data was digitally stored using HYPACK 2017 Software. A Trimble R-8 RTK GPS and a TSS DMS-25 dynamic motion sensor were used onboard the

survey vessel to provide instantaneous tide corrections and attitude corrections. Manual tide readings were taken while conducting the onshore portion of the profile to verify onboard tide readings. In order to maintain the vessel navigation along the profile lines, HYPACK 2017 navigation software was used. This software provided horizontal position to the sounding data allowing real-time review of the data in plan view or cross-section format. HYPACK 2017 also provided navigation to the helm to minimize deviation from the online azimuth.

Horizontal and vertical positioning checks were conducted at the beginning and end of each day as described in phase one (1) of the survey. The sounder was calibrated via bar-checks and a sound velocity probe at the beginning and end of the day. The DIGIBAR PRO sound velocity meter offers a fast additional calibration for sound velocity as compared to the traditional bar-check. Bar-checks were performed from a depth of five (5) feet to a depth of at least twenty-five (25) feet. Analog data showing the results of the bar-check calibration was displayed on the sounder charts at five (5) foot increments during descent of the bar. Offshore data was collected within one (1) week of onshore data collection for each line.

Phase Four: Data Reduction/Submittals

Upon completion of the field work, data was edited and reduced with Trimble Business Center, HYPACK 2017, and APTIM's internal software programs. The upland and nearshore portions of the beach profile were viewed and edited in Trimble Business Center and a comma delimited XYZ file was created. The offshore raw digital data was viewed and edited in HYPACK 2017's *Single Beam Editor*. The offshore RTK GPS tide data that was collected was compared to the manually collected RTK GPS nearshore tide data, local observed, and predicted tides for data verification purposes. Tide corrected offshore data was exported and a comma delimited XYZ file was created. All overlapping profile data was compared in cross section to ensure system accuracy. The edited beach profile data and offshore profile data were merged and a representative cross-section was derived for each profile line. The cross sections were developed using internal APTIM plotting programs.

The final plots were edited and reviewed with comparisons to previous years; discrepancies were noted and resolved. The final approved cross-section data was prepared in the required formats for submittal (**Appendix 3**). Digital data is provided in the State required vertical datum NAVD88.

Map Preparation:

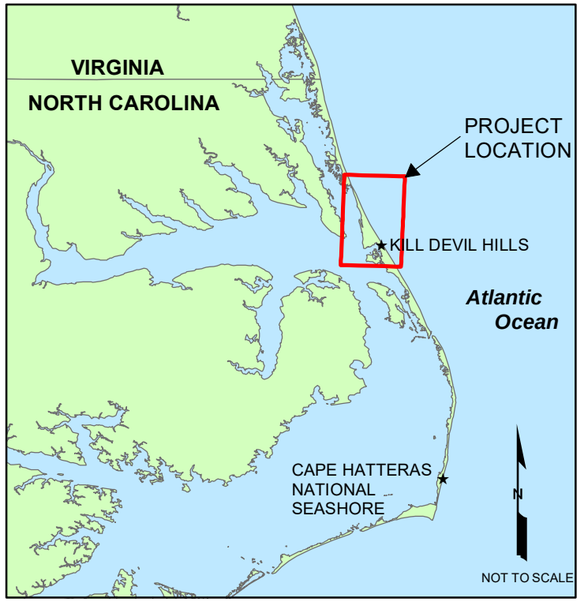
Upon completion of the surveys and data reduction, the survey maps were prepared in ArcGIS 10.3. In order to avoid congestion, the survey maps do not show all of collected

elevations but enough to give an accurate depiction of the cross sections. The survey maps display profile data and control monument locations plotted against NCONE 2016 aerial photographs.

Ground Digital Photography:

Surveyors from APTIM collected three (3) digital photos at a mid-beach location at each profile location. The three (3) photos included one (1) in each shore-parallel direction and one (1) landward toward the monument. Wherever possible, an additional digital photo was taken of the control identification or stamping on the monument.

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK, AND TOWN OF KILL DEVIL HILLS



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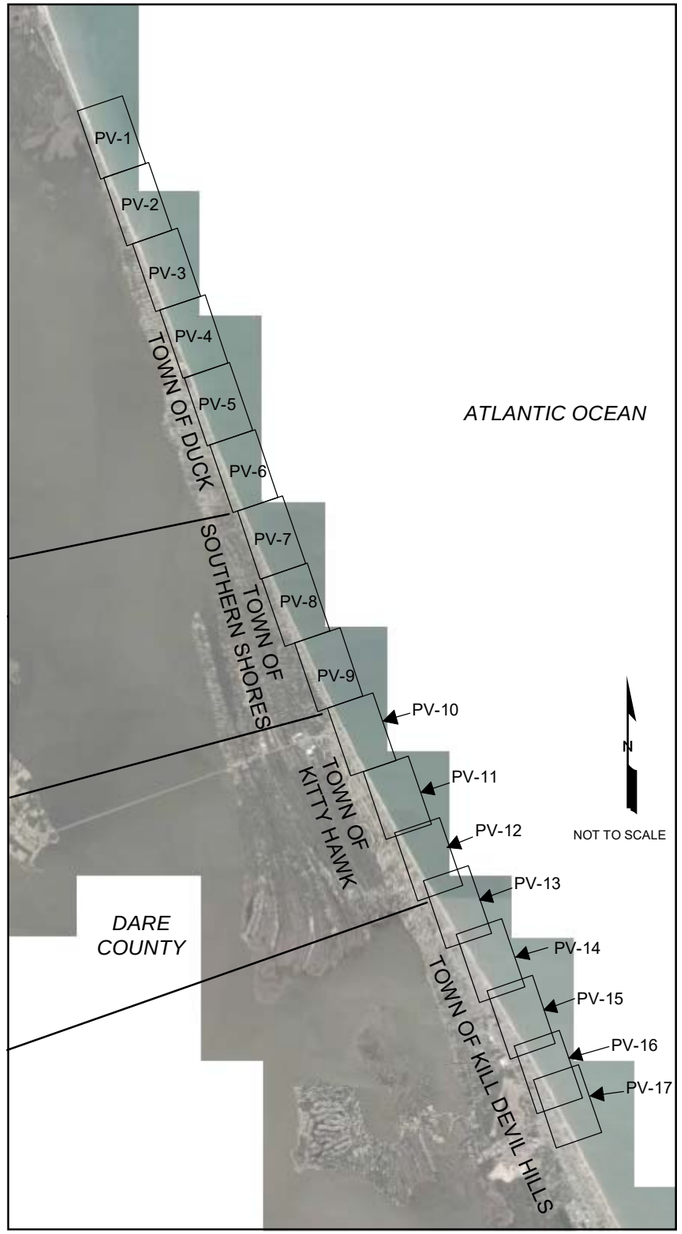

CONTROL USED BY APTIM 2017 SURVEY
DATUMS: NAD83/2011 / NAVD88

STATION	NORTHING	EASTING	AZIMUTH
-170+56	887172.90	2963880.50	66.60
-163+99	886569.90	2964142.00	66.60
-157+41	885966.90	2964403.50	66.60
-150+00	885364.00	2964665.00	65.31
-140+00	884444.00	2965116.00	65.31
-130+00	883452.00	2965239.00	65.31
-120+00	882604.00	2965920.00	65.31
-110+00	881697.00	2966366.00	62.57
-100+00	880778.00	2966790.00	62.57
-90+00	879895.00	2967110.00	62.57
-80+00	878988.00	2967533.00	62.57
-70+00	878106.00	2967951.00	62.57
-60+00	877175.00	2968381.00	62.57
-50+00	876228.00	2968838.00	62.57
-40+00	875440.00	2969249.00	62.57
-30+00	874496.08	2969731.60	62.57
-20+00	873607.16	2970189.67	62.57
-10+00	872720.97	2970653.00	62.57
0+00.00	871890.80	2971224.20	62.60
9+99.90	871003.30	2971685.80	62.60
20+02.68	870116.70	2972153.20	62.20
30+05.52	869230.00	2972621.70	62.20
40+23.88	868329.70	2973097.50	62.20
50+28.29	867441.70	2973566.70	62.20
60+50.00	866538.40	2974044.00	62.20
70+02.90	865695.80	2974489.10	62.20
80+15.19	864800.80	2974962.00	62.20
89+56.91	863968.20	2975401.90	62.20
99+99.71	863052.20	2975900.20	61.50
109+99.46	862189.90	2976406.10	59.60
119+99.14	861327.70	2976911.90	59.60
130+33.04	860436.00	2977435.10	59.60
138+27.64	859735.48	2977811.33	59.60
149+99.46	858740.05	2978430.26	59.60
159+99.55	857895.27	2978966.59	59.60
169+70.21	857040.44	2979427.66	59.60
179+87.62	856163.07	2979942.69	59.60
189+87.10	855301.16	2980448.64	59.60
199+93.01	854433.71	2980957.84	59.58
209+74.44	853579.14	2981440.37	60.53
219+99.94	852686.23	2981944.55	60.53
229+83.39	851830.15	2982428.55	60.52
240+41.84	850908.80	2982949.45	60.52
249+81.53	850076.05	2983384.80	61.90
260+17.44	849165.95	2983879.57	61.90

CONTROL USED BY APTIM 2017 SURVEY
DATUMS: NAD83/2011 / NAVD88

STATION	NORTHING	EASTING	AZIMUTH
269+49.25	848341.66	2984314.02	62.20
279+80.81	847429.13	2984795.03	62.20
289+99.14	846547.02	2985305.30	62.20
299+92.48	845649.70	2985733.15	62.20
309+71.20	844785.81	2986193.06	61.97
320+05.37	843872.99	2986679.03	61.97
329+88.80	843003.79	2987138.95	62.10
340+20.02	842092.34	2987621.23	62.12
349+69.94	841269.59	2988097.30	62.12
359+82.85	840357.49	2988539.16	62.12
369+89.02	839485.48	2989042.40	62.12
PI-17	920098.90	2950657.30	70.00
PI-18	919175.40	2951026.00	70.00
D-01	918267.70	2951387.50	70.00
D-02	917384.40	2951733.80	70.00
D-03	916429.40	2952103.00	70.00
D-04	915495.30	2952464.00	70.00
D-05	914598.00	2952849.30	70.00
D-06	913696.90	2953224.40	70.00
D-07	912798.80	2953607.30	70.00
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D-21	900958.70	2958472.10	70.00
D-22	900228.80	2958754.00	70.00
D-23	899515.60	2958992.70	70.00
D-24	898739.80	2959267.20	70.00
D-25	897824.30	2959601.70	70.00
D-26	896902.30	2959928.60	70.00
D-27	895981.90	2960250.60	70.00
D-28	895073.00	2960604.10	70.00
D-29	894166.20	2960963.60	70.00
D-30	893257.60	2961317.70	70.00
D-31	892350.70	2961676.70	70.00
D-32	891379.40	2962078.10	70.00

CONTROL USED BY APTIM 2017 SURVEY
DATUMS: NAD83/2011 / NAVD88

STATION	NORTHING	EASTING	AZIMUTH
D-33	890553.20	2962439.40	70.00
D-34	889616.10	2962839.60	70.00
SS-01	888697.70	2963230.40	70.00
SS-02	887775.80	2963619.00	70.00

DARE COUNTY A-MON CONTROL

MON STAMPING	NORTHING	EASTING	M. ELEV.
ARCH 2005	854412.25	2979783.79	11.64
KITTY 1962	859358.84	2977204.86	9.17
865 1370 C 1977	900621.51	2957662.02	18.46
CAFFEY 1935	915308.87	2952084.11	1.99
C255 1981	900856.11	2958600.06	16.89
865 1370 D 1977	**VERTICAL ONLY**		7.43

LEGEND

⊕	PROFILE STATION
⊞	CONTROL MONUMENT
PV	PLAN VIEW
CS	COVER SHEET
APTIM	APTIM COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA INC.
C.O.L.	CERTIFICATE OF LICENSURE
NAVD	NORTH AMERICAN VERTICAL DATUM
NAD	NORTH AMERICAN DATUM
NTS	NOT TO SCALE
Rd	ROAD
NC	NORTH CAROLINA
AZ	AZIMUTH
MON	MONUMENT
ID	IDENTIFICATION
MK	MARK
U.S.	UNITED STATES OF AMERICA

APTIM COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA, INC.
4038 MASONBORO LOOP RD.
WILMINGTON, NC 28409
PH. (910) 791-9494
FAX (910) 791-4129
COL #C2331

No.	Description	Date

Designed by: M. Lowiec
Drawn by: J. Walker
Date: March 2018
Checked by: M. Lowiec
Reviewed by: J. Samberg
Submitted by: M. Lowiec
Comm. No.: 636220429
Plot Scale: AS NOTED

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK, AND TOWN OF KILL DEVIL HILLS

COVER SHEET

DRAWING NO.

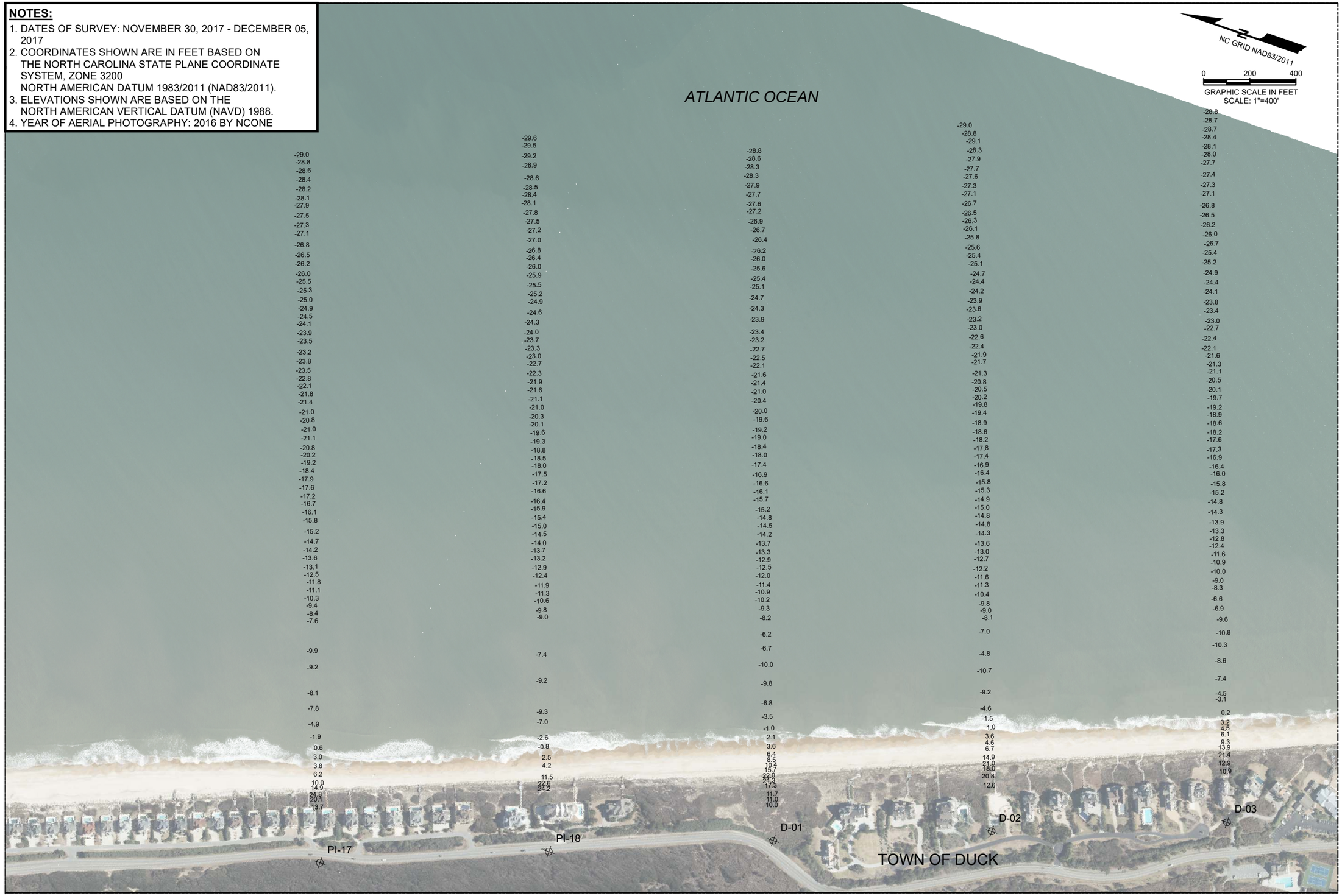
CS

SHEET 1 OF 18

G:\Enterprise\NorthCarolina\636220429_DARE_PostCon\Survey_Charts\MXD\CS.mxd

NOTES:

1. DATES OF SURVEY: NOVEMBER 30, 2017 - DECEMBER 05, 2017
2. COORDINATES SHOWN ARE IN FEET BASED ON THE NORTH CAROLINA STATE PLANE COORDINATE SYSTEM, ZONE 3200 NORTH AMERICAN DATUM 1983/2011 (NAD83/2011).
3. ELEVATIONS SHOWN ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
4. YEAR OF AERIAL PHOTOGRAPHY: 2016 BY NCONE



MATCHLINE SHEET 3 OF 18

APTIM COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA, INC.

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Reference Files:

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK, AND TOWN OF KILL DEVIL HILLS

PLAN VIEW

DRAWING NO.

PV-1

SHEET 2 OF 18

Document Path: G:\Enterprise\NorthCarolina\636220429_DARE_PostConSurvey_Charts\MXD\PV1.mxd

NOTES:

1. DATES OF SURVEY: NOVEMBER 30, 2017 - DECEMBER 05, 2017
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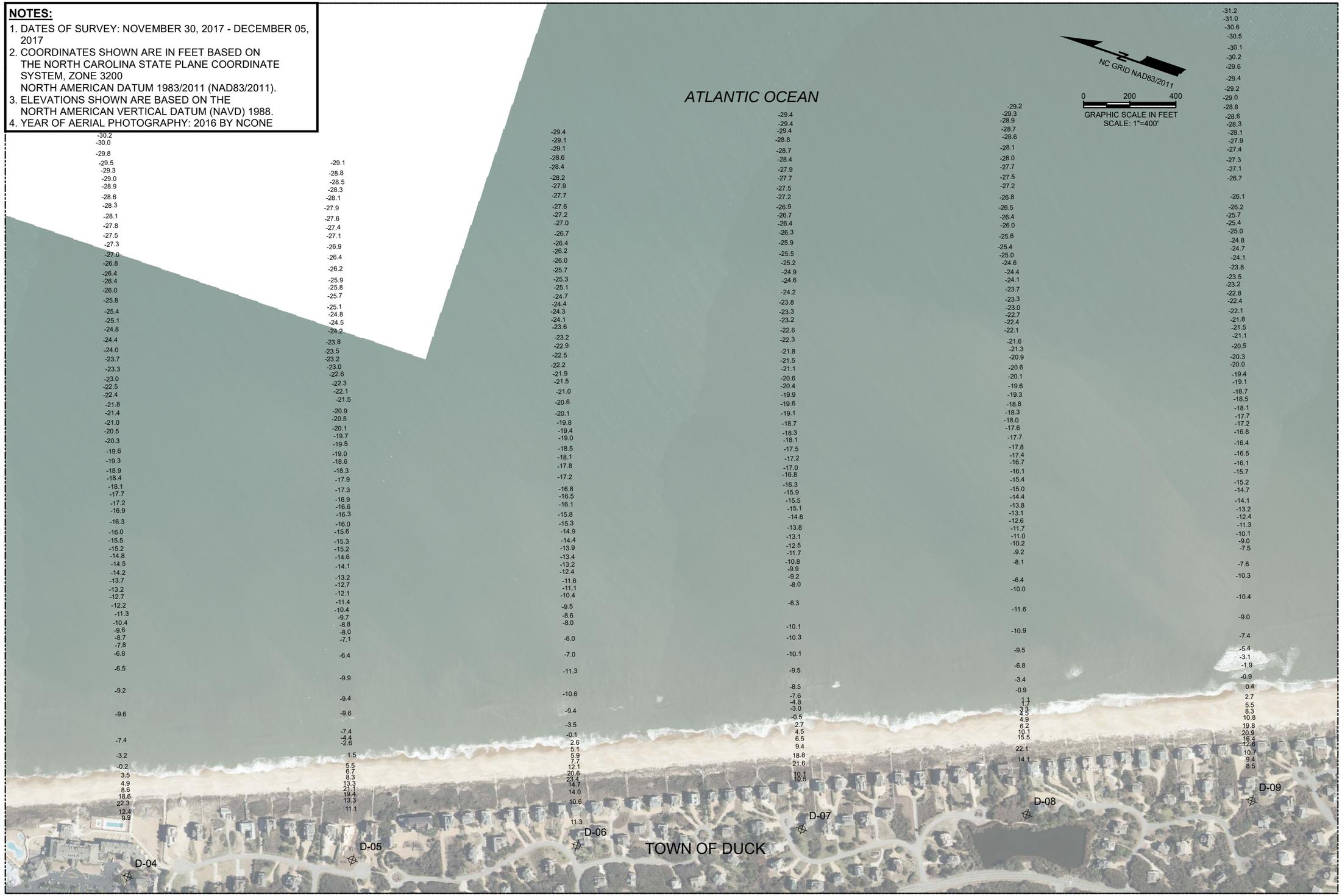
3. ELEVATIONS SHOWN ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
4. YEAR OF AERIAL PHOTOGRAPHY: 2016 BY NCONE



MATCHLINE SHEET 2 OF 18

MATCHLINE SHEET 4 OF 18

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COL #C2331

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Date: March 2018
Plot Scale: AS NOTED

Checked by: M. Lowiec
Reviewed by: J. Samberg
Submitted by: M. Lowiec
Comm. No.: 636220429

Reference Files:

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK, AND TOWN OF KILL DEVIL HILLS

PLAN VIEW

DRAWING NO.

PV-2

SHEET 3 OF 18

NOTES:

1. DATES OF SURVEY: NOVEMBER 30, 2017 - DECEMBER 05, 2017
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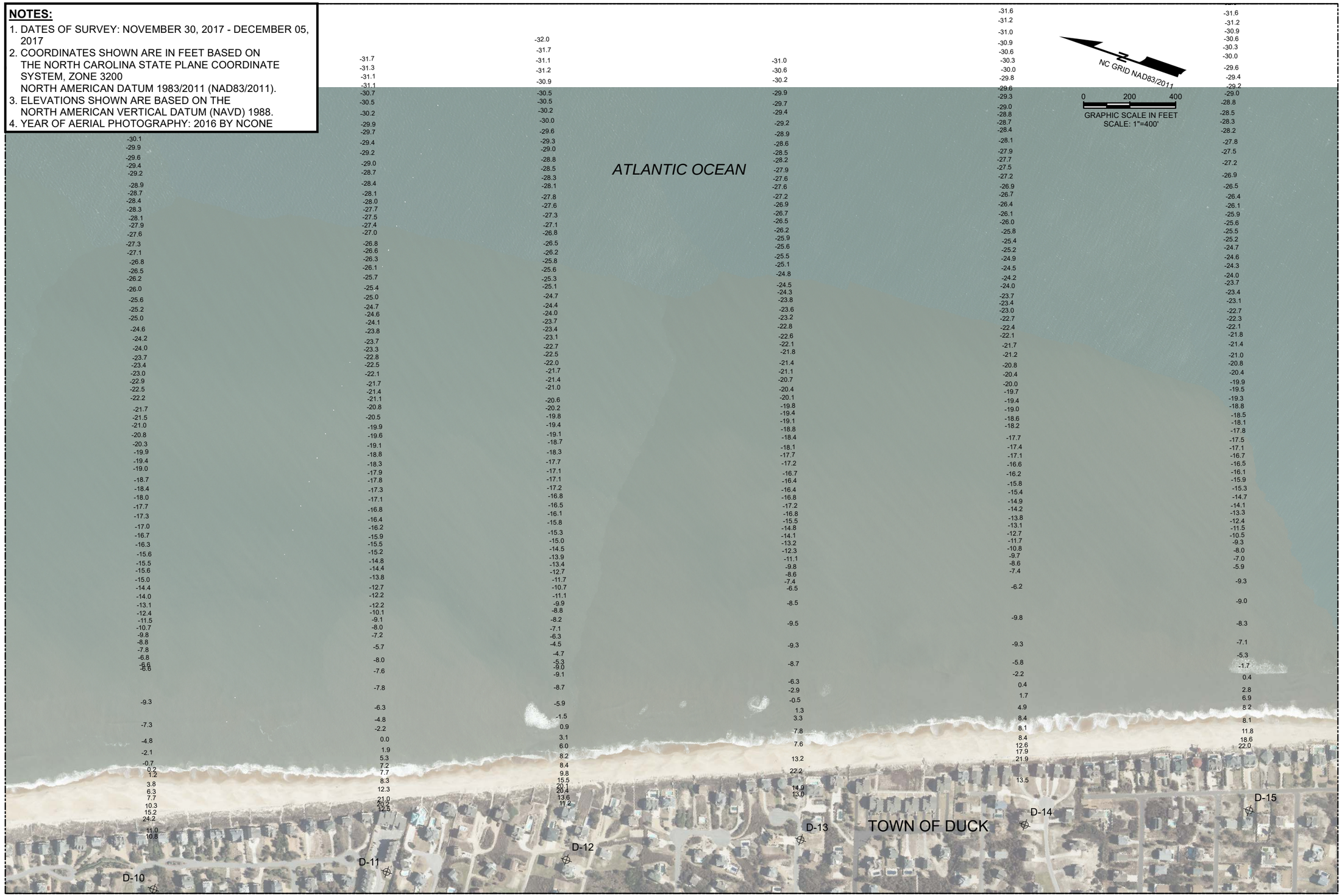
3. ELEVATIONS SHOWN ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
4. YEAR OF AERIAL PHOTOGRAPHY: 2016 BY NCONE



MATCHLINE SHEET 3 OF 18

MATCHLINE SHEET 5 OF 18

APTIM COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA, INC.

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WILMINGTON, NC 28409

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COL #C2331

No.	Description	Date

Designed by: M. Lowiec
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Date: March 2018
Plot Scale: AS NOTED

Checked by: M. Lowiec
Reviewed by: J. Samberg
Submitted by: M. Lowiec
Comm. No.: 636220429

Reference Files:

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK, AND TOWN OF KILL DEVIL HILLS

PLAN VIEW

DRAWING NO.

PV-3

SHEET 4 OF 18

Document Path: G:\Enterprise\NorthCarolina\636220429_DARE_PostConSurvey_Charts\MXD\PV3.mxd

NOTES:

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3. ELEVATIONS SHOWN ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
4. YEAR OF AERIAL PHOTOGRAPHY: 2016 BY NCONE

MATCHLINE SHEET 4 OF 18

MATCHLINE SHEET 6 OF 18

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COL #C2331

No.	Description	Date

Designed by: M. Lowiec
Drawn by: J. Walker
Date: March 2018
Plot Scale: AS NOTED

Checked by: M. Lowiec
Reviewed by: J. Samberg
Submitted by: M. Lowiec
Comm. No.: 636220429

Reference Files:

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK,AND TOWN OF KILL DEVIL HILLS

PLAN VIEW

DRAWING NO.

PV-4

SHEET 5 OF 18

NOTES:

1. DATES OF SURVEY: NOVEMBER 30, 2017 - DECEMBER 05, 2017
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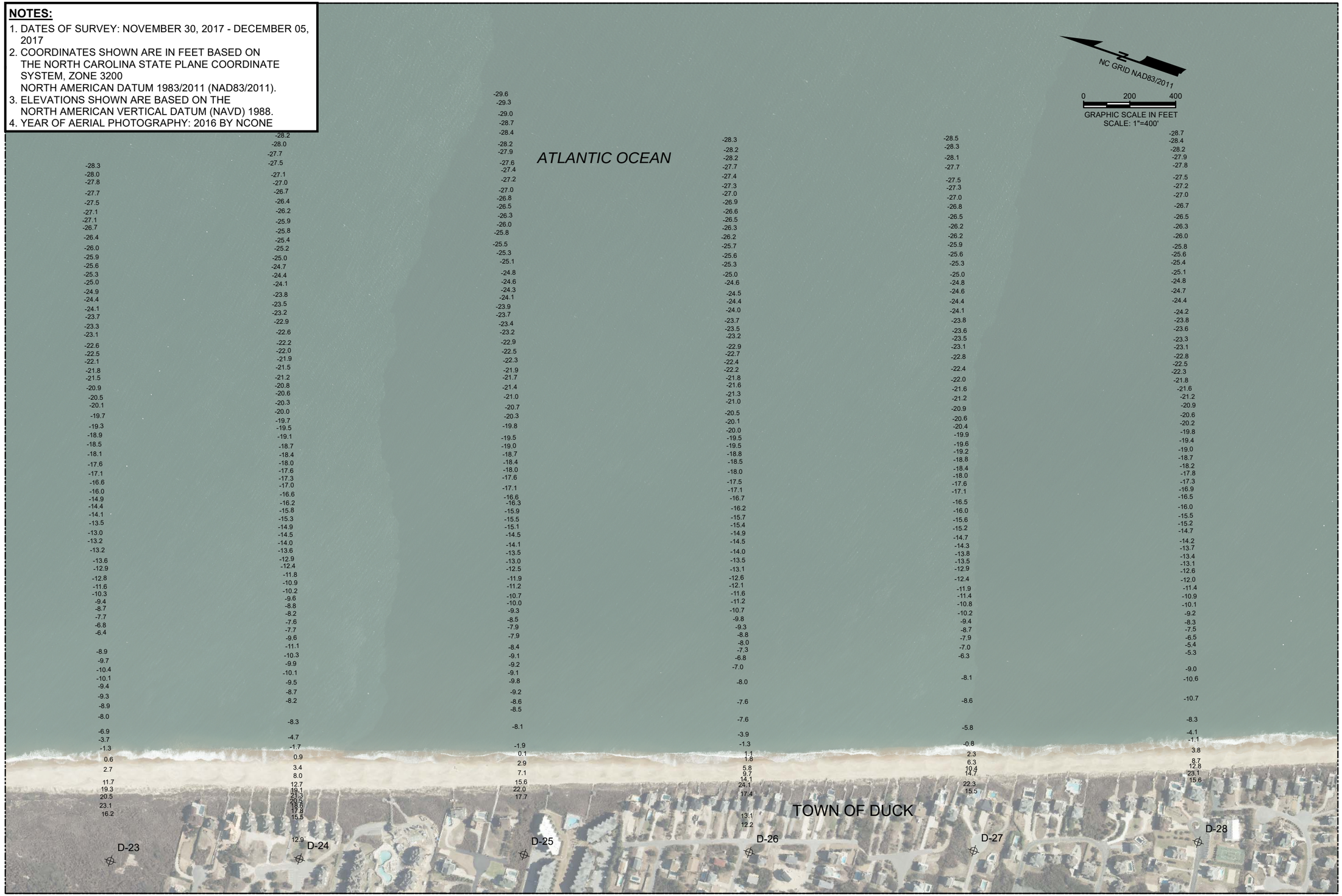
3. ELEVATIONS SHOWN ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
4. YEAR OF AERIAL PHOTOGRAPHY: 2016 BY NCONE



MATCHLINE SHEET 5 OF 18

MATCHLINE SHEET 7 OF 18

APTIM COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA, INC.

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WILMINGTON, NC 28409

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COL #C2331

No.	Date	Description

Checked by: M. Lowiec
Reviewed by: J. Sanberg
Designed by: M. Lowiec
Drawn by: J. Walker
Submitted by: M. Lowiec
Date: March 2018
Comm. No.: 636220429
Plot Scale: AS NOTED

Reference Files:

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK, AND TOWN OF KILL DEVIL HILLS

PLAN VIEW

DRAWING NO.

PV-5

SHEET 6 OF 18

Document Path: G:\Enterprise\NorthCarolina\636220429_DARE_PostConSurvey_Charts\MXD\PV5.mxd

NOTES:

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3. ELEVATIONS SHOWN ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
4. YEAR OF AERIAL PHOTOGRAPHY: 2016 BY NCONE

MATCHLINE SHEET 6 OF 18

MATCHLINE SHEET 8 OF 18

APTIM COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA, INC.

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WILMINGTON, NC 28409

PH. (910) 791-9494
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COL #C2331

No.	Date	Description

Designed by: M. Lowiec
Drawn by: J. Walker
Date: March 2018
Plot Scale: AS NOTED

Checked by: M. Lowiec
Reviewed by: J. Samberg
Submitted by: M. Lowiec
Comm. No.: 636220429

Reference Files:

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK, AND TOWN OF KILL DEVIL HILLS

PLAN VIEW

DRAWING NO.

PV-6

SHEET 7 OF 18

Document Path: G:\Enterprise\NorthCarolina\636220429_DARE_PostConSurvey_Charts\MXD\PV6.mxd

NOTES:

1. DATES OF SURVEY: NOVEMBER 30, 2017 - DECEMBER 05, 2017
2. COORDINATES SHOWN ARE IN FEET BASED ON THE NORTH CAROLINA STATE PLANE COORDINATE SYSTEM, ZONE 3200 NORTH AMERICAN DATUM 1983/2011 (NAD83/2011).
3. ELEVATIONS SHOWN ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
4. YEAR OF AERIAL PHOTOGRAPHY: 2016 BY NCONE

MATCHLINE SHEET 7 OF 18

MATCHLINE SHEET 9 OF 18

APTIM COASTAL PLANNING & ENGINEERING OF NORTH CAROLINA, INC.

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WILMINGTON, NC 28409

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COL #C2331

No.	Description	Date

Designed by: M. Lowiec
Drawn by: J. Walker
Date: March 2018
Plot Scale: AS NOTED

Checked by: M. Lowiec
Reviewed by: J. Samberg
Submitted by: M. Lowiec
Comm. No.: 636220429

Reference Files:

2017 DARE COUNTY, NC POST-CONSTRUCTION AND MONITORING BEACH PROFILE SURVEY REPORT: TOWN OF DUCK, TOWN OF SOUTHERN SHORES, TOWN OF KITTY HAWK, AND TOWN OF KILL DEVIL HILLS

PLAN VIEW

DRAWING NO.

PV-7

SHEET 8 OF 18

Document Path: G:\Enterprise\NorthCarolina\636220429_DARE_PostConSurvey_Charts\MXD\PV7.mxd

Survey Report Notes

Survey Title:	2017 Town of Duck Beach Profile Survey Report
Prepared Date:	April 2018
Prepared For:	Town of Duck, NC
Prepared By:	APTIM Coastal Planning & Engineering of North Carolina, Inc.
Dates of Survey:	November 30, 2017 through December 05, 2017
Survey Location:	Town of Duck PI-17 through D-34

Notes:

1. The survey is neither valid nor complete without both the survey report and described survey maps. Digital data files encompassing the following have also been provided in the following formats listed.

   - *Monument Information Report* ***(Appendix 1)***
   - *ASCII file (profile xyz data. Digital only)* ***(Appendix 2)***
   - *Profile Plots* ***(Appendix 3)***
   - *Ground Digital Photography* ***(Appendix 4)***
   - *Project field books (Digital Only)****(Appendix 5)***

2. The information on this map represents the results of the survey on the dates indicated and can only be considered as indicating the general conditions existing at the time.

3. The coordinates shown are in US survey feet based on the vertical and horizontal data that was collected and presented relative to the North American Vertical Datum of 1988 (NAVD88) and the North Carolina State Plane Coordinate System, North American Datum of 1983/2011 (NAD 83/2011) zone 3200.

4. Vertical measurements are based on second order monuments CAFFEY, ARCH, C255, TIDAL C, TIDAL D, KITTY per published NGS coordinates.

5. Bearings are based on a bearing of South 24° 27’ 33” East between NGS second order monuments CAFFEY and ARCH per published NGS coordinates.

6. Underground and subaqueous improvements and/or utilities were not located as part of this survey and should be field verified prior to any dredging or construction activities.

7. Refer to APTIM field book No. 489 and “Swims” for the onshore portion and book No. 50 for the offshore portion.

8. Aids to navigation were not located during this survey.

9. Soundings were collected using an Odom Hydrotrac, Single Frequency, survey grade sounder. The sounder was calibrated prior to the start of the survey following manufacturers recommended procedures.

10. This survey was conducted for the Town of Duck for use as a topographic and hydrographic survey.

APPENDIX OVERVIEW

1) Monument Information Report
Data collected during the survey is entered in a spreadsheet format and compared to data provided by NGS. This comparison shows differences in northings, eastings and elevation of NGS published control, what was collected in the field, and what was used during profile reduction.

2) XYZ data (digital only)
Offshore survey data was converted into APTIM files. Onshore data was reduced by standard means of reduction and also entered into APTIM format and merged with the offshore data. APTIM format is used for in-house plotting, volume computations and other engineering analyses. The APTIM formatted data was converted into xyz format. The xyz data is provided in the datum collected (NAVD88) as per state standards.

3) Profile Plots
Profile plots of this year's survey data were compared with historical profile data.

4) Ground Digital Photography
APTIM surveyors collected three (3) digital photos at a mid-beach location at each profile location. The three (3) photos included one (1) in each shore-parallel direction and one (1) landward toward the monument. In addition, wherever possible a digital photo was taken of the control identification or stamping on the monument.

5) Field Book Pages (digital only)
This appendix includes copies of the field book pages used for the survey. Refer to APTIM field book No. 489 and "Swims" for the onshore portion. Navigation field book No. 50 for the offshore survey.

APPENDIX 1

MONUMENT INFORMATION REPORT

APPENDIX 1: Duck Monument Information

CONTROL MONUMENT USED BY APTIM FOR 2017 TOWN OF DUCK BEACH PROFILE TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT NOVEMBER 2017	
DATUMS: NAD83/2011- NAVD1988	
Designation	ARCH
Stamping	ARCH 2005
Northing	854412.25
Easting	2979783.79
Horizontal Root Mean Square Error	0.123
Elevation	11.64
Vertical Root Mean Square Error	0.004
Description	Located about 3.2 miles NW of Kill Devil Hills and 4.1 miles SSW of Southern Shores. On US 158 Bypass , 2.4 miles west from the main entrance to The Wright Brothers Memorial to Arch Street, in the northwest quadrant. 57.2 ft. West-Southwest of the centerline of US 158 Southbound Lanes. The Disk is a commemorative of the Wright Brothers first flight NGS, NCGS, NOAA, and NPS agency inscriptions.

Monument: L230

Location Verification: L230

Mean of Inverse Shots - Published Versus APTIM Found				
Monument	No. of Shots	ΔN	ΔE	ΔZ
ARCH	16	-0.01	-0.01	-0.06

CONTROL MONUMENT USED BY APTIM FOR 2017 TOWN OF DUCK BEACH PROFILE TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT FEBRUARY 2017	
DATUMS: NAD83/2011 - NAVD1988	
Designation	C255
Stamping	C255 1981
Northing	900856.11
Easting	2958600.06
Horizontal Root Mean Square Error	0.106
Elevation	16.89
Vertical Root Mean Square Error	0.014
Description	A National Geodetic Survey pin inside a protective casing with lid approximately 3 inches below ground and located between the two steps on the West side of the Army Corp of Engineer's Field Research Facility (1261 Duck Road), approximately 355 feet East of the main parking lot gate, 15 feet South of the Northerly steps, 15 feet North of the Southerly steps, and 2.7 feet West of the flag pole.

NO IMAGE

Monument: C255

Location Verification: C255

Mean of Inverse Shots - Published Versus APTIM Found				
Monument	No. of Shots	ΔN	ΔE	ΔZ
C255	28	0.01	0.06	-0.01

CONTROL MONUMENT USED BY APTIM FOR 2017 TOWN OF DUCK BEACH PROFILE TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT NOVEMBER 2017	
DATUMS: NAD83/2011 - NAVD1988	
Designation	CAFFEY
Stamping	CAFFEY 1935
Northing	915308.87
Easting	2952084.11
Horizontal Root Mean Square Error	0.254
Elevation	1.99
Vertical Root Mean Square Error	0.051
Description	A U.S. Coast & Geodetic Survey disk in concrete located in thick vegetation approximately 140 feet West of Duck Road and 40 feet South of a parking lot for 1566 Duck Road

Monument: CAFFEY

NO IMAGE

Location Verification: CAFFEY

Mean of Inverse Shots - Published Versus APTIM Found				
Monument	No. of Shots	ΔN	ΔE	ΔZ
CAFFEY	19	-0.01	0.01	0.05

CONTROL MONUMENT USED BY APTIM FOR 2017 TOWN OF DUCK BEACH PROFILE TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT NOVEMBER 2017	
DATUMS: NAD83/2011- NAVD1988	
Designation	KITTY
Stamping	KITTY 1962
Northing	849159.56
Easting	298928.60
Horizontal Root Mean Square Error	0.147
Elevation	9.17
Vertical Root Mean Square Error	0.036
Description	Located about 0.65 miles east of the post office in kitty hawk. A Standard disk set in a 12x12 inch concrete monument and tamped Kitty 1962 is 12 feet east-southeast of the intersection. The mark is flush with ground.

Monument: KITTY

Location Verification: KITTY

Mean of Inverse Shots – OPUS Solution Versus APTIM Found				
Monument	No. of Shots	ΔN	ΔE	ΔZ
KITTY	18	0.01	0.01	-0.03

CONTROL MONUMENT USED BY APTIM FOR 2017 TOWN OF DUCK BEACH PROFILE TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT NOVEMBER 2017	
DATUMS: NAD83/2011 - NAVD1988	
Designation	TIDAL C
Stamping	865 1370 1977
Northing	900621.51
Easting	2957662.02
Horizontal Root Mean Square Error	0.147
Elevation	18.46
Vertical Root Mean Square Error	0.036
Description	A National Ocean Survey disk protected by an open pipe approximately 6 inches above ground and located on the Army Corp of Engineer's Field Research Facility property (1261 Duck Road) approximately 600 feet East of Duck Road, 300 feet West of the gazebo, and 100 feet North of the access road.

Monument: Tidal C

Location Verification: Tidal C

Mean of Inverse Shots – OPUS Solution Versus APTIM Found				
Monument	No. of Shots	ΔN	ΔE	ΔZ
TIDAL C	12	0.01	-0.01	0.00

CONTROL MONUMENT USED BY APTIM FOR 2017 TOWN OF DUCK BEACH PROFILE TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT NOVEMBER 2017	
DATUMS: NAD83/2011 - NAVD1988	
Designation	TIDAL D
Stamping	1370 D 1979
Northing	900450.64
Easting	2957190.64
Horizontal Root Mean Square Error	2.051
Elevation	18.46
Vertical Root Mean Square Error	0.078
Description	Attached to the top of a stainless steel rod driven into the ground and inside a 4-inch PVC pipe that projects 0.6 meters above ground, the disk is recessed 0.3 meters below the top of the pipe. Used as a vertical check only.

NO IMAGE

Monument: TIDAL D

NO IMAGE

Location Verification: TIDAL D

Mean of Inverse Shots – OPUS Solution Versus APTIM Found				
Monument	No. of Shots	ΔN	ΔE	ΔZ
TIDAL D	4	1.82	-0.94	-0.07

TOWN OF DUCK STATION INFORMATION			
NOVEMBER 2017			
DATUMS: NAD83/90 & NAVD88			
STATION	**NORTHING**	**EASTING**	**AZIMUTH**
PI-17	920098.86	2950657.32	70
PI-18	919175.36	2951025.99	70
D-01	918267.75	2951387.52	70
D-02	917384.44	2951733.76	70
D-03	916429.37	2952102.95	70
D-04	915495.29	2952464.03	70
D-05	914597.97	2952849.30	70
D-06	913696.93	2953224.38	70
D-07	912798.76	2953607.33	70
D-08	911897.95	2953983.04	70
D-09	910994.82	2954356.65	70
D-10	910066.74	2954759.12	70
D-11	909133.14	2955158.05	70
D-12	908412.53	2955461.41	70
D-13	907478.35	2955874.29	70
D-14	906578.33	2956252.15	70
D-15	905677.78	2956628.57	70
D-16	904767.65	2956978.72	70
D-17	903863.92	2957333.66	70
D-18	902886.47	2957718.79	70
D-19	902331.03	2957932.45	70
D-20	901760.74	2958139.73	70
D-21	900958.69	2958472.08	70
D-22	900228.83	2958754.03	70
D-23	899515.64	2958992.70	70
D-24	898739.78	2959267.16	70
D-25	897824.26	2959601.68	70
D-26	896902.26	2959928.60	70
D-27	895981.88	2960250.61	70
D-28	895072.97	2960604.07	70
D-29	894166.25	2960963.56	70
D-30	893257.57	2961317.69	70
D-31	892350.69	2961676.73	70
D-32	891379.42	2962078.13	70
D-33	890553.16	2962439.37	70
D-34	889616.07	2962839.65	70

TOWN OF SOUTHERN SHORES STATION INFORMATION			
NOVEMBER 2017			
DATUMS: NAD83/90 & NAVD88			
STATION	**NORTHING**	**EASTING**	**AZIMUTH**
-187+14	888697.70	2963230.40	70.00
-177+13	887775.80	2963619.00	70.00
-170+56	887172.90	2963880.50	66.60
-163+99	886569.90	2964142.00	66.60
-157+41	885966.90	2964403.50	66.60
-150	885364.00	2964665.00	65.31
-140	884444.00	2965116.00	65.31
-130	883452.00	2965239.00	65.31
-120	882604.00	2965920.00	65.31
-110	881697.00	2966366.00	62.57
-100	880778.00	2966790.00	62.57
-90	879895.00	2967110.00	62.57
-80	878988.00	2967533.00	62.57
-70	878106.00	2967951.00	62.57
-60+00	877175.00	2968381.00	62.57
-50+00	876228.00	2968838.00	62.57
-40+00	875440.00	2969249.00	62.57
-30+00	874496.08	2969731.60	62.57
-20+00	873607.16	2970189.67	62.57
-10+00	872720.97	2970653.00	62.57

APPENDIX 2: Profile XYZ Data
(Available in digital format only)

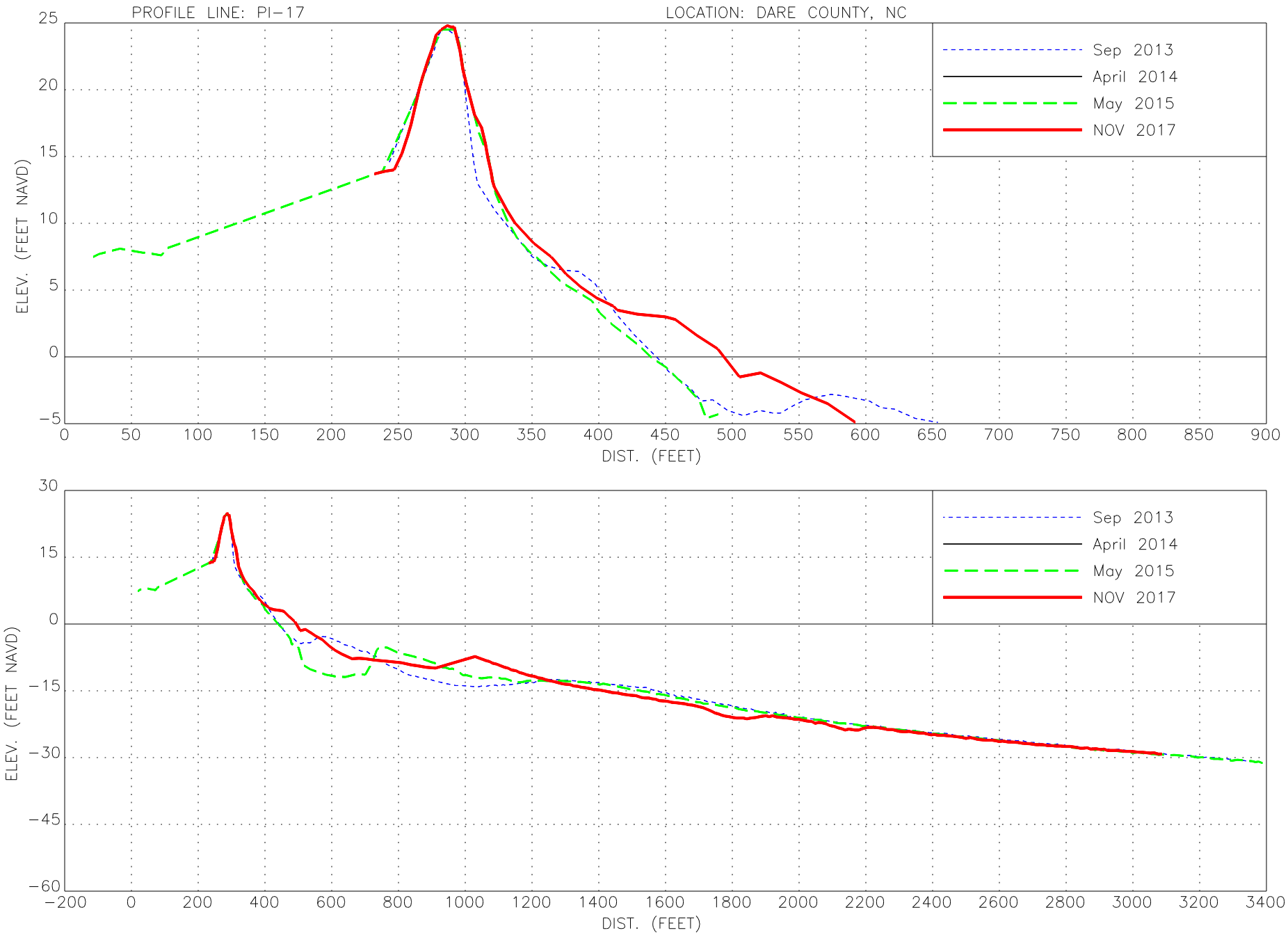
Sub-Appendix 2A: Town of Duck
(File: DUCK_1117_ALL.xyz)

Sub-Appendix 2B: Southern Shores
(File: SSHORES1117_ALL.xyz)

APPENDIX 3

PROFILE PLOTS

APPENDIX 3: Duck Beach Profiles Plots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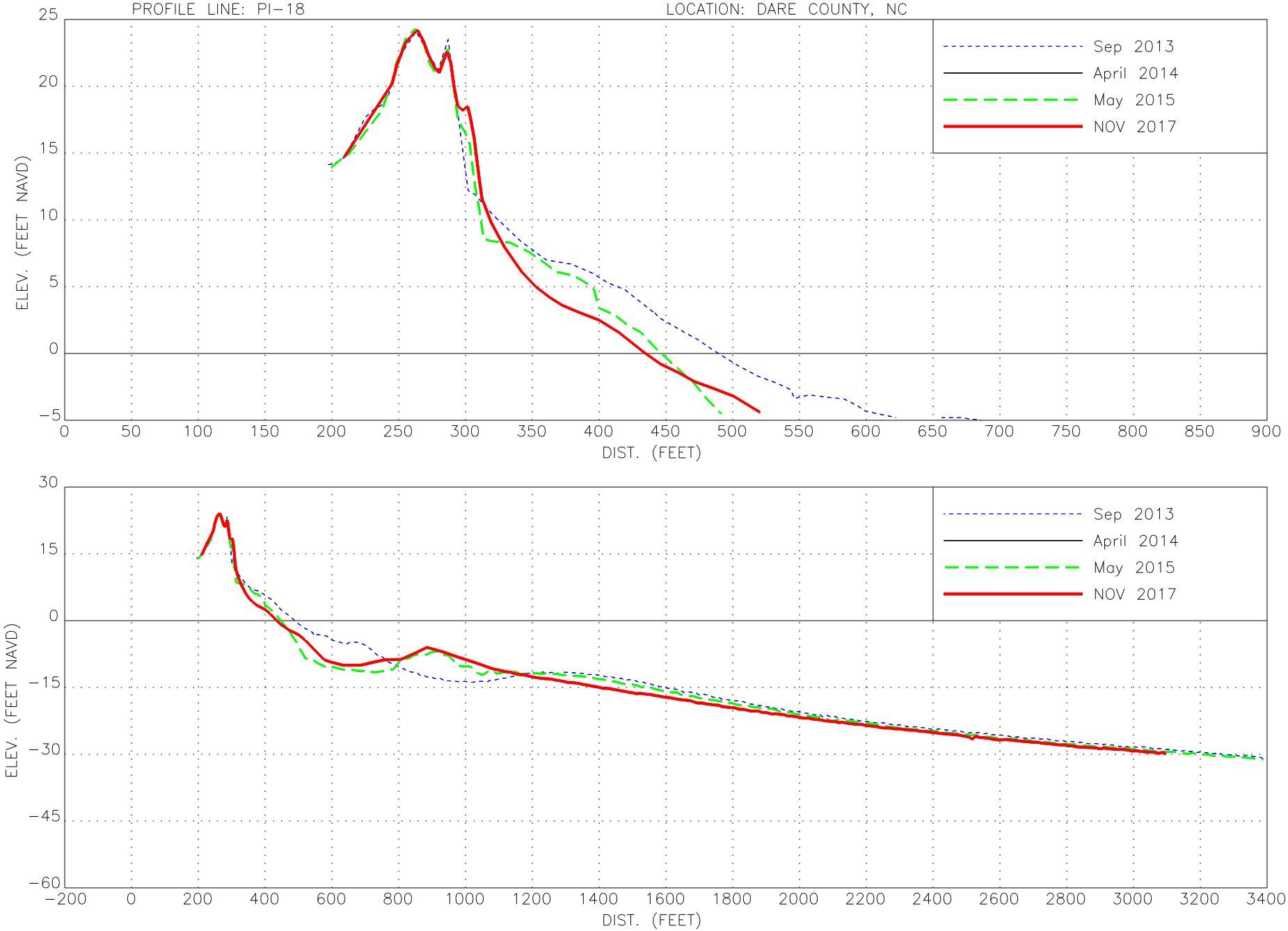
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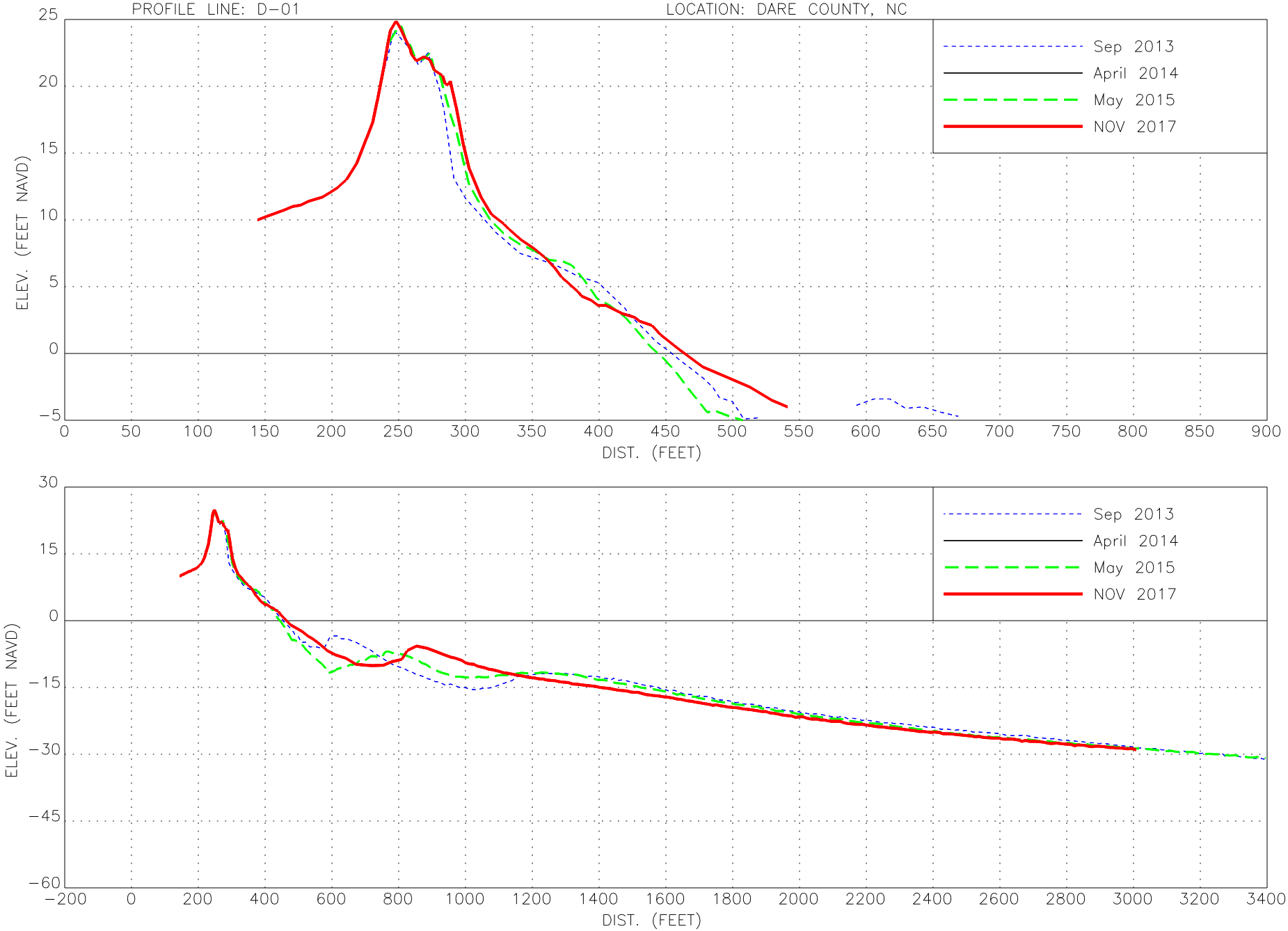
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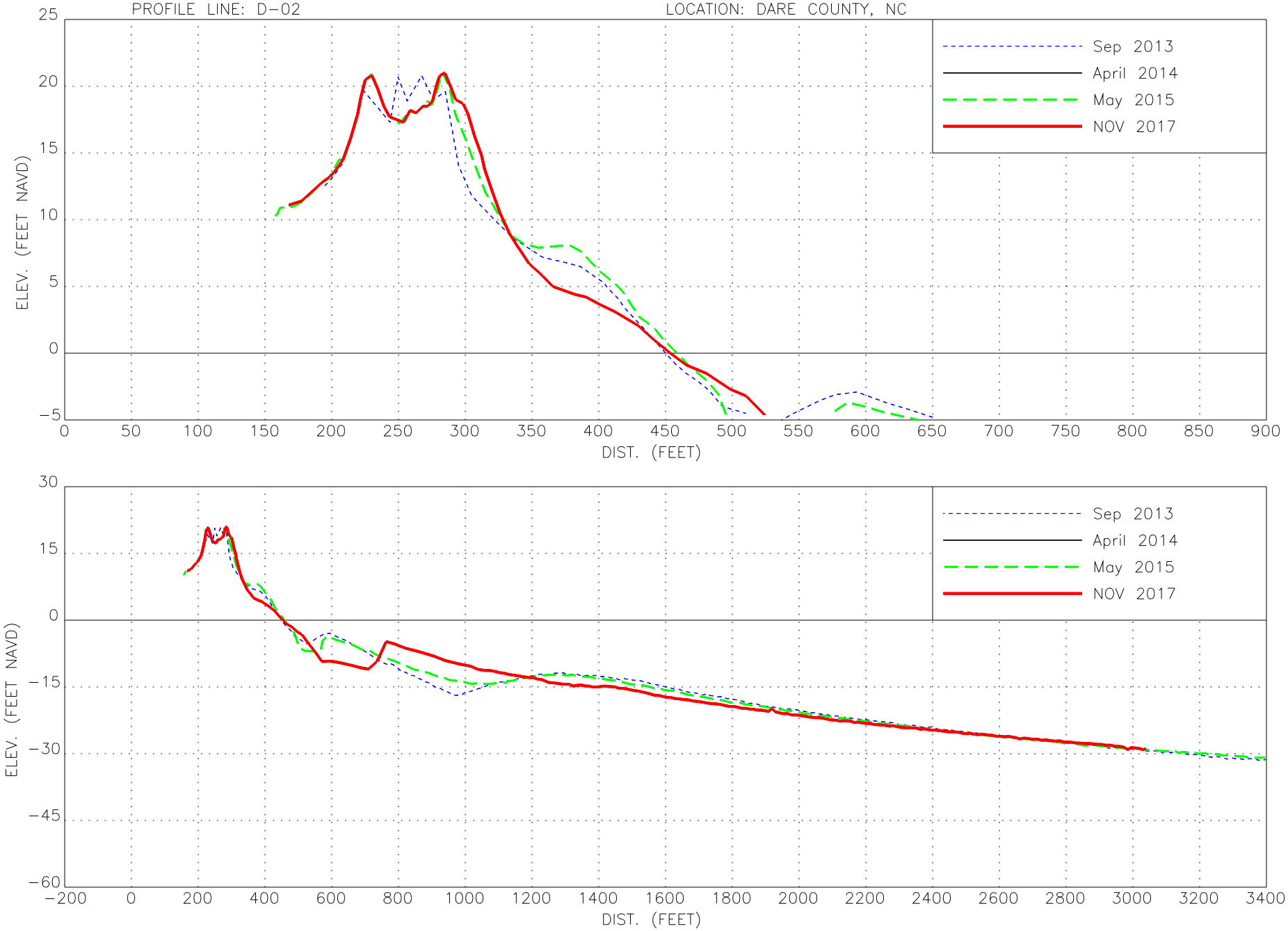
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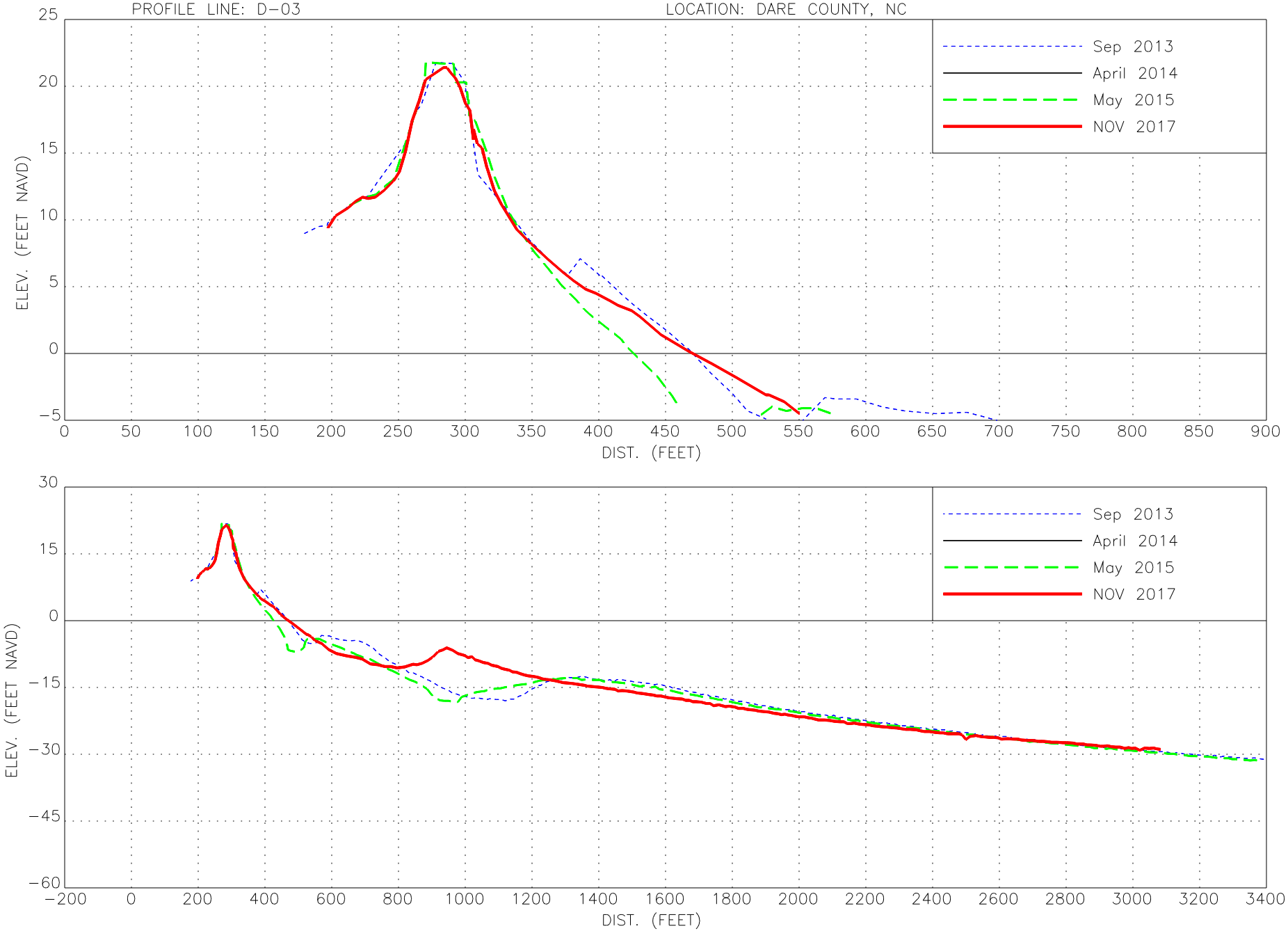
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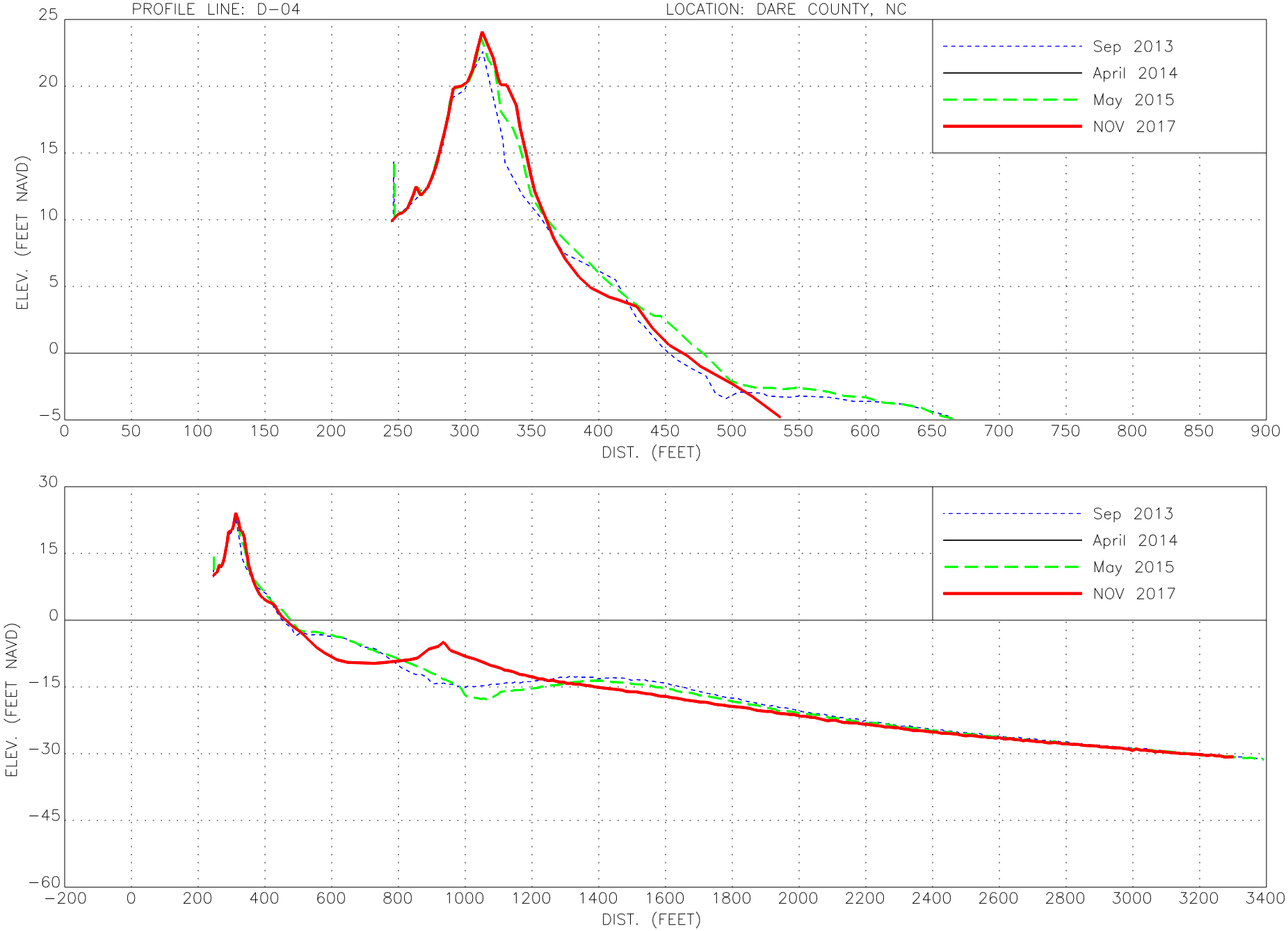
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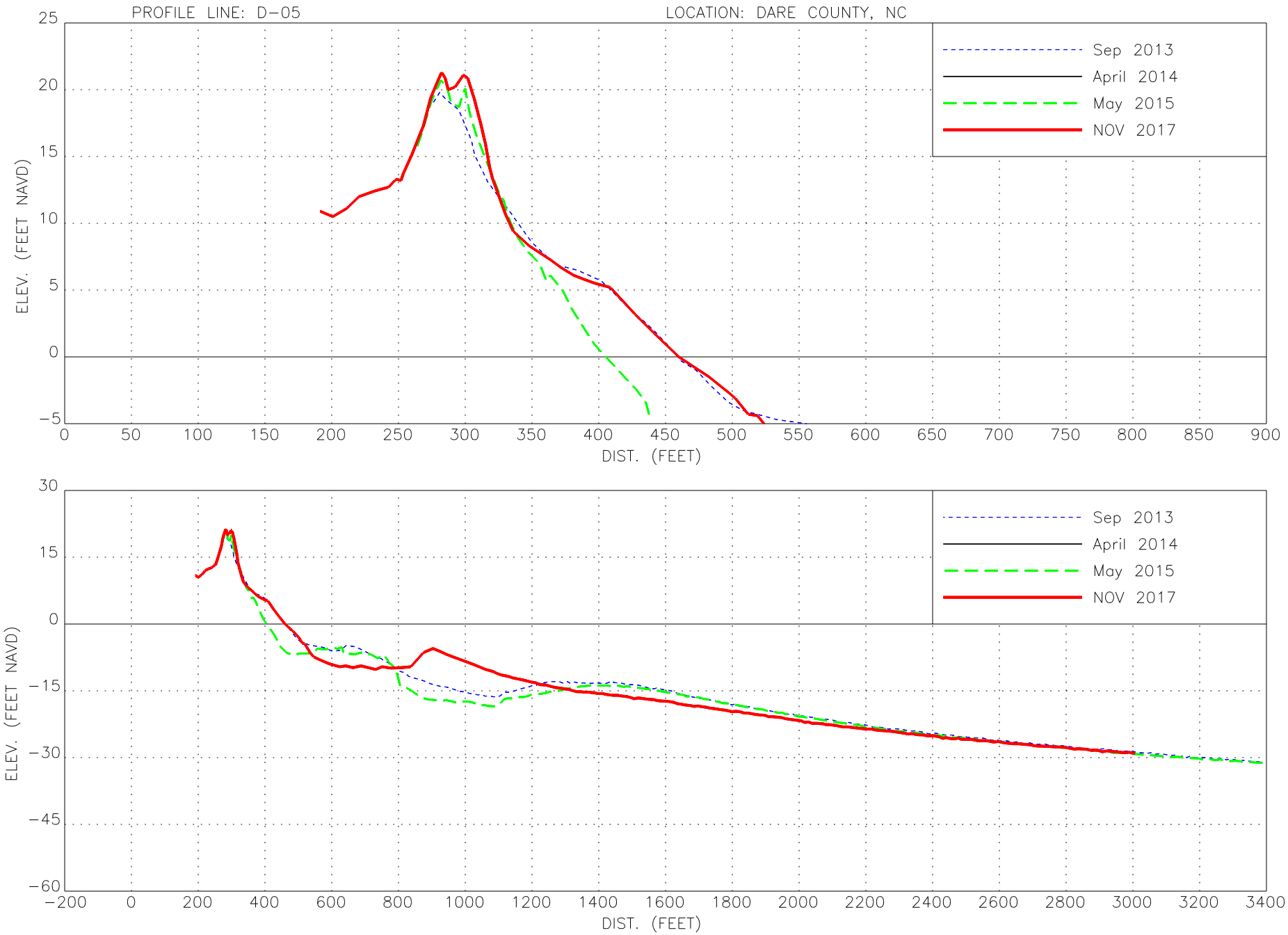
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DIST. (FEET)
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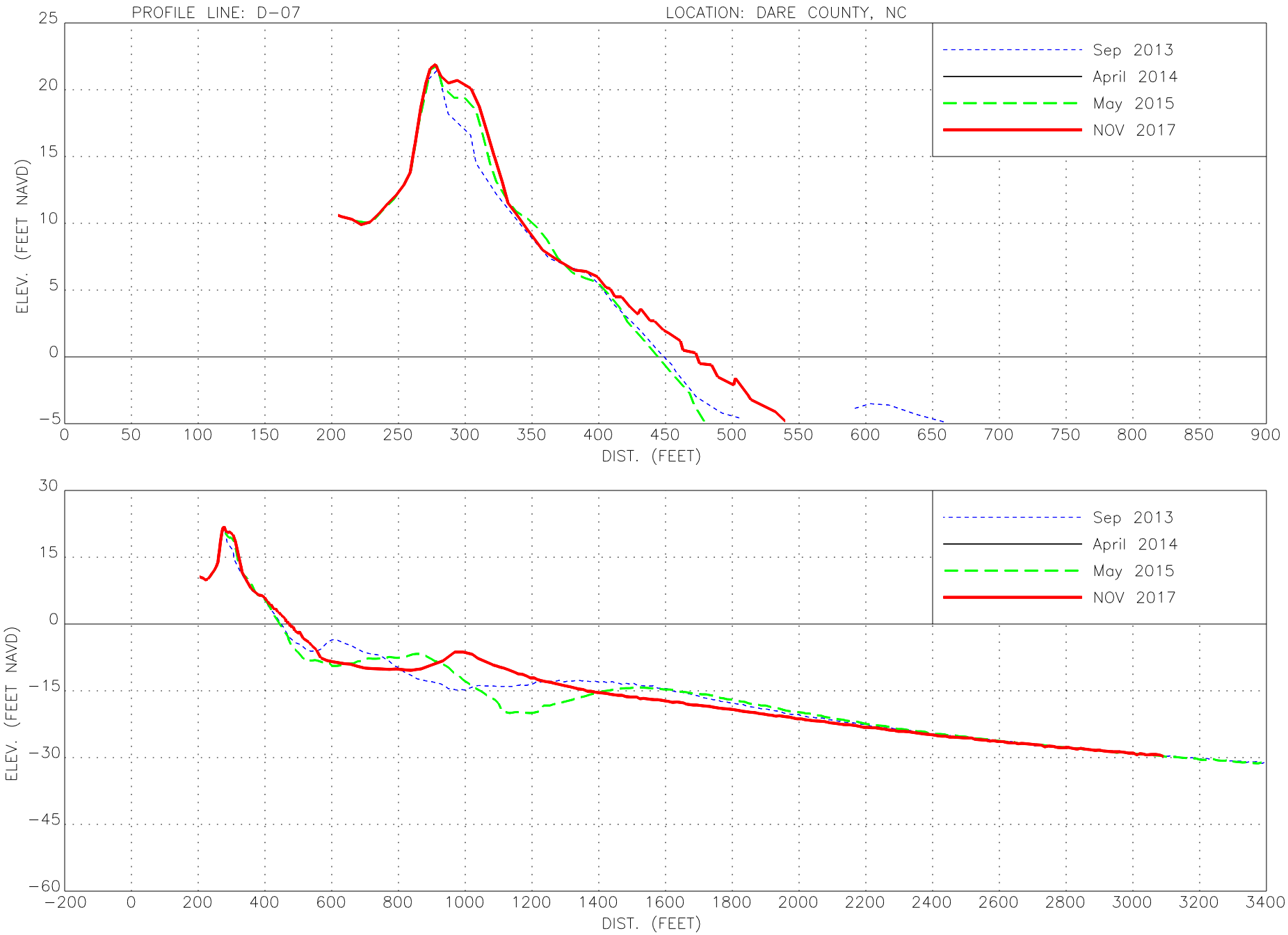
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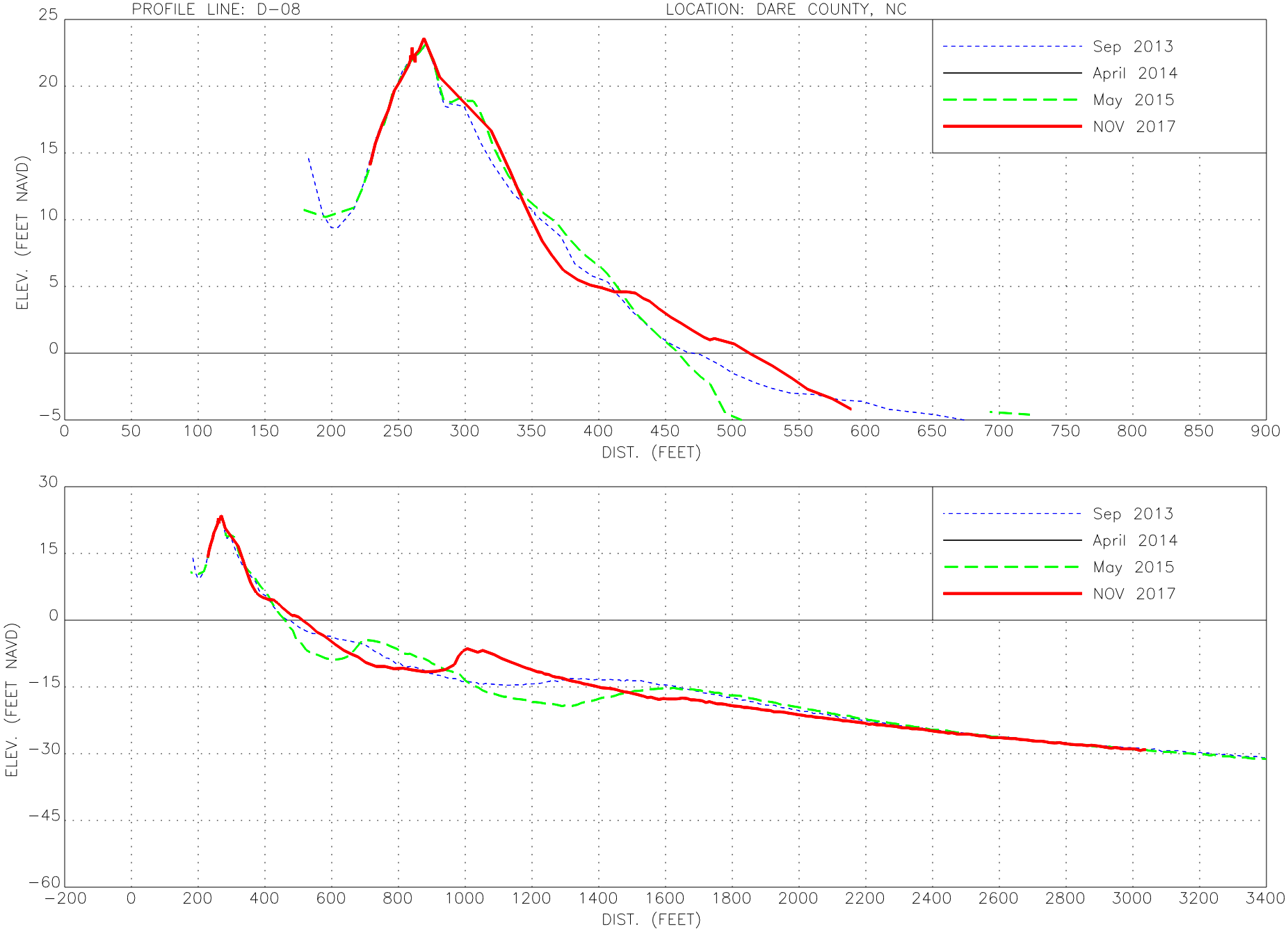
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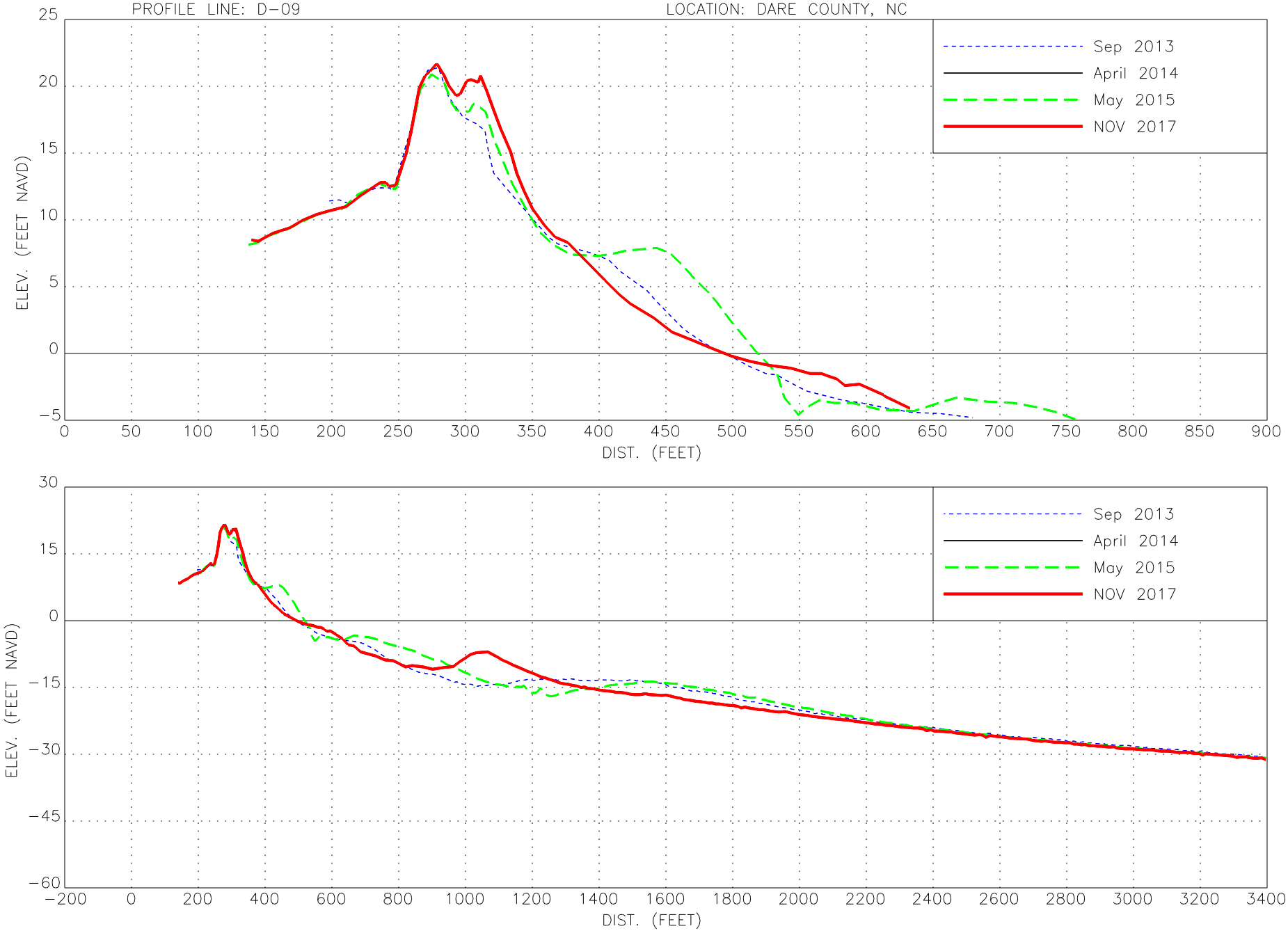
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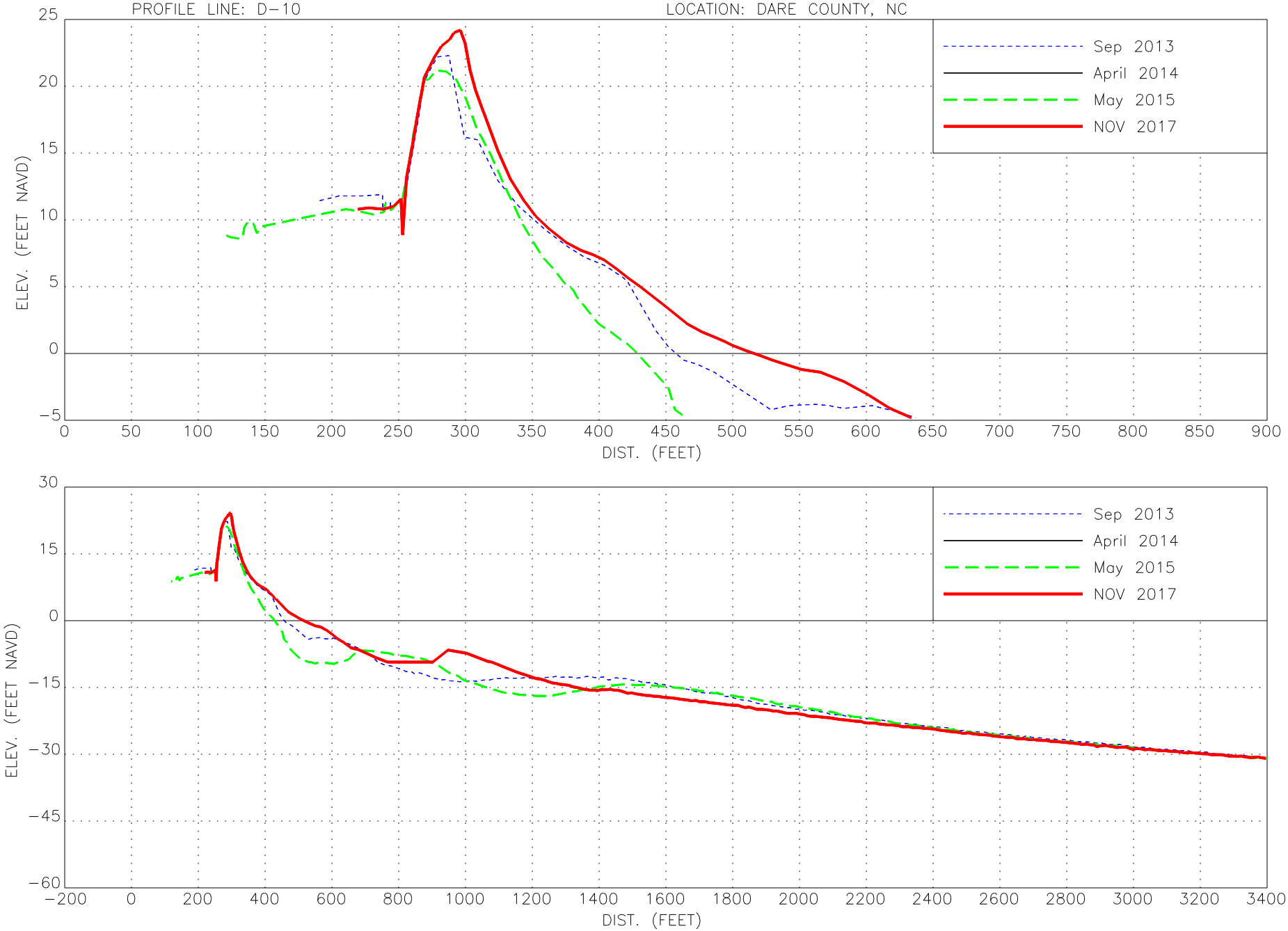
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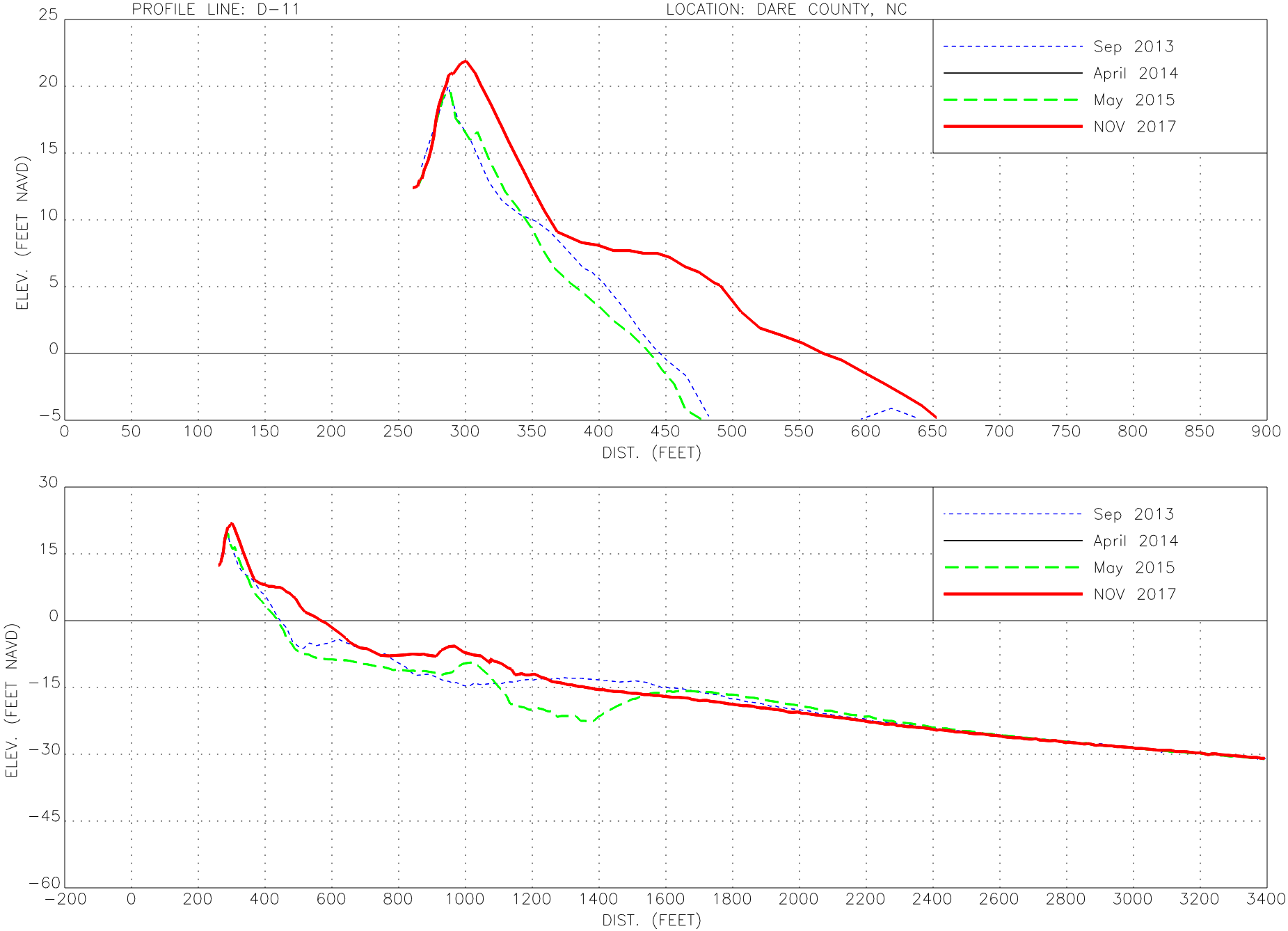
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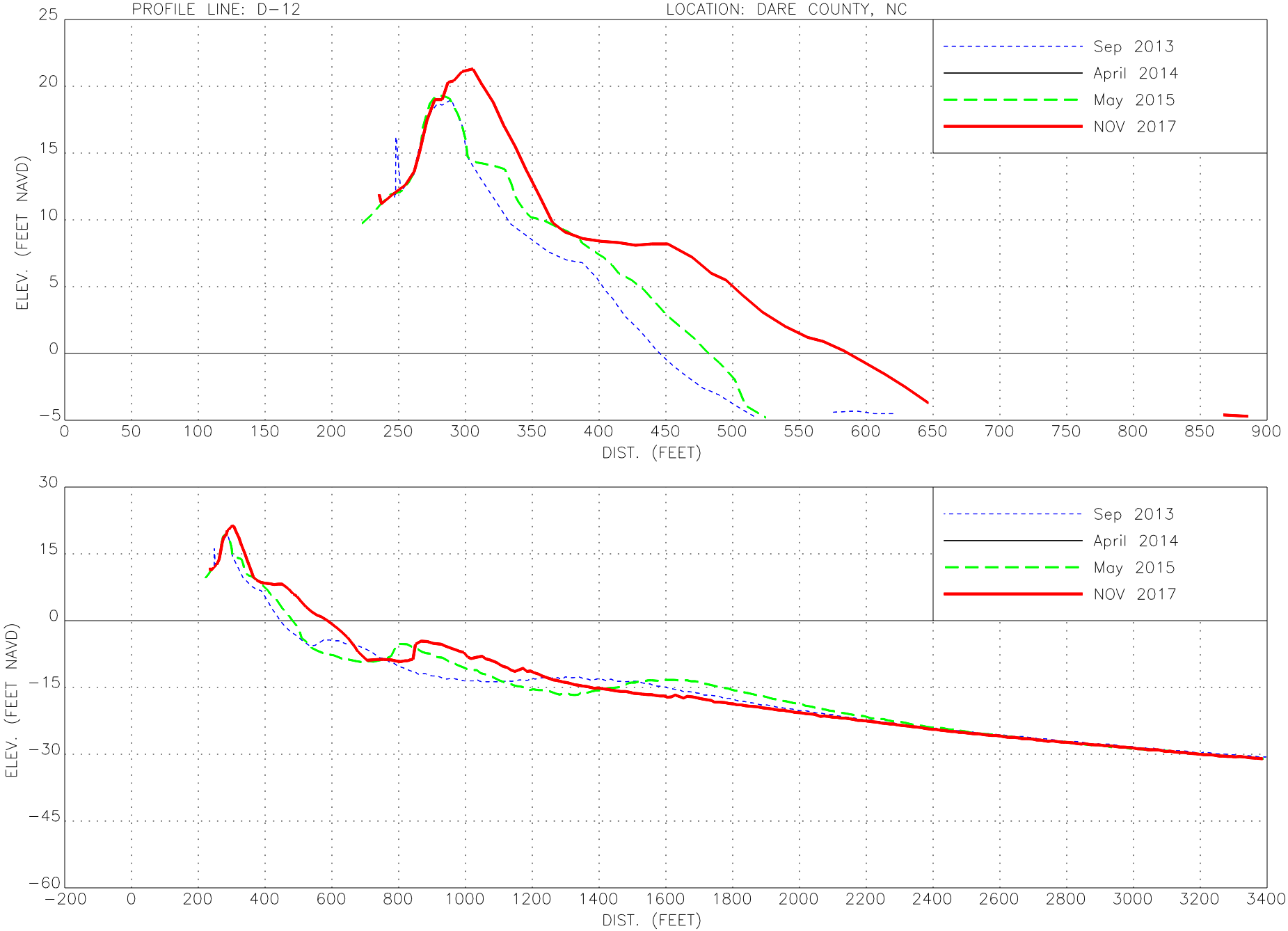
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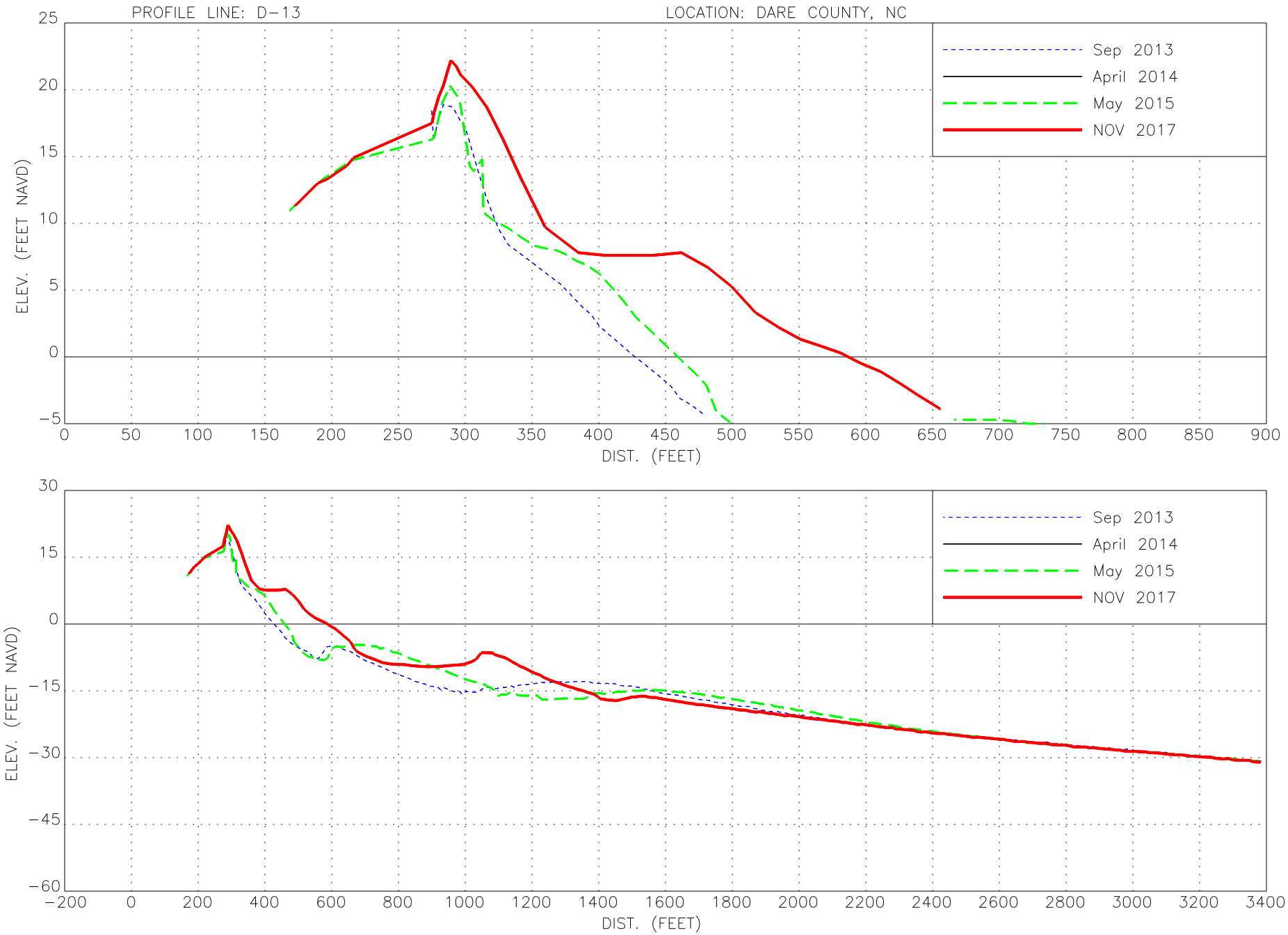
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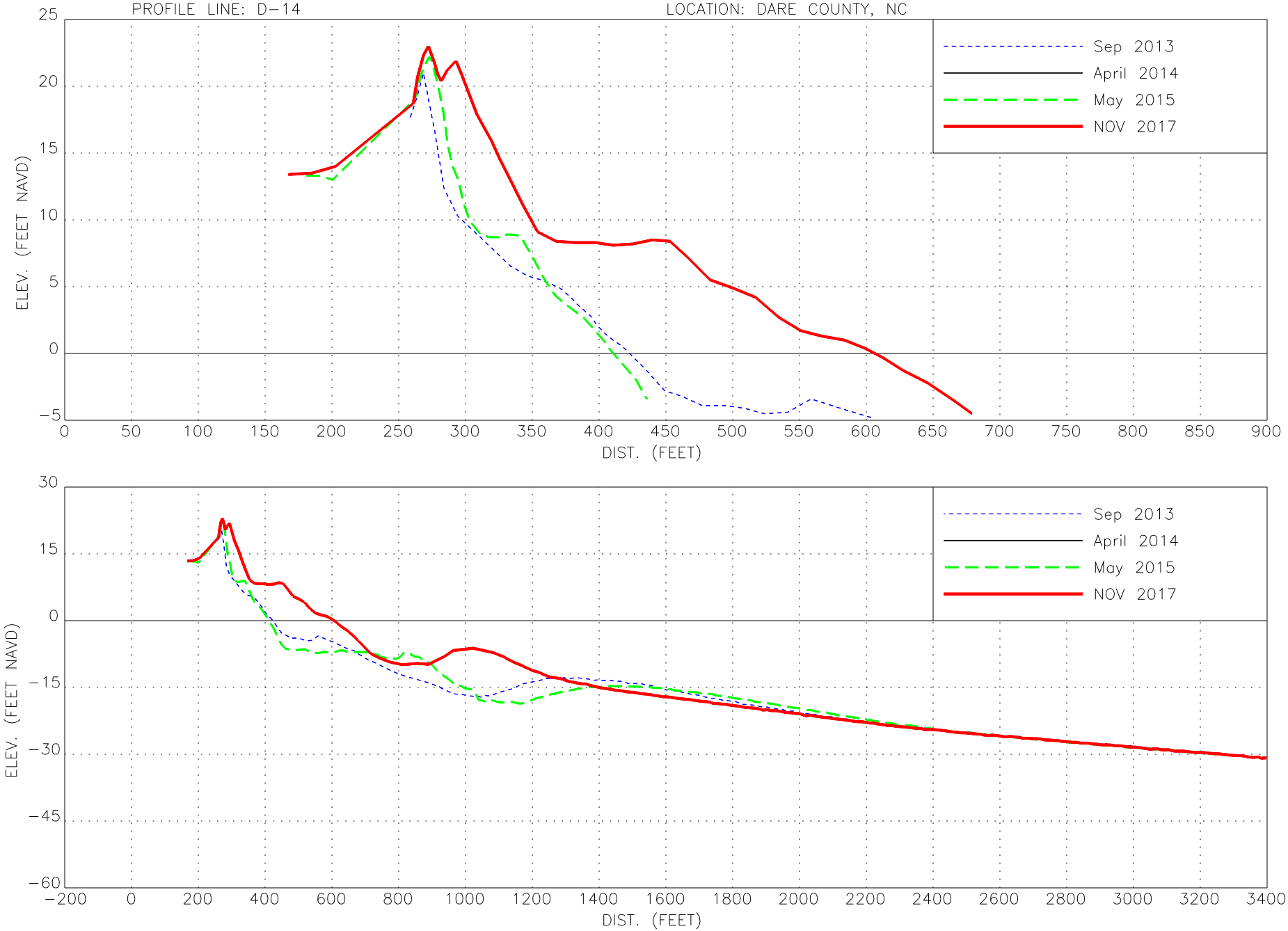
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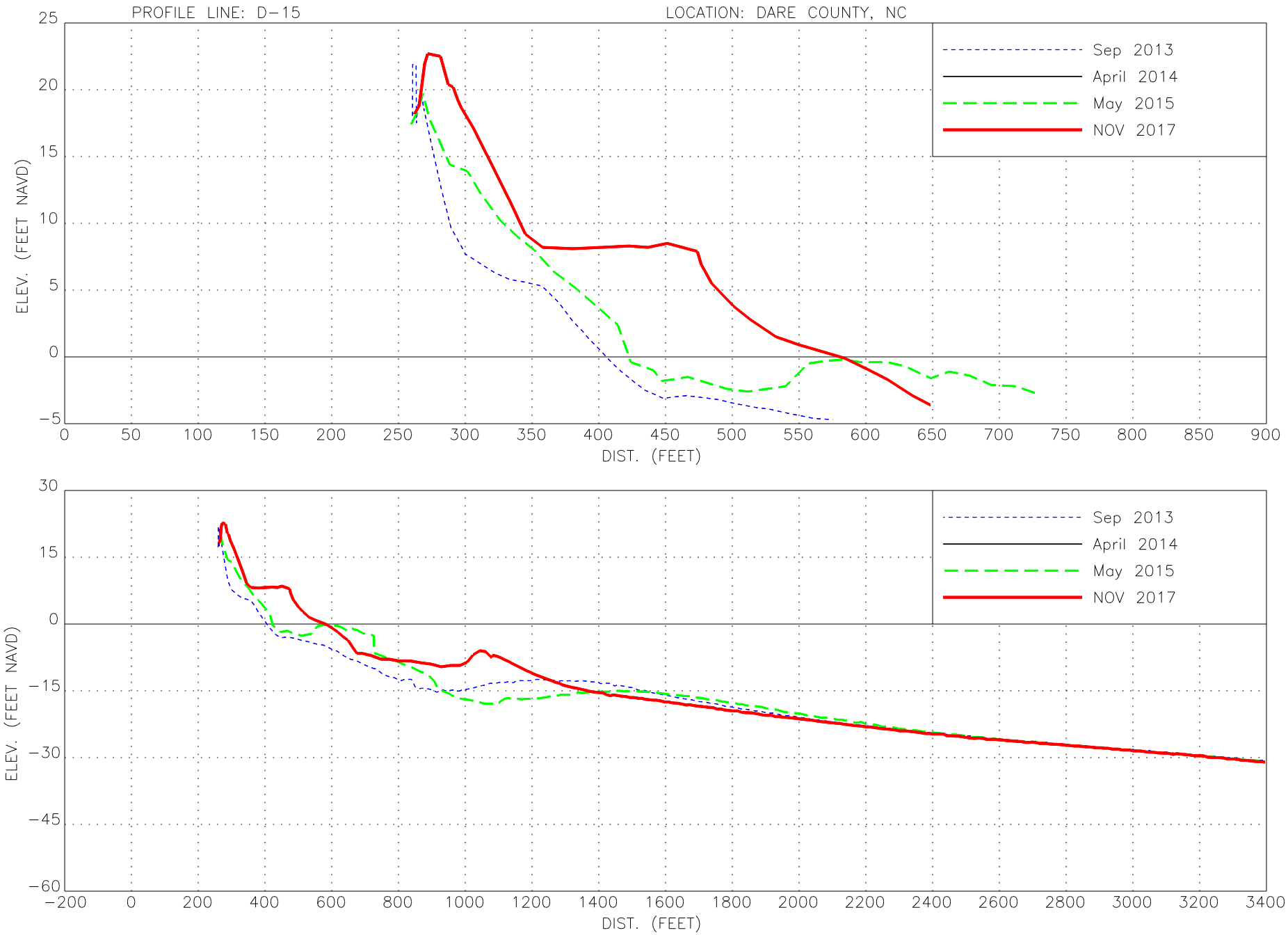
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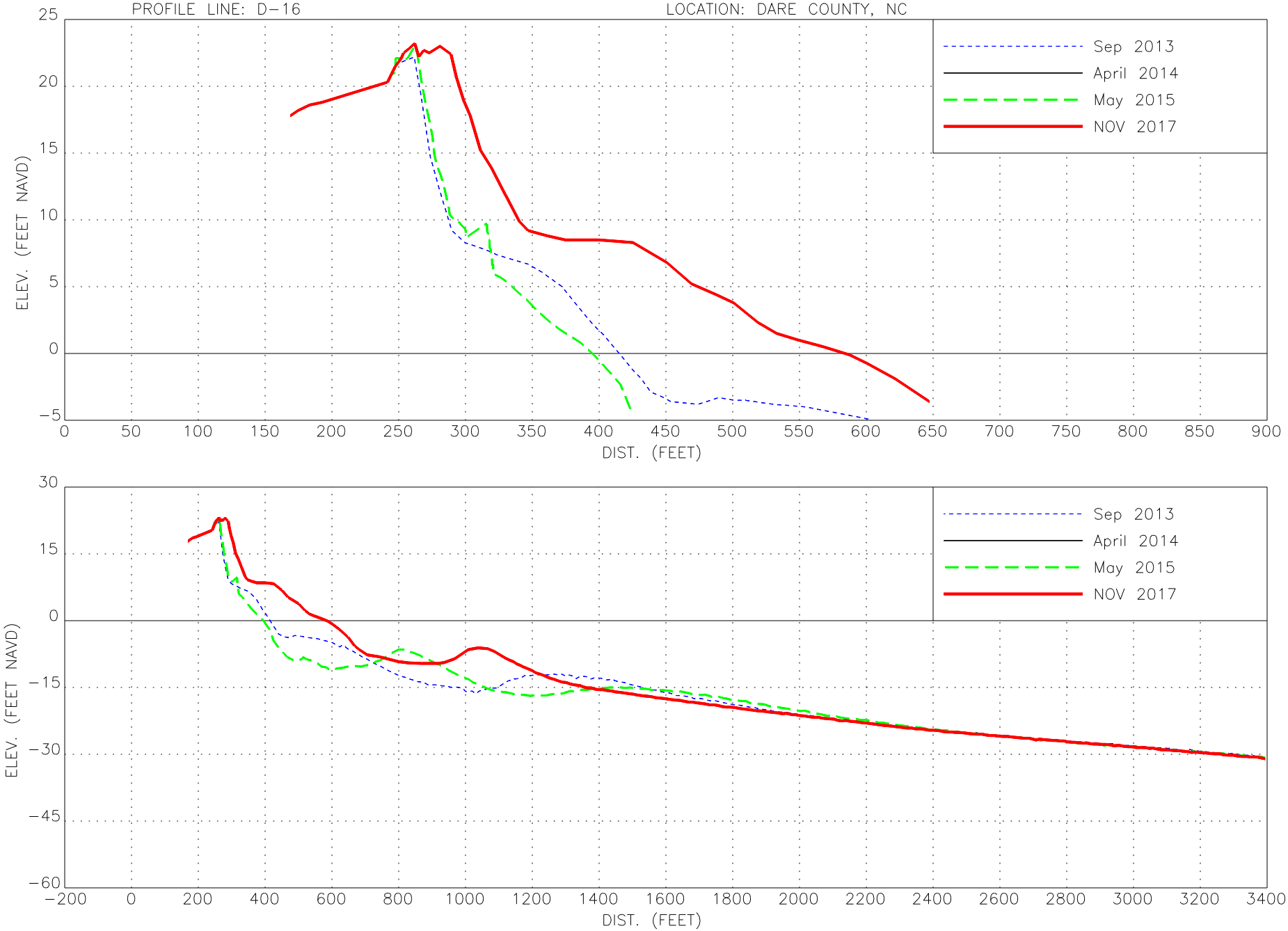
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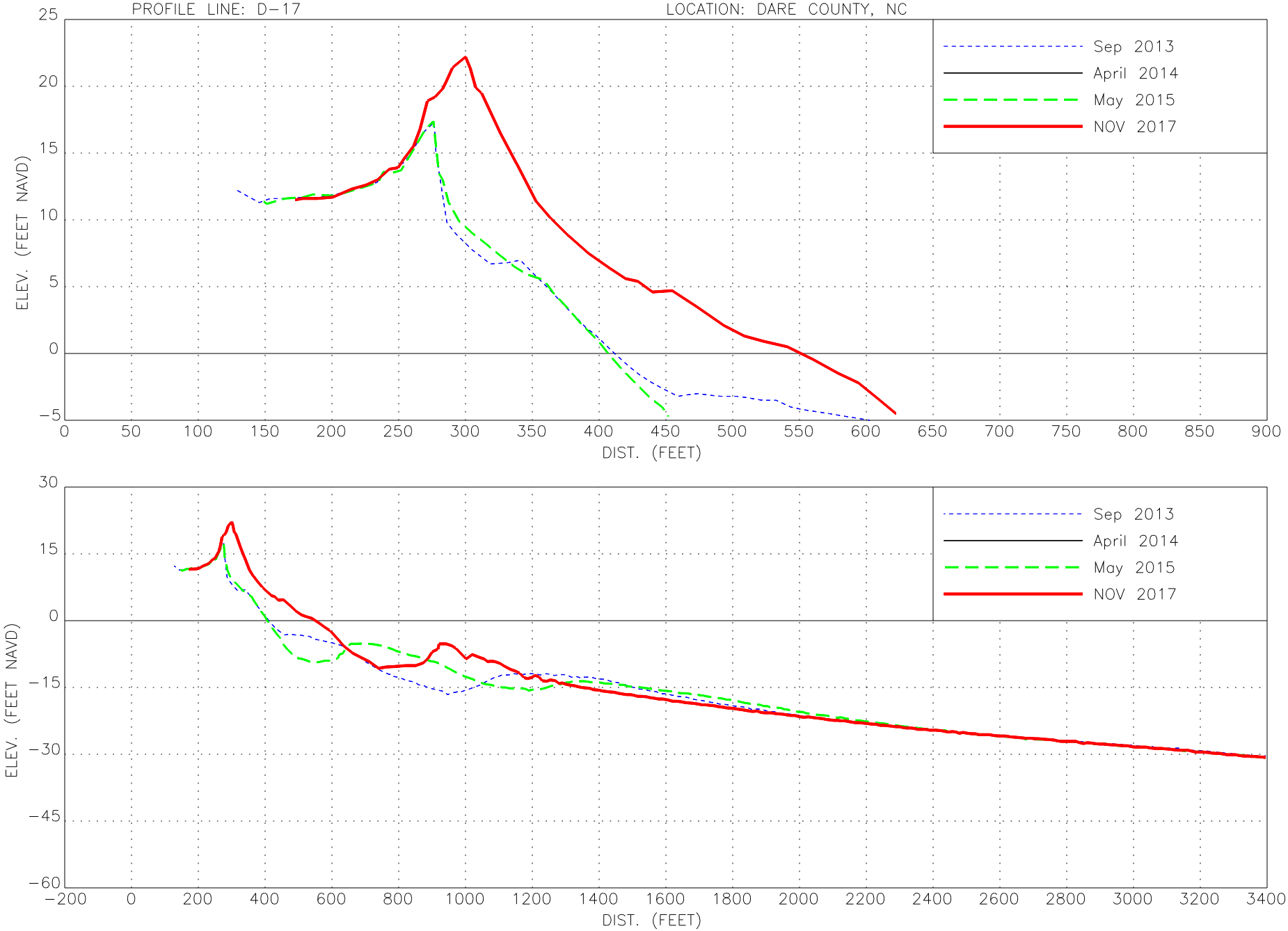
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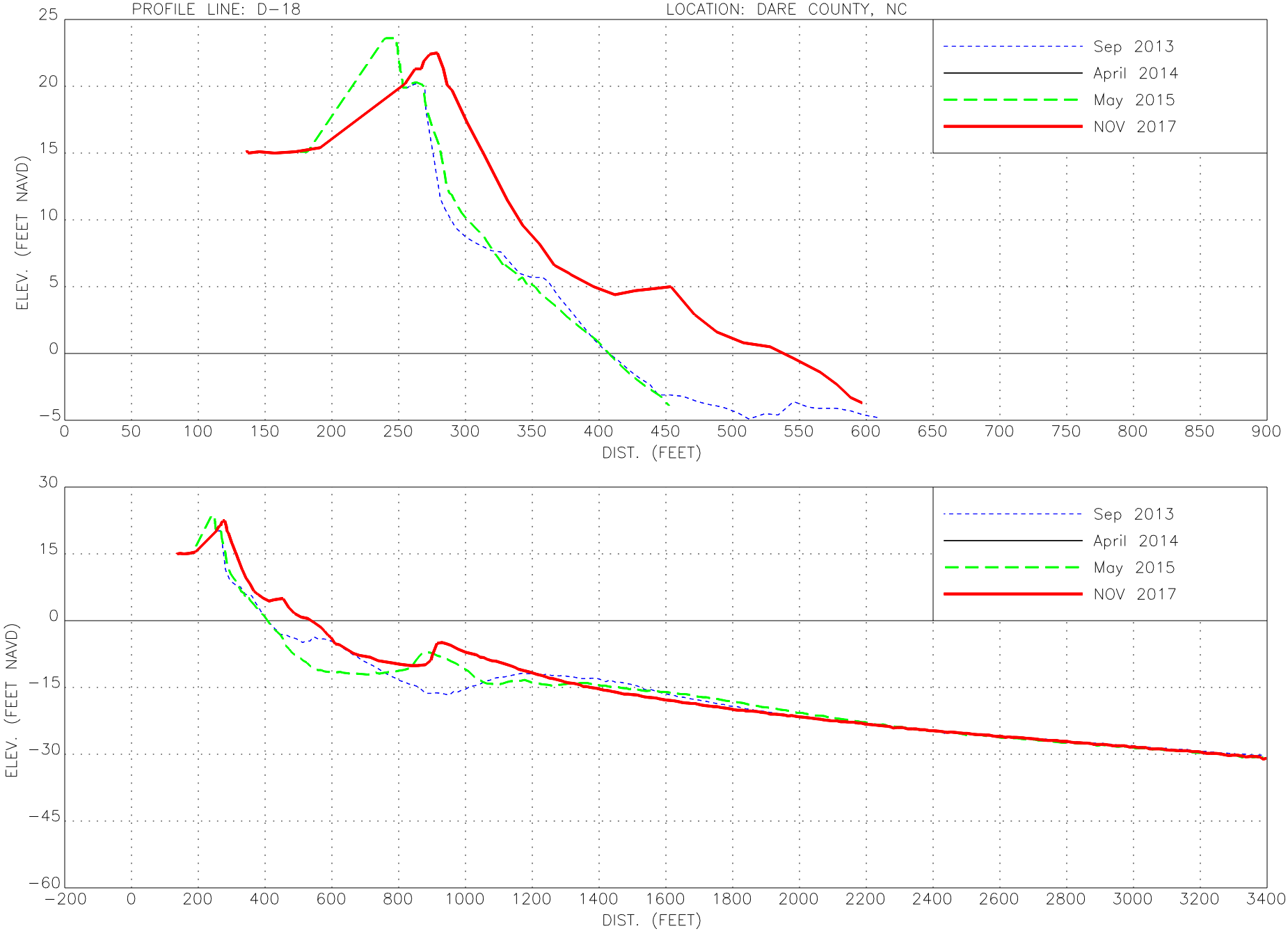
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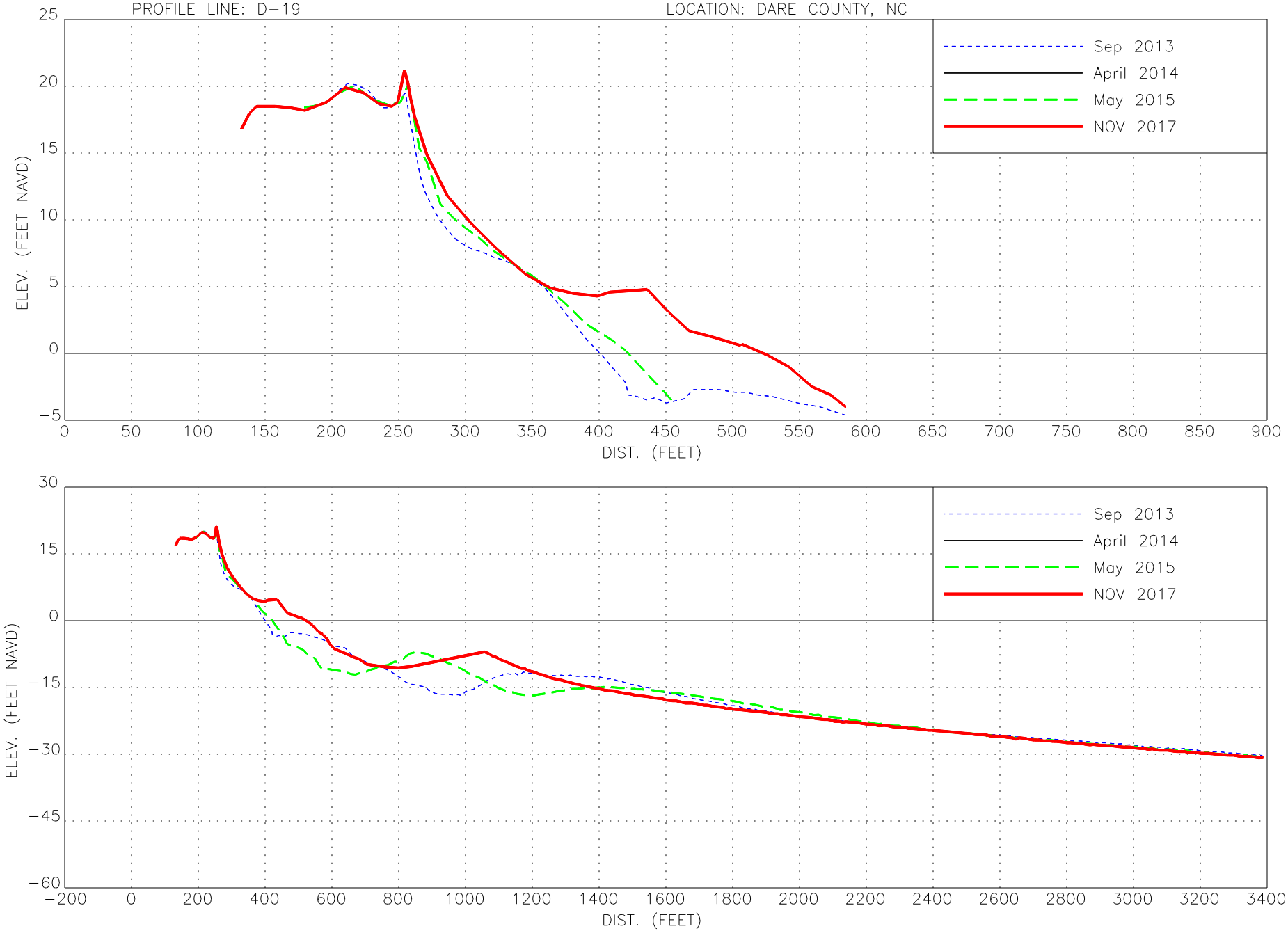
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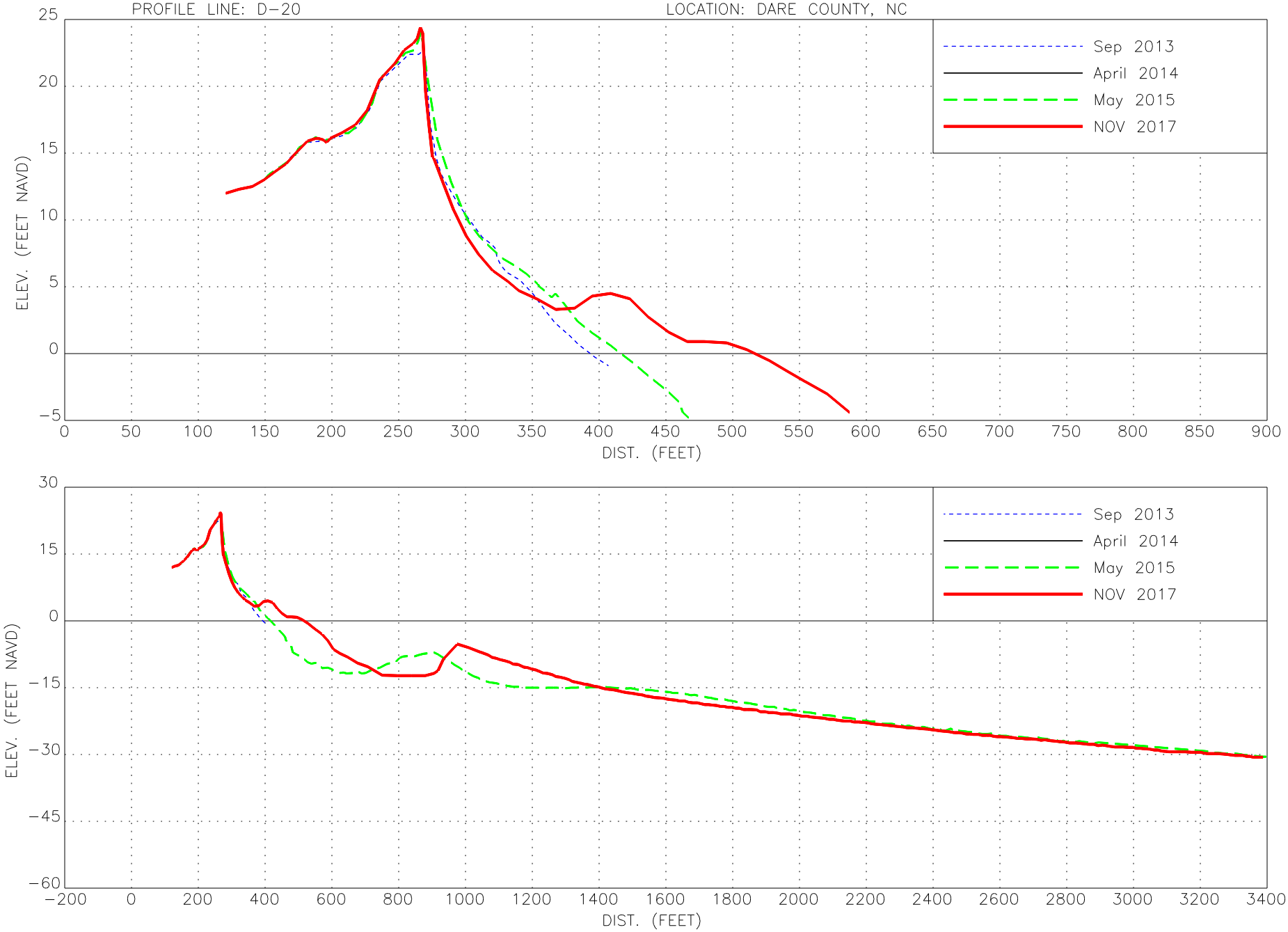
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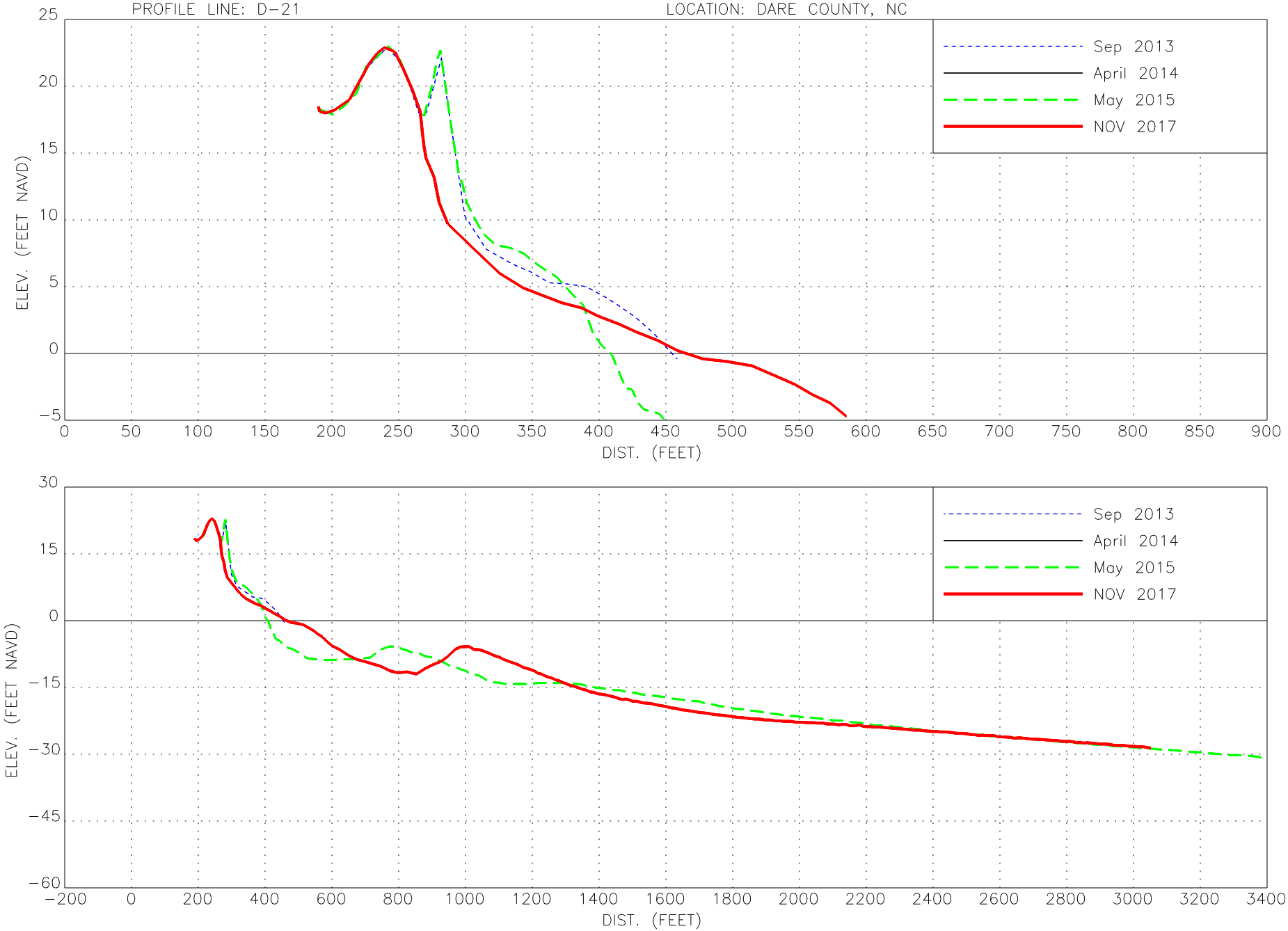
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April 2014
May 2015
NOV 2017
ELEV. (FEET NAVD)
DIST. (FEET)
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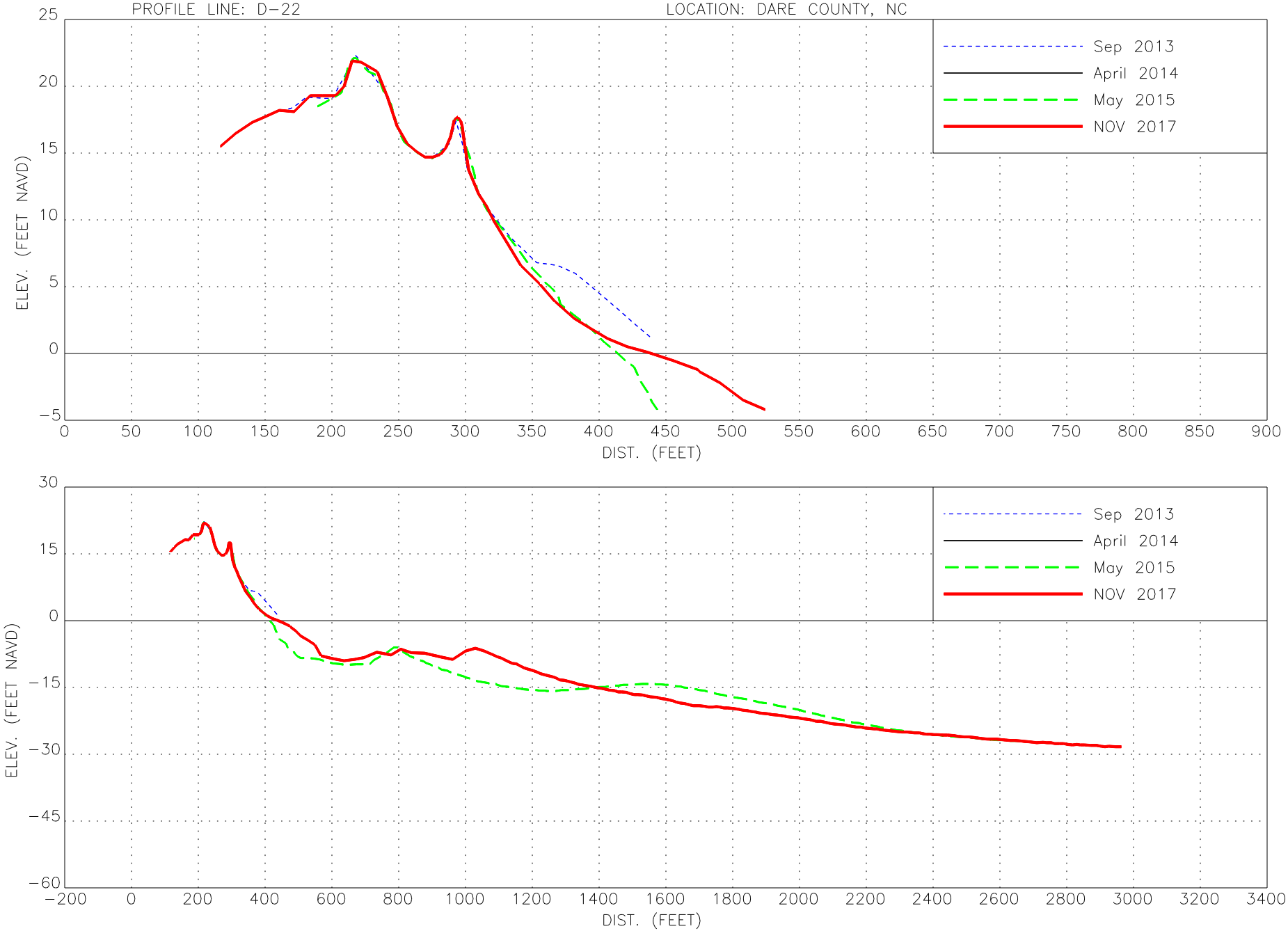
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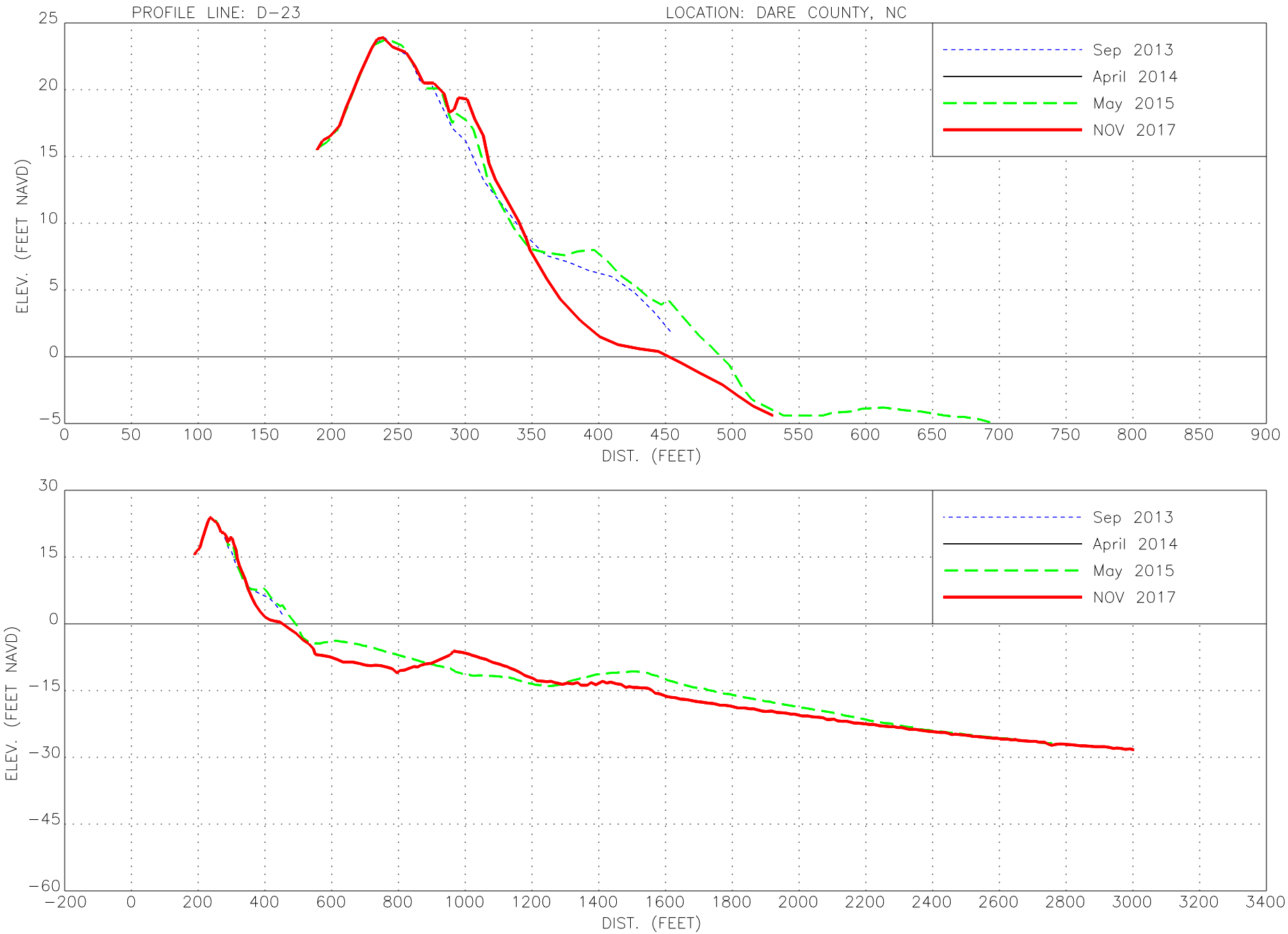
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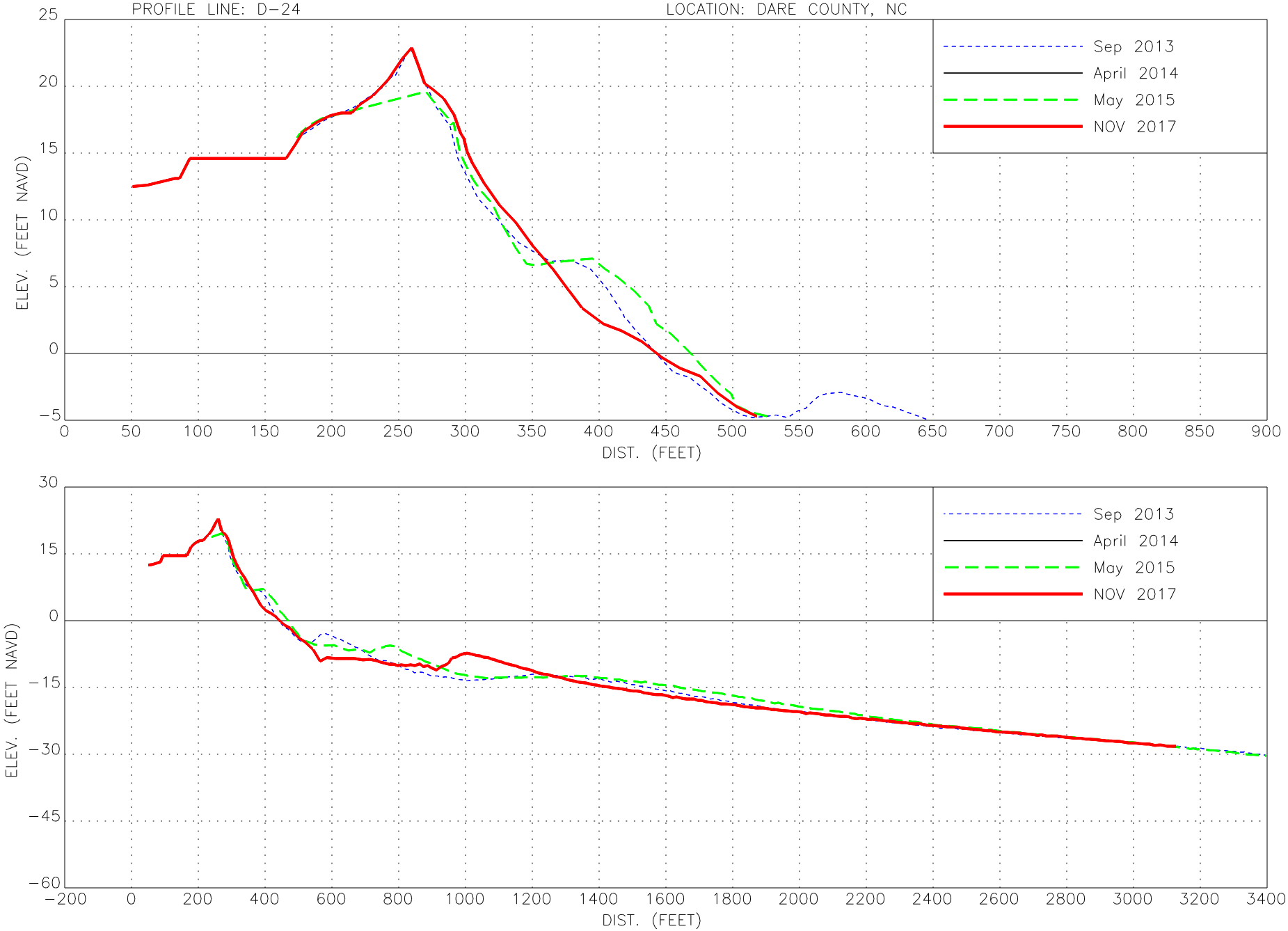
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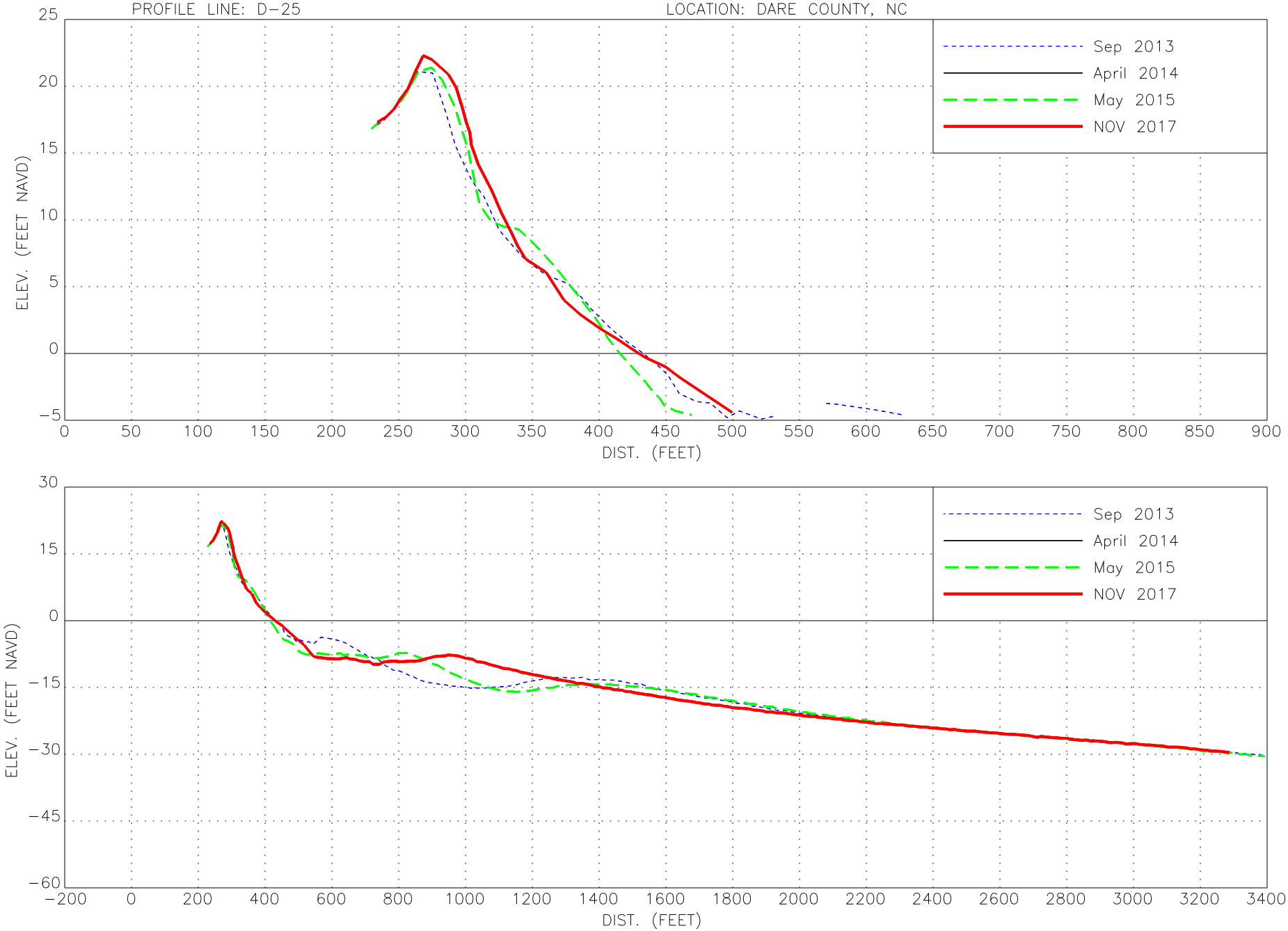
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ELEV. (FEET NAVD)
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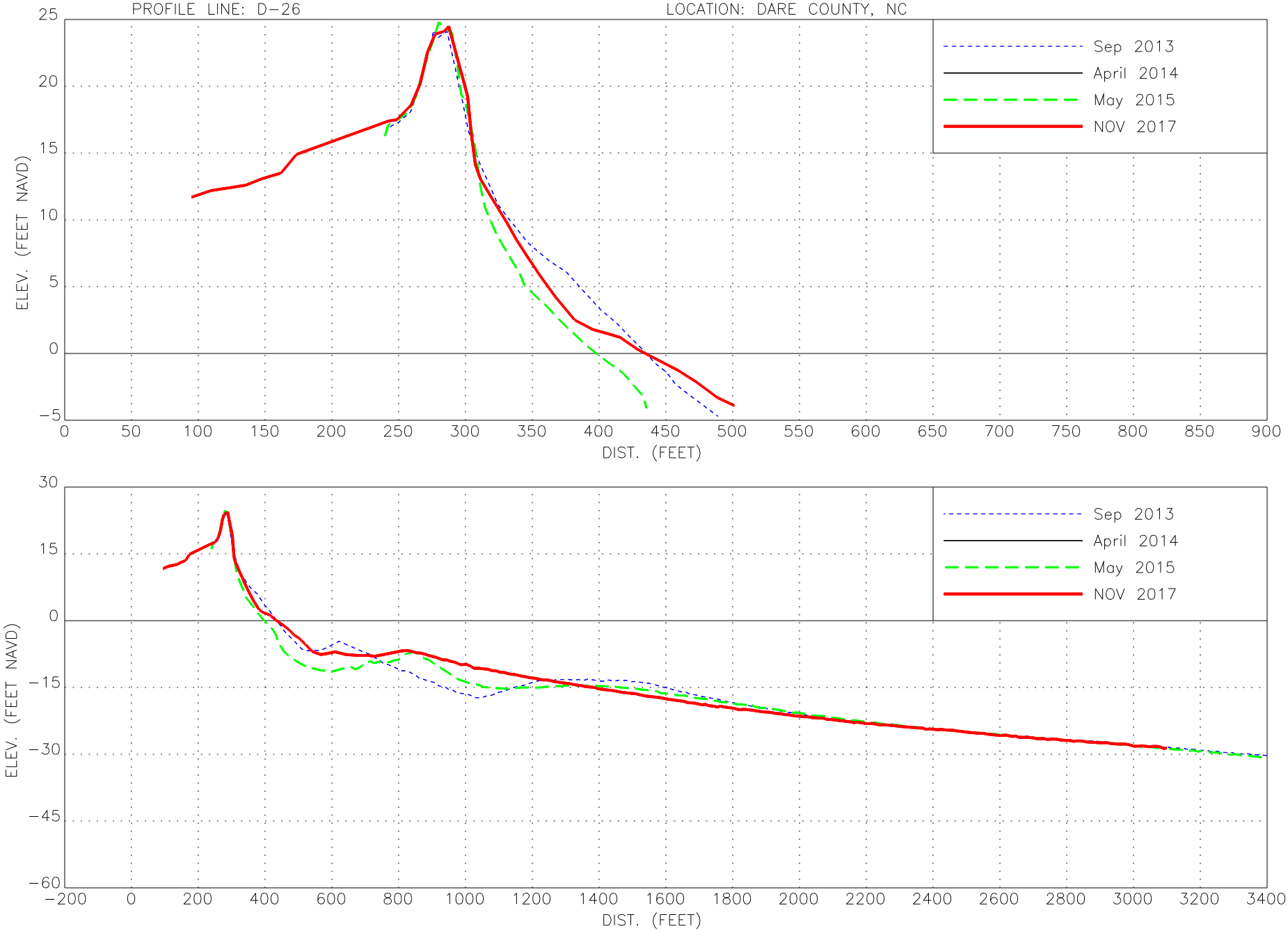
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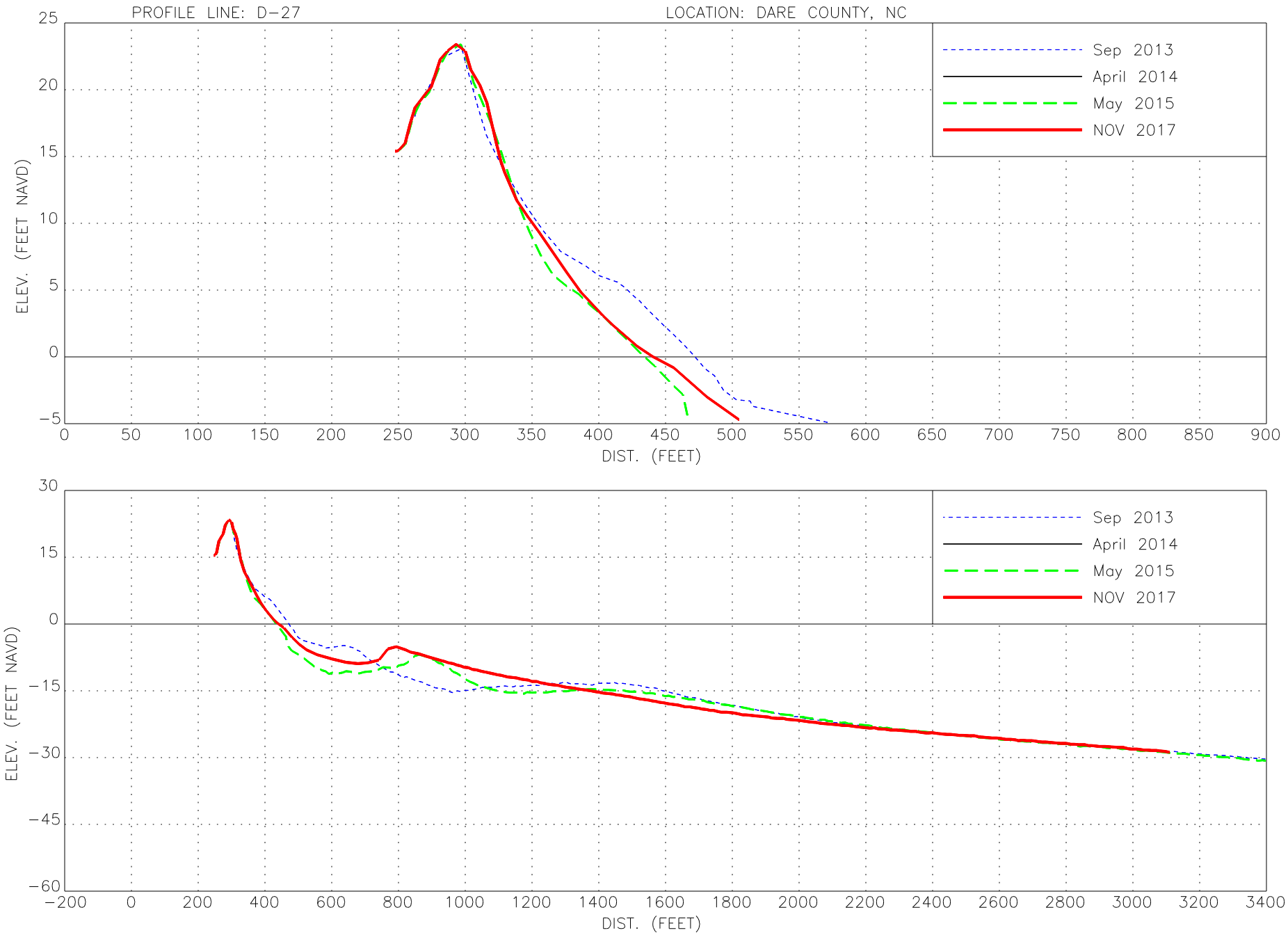
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DIST. (FEET)
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PROFILE LINE: D-28
LOCATION: DARE COUNTY, NC
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April 2014
May 2015
NOV 2017
ELEV. (FEET NAVD)
DIST. (FEET)
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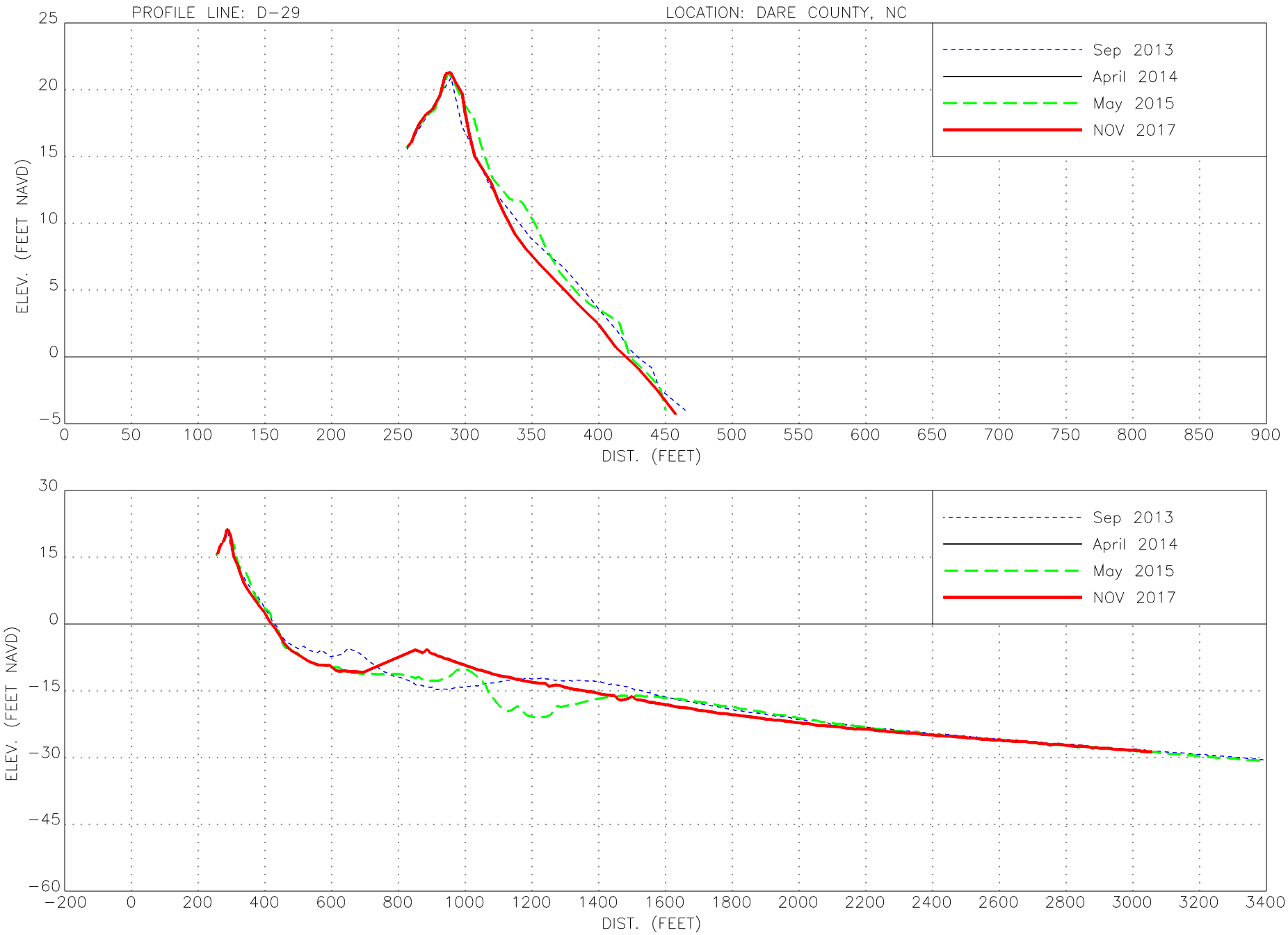
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May 2015
NOV 2017
ELEV. (FEET NAVD)
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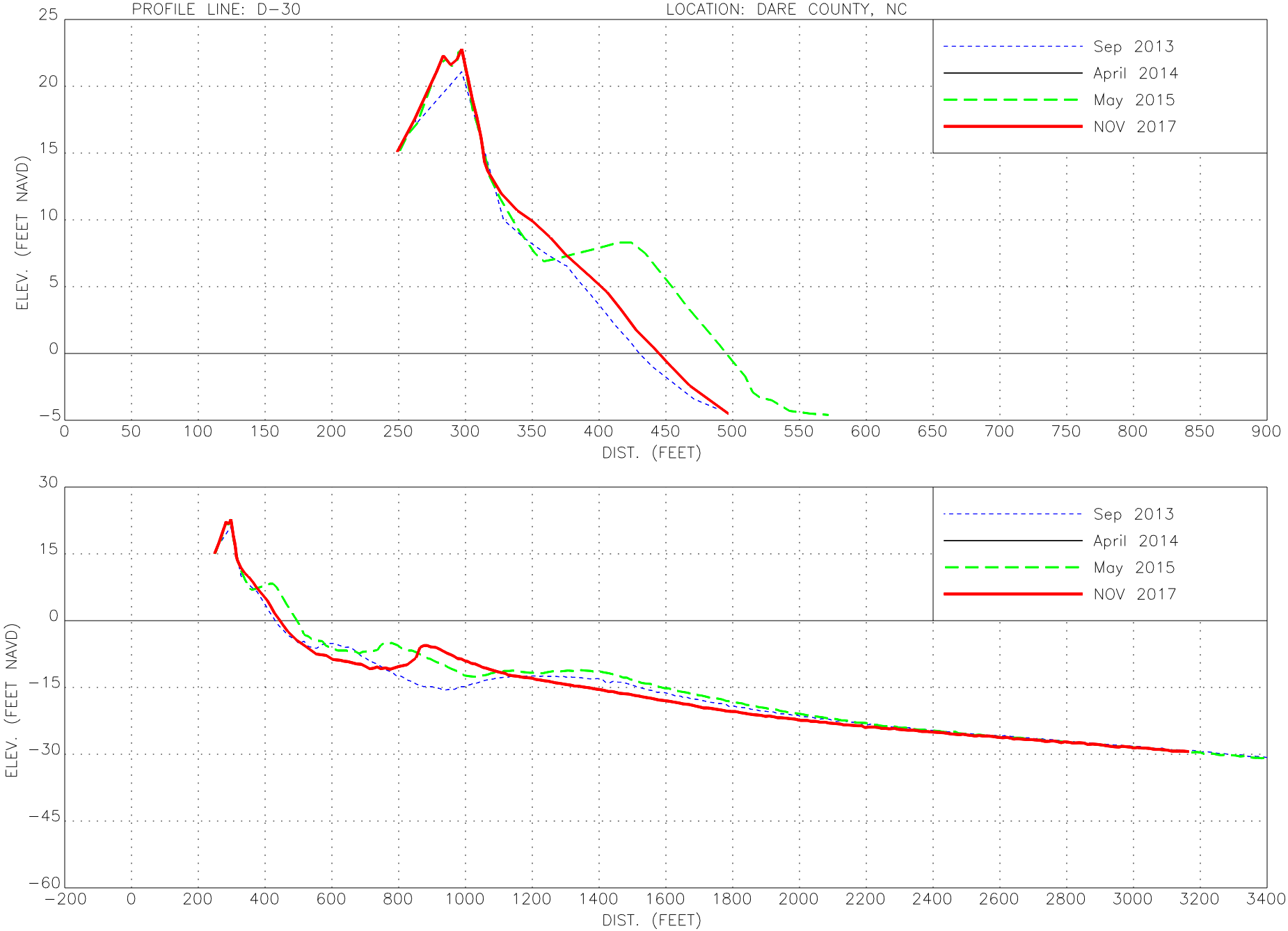
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DIST. (FEET)
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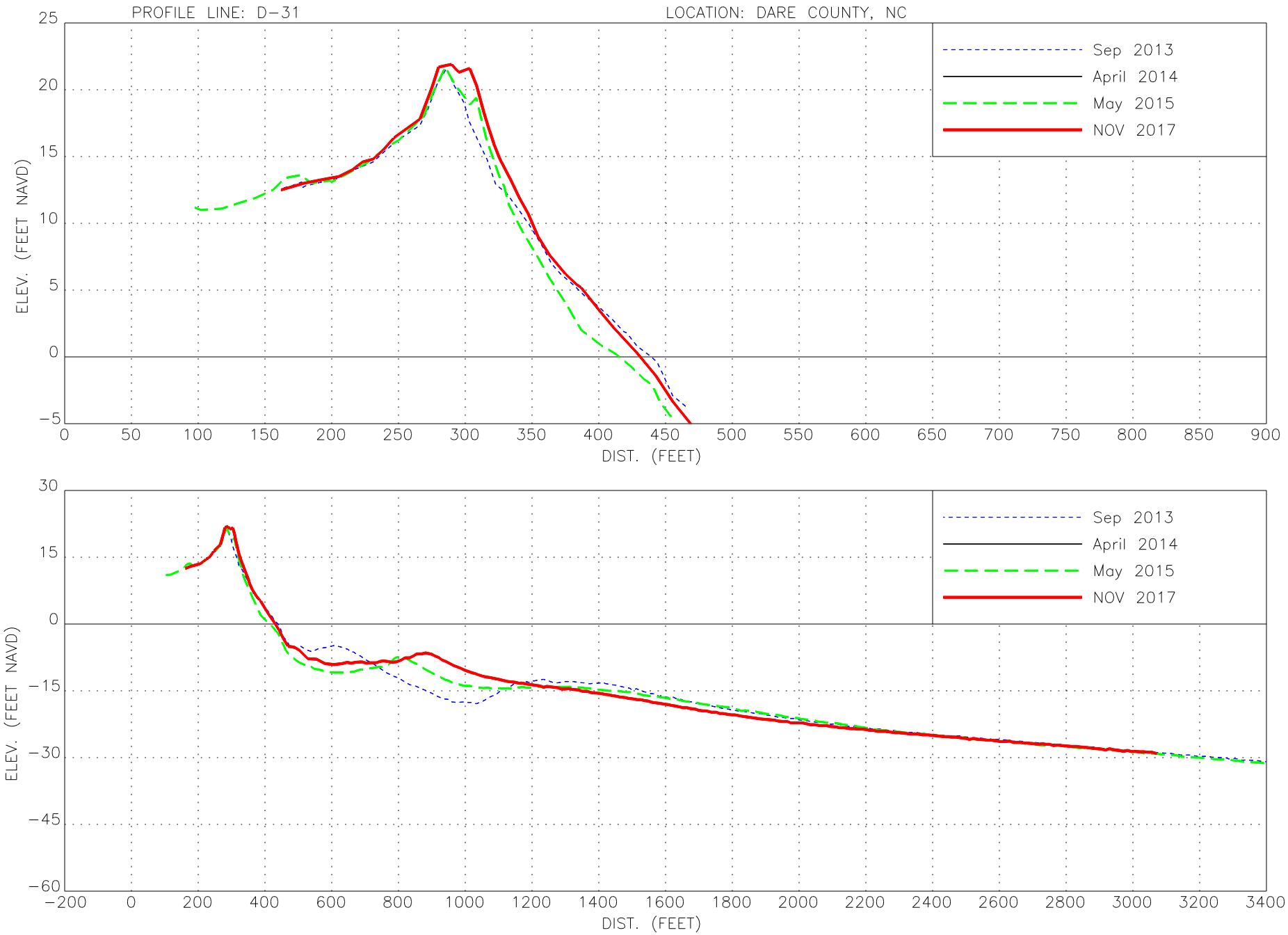
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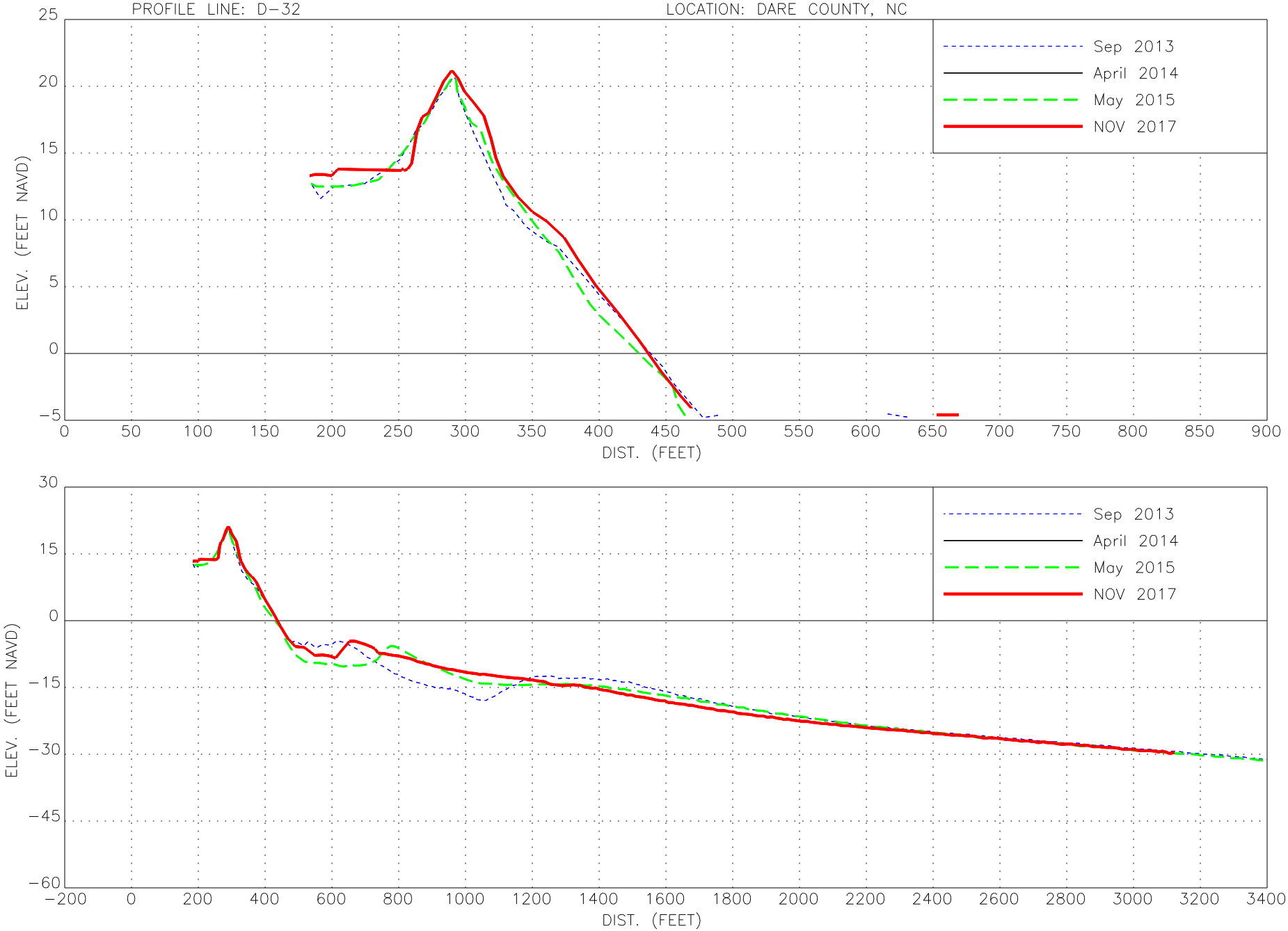
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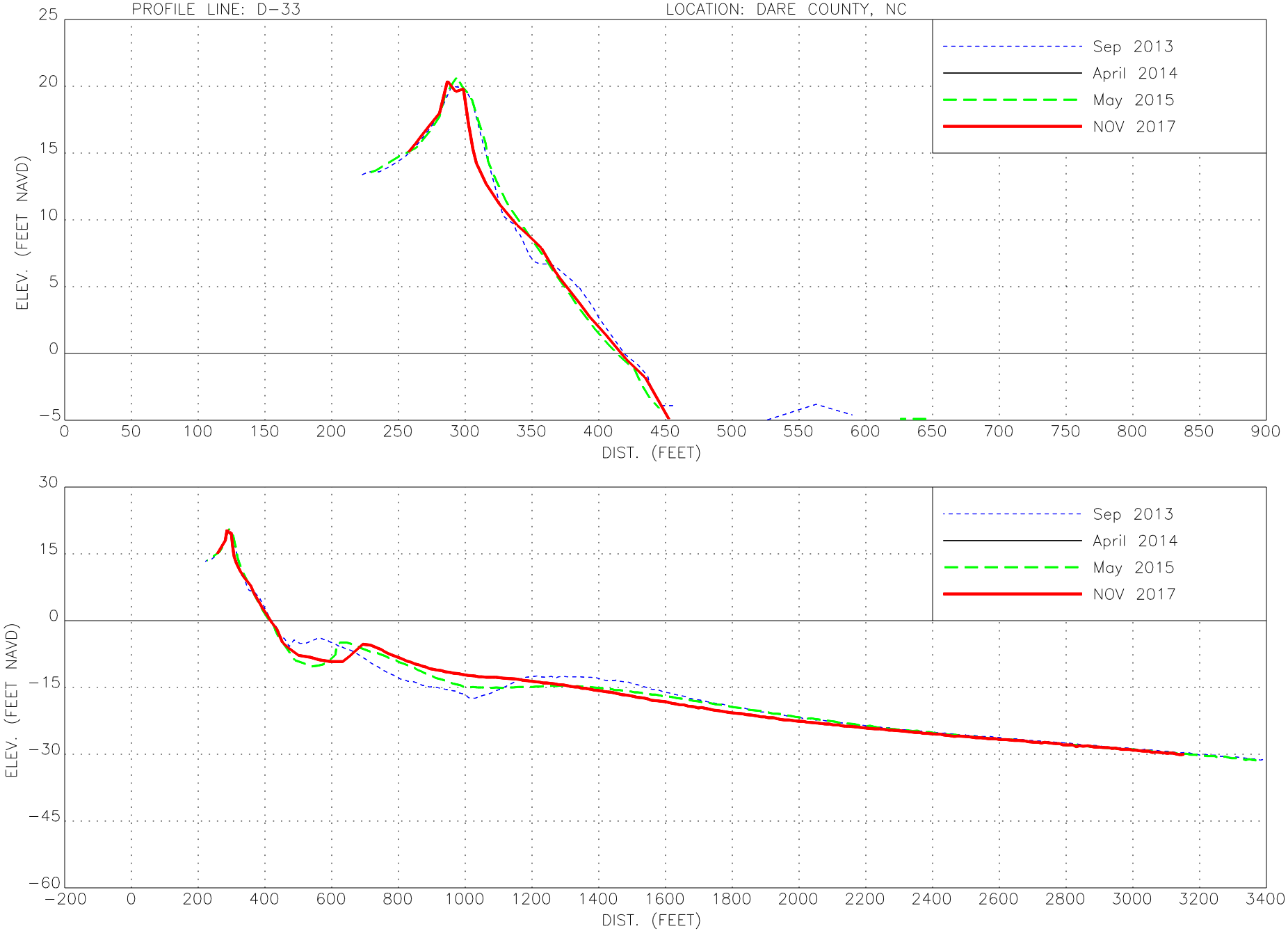
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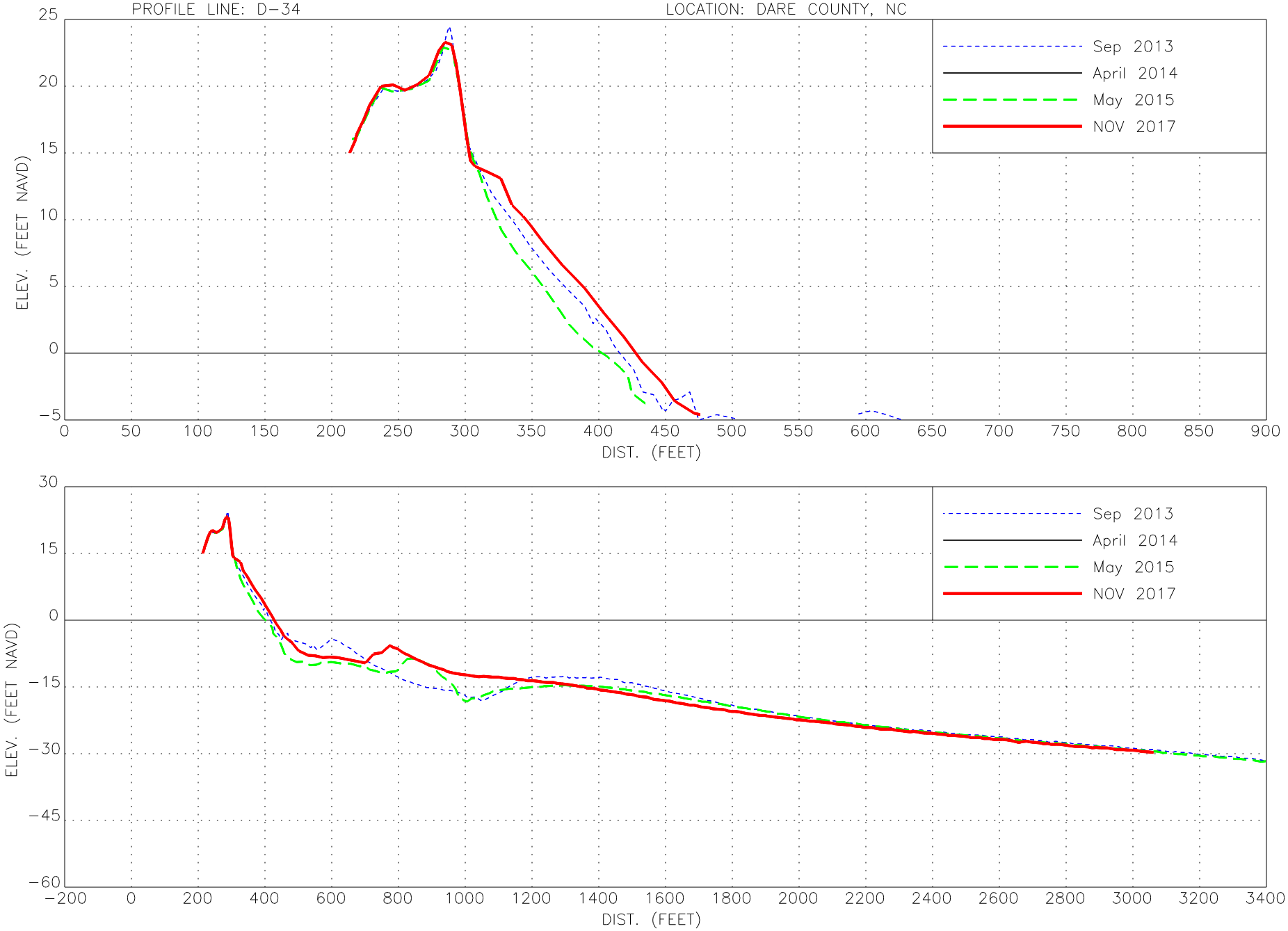
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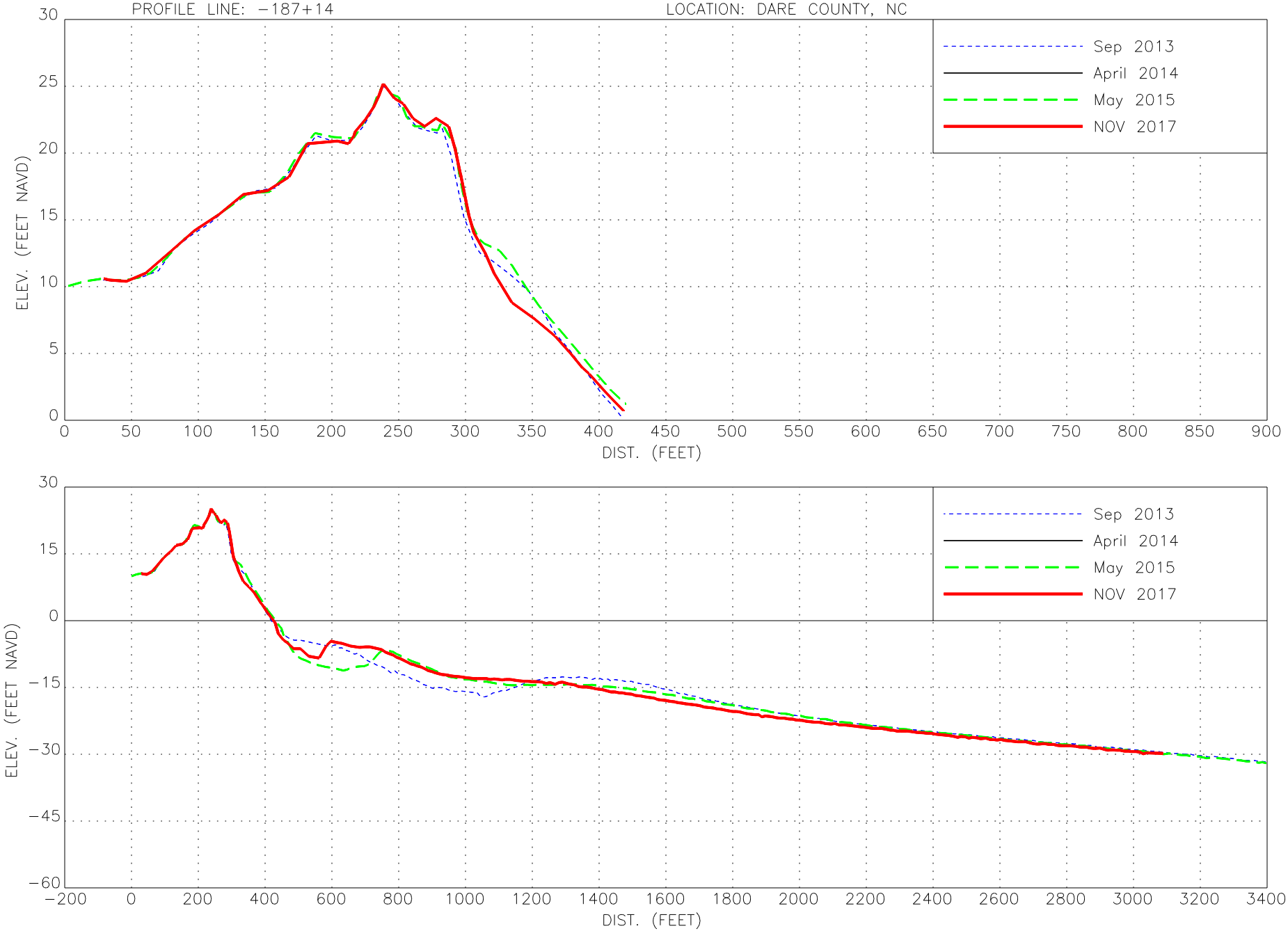
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DIST. (FEET)
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Sep 2013
April 2014
May 2015
NOV 2017
ELEV. (FEET NAVD)
DIST. (FEET)
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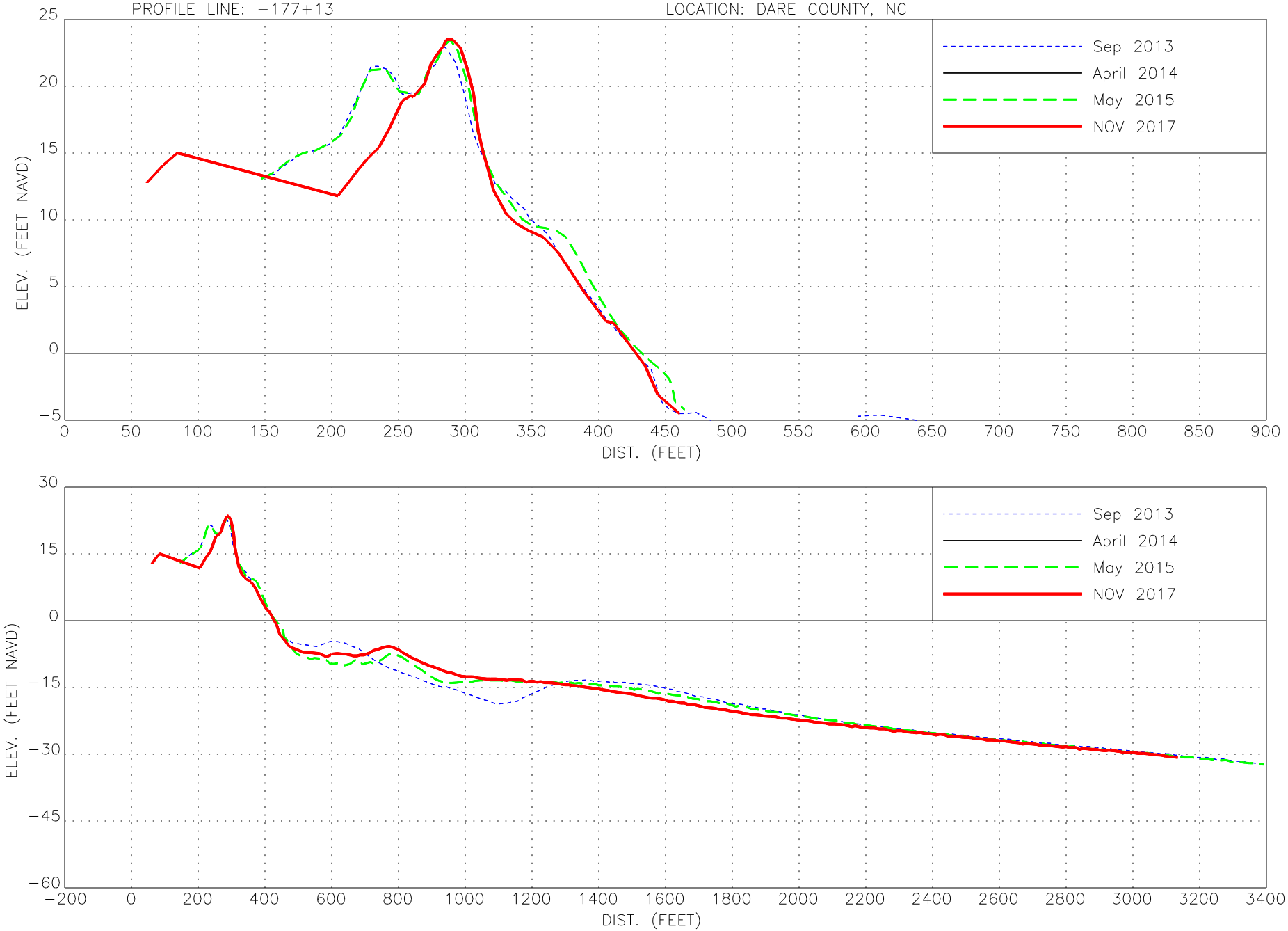
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APPENDIX 4

GROUND DIGITAL PHOTOGRAPHY

APPENDIX 4: Duck Ground Digital Photography

(Individual High Resolution Images Included as Digital Copy)

Ground Digital Photography
Monument

PI-17

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

PI-18

North View

South View

Landward View

No Image

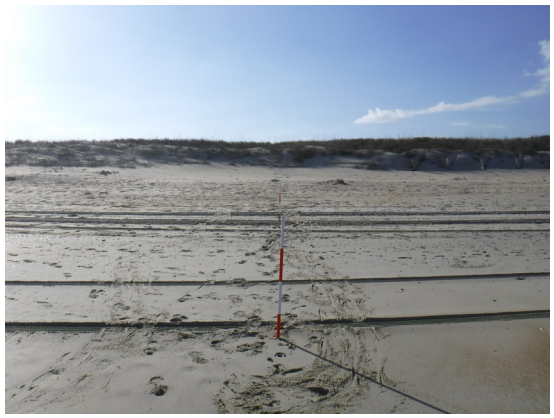
Monument – Reference Point

Ground Digital Photography
Monument

D-01

North View

South View



Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-02

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-03

North View

South View

Landward View

No Image

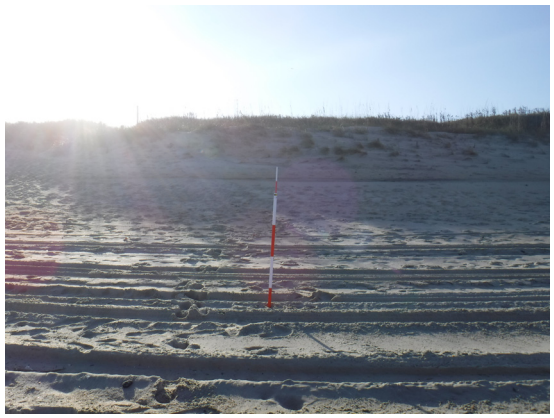
Monument – Reference Point

Ground Digital Photography
Monument

D-04

North View

South View



Landward View

No Image

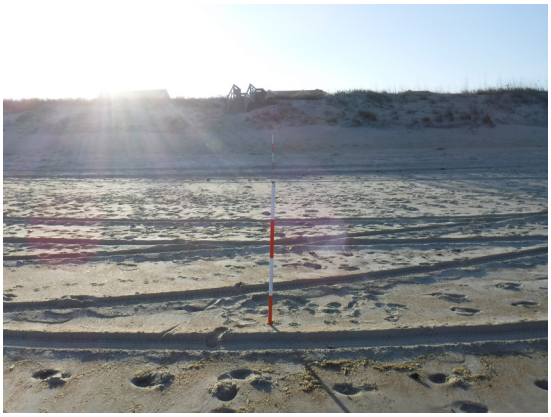
Monument – Reference Point

Ground Digital Photography
Monument

D-05

North View

South View



Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-06

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-07

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-08

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-09

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-10

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-11

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-12

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-13

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-14

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-15

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-16

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-17

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-18

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-19

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-20

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-21

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-22

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-23

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-24

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-25

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-26

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-27

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-28

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-29

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-30

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-31

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-32

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-33

North View

No Image

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

D-34 (-197+12)

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

SS-01 (-187+14)

North View

South View

Landward View

No Image

Monument – Reference Point

Ground Digital Photography
Monument

SS-02 (-177+13)

North View

South View

Landward View

No Image

Monument – Reference Point

APPENDIX 5

FIELD BOOK PAGES

Available in digital format only.

If you would like to see these pages, please contact the Town of Duck Office at 252-255-1234 or email info@townofduck.com