APPENDIX H

Integration of the ADCP Cross Sections
to Determine Net Solids Flux Considering Time-of Travel
and Normalizing by Flow or Cross Sectional Area Basis

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Subject: Passaic River Pilot Dredging "Pairwise" Analysis

The Scope of Work for this task included completion of a “pairwise” analysis of the Environmental Dredging Pilot Study data gathered by the R/V Caleta on December 5 and 6, 2005 within the Lower Passaic River Restoration Project area. Measurements from this vessel were gathered via Acoustic Doppler Current Profiler (ADCP). The October 2006 Pilot Study associated with this project evaluated the quality of the ADCP data with a goal of determining the overall effect of the pilot dredging operations. However, this report essentially evaluated data from ADCPs located on four fixed moorings (Moorings 1, 2, 4, and 5; identified in that Pilot Study as Transect A and Transect F) and on the R/V Caleta, and has not addressed the effects of temporal differences of the measurements on comparing measured sediment upflow and downflow of dredging. Comments generated by review of the previous analyses demonstrated the need to evaluate additional data by pairwise comparisons to determine the effect of the pilot dredging and also account for time travel of sediment particles between boat passes.

CALETA PASS EVALUATION AND PAIRING

The methodology used in this August 2007 “pairwise” analysis is similar to the one used in the October 2006 Pilot Study, with the exception of the requirement to identify and isolate individual cross-river passes of the R/V Caleta. There were 401 passes identified through the data set. In order to qualify as a pass:

1. The pass needed to cover more than 250 feet in north-south direction over the river.
2. The pass needed to have monotonically increasing or decreasing north-south coordinates.
3. East-west coverage of the pass should have been less than north-west coverage (i.e. direction of the boat had to be within 45 degrees from the true north); and
4. There had to be at least 5 pings (i.e. data points) across the pass.

The subsequent step was to compare an upflow R/V Caleta pass to the downflow pass that most closely correlated to the location of a tracked ideal particle. Several approaches were tested by Earth Tech in order to find the “pairings” of upflow and downflow R/V Caleta passes. Ultimately, it was determined that the highest quality pairings were matched based on minimizing the distance between a downflow pass and the location of the tracked ideal particle. In order to calculate this match, data from the R/V Caleta’s ADCP database were used to calculate the average velocity of the entire cross section of the river at the exact location of the R/V Caleta pass. This involved looking at not only the surface water velocity across the width of the river, but also at the velocity across the river at each monitoring depth of the R/V Caleta ADCP (every 25 centimeters within the water column). For each pass, the average cross-sectional velocity of a particle in that pass was used to calculate the location of that particle at points downstream that corresponded to subsequent passes of the R/V Caleta. The velocity of the particle was updated by the subsequent passes even if the subsequent pass was not a qualifying match (i.e. Lagrangian particle approach) assuming uniform cross-sectional velocity of the river stretch between the tracked particle and the unqualified pass. Only passes that were within 250 feet (as calculated using New Jersey State Plane Coordinates; NJSPC) of the tracked ideal particle were considered. If an upflow pass matched with more than one downflow pass, the smallest absolute distance between the pass was considered to be a good match. Using this method, eighteen (18) matching pairs were identified from data for December 5, 6, 7, 8, and 10, 2005. Figures 1 through 5 show color-coded pairs for each day of these measurements, respectively.

DATA ADJUSTMENT

After matching pairs were identified, two different methods were used to adjust the data to match actual river conditions. Adjustment was required for two reasons: first, the Caleta passes did not span the entire width of the river, from bank to bank; secondly, the water flux (i.e., volume of water moving per given time) and Total Suspended Solids (TSS) flux (kilograms of TSS moving per given time) at an upflow pass were not necessarily equivalent to water flux and TSS flux at the downflow pass.

The first method (Method 1, as shown in the attached table) adjusted data based on the river’s flow. The TSS flux increase (%), which is presented in terms of upstream TSS flux, was determined by calculating the TSS flux per water flux difference between the upstream and downstream points. For reference, the water flux imbalance (an error that is “built into” the TSS flux increase by this method) was also calculated and is shown in the following table. The TSS flux increases (%) for all eighteen passes are shown in the attached table.

The second method (Method 2, as shown in the attached table) compared the coverage area of the upflow and downflow passes (as measured by R/V Caleta's ADCP) to the total area of those two cross-sections. Earth Tech used pre-dredging bathymetric data, shipboard data from the R/V Caleta, and tidal measurements to calculate cross-sectional area for each ship pass analyzed. Pressure readings at moorings, recorded every 30 minutes between December 1 and 12, 2005, were averaged to determine mean sea level for the Project area. Water surface elevations (WSE) were then calculated based on 30-minute time intervals and their associated difference with the calculated mean sea level. For the purpose of determining the WSE for a one-minute interval (used in calculating the cross-sectional area of a ship pass), the change in tidal elevations between two 30-minute intervals was calculated using linear interpolation. Data from R/V Caleta ship tracking were input into AutoDesk Land Desktop for analysis. Each ship pass analyzed was assigned a line, perpendicular to the river flow, to calculate the cross-sectional area. Based on the position of the cross-sectional lines and existing bathymetric survey data, the river bottom profiles were calculated. Given the river bottom profile and the WSE, the cross sectional area for each ship pass at a certain time was calculated. For some ship passes that could be assigned to two existing calculated lines, Earth Tech also calculated areas for alternate lines to verify accuracy. Results indicate that cross-sectional areas may vary between 0.0 and 6.96% depending on which line of reference is used. The average variance in cross-sectional areas for alternative lines of reference was 2.37%. Of the eighteen passes identified using the pairing methodology, two passes could not be adjusted using Method 2 because the R/V Caleta passes included poor data quality (i.e. GPS coordinates). A ratio of the calculated cross-sectional area to the ADCP-covered cross sectional area was used to adjust the calculated water flux and TSS flux associated with each upflow and downflow pass. For reference, the area imbalance (an error that is "built into" the TSS flux increase by this method) was calculated and is shown in the following table. The flux increase (%) was calculated as the difference in adjusted TSS flux values from the upstream pass to the downstream pass. TSS flux increases (%) for sixteen of the eighteen passes are shown in the attached table.

Negative values associated with water flux and TSS flux in both adjustment methods indicate a change in the flow direction of the river correlating to ebb and flood tides (i.e. negative value indicates flux towards west). TSS flux increases from upflow to downflow cross-section for both methods, as well as the imbalances for each method (water flux imbalance for Method 1, and area imbalance for Method 2) have been plotted for each of the eighteen pairs in Figure 6.

The results indicate that the error based on the imbalance (i.e. water flux for Method 1 and area ratio for Method 2) is on the same order of magnitude as the TSS flux increase. Some pairs even indicate negative TSS flux increase which translates into less sediment flux measured downflow of the dredge.

							METHOD 1: FLOW-ADJUSTED						METHOD 2: AREA-ADJUSTED							
No.	Pairs	Figure Number	Distance Between Pass and Ideal Particle (ft)*	Average Y (NJSPC ft)	Average X (NJSPC ft)	Cross-Sectional Average Velocity (m/s)	Water flux (m^3/s)	Water Flux Imbalance (%)	TSS Flux (kg/s)	TSS Flux per Water Flux (kg/m^3)	TSS Flux per Water Flux, Difference (kg/m^3)	Method 1 TSS Flux Increase (%)	ADCP Covered Cross-Sectional Area (m^2)	Cross-Sectional Area (m^2)	Ratio	Area Imbalance (%)	Adjusted Water Flux (m^3/s)	Adjusted Water Flux Difference (%)	Adjusted TSS Flux (kg/s)	TSS Flux Difference (kg/s)	Method 2 TSS Flux Increase (%)
1	12/5/05 12:13:51	1	-61	695359	593812	0.209	129	42.95	2.14	0.017	0.0130	78.48	528	684	1.29	23.04	167	43.49	2.77	4.32	156.10
	12/5/05 12:42:43			695544	595209	0.325	184		5.46	0.030			520	675	1.30		240		7.09		
2	12/5/05 12:36:03		-240	695382	593839	0.306	177	-35.70	3.90	0.022	0.0037	16.65	494	689	1.40	51.62	247	-4.79	5.45	0.60	11.07
	12/5/05 12:57:51			695463	594950	0.323	114		2.93	0.026			320	662	2.07		235		6.05		
3	12/5/05 15:15:28		95	695346	593842	0.557	190	14.36	12.03	0.063	0.0113	17.81	342	485	1.42	29.55	270	2.27	17.08	3.50	20.48
	12/5/05 15:21:52			695489	594629	0.533	218		16.21	0.075			386	490	1.27		276		20.58		
4	12/5/05 16:13:42		230	695363	593784	0.527	168	16.40	7.12	0.042	0.0063	14.86	326	450	1.38	27.53	232	6.33	9.82	2.17	22.13
	12/5/05 16:22:45			695566	594924	0.509	196		9.52	0.049			362	457	1.26		247		12.00		
5	12/6/05 14:50:49	2	-42	695471	594138	0.632	268	-19.21	9.74	0.036	0.0135	37.27	410	565	1.38	32.09	369	-13.65	13.42	2.49	18.53
	12/6/05 14:55:09			695482	594609	0.594	216		10.80	0.050			379	558	1.47		319		15.90		
6	12/6/05 15:35:08		220	695402	594224	0.601	221	29.71	9.11	0.041	0.0055	13.41	365	513	1.40	28.82	310	1.13	12.80	1.88	14.70
	12/6/05 15:36:48			695481	594641	0.578	286		13.40	0.047			465	509	1.10		313		14.68		
7	12/7/05 9:08:36	3	-92	695460	594609	-0.269	-108	21.01	-1.59	0.015	0.0033	22.28	390	509	1.30	23.29	-141	-0.39	-2.07	-0.45	21.80
	12/7/05 9:28:04			695324	593478	-0.278	-131		-2.35	0.018			479	514	1.07		-141		-2.52		
8	12/7/05 9:39:40		-219	695484	594629	-0.310	-136	-11.78	-2.73	0.020	0.0048	24.12	425	547	1.29	26.45	-175	-6.92	-3.52	-0.55	15.53
	12/7/05 9:57:28			695322	593350	-0.304	-120		-2.99	0.025			418	568	1.36		-163		-4.07		
9	12/7/05 15:55:58		45	695401	594044	0.516	200	5.96	4.07	0.020	0.0041	20.09	377	506	1.34	25.40	268	5.34	5.46	1.45	26.50
	12/7/05 16:02:10			695479	594681	0.503	212		5.18	0.024			394	525	1.33		282		6.90		
10	12/8/05 10:03:37	4	33	695451	594563	-0.390	-164	-5.71	-3.26	0.020	0.0083	41.79	398	498	1.25	22.45	-206	-2.77	-4.07	-1.54	37.87
	12/8/05 10:16:29			695361	593570	-0.383	-155		-4.35	0.028			406	523	1.29		-200		-5.62		
11	12/8/05 11:54:04		-62	695513	594830	-0.364	-177	-4.81	-5.22	0.029	-0.0036	-12.18	468	676	1.45	30.81	-256	-10.96	-7.55	1.65	-21.81
	12/8/05 12:13:12			695329	593439	-0.320	-169		-4.37	0.026			487	658	1.35		-228		-5.90		
12	12/8/05 11:52:12		196	695496	594583	-0.416	-176	-20.64	-5.48	0.031	-0.0067	-21.40	419	674	1.61	38.22	-283	-20.18	-8.82	3.28	-37.26
	12/8/05 12:14:24			695294	593221	-0.335	-139		-3.42	0.025			412	668	1.62		-226		-5.53		
13	12/10/05 8:44:43	5	35	695363	593762	0.397	103	-40.74	3.60	0.035	0.0036	10.24	258	442	1.71	55.07	176	-23.10	6.18	-0.94	-15.23
	12/10/05 8:54:55			695425	594590	0.299	61		2.35	0.039			190	422	2.23		136		5.24		
14	12/10/05 8:47:35		-4	695446	594213	0.388	124	-5.65	3.65	0.029	0.0012	4.25	303	441	1.45	31.92	180	-4.71	5.30	-0.04	-0.66
	12/10/05 8:53:23			695471	594659	0.396	117		3.59	0.031			300	441	1.47		172		5.27		
15	12/10/05 8:49:11		-26	695470	594221	0.415	137	-9.85	4.18	0.0304	-0.0004	-1.48	348	440	1.27	21.78	174	-8.91	5.30	-0.54	-10.26
	12/10/05 9:07:38			695576	595471	0.385	124		3.72	0.0300			322	412	1.28		158		4.75		
16	12/10/05 9:32:28		211	695414	594241	0.368	119	28.44	3.90	0.033	0.0017	5.13	316	414	1.31	23.64	156	12.48	5.11	0.93	18.25
	12/10/05 9:34:47			695484	594620	0.414	153		5.27	0.035			363	417	1.15		175		6.04		
17	12/10/05 12:53:17		68	695603	594518	-0.552	-215	-6.30	-9.15	0.043	-0.0011	-2.55	382	AREA CROSS SECTION DATA QUALITY WAS POOR							
	12/10/05 12:57:29			695626	594157	-0.566	-201		-8.36	0.042			359	AREA-ADJUSTMENT COULD NOT BE COMPLETED							
18	12/10/05 13:39:23		53	695779	594781	-0.528	-245	-16.65	-10.08	0.041	-0.0051	-12.40	458	AREA CROSS SECTION DATA QUALITY WAS POOR							
	12/10/05 13:58:22			695557	592984	-0.411	-204		-7.36	0.036			488	AREA-ADJUSTMENT COULD NOT BE COMPLETED							

*- A negative value indicates that the pass is to the west of the modeled ideal particle. Smaller value indicates closer match between tracked particle and subsequent Caleta (boat) pass.

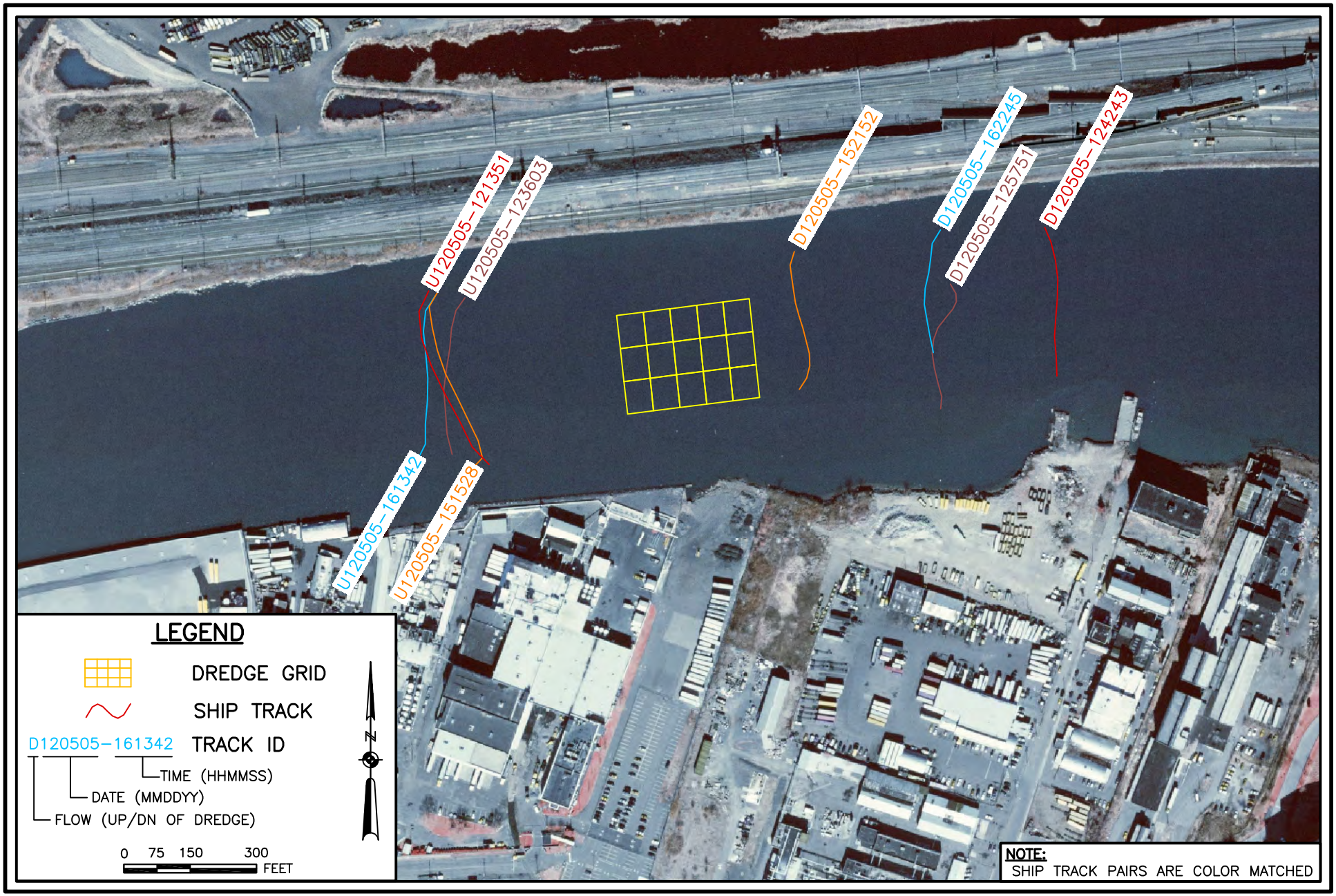

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Figure 1
December 5, 2005 R/V Caleta Ship Track Pairs
Passaic River Environmental Dredging Pilot Study

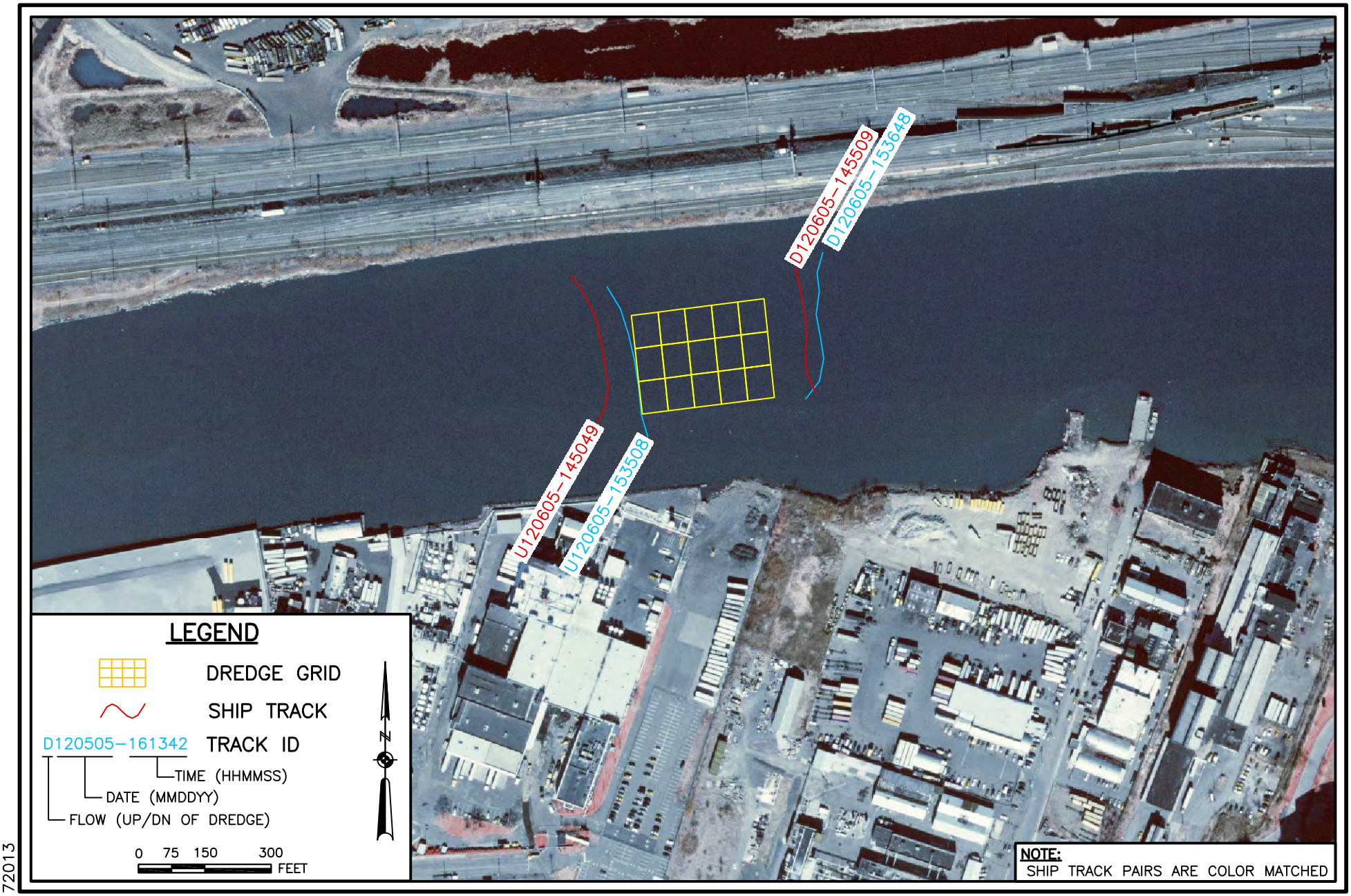

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Figure 2
December 6, 2005 R/V Caleta Ship Track Pairs
Passaic River Environmental Dredging Pilot Study

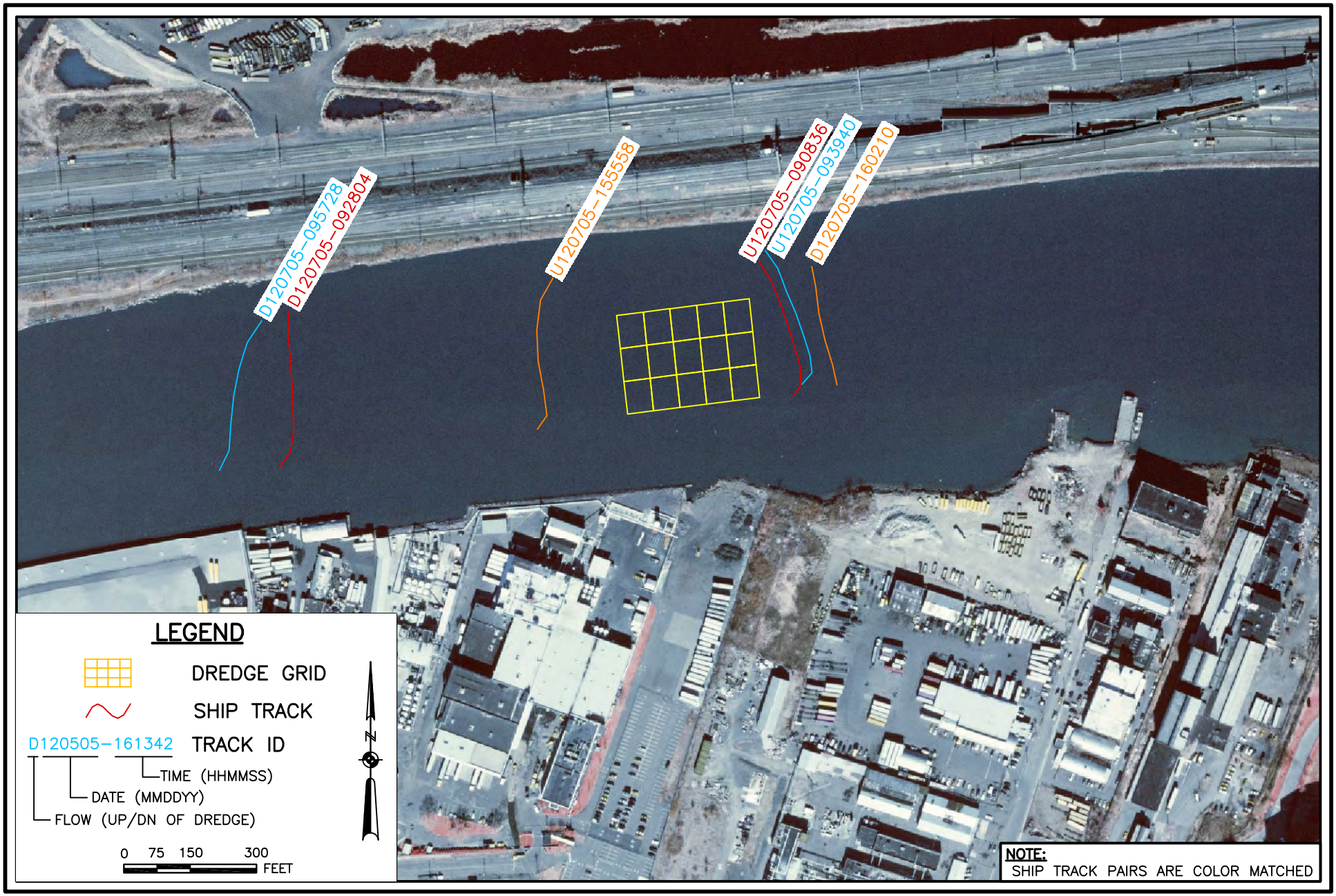

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Figure 3
December 7, 2005 R/V Caleta Ship Track Pairs
Passaic River Environmental Dredging Pilot Study

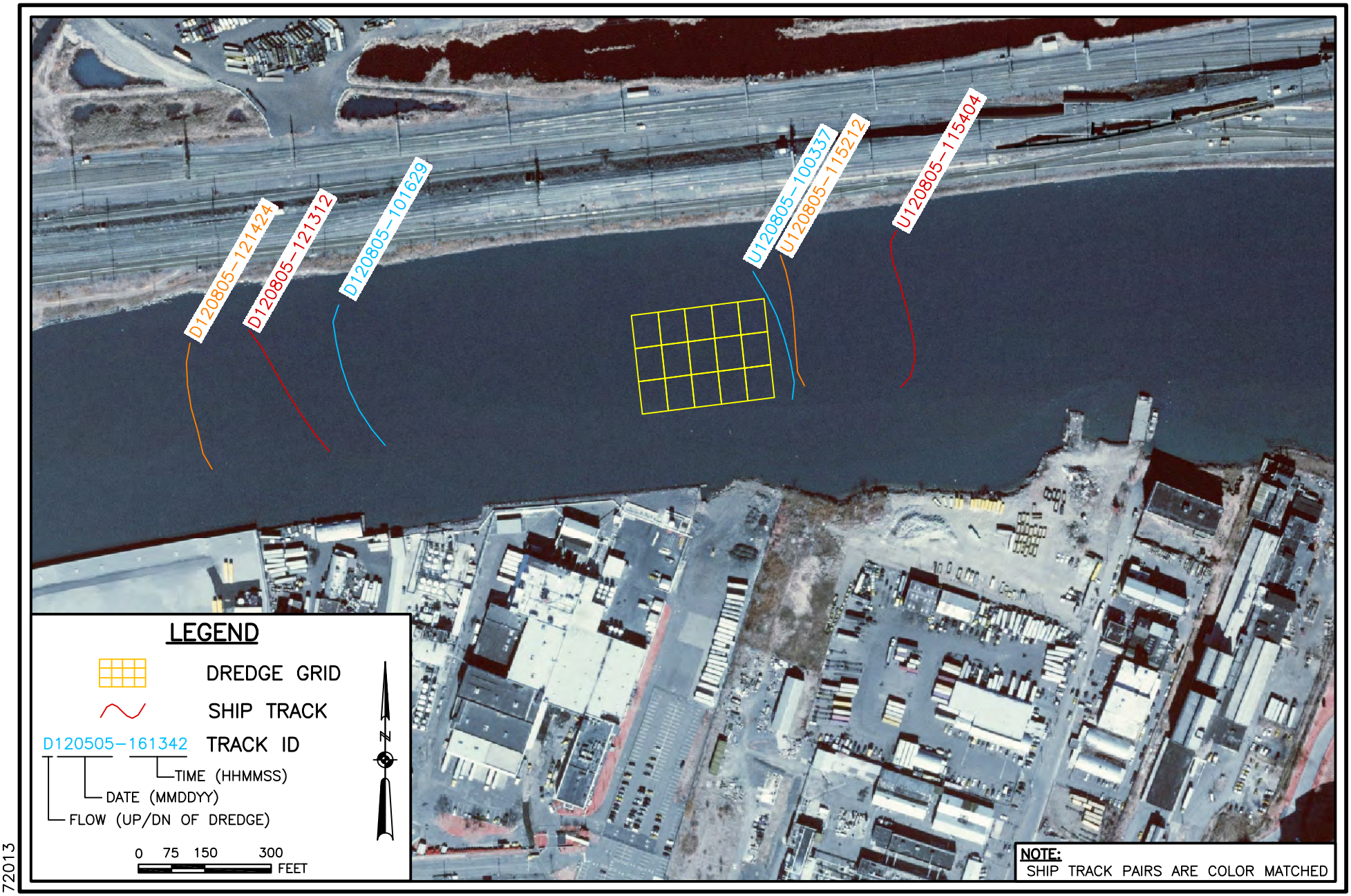

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Figure 4
December 8, 2005 R/V Caleta Ship Track Pairs
Passaic River Environmental Dredging Pilot Study

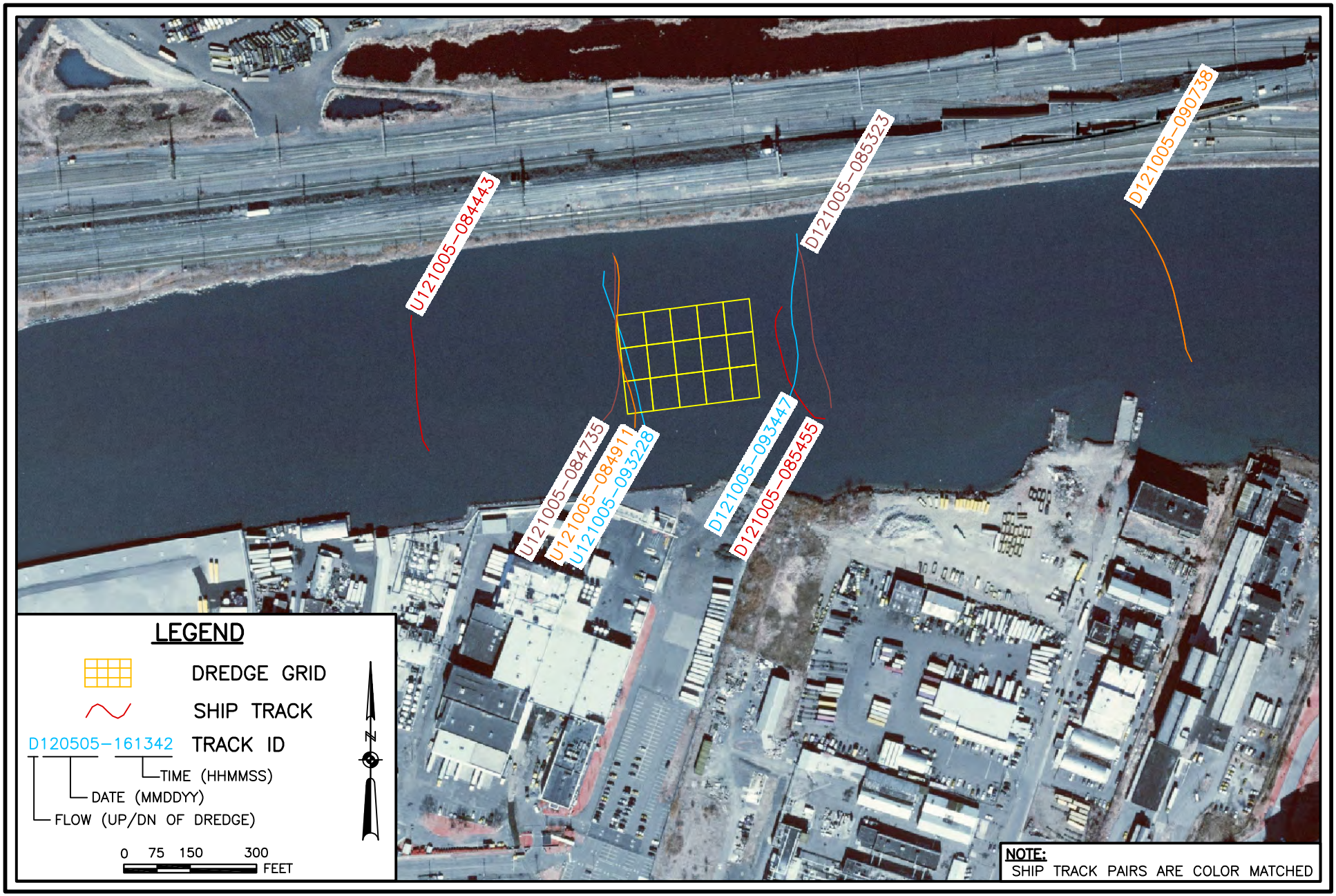

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Figure 5
December 10, 2005 R/V Caleta Ship Track Pairs
Passaic River Environmental Dredging Pilot Study

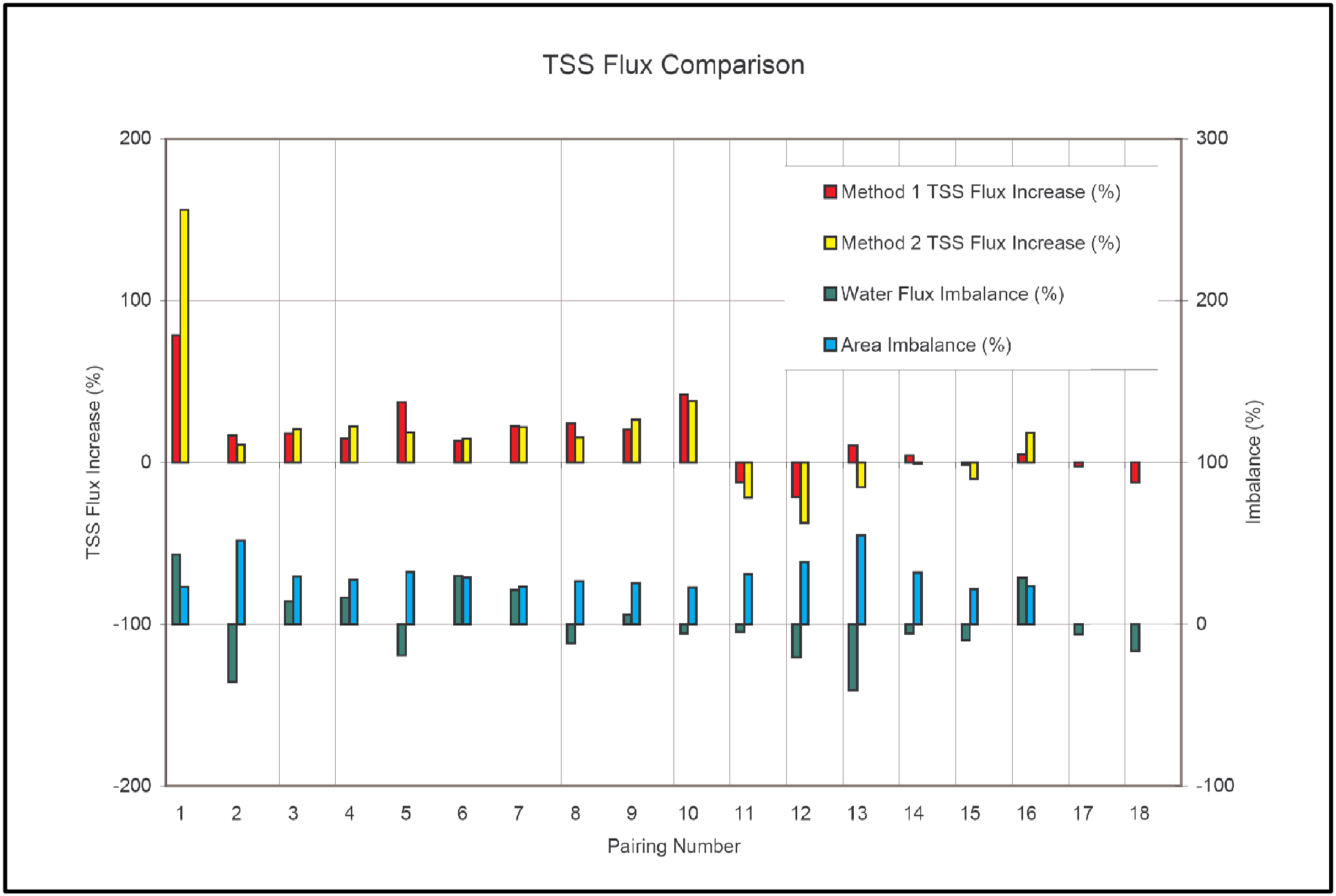

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Figure 6
Pairwise TSS Flux Comparison
Passaic River Environmental Dredging Pilot Study