SUPPLEMENTAL INFORMATION

List of Tables

TEST OF GROUNDWATER P FLUX ASSUMPTION

Methods

Measured runoff amounts at the outflow structure were compared with predicted runoff from a simple water balance to test whether larges fluxes of water were flowing into or out of Juniper Bay from the surrounding area. The years 2011 and 2012 had complete datasets for rainfall and runoff measured at the outflow structure. Predicted runoff was calculated as the difference between measured rainfall and estimated ET by the Thornthwaite method (Thornthwaite 1948) using monthly temperature data from the nearby Lumberton Regional Airport (NOAA NCDC 2013).

To further test the assumption that water and P fluxes into or out of Juniper Bay were minimal, P concentration gradients were evaluated across the four piezometer transects examined by Pati (2006), along with concurrent hydrologic head gradients. These piezometer transects spanned the perimeter ditch, and included nests of piezometers at 25 and 75 m outside of the bay, and 5, 25, and 75 m inside the bay, relative to the perimeter ditch. Nests of piezometers were installed with screen-openings of one piezometer intersecting each of three layers of sand (identified as surface, middle, and deep by (Pati 2006) which were separated by two layers of clay. Heads in each piezometer in each nest were measured six times during this study, and TP and DRP were monitored in the nests located 25 m outside the bay at the time of each piezometer measurement. Phosphorus concentrations and heads were determined for all piezometers once on May 15, 2013 to evaluate P concentration gradients in each sand layer. Piezometers were sampled by purging each piezometer with three pore volumes of water with peristaltic pumps. Each sample was filtered and acidified for preservation using HCl acid, and submitted to the North Carolina State University Environmental and Agricultural Testing Service (Raleigh, North Carolina, USA) for analysis as previously described for the surface water outflow samples. Porewater velocity was determined in each layer of each transect using *in-situ* Ksat values reported by Pati (2006). Pati reported soil texture classes of each horizon in which piezometers were installed, but did not report bulk densities or porosities. Textural classes included sands, loamy sands, and sandy loams. Ewing reported an average bulk density of 1.40 g cm^{-3} (se ±0.04 g cm^{-3}) for those same textures in three reference Carolina bays. That bulk density was used to estimate a porosity of 0.47 for further porewater velocity estimations.

Results and Discussion

Measured rainfall, runoff, and runoff ratios as well as predicted ET, runoff, and runoff ratios for 2011 and 2012 are shown in SI Tables 4, 5, and 6, respectively. For both 2011 and 2012 the measured runoff and the runoff predicted using a simple water balance were very close, indicating that water flux into or out of Juniper Bay from the surrounded landscape was likely minimal.

The distribution of hydraulic head and total P concentrations across four transects of the Juniper Bay perimeter are summarized in Appendix 7. Groundwater gradients corresponded to gradients predicted by Pati (2006). The highest P concentrations were observed outside of the perimeter ditch, with the lowest concentrations occurring within Juniper Bay for the NW, NE, and SW transects. The P concentrations in the SE transect were mostly below the detection limit for all nests. Extractable P analysis of auger borings from Ewing (2012) suggest that some of the high concentrations of P found here might originate from minerals in the underlying sediments, and are likely not from P loss from Juniper Bay or any of the nearby agricultural fields.

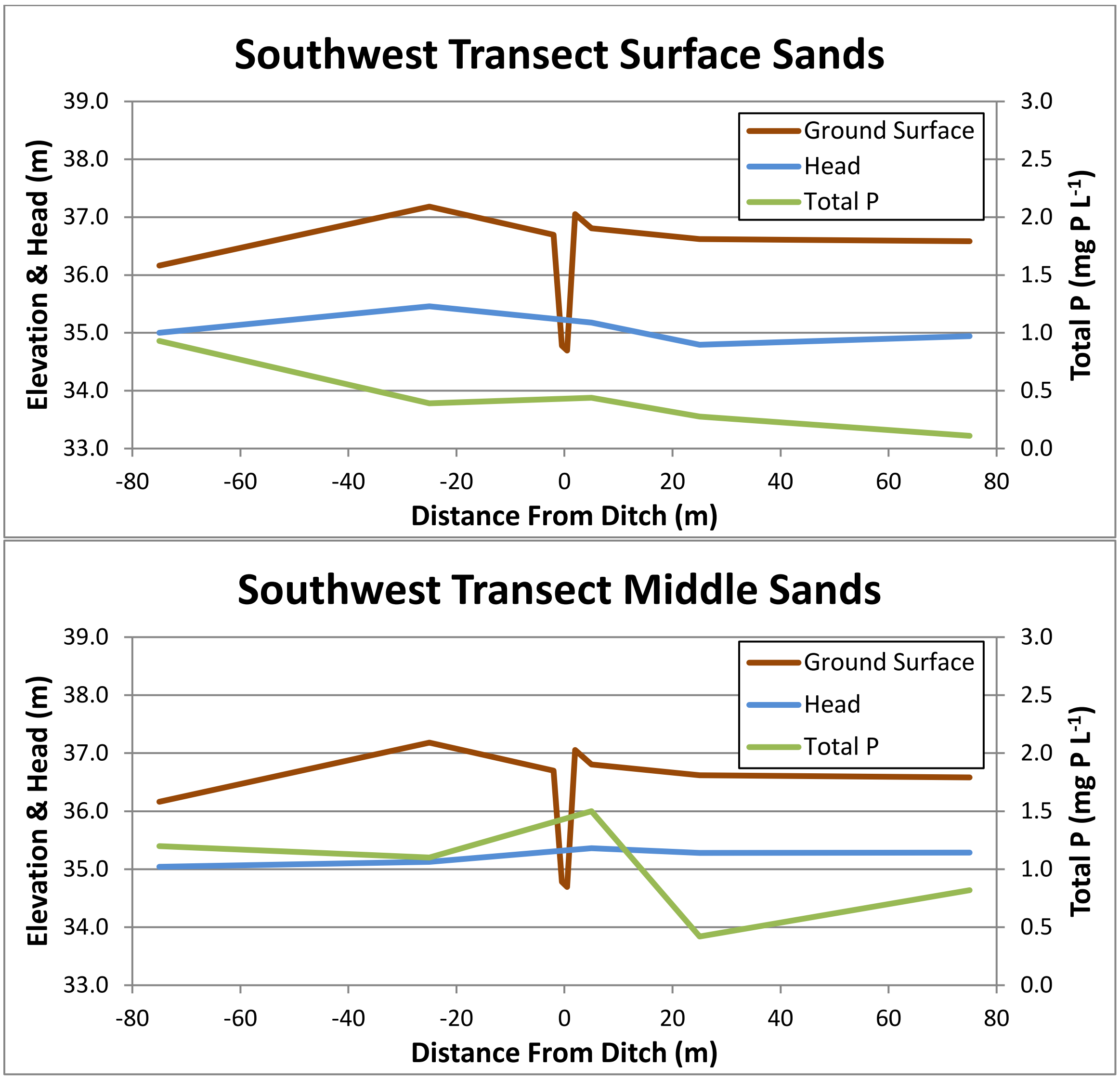
SI Table 1. Water Balance Test of Hydrology Assumptions.

Year	Rainfall	Runoff	Runoff Ratio	Thornthwaite ET	Estimated Runoff	Estimated Runoff Ratio
	mm	mm		mm	mm	
2011	956	28	0.03	874	82	0.09
2012	1020	145	0.14	851	169	0.17

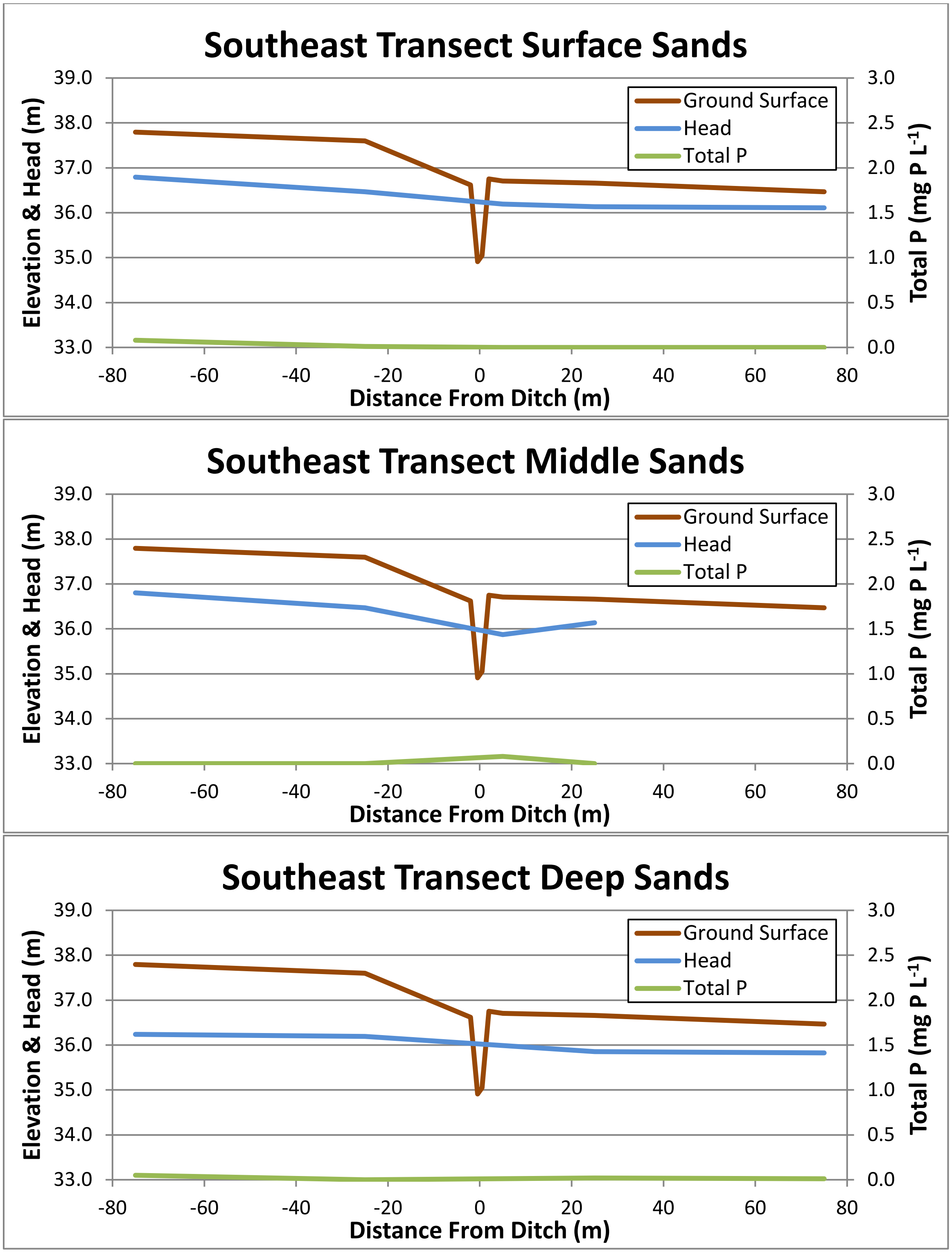
SI Table 2. Estimations of Flow for Each Transect and Sand Layer. Porewater velocity was estimated from Hydraulic gradients and soil properties for the four piezometer transects at Juniper Bay. The saturated conductivities used were reported by Pati (2006). Porosity was estimated from average bulk densities reported by Ewing (2003). Hydraulic gradients were calculated from measurements made on May 15, 2013. Flow rates were small overall, due to both the small gradients present, and the low conductivities.

Transect	Sand Layer	Ksat	Outside H	Inside H	ΔH	Distance	Gradient	Porosity	q	v	Distance per Year	Flow Direction
		m/s	m	m	m	m			m/s	m/s	m	
NE	Surface	5.3E-05	36.44	35.82	0.62	150	4.13E-03	0.47	2.2E-07	4.7E-07	15	In
NE	Middle	3.1E-05	35.57	35.83	-0.26	150	-1.73E-03	0.47	-5.4E-08	-1.1E-07	-4	Out
NE	Deep	7.8E-05	35.63	35.82	-0.19	150	-1.27E-03	0.47	-9.9E-08	-2.1E-07	-7	Out
NW	Surface	5.6E-06	36.80	36.19	0.61	150	4.07E-03	0.47	2.3E-08	4.8E-08	2	In
NW	Middle	1.2E-04	36.83	36.30	0.53	150	3.53E-03	0.47	4.2E-07	9.0E-07	28	In
NW	Deep	7.2E-06	36.80	36.30	0.50	150	3.33E-03	0.47	2.4E-08	5.1E-08	2	In
SW	Surface	1.3E-05	35.00	34.94	0.06	150	4.00E-04	0.47	5.2E-09	1.1E-08	0	In
SW	Middle	1.9E-05	35.04	35.29	-0.25	150	-1.67E-03	0.47	-3.2E-08	-6.7E-08	-2	Out
SE	Surface	3.9E-05	36.90	36.11	0.79	150	5.27E-03	0.47	2.1E-07	4.4E-07	14	In
SE	Middle	1.7E-05	36.80	36.13	0.67	80	8.37E-03	0.47	1.4E-07	3.0E-07	10	In
SE	Deep	4.9E-05	36.24	35.83	0.41	150	2.73E-03	0.47	1.3E-07	2.8E-07	9	In

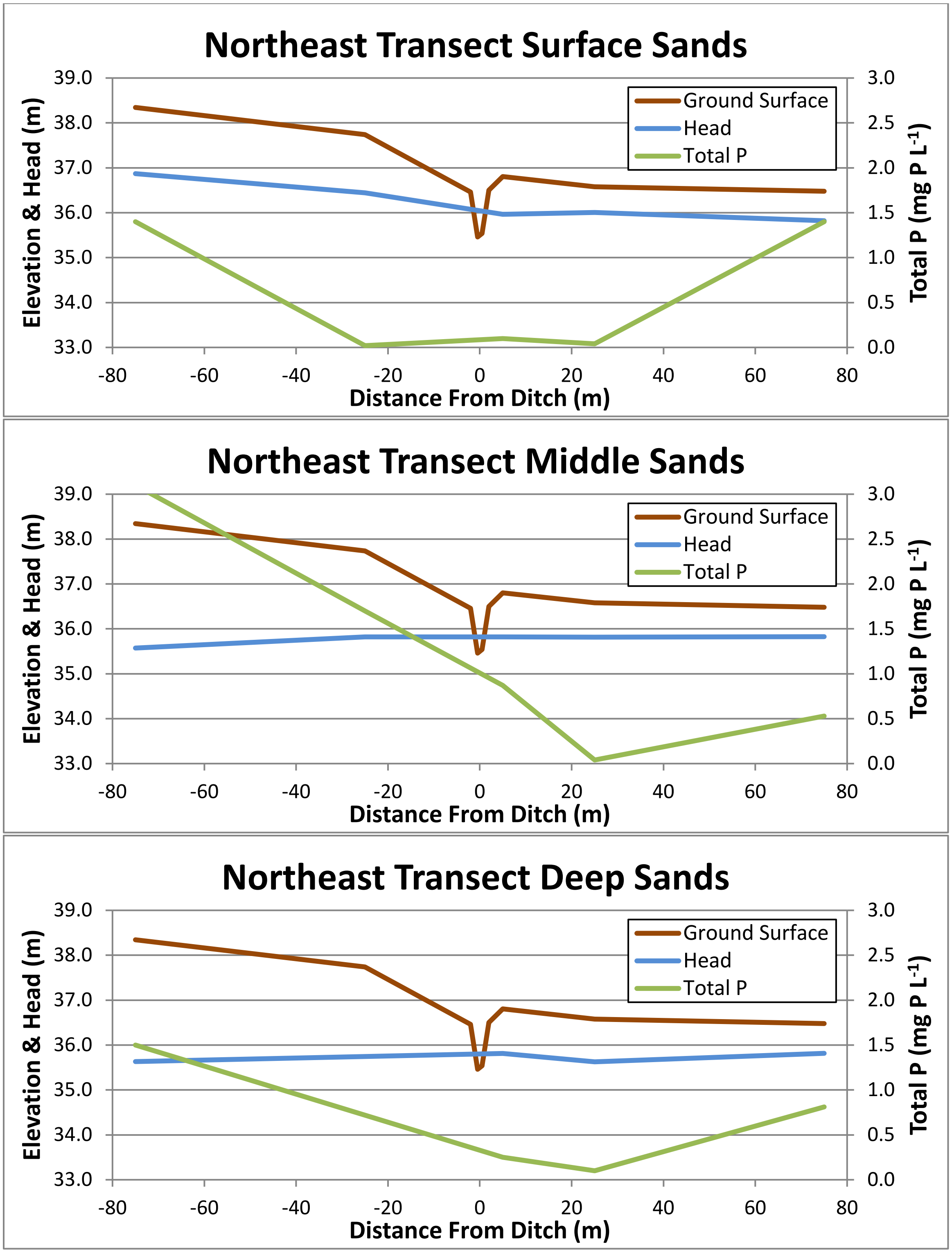
SI Figures 1-4 show elevation and head on the left y-axis, total P concentration on the right y-axis, and the distance from the ditch on the x-axis. The transects go (left to right) from outside the bay, across the ditch, and into the bay. Measurements for SI Figures 2-5 were taken on May 15, 2013.



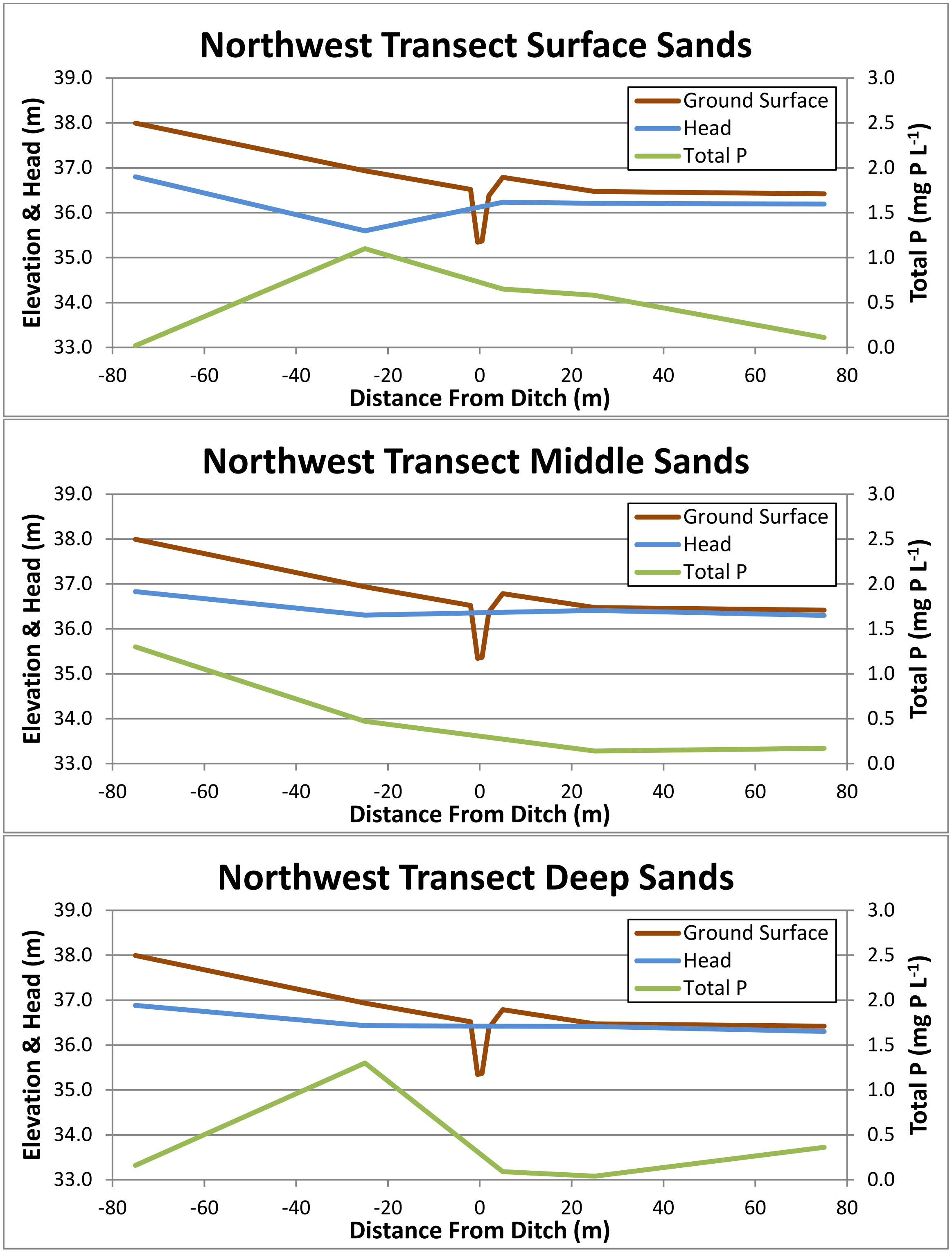
SI Figure 1. Piezometer Transect Across the Southwest Rim of Juniper Bay.



SI Figure 2. Piezometer Transect Across the Southeast Rim of Juniper Bay.



SI Figure 3. Piezometer Transect Across the Northeast Rim of Juniper Bay.



SI Figure 4. Piezometer Transect Across the Northwest Rim of Juniper Bay.

SUPPLEMENTAL TABLES AND FIGURES

SI Table 3. Soil Total P content (kg P ha^{-1}) in 2005 and 2013.

			2005 TP			2013 TP		
Soil Type	**Depth**	**Area**	**TP**		**se**	**TP**		**se**
	cm	ha	kg P ha^{-1}			kg P ha^{-1}		
Mineral	15	186	184	±	20	198	±	23
Mineral	30	186	103	±	11	87	±	10
Mineral	100	186	355	±	51	307	±	44
Organic	15	105	386	±	59	311	±	48
Organic	30	105	177	±	28	240	±	37
Organic	100	105	531	±	119	456	±	102

SI Table 4. Changes in Mehlich-3 P.

		2005					2013				
Soil Type	**Depth**	**LSMean**	**se**	**Significance**			**LSMean**	**se**	**Significance**		
	cm	kg P m^{-3}		†	‡	§	kg P m^{-3}		†	‡	§
Mineral	15	0.059	0.005	A	A	A	0.061	0.005	A	A	A
Mineral	30	0.031	0.003	A	B	A	0.031	0.002	A	B	A
Mineral	100	0.005	0.001	A	C	A	0.016	0.003	A	B	A
Organic	15	0.054	0.007	A	A	A	0.044	0.005	A	A	A
Organic	30	0.014	0.002	A	B	B	0.019	0.002	A	B	B
Organic	100	0.004	0.001	A	C	A	0.011	0.003	A	B	A

†Comparison of Mehlich-3 P concentration between years for a given soil type and depth in column

‡Comparison of Mehlich-3 P concentration between depths within a given year and soil type in column

§Comparison of Mehlich-3 P concentration between soil types within a given year at a given depth in column

Means with the same letter not significantly different (α=0.05).

SI Table 5. Mehlich-3 P content (kg P ha^{-1}) in 2005 and 2013.

			2005 Mehlich-3 P			2013 Mehlich-3 P		
Soil Type	**Depth**	**Area**	**TP**		**se**	**TP**		**se**
	cm	ha	kg P ha^{-1}			kg P ha^{-1}		
Mineral	15	186	89	±	8	92	±	8
Mineral	30	186	47	±	5	47	±	3
Mineral	100	186	35	±	7	112	±	21
Organic	15	105	81	±	11	66	±	8
Organic	30	105	21	±	3	29	±	3
Organic	100	105	28	±	7	77	±	21

SI Table 6. Monthly Rainfall from January 2005 to December 2012.

Month	2005	2006	2007	2008	2009	2010	2011	2012
	mm	mm	mm	mm	mm	mm	mm	mm
Jan	†50.5	†68.8	†16.0	†71.1	†31.8	81.3	†33.7	†69.4
Feb	†41.4	69.9	†43.7	‡104.6	†41.9	‡104.2	‡119.5	69.4
Mar	†48.5	†14.0	†35.6	93.5	83.8	†80.4	100.8	90.9
Apr	49.8	42.2	63.2	90.9	†27.2	†17.0	60.6	53.0
May	†36.8	†123.7	†40.4	73.4	235.5	76.5	92.0	152.1
Jun	†47.2	131.8	†83.1	†69.9	114.0	‡167.7	†37.1	103.1
Jul	113.5	†110.0	†13.2	†86.6	†100.1	‡248.9	†88.6	†88.9
Aug	†13.5	138.4	†59.7	‡161.0	145.8	†73.9	‡178.1	‡212.7
Sep	†33.8	†25.7	†10.9	‡206.2	†8.1	190.9	91.2	81.3
Oct	60.2	†17.3	†43.4	†20.1	67.6	†30.3	54.7	†30.0
Nov	81.0	†87.6	†2.3	‡115.3	‡174.8	†32.0	81.3	†0.3
Dec	†48.8	71.4	101.3	71.9	‡148.3	57.2	17.8	68.8
Total	†625.1	†900.7	†512.8	†1164.6	1178.8	1160.3	†955.6	†1019.8

†Below normal and ‡above normal rainfall according to the Robeson County, NC USDA NRCS WETS table (USDA-NRCS 2021).

SI Table 7. Monthly ET between January 2005 and December 2012. Evapotranspiration was measured remotely for 2005-2009, and estimated using the Thornthwaite equation in from 2010 to 2012.

Month	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
	mm	mm	mm	mm	mm	mm	mm	mm
Jan	20	20	21	19	17	5	3	18
Feb	24	28	25	25	22	6	21	18
Mar	31	33	41	35	33	29	30	56
Apr	47	42	37	41	51	65	63	58
May	69	61	66	60	70	106	96	102
Jun	86	79	72	83	115	150	147	112
Jul	96	96	83	111	93	148	156	155
Aug	86	95	94	103	85	149	144	128
Sep	66	62	73	68	66	121	108	103
Oct	36	32	40	32	40	65	50	59
Nov	25	25	13	18	18	30	35	19
Dec	20	19	16	16	15	2	23	24
Total	606	592	581	609	625	877	874	851

SI Table 8. Monthly runoff between January 2005 and December 2012. Runoff was estimated using a simple water balance for 2005-2010, and measured directly for 2011 and 2012. For estimations of P, months with negative estimated runoff were assumed to have no runoff.

Month	2005	2006	2007	2008	2009	2010	2011	2012
	mm	mm	mm	mm	mm	mm	mm	mm
Jan	30	49	-5	52	14	77	4	0
Feb	18	42	19	80	20	98	22	0
Mar	18	-19	-5	59	51	52	0	1
Apr	3	0	26	50	-24	-48	0	0
May	-32	62	-26	13	166	-30	0	0
Jun	-39	52	11	-14	-1	17	0	0
Jul	18	14	-70	-24	7	101	0	79
Aug	-73	43	-35	58	61	-76	0	61
Sep	-32	-36	-62	139	-58	69	1	3
Oct	25	-15	4	-12	27	-35	0	0
Nov	56	63	-11	98	157	2	0	0
Dec	29	52	86	56	133	56	0	0
Total	19	308	-68	556	554	283	28	145

SI Table 9. Monthly P exports between January 2005 and December 2012. Export was estimated as the product of runoff volume and P concentration in the runoff. For estimations of P, months with negative estimated runoff were assumed to have no runoff.

Month	2005	2006	2007	2008	2009	2010	2011	2012
	kg P	kg P	kg P	kg P	kg P	kg P	kg P	kg P
Jan	0.91	4.76	0.27	14.45	8.92	13.73	0.48	0.00
Feb	1.65	5.87	7.17	0.00	4.18	17.20	3.25	0.00
Mar	1.00	0.00	0.00	0.00	12.48	7.93	0.02	0.03
Apr	0.04	0.00	7.10	11.13	0.00	0.00	0.00	0.01
May	0.00	4.41	0.00	0.00	21.93	0.00	0.01	0.01
Jun	0.00	1.55	0.00	0.00	0.00	2.20	0.00	0.03
Jul	0.00	0.00	0.00	0.00	0.00	7.22	0.00	5.88
Aug	0.00	0.00	0.00	7.96	0.64	0.00	0.02	5.66
Sep	0.00	0.00	0.00	50.00	0.00	1.24	0.01	0.20
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	2.34	5.52	0.00	9.50	3.53	0.09	0.00	0.00
Dec	2.01	4.71	23.55	25.86	28.23	1.80	0.00	0.02
Total	7.95	26.82	38.08	118.90	79.92	51.42	3.79	11.82

SI Figure 5. The apparatus used for collection of atmospheric deposition of P, alongside a tipping bucket rain gauge and a traditional rain gauge. The sample collection bottle is not shown.

PHOSPHORUS FRACTIONATION

Methods

A separate experiment was conducted in 2010 to examine differences in the fractions of phosphorus between Juniper Bay and two nearby reference Carolina Bays that have never been drained or farmed. Soil samples were collected from Juniper Bay and the two reference Carolina Bays in 2010. The reference Carolina Bays were described in detail by Ewing et al (2012). Composites samples were made of the 0-120-cm deep profiles of the Ponzer muck (loamy, mixed, dysic, thermic Terric Haplosaprists) and Leon sand (sandy, siliceous, thermic Aeric Alaquods) with one composite profile of each series under agricultural management and one of each series under natural wetland vegetation. Sample composites from five depths were prepared for Hedley fractionation analysis, from which approximately 0.5 g samples (oven dry) were taken through a Hedley fractionation (Hedley et al 1982a; Hedley et al 1982b) following modifications as described by Richter et al (2006), including four 16-hour sequential extractions of P. Inorganic P (Pi) was determined colorimetrically in sodium bicarbonate, sodium hydroxide, and two concentrations of hydrochloric acid (Murphy and Riley 1962). Organic phosphorus, Po, was determined by subtracting Pi from total P determined after extracts were digested with ammonium persulfate and sulfuric acid (US Environmental Protection Agency 1979). Residual P was estimated from the remaining soil which was subjected to concentrated sulfuric acid digestion at 360˚C. Separate unfractionated samples were analyzed for total phosphorus via nitric-perchloric acid digestion in order to compare with the recovery of P obtained through summation of all component fractions.

Results and Discussion

Throughout the upper 120-cm, total soil P in agricultural Histosols were substantially greater than in uncultivated controls. In agricultural mineral soils total P was greater than in uncultivated reference Carolina Bays throughout the upper 30 or 60 cm. Organic P was elevated by agricultural practices more than Pi in both organic and mineral soils. There was little indication of Ca-associated P, even in the agricultural soils that had been limed.

There appears to be a large potential for these wetland organic and mineral soils to serve as sinks for added P. Both Po and Pi were greater in bicarbonate- and sodium hydroxide-fractions of soil P, taken to represent exchangeable Pi, sorbed Pi, Po at pH 8.5, and Pi and Po susceptible to desorption or alkaline hydrolysis (e.g., ester P). Residual P was also greater in agricultural soils.

SI Table 10. Summary of soil P fractions from Juniper Bay and two reference Carolina Bays

		Juniper Bay			Reference Bays		
Soil Type	**Depth**	Sum of Po	Sum of Pi	TP	Sum of Po	Sum of Pi	TP
	cm	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
Mineral	0-15	128	82	209	30	5	34
Mineral	15-30	72	25	97	8	5	13
Mineral	30-60	29	8	36	21	-3	18
Mineral	60-90	29	13	41	24	5	29
Mineral	90-120	37	35	72	35	31	65
Organic	0-15	343	74	417	428	159	588
Organic	15-30	291	92	383	117	59	177
Organic	30-60	110	59	169	52	4	57
Organic	60-90	53	46	99	36	6	41
Organic	90-120	54	37	91	28	5	33

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