APPENDIX F —INDICATORS OF HYDROLOGIC ALTERATION (IHA)

Indicators of Hydrologic Alteration for the Wekiva River at SR46

Indicators of Hydrologic Alteration (IHA) is a commonly used approach for characterizing temporal variability in the hydrologic regimes of flowing systems. IHA is also used to quantify the degree of system alteration resulting from perturbation (e.g., groundwater withdrawal, dam operation, flow diversion, etc.; Richter et al. 1996). The IHA approach is based on calculating and interpreting a suite of ecologically relevant flow statistics (i.e., indicators) that are important to river ecosystems and sensitive to disturbance.

The Nature Conservancy's IHA software (version 7.1) was used to calculate the standard suite of hydrologic indicators for the Wekiva River at SR 46, for both the no-pumping (NP) and current-pumping (CP) condition flow timeseries. IHA is typically used for large rivers, and so this analysis was only conducted for the mainstem Wekiva River at SR46. IHA results for the NP and CP conditions were compared to determine whether withdrawal results in a significant change to one or more of these ecologically relevant parameters. For each flow condition, 30 IHA parameters were calculated; these statistical parameters are divided into the following five groups:

- Group 1: Parameters that characterize seasonal patterns using magnitude and timing of monthly flows; indicators of habitat availability (wetted area, volume);
- Group 2: Parameters that characterize extreme conditions; magnitude and duration of annual extreme events important for physical structure and timing of reproduction for some species;
- Group 3: Parameters that characterize the timing of annual extreme (high and low) water conditions that can be key to some species' life-cycle stages;
- Group 4: Parameters that characterize the frequency and duration of high (above the P25 exceedance flow) and low (below the P75 exceedance flow) flood pulses; and
- Group 5: Parameters that characterize the rate and frequency of flow changes.

IHA parameter values, for each flow withdrawal scenario (no-pumping and current-pumping conditions), are presented below (Table F-1). For the majority of parameters, the percent reduction in value from the no-pumping to current-pumping condition is relatively small (i.e., most are less than 10%). However, some are greater than a 10% reduction, and some reflect even higher change (e.g., number of low flood pulses under current-pumping condition).

IHA software was used to compare all parameters between NP and CP flow conditions, to evaluate potential hydrologic alteration due to withdrawal. Median values for all parameters (under both conditions) were calculated, in addition to coefficients of dispersion (CDs) which equals: (75^{th} percentile - 25^{th} percentile) / 50^{th} percentile (i.e., range normalized by median; Table F-2).

In addition to the 30 IHA parameters, 32 environmental flow components (EFCs) were also calculated, including low flows, extreme low flows, high flow pulses, small floods and large floods (Table F-3). These flood and drought statistics are ecologically relevant; it is recognized by river ecologists that high and low flow events are necessary to provide the full

Table F-1. Indicators of Hydrologic Alteration parameter values for Wekiva River at SR 46 no-pumping (NP) and current-pumping (CP) conditions; Difference between NP and CP values and CP as percent reduction from NP presented. Negative values represent an increase under CP, relative to NP condition; date of min and max flow are Julian dates. Parameter values are averaged across the entire POR (71 years).

		NP	CP	NP minus CP	(NP-CP)/NP (%)
Group 1: mean for each calendar month over POR	January	265.9	240.0	25.9	9.7
	February	265.3	239.0	26.2	9.9
	March	266.1	239.7	26.4	9.9
	April	255.0	228.5	26.5	10.4
	May	242.1	215.7	26.4	10.9
	June	281.0	255.3	25.7	9.2
	July	310.0	283.9	26.1	8.4
	August	331.3	305.3	26.0	7.8
	September	341.0	314.8	26.1	7.7
	October	308.9	282.7	26.2	8.5
	November	275.8	249.4	26.4	9.6
	December	268.0	242.0	26.1	9.7
Group 2: Annual minimum and maximum flows (means of all years in POR)	1-day min	215.1	189.3	25.8	12.0
	3-day min	217.1	190.7	26.4	12.2
	7-day min	218.8	192.4	26.4	12.1
	30-day min	226.5	200.0	26.4	11.7
	90-day min	243.7	217.4	26.3	10.8
	1-day max	824.3	804.4	19.9	2.4
	3-day max	796.7	775.8	20.9	2.6

		NP	CP	NP minus CP	(NP-CP)/NP (%)
Group 2, cont.	7-day max	710.1	687.4	22.6	3.2
	30-day max	483.4	458.6	24.8	5.1
	90-day max	387.6	362.2	25.4	6.6
Group 3: Timing of annual extremes (Julian date)	Date min	173.5	173.5	0.0	0.0
	Date max	211.3	211.3	0.0	0.0
Group 4: Frequency and duration extreme flow pulses	Low pulse count (#)	5.3	7.7	-2.5	-46.4
	Low pulse duration (mean)	11.9	13.1	-1.1	-9.3
	High pulse count (#)	6.7	5.8	0.9	13.9
	High pulse duration (mean)	9.2	8.3	0.9	10.1
Group 5: Rate and frequency of water condition change	Rise rate	8.1	8.4	-0.3	-4.1
	Fall rate	-3.2	-3.7	0.4	-14.0

Table F-2. Indicators of Hydrologic Alteration parameter values for Wekiva River at SR 46 no-pumping (NP) and current-pumping (CP) conditions. Median values and coefficient of dispersion (CD) are presented for NP and CP; deviation factors and significance counts are also presented (see text for definitions); significance counts < 0.05 are in bold

	IHA Parameter	Median		Coeff. Of Dispersion		Deviation Factor		Significance Count	
		NP	CP	NP	CP	Medians	CD	Medians	CD
Group 1	January	255.70	229.30	0.21	0.23	0.103	0.122	**0.001**	0.566
	February	266.30	240.80	0.23	0.26	0.096	0.113	**0.003**	0.483
	March	250.10	223.40	0.24	0.27	0.107	0.157	**0.005**	0.449
	April	249.10	222.70	0.25	0.29	0.106	0.142	**0.007**	0.358
	May	244.30	218.40	0.21	0.24	0.106	0.160	**0.000**	0.320
	June	259.00	234.00	0.23	0.24	0.096	0.070	**0.002**	0.826
	July	298.50	271.20	0.30	0.33	0.091	0.108	**0.010**	0.705
	August	318.40	294.50	0.24	0.26	0.075	0.080	**0.041**	0.700
	September	312.40	284.80	0.27	0.30	0.088	0.117	**0.019**	0.716
	October	298.80	272.00	0.28	0.30	0.090	0.103	**0.028**	0.642
	November	269.90	243.20	0.19	0.22	0.099	0.111	**0.000**	0.562
	December	257.70	231.10	0.20	0.22	0.103	0.140	**0.000**	0.463
Group 2	1-day minimum	212.30	184.60	0.19	0.20	0.131	0.060	**0.000**	0.691
	3-day minimum	213.30	186.50	0.17	0.20	0.126	0.144	**0.000**	0.360
	7-day minimum	214.90	188.60	0.18	0.20	0.123	0.131	**0.000**	0.436
	30-day minimum	224.20	197.10	0.16	0.19	0.121	0.155	**0.000**	0.408
	90-day minimum	237.40	211.20	0.20	0.23	0.110	0.120	**0.000**	0.507

	IHA Parameter	Median		Coeff. Of Dispersion		Deviation Factor		Significance Count	
		NP	CP	NP	CP	Medians	CD	Medians	CD
Group 2, cont.	1-day maximum	747.10	723.90	0.47	0.49	0.031	0.036	0.703	0.837
	3-day maximum	724.10	701.30	0.46	0.48	0.031	0.026	0.723	0.854
	7-day maximum	655.10	635.80	0.45	0.47	0.029	0.034	0.606	0.854
	30-day maximum	447.00	421.60	0.40	0.42	0.057	0.058	0.093	0.778
	90-day maximum	381.50	355.90	0.25	0.27	0.067	0.084	0.136	0.628
Group 3	Date of minimum	151.00	151.00	0.13	0.12	0.000	0.065	0.931	0.909
	Date of maximum	236.00	236.00	0.25	0.25	0.000	0.000	0.943	0.995
Group 4	Low pulse count	4.00	8.00	1.75	0.63	1.000	0.643	**0.000**	**0.019**
	Low pulse duration	7.00	9.00	1.29	0.94	0.286	0.265	**0.043**	0.261
	High pulse count	7.00	5.00	0.57	0.60	0.286	0.050	**0.011**	0.952
	High pulse duration	7.00	7.25	0.71	0.83	0.036	0.159	0.880	0.399
Group 5	Rise rate	7.70	7.97	0.39	0.37	0.035	0.061	0.474	0.795
	Fall rate	-3.11	-3.46	-0.40	-0.43	0.113	0.087	0.057	0.628

Table F-3. Summary of IHA Environmental Flow Components (EFC) for Wekiva River at SR 46 no-pumping (NP) and current-pumping (CP) conditions; CD = coefficient of dispersion; significance counts < 0.05 are in bold.

		Deviation Factor		Significance Count	
	EFC Parameter	**Median**	**CD**	**Median**	**CD**
Low Flow	January low flow	0.05	0.08	**0.024**	0.693
	February low flow	0.06	0.14	**0.001**	0.447
	March low flow	0.05	0.28	**0.045**	0.181
	April low flow	0.03	0.12	0.230	0.534
	May low flow	0.06	0.46	**0.002**	**0.016**
	June low flow	0.05	0.13	**0.016**	0.548
	July low flow	0.05	0.17	**0.044**	0.293
	August low flow	0.06	0.10	**0.002**	0.558
	September low flow	0.02	0.18	0.100	0.565
	October low flow	0.08	0.14	**0.001**	0.332
	November low flow	0.06	0.02	**0.003**	0.907
	December low flow	0.06	0.12	**0.012**	0.530
Extreme Low Flow	Extreme low peak	0.02	0.66	**0.008**	0.066
	Extreme low duration	0.06	0.41	0.747	0.235
	Extreme low timing	0.04	0.05	0.554	0.904
	Extreme low frequency	4.00	0.65	**0.000**	**0.014**
High Flow Pulse	High flow peak	0.03	0.09	0.167	0.749
	High flow duration	0.17	0.02	0.221	0.955

		Deviation Factor		Significance Count	
	EFC Parameter	Median	CD	Median	CD
High Flow Pulse, cont.	High flow timing	0.05	0.09	0.442	0.624
	High flow frequency	0.17	0.10	0.339	0.730
	High flow rise rate	0.27	0.20	**0.004**	0.219
	High flow fall rate	0.34	0.23	**0.000**	0.296
Small Flood	Small flood peak	0.00	0.19	0.915	0.530
	Small flood duration	0.29	0.29	0.256	0.412
	Small flood timing	0.00	0.02	0.966	0.952
	Small flood rise rate	0.98	0.44	0.145	0.570
	Small flood fall rate	0.50	0.34	**0.049**	0.310
Large Flood	Large flood peak	0.04	0.07	0.777	0.886
	Large flood duration	0.23	0.48	0.727	0.486
	Large flood timing	0.00	0.03	0.699	0.931
	Large flood rise rate	0.68	0.19	0.230	0.739
	Large flood fall rate	0.04	0.20	0.895	0.671

spectrum of ecological functions that maintain a system's integrity over time (Richter et al., 1996, Poff et al., 1997). Low flows have a strong influence on the diversity and abundance of river flora and fauna. High flows increase access to habitats, especially during important migration seasons, inundate floodplains supporting important nutrient and carbon pathways including the base of production for various river food webs (see attachment for more details regarding ecosystem functions of different EFCs). Default software threshold values were used for EFC parameters; these include:

High flow threshold: All flows greater than the 75th percentile of daily flows are classified as high flows. The 75th percentile flow *as defined in the IHA software* is equal to a 25th

exceedance percentile flow (i.e., this will be referred to as a P25 flow elsewhere in this MFLs report).

Low flow threshold: All flows less than or equal to the 50th percentile of daily flows are classified as low flow events.

High flow start rate threshold: When flows are between the high flow and low flow thresholds, this parameter controls the start of high flow events. It also controls whether the ascending limb of an event is restarted from the descending limb. The default value is the 75th *exceedance* percentile flow (called the 25th percentile flow in the IHA software).

High flow end rate threshold: When flows are between the high flow and low flow thresholds, this parameter is used to end high flow events during their descending limb. It also controls the transition between the ascending and descending limb of an event. The default value is the 90th *exceedance* percentile flow (called the 10th percentile flow in the IHA software).

Small flood minimum peak flow: All high flow events with a peak flow greater than or equal to a 2-year return interval flood; high flow events are defined above.

Large flood minimum peak flow: All high flow events with a peak flow greater than or equal to a 10-year return interval flood; high flow events are defined above.

Extreme low flows: All low flow days with a flow value less than or equal to the 10th percentile of daily low flows were classified as extreme low flows. The 10th percentile flow *as defined in the IHA software* is equal to a 90th *exceedance* percentile flow (i.e., this will be referred to as a P90 flow elsewhere in this MFLs report).

A deviation factor, which equals: | NP-CP | / NP, was calculated for both medians and CDs for all IHA and EFC parameters; this is similar to a percent reduction in the parameter under the CP condition. According to IHA developers, a deviation factor at or above 10% (i.e., 0.10) is an indicator that instream habitat is sensitive to and could be harmed by flow reduction (Richter et al. 2011). About half of the parameter medians and coefficients of dispersion had deviation factors above 10%. Most were in groups 1 and 2 and most were very close to 10%.

A significance count was calculated for both medians and CDs; this equals the fraction of 1,000 random trials (i.e., shuffles of the data) for which the deviation values (for median and CD) is greater than for the real data. Significance count interpretation is similar to a *p*-value, with values closer to 0 representing a significant difference between NP and CP, and values closer to 1 representing no significant difference between the two conditions (Tables F-2 and F-3).

All IHA parameters in group 1 and about half in group 2 had significantly different medians (i.e., significance counts < 0.05). In group 2 these were all minima, indicating significantly different low flows, but not high flows. This is to be expected because the difference between NP and CP is due to groundwater pumping, which affects baseflow more than higher flows.

Very few EFCs exhibited a large change between the NP and CP conditions. However, there were significant differences in the median values of a couple of low flow parameters, including numerous monthly low flows and two of the extreme low flow parameters (Table F-3). A few of these same low flow parameters also exhibited significantly different coefficients of dispersion between the two flow scenarios, suggesting changes to low flow variability under the CP condition (Table F-3).

Overall, the magnitude of change (difference between medians) for all IHA parameters was moderate (about 9%), which is similar to the difference in long-term mean flow difference (8.7%). Very few EFC parameters exhibited a significant change to central tendency (median) or variability (coefficient of dispersion), though several of the low flow parameters do exhibit some change.

Given that numerous IHA parameters are right on the edge of exhibiting significant differences (e.g., deviations factors ≥ 10%, and significance counts < 0.05), and that numerous low flow EFCs are exhibiting change, this analysis indicates that the current-pumping condition is not overly constraining (i.e., changes in important flow statistics are starting to exhibit significant changes at current-pumping). This supports setting the limit of pumping at the current-pumping condition for the Wekiva River and contributing water bodies.