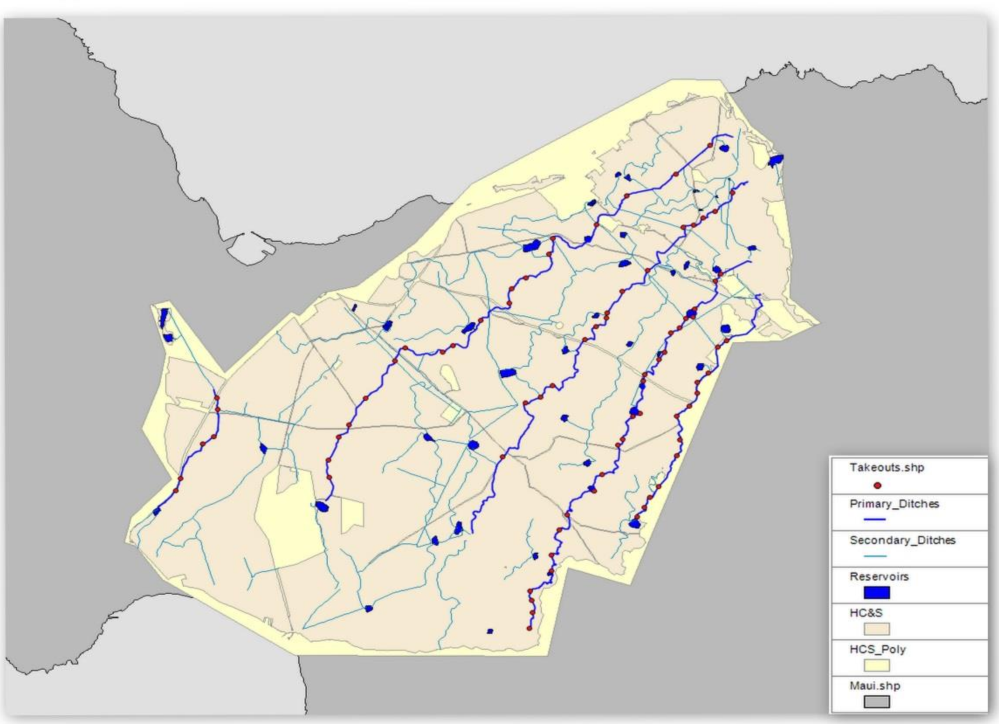
Summary of HC&S Irrigation Ditch Seepage Measurement JWIII – Sept 2013

Estimated seepage based on published values for **concrete-lined ditches** combined with GIS measured (length) and estimated (width) HC&S ditch dimensions:

1. **Seepage rates** from literature range from **0.01 ft/day** (pristine) to **0.43 ft/day** (degraded).
2. **Length** of HC&S ditches ***calculated*** from available GIS (see map below).
   Primary ditches (Hamakua, Kauhikoa, Lowrie, Haiku, Waihee)=228,555ft/5280 = **43.3 mi**
   Secondary ditches (within HC&S boundary) = 623,528 ft / 5280 = **118.1 mi**
3. **Width** of HC&S ditches **estimated** from observed values and assumption of tapering width, from head to tail, for primary ditches, and uniform width, from head to tail, for secondary ditches.
   Primary ditches = 17 ft
   Secondary ditches = 8 ft
4. **Area** of HC&S ditches, at maximum capacity, ***estimated,*** total is **203.7 acres**
   Primary ditches = 228,555*17= 3,885,435 ft^2/43560 = **89.2 acres**
   Secondary ditches = 623,528*8 = 4988224 ft^2 /43560 = **114.5 acres**
5. **Wetted perimeter** of HC&S ditches, at maximum capacity, ***approximately*** = surface area
6. Allen estimates **4-20 mgd** seep, based on **124 acres** surface area with **0.1-0.5 ft/day** seep rate
7. Jeong estimates **217 mgd** inflow to HC&S plantation (THIS VALUE SHOULD BE VERIFIED)
8. Allen/Dunbar measured reservoir seep at **0.14 ft/day**, suggest concrete ditches ½ this value
9. SO: Wolfe estimates, based on ½ pond seep rate (0.07 ft/day)
   Primary ditches: 89.2 acres * 43650 ft^2/acre * 0.07 ft/day * 7.48 gal/ft^3 = **2.03 mgd**
   Secondary ditches: 114.5 acres * 43560 ft^2/acre * .07 ft/day * 7.48 gal/ft^3 = **2.6 mgd**
   Total: 2.03 mgd + 2.6 mgd = **4.63 mgd**

WORST CASE (0.43 ft/day)**:** Primary = 12.5 mgd**,** Secondary = 16.0 mgd**,** Total = **18.5 mgd**



Seepage Rates Summarized from multiple sources:

Leigh & Fipps (table in multiple reports - TWRI, 2002-20011)
Sources - 1)DeMaggio (1990), 2)USBR (1963), 3) Nayak et al. (1996), 4)Nofzinger (1979)

		Seepage (ft/day)	
Lining/soil type	Source	Low	High
Unlined	1	0.30	3.53
Portland cement	2	0.07	0.07
Compacted earth	2	0.07	0.07
Unlined	3	1.52	1.52
Brick Masonry	3	0.30	0.30
Clay	4	0.05	0.40
Loam	4	0.60	1.00
Sand	4	0.53	2.60
Compacted earth	4	0.01	0.08
Plastic	4	0.01	0.50
Concrete	4	**0.01**	**0.43**
Gunite	4	0.01	0.13

Sonnichsen (1993)
Sources: 1) USDA(1985), 2) Idaho(1975), 3) Kraatz(1977), 4) USBR(1987), 5) Kishel(1989),

6) USBR Guidelines, 7) Weimer(1987), 8) Netz(1980), 9) Worstell(1976)

		Seepage (ft/day)	
Lining/soil type	Source	Low	High
Gravels	1, 9	1.20	1.35
Gravelly Sands	1,3	1.14	1.18
Sand, Gravelly Sandy Loam	1,2,8,9	1.04	1.17
Loam, Sandy Loam	1,8,9	0.90	1.08
Gravelly Clay Loam	1,9	0.80	0.90
Clay Loam	2,8,9	0.24	0.65
Hardpan, Soil Lining	1,2,4,6,9	0.08	0.30
Concrete	1,2,5,6,9	**0.35**	**0.40**
Plastic	2,3	0.14	0.17
Pipe	7	0.007	0.007

Several other sources available, compiling.

Spring 2012 – Ditch dimensions and visual condition survey

Primary ditches evaluated: **Hamakua, Kahuikoa, Lowrie, Haiku, and Waihee**
Secondary ditches not evaluated

1. **Length:** GPS individual take-out points, **measured** individual reaches using GIS
2. **Width:** Measured head and tail sections, assume even taper over entire length, **estimate width** as % of cumulative length at take-out points
3. **Wetted perimeter:** assume a) uniform trapezoid shape from head to tail, b) bottom width = 1/2 top width, c) depth = ½ top width, d) uniform taper along entire length, THEN: wetted perimeter, at max capacity, is approximately equal to width
4. **Concrete condition** based on visual observation of cracks and holes (1=best, 2=good, 3=fair, 4=poor)
5. **Vegetation condition** based on visual observation of % coverage (1: <25, 2: 25-50 3: 50-75, 4: >75)

DIMENTIONS			CONDITION (Visual Rank, 1= best, 4=worst)		
Reach (Nam#)	Length (ft)	Width (ft)	Cracks (1-4)	Vegetation (1-4)	Combined (unity, 0-1)
Ham1	377	22	2	2	0.33
Ham2	7507	18	1	2	0.17
Ham3	1040	17	1	2	0.17
Ham4	75	17	1	1	0.00
Ham5	3245	16	1	1	0.00
Ham6	1450	15	1	1	0.00
Ham7	1168	14	1	1	0.00
Ham8	1644	14	2	2	0.33
Ham9	1631	13	2	3	0.50
Ham10	33	13	2	3	0.50
Ham11	2864	11	3	3	0.67
Ham12	1893	10	3	3	0.67
Ham13	66	10	1	1	0.00
Ham14	30	10	2	3	0.50
Ham15	1401	10	4	3	0.83
Ham16	2392	8	1	1	0.00
Ham17	1526	8	2	3	0.50
Ham18	1299	7	2	3	0.50
Ham19	1516	6	2	3	0.50
Ham20	79	6	1	3	0.33
Ham21	36	6	1	3	0.33
Ham22	39	6	1	3	0.33
Kau1	3294	20	1	1	0.00
Kau2	1115	19	1	1	0.00
Kau3	1086	19	1	1	0.00
Kau4	3415	18	1	1	0.00
Kau5	863	18	1	2	0.17
Kau6	46	18	1	2	0.17
Kau7	679	18	1	2	0.17
Kau8	1299	18	1	2	0.17
Kau9	1004	17	1	2	0.17
Kau10	2411	17	2	3	0.50
Kau11	43	17	1	1	0.00
Kau12	876	17	2	3	0.50
Kau13	2697	16	2	3	0.50
Kau14	486	16	1	3	0.33
Kau15	902	16	1	3	0.33
Kau16	1339	16	1	2	0.17
Kau17	2343	15	1	2	0.17
Kau18	814	15	1	3	0.33
Kau19	3048	14	1	3	0.33
Kau20	915	14	1	3	0.33

Kau21	4626	13	1	3	0.33
Kau22	46	13	1	3	0.33
Kau23	1401	13	1	3	0.33
Kau24	869	13	1	3	0.33
Kau25	4360	12	1	3	0.33
Kau26	374	12	1	3	0.33
Kau27	2569	11	1	3	0.33
Kau28	3950	10	1	3	0.33
Kau29	180	10	1	1	0.00
Kau30	2254	10	1	3	0.33
Kau31	3839	9	2	3	0.50
Kau32	935	9	1	3	0.33
Kau33	56	9	1	3	0.33
Kau34	1453	8	1	3	0.33
Kau35	1988	8	1	3	0.33
Kau36	49	8	1	3	0.33
Low1	1923	25	2	3	0.50
Low2	36	25	1	2	0.17
Low3	390	25	2	2	0.33
Low4	151	25	1	2	0.17
Low5	2743	24	1	3	0.33
Low6	1709	24	2	3	0.50
Low7	1414	24	2	3	0.50
Low8	781	23	1	1	0.00
Low9	95	23	1	1	0.00
Low10	95	23	3	2	0.50
Low11	5961	22	3	3	0.67
Low12	1086	22	1	1	0.00
Low13	3950	21	1	2	0.17
Low14	2615	21	2	2	0.33
Low15	541	21	1	2	0.17
Low16	1614	21	2	2	0.33
Low17	2549	20	2	2	0.33
Low18	1247	20	2	2	0.33
Low19	49	20	2	2	0.33
Low20	5778	19	2	2	0.33
Low21	886	19	2	3	0.50
Low22	1982	18	1	3	0.33
Low23	1686	18	1	3	0.33
Low24	840	18	2	3	0.50
Low25	1175	18	2	3	0.50
Low26	2651	17	1	3	0.33
Low27	2359	17	1	3	0.33
Low28	522	17	1	3	0.33
Low29	748	17	1	3	0.33
Low30	279	17	1	3	0.33
Low31	2152	16	2	3	0.50
Low32	6946	15	2	3	0.50
Hai1	131	26	1	1	0.00
Hai2	446	26	1	1	0.00
Hai3	187	26	1	1	0.00
Hai4	2221	25	1	1	0.00
Hai5	4370	25	1	1	0.00
Hai6	23	25	1	1	0.00
Hai7	5259	24	1	1	0.00
Hai8	187	24	1	1	0.00
Hai9	1614	23	1	3	0.33
Hai10	89	23	1	3	0.33
Hai11	2178	23	1	1	0.00
Hai12	820	23	1	1	0.00
Hai13	85	23	1	1	0.00
Hai14	102	23	1	1	0.00
Hai15	2287	22	1	2	0.17
Hai16	3789	21	1	3	0.33
Hai17	180	21	1	3	0.33
Hai18	72	21	1	3	0.33

Hai19	89	21	1	3	0.33
Hai20	1932	21	1	3	0.33
Hai21	4213	20	1	3	0.33
Hai22	1982	20	1	3	0.33
Hai23	92	20	1	3	0.33
Hai24	1489	19	1	3	0.33
Hai25	4183	19	1	3	0.33
Hai26	1132	18	1	3	0.33
Hai27	3622	18	1	3	0.33
Hai28	1093	18	1	2	0.17
Hai29	607	17	1	2	0.17
Hai30	3583	17	2	3	0.50
Hai31	1614	16	1	1	0.00
Hai32	56	16	1	1	0.00
Hai33	141	16	1	1	0.00
Hai34	5092	15	1	1	0.00
Hai35	3419	15	1	2	0.17
Hai36	1841	14	1	2	0.17
Hai37	2651	14	1	2	0.17
Hai38	1916	14	1	2	0.17
Hai39	2746	13	2	1	0.17
Wai1	1053	10	1	1	0.00
Wai2	1240	9	1	1	0.00
Wai3	20	9	1	1	0.00
Wai4	30	9	1	1	0.00
Wai5	36	9	1	1	0.00
Wai6	66	9	1	1	0.00
Wai7	2454	9	1	1	0.00
Wai8	115	9	1	1	0.00
Wai9	200	9	1	1	0.00
Wai10	1437	8	1	1	0.00
Wai11	4364	7	1	1	0.00
Wai12	1388	7	1	1	0.00
Wai13	2533	6	2	1	0.17

December 2011 - preliminary seepage measurement, Teledyne StreamPro ADCP (surface boat)

1. **Single reach**, 2 flow measurements at inflow and outflow, 3 hours apart, ditch near max capacity
2. Inflow 151.296 ft^3/s, outflow 149.182 ft^3/s, seepage 2.11ft^3/s, area 134540ft^2 = seep **1.33ft/day**
3. 1.33ft/day = ~133x max for pristine concrete (0.01), ~3x max for degraded concrete (0.43)

March 2012 – multiple measurements, differing ditch condition, differing geology

1. Measure ditch seepage of differing condition (best, worst), in two soils (Waihee, all others)
2. Utilize Solinst level loggers to determine level/flow changes during measurement
3. Teledyne **StreamPro ADCP** (boat mounted) for flow measurements
4. Eight inflow/outflow reaches evaluated (3 measurements, each)
5. **Ott ACP** (acoustic current profiler) hand-held (staff mounted) for flow measurements
6. One inflow/outflow reach evaluated (3 measurements)
7. Results inaccurate, due to large fluctuation in flow, between inflow/outflow measurements
8. **Seep estimates 100-4000x max theoretical** (i.e., more seeping than inflowing, not possible)
9. Recommend purchase new technology (Sontek IQ Plus ADCP)

Date ddmmyyy	Instrument	Position	Ditch	Reach	Length (ft)	Width (ft)	Condition	Q (ft^3/s)	$\bar{x}$ Q (ft^3/s)	Qi-Qo (ft^3/s)	$\bar{x}$ S (ft/day)
5-Mar-2012	StreamPro	Inflow	Hamakua	15	1401	18	Poor	40.63			
5-Mar-2012	StreamPro	Inflow	Hamakua	15	1401	18	Poor	42.24			
5-Mar-2012	StreamPro	Inflow	Hamakua	15	1401	18	Poor	41.42	41.43		
5-Mar-2012	StreamPro	Outflow	Hamakua	15	1401	18	Poor	36.90			
5-Mar-2012	StreamPro	Outflow	Hamakua	15	1401	18	Poor	32.07			
5-Mar-2012	StreamPro	Outflow	Hamakua	15	1401	18	Poor	35.99	34.99	6.44	-21.6
5-Mar-2012	StreamPro	Inflow	Hamakua	12-15	3389	18	Poor	45.70			
5-Mar-2012	StreamPro	Inflow	Hamakua	12-15	3389	18	Poor	43.40			
5-Mar-2012	StreamPro	Inflow	Hamakua	12-15	3389	18	Poor	46.12	45.07		
5-Mar-2012	StreamPro	Outflow	Hamakua	12-15	3389	18	Poor	53.84			
5-Mar-2012	StreamPro	Outflow	Hamakua	12-15	3389	18	Poor	54.99			
5-Mar-2012	StreamPro	Outflow	Hamakua	12-15	3389	18	Poor	53.96	54.26	-9.19	12.7
6-Mar-2012	StreamPro	Inflow	Kauhikoa	4	3055	15	Good	55.46			
6-Mar-2012	StreamPro	Inflow	Kauhikoa	4	3055	15	Good	56.69			
6-Mar-2012	StreamPro	Inflow	Kauhikoa	4	3055	15	Good	53.48	55.21		
6-Mar-2012	StreamPro	Outflow	Kauhikoa	4	3055	15	Good	58.57			
6-Mar-2012	StreamPro	Outflow	Kauhikoa	4	3055	15	Good	60.78			
6-Mar-2012	StreamPro	Outflow	Kauhikoa	4	3055	15	Good	58.52	59.29	-4.08	7.5
6-Mar-2012	StreamPro	Inflow	Kauhikoa	4	1720	15	Good	68.26			
6-Mar-2012	StreamPro	Inflow	Kauhikoa	4	1720	15	Good	68.90			
6-Mar-2012	StreamPro	Inflow	Kauhikoa	4	1720	15	Good	66.29	67.82		
6-Mar-2012	StreamPro	Outflow	Kauhikoa	4	1720	15	Good	58.57			
6-Mar-2012	StreamPro	Outflow	Kauhikoa	4	1720	15	Good	60.78			
6-Mar-2012	StreamPro	Outflow	Kauhikoa	4	1720	15	Good	58.52	59.29	8.53	-28.0
7-Mar-2012	StreamPro	Inflow	Kauhikoa	17-18	2588	15	Good	95.31			
7-Mar-2012	StreamPro	Inflow	Kauhikoa	17-18	2588	15	Good	95.88			
7-Mar-2012	StreamPro	Inflow	Kauhikoa	17-18	2588	15	Good	98.78	96.66		

7-Mar-2012	StreamPro	Outflow	Kauhikoa	17-18	2588	15	Good	78.15			
7-Mar-2012	StreamPro	Outflow	Kauhikoa	17-18	2588	15	Good	78.51			
7-Mar-2012	StreamPro	Outflow	Kauhikoa	17-18	2588	15	Good	76.95	77.87	18.79	-40.9
7-Mar-2012	StreamPro	Inflow	Hamakua	11-12	4121	18	Ok	48.24			
7-Mar-2012	StreamPro	Inflow	Hamakua	11-12	4121	18	Ok	47.60			
7-Mar-2012	StreamPro	Inflow	Hamakua	11-12	4121	18	Ok	48.38	48.07		
7-Mar-2012	StreamPro	Outflow	Hamakua	11-12	4121	18	Ok	62.79			
7-Mar-2012	StreamPro	Outflow	Hamakua	11-12	4121	18	Ok	61.87			
7-Mar-2012	StreamPro	Outflow	Hamakua	11-12	4121	18	Ok	63.07	62.58	-14.50	16.5
8-Mar-2012	StreamPro	Inflow	Waihee	12	2780	12	Ok	21.54			
8-Mar-2012	StreamPro	Inflow	Waihee	12	2780	12	Ok	20.98			
8-Mar-2012	StreamPro	Inflow	Waihee	12	2780	12	Ok	21.22	21.25		
8-Mar-2012	StreamPro	Outflow	Waihee	12	2780	12	Ok	10.49			
8-Mar-2012	StreamPro	Outflow	Waihee	12	2780	12	Ok	10.38			
8-Mar-2012	StreamPro	Outflow	Waihee	12	2780	12	Ok	10.98	10.62	10.63	-27.0
8-Mar-2012	Ott ACP	Inflow	Waihee	13	2500	12	Good	16.99			
8-Mar-2012	Ott ACP	Inflow	Waihee	13	2500	12	Good	16.72			
8-Mar-2012	Ott ACP	Inflow	Waihee	13	2500	12	Good	16.26	16.66		
8-Mar-2012	Ott ACP	Outflow	Waihee	13	2500	12	Good	15.01			
8-Mar-2012	Ott ACP	Outflow	Waihee	13	2500	12	Good	16.74			
8-Mar-2012	Ott ACP	Outflow	Waihee	13	2500	12	Good	17.08	16.28	0.38	-1.1
9-Mar-2012	StreamPro	Inflow	Waihee	2	1942	12	Good	42.06			
9-Mar-2012	StreamPro	Inflow	Waihee	2	1942	12	Good	41.00			
9-Mar-2012	StreamPro	Inflow	Waihee	2	1942	12	Good	41.21	41.42		
9-Mar-2012	StreamPro	Outflow	Waihee	2	1942	12	Good	34.47			
9-Mar-2012	StreamPro	Outflow	Waihee	2	1942	12	Good	33.87			
9-Mar-2012	StreamPro	Outflow	Waihee	2	1942	12	Good	35.74	34.69	6.73	-24.4

July 2012 – preliminary measurement with new instrument, **SonTek IQ Plus ADCP** (bottom mount)

1. Develop portable, **sled-mount** deployment technology (non-standard for SonTek IQ instrument)
2. Work **single reach** (Lowrie 12), inflow/outflow, concurrently with 2 instruments
3. Measured **difference between instruments**, at same location
4. Measured **inflow/outflow** of same reach repeated times (~12)
5. Re-survey cross-sections at previously measured Inflow Outflow points
6. Determine accurate wetted perimeters of previously measured test reaches
7. Conduct Velocity Index measurements at one test reach (not calculated)

July 2012- Dec 2012 – Justin Lau collects inflow/outflow data using IQ instrument

1. Inflow/Outflow files exported from SonTek, processed with Excel
2. Check IQ roll, pitch, SNR1-4 signals for steady instrument readings
3. Rolling regression of depth signal using 30 minute (15 – 2 minute readings) sliding window
4. Select periods of data with minimum slope and sd
5. Lag outflow within expected flow range between inflow/outflow points
6.

Reach (ID)	Length (ft)	Width (ft)	Inflow (ft3/s)	Outflow (ft3/s)	Seep (ft3/s)	Seep (ft/d)
Hai30	3625	9.4	2.78	3.59	0.81	2.0
Hai30	3625	9.4	2.90	3.24	0.34	0.8
Hai30	3625	9.4	2.83	3.70	0.87	2.2
Hai34	5130	10.8	28.01	29.93	1.92	2.9
Hai34	5130	12.3	49.11	50.92	1.81	2.4
Hai34	5130	11.8	44.62	43.59	-1.02	-1.4
Ham6	1401	8.8	23.43	23.80	0.37	2.5

Ham6	1401	10.9	55.84	55.17	-0.67	-3.7
Ham6	1401	10.7	53.05	52.79	-0.26	-1.5
Ham15	1329	11.0	25.55	24.48	-1.07	-6.2
Ham15	1329	10.6	17.77	17.38	-0.39	-2.3
Ham15	1329	11.3	28.93	28.77	-0.16	-0.9
Kau4	3665	10.1	48.93	47.07	-1.86	-4.2
Kau4	3665	10.2	49.05	48.04	-1.01	-2.3
Kau4	3665	10.5	52.01	50.42	-1.59	-3.5
Kau31	3398	11.2	19.63	11.30	-8.33	-18.5
Kau31	3398	8.2	7.88	6.32	-1.56	-4.7
Low12	1066	13.5	51.81	47.28	-4.52	-26.6
Low12	1066	13.5	51.76	44.83	-6.93	-40.8
Low12	1066	13.5	51.65	46.45	-5.20	-30.6
Low13	3911	21.4	75.84	71.96	-3.88	-3.9
Low13	3911	20.2	98.83	95.94	-2.89	-3.1
Low13	3911	19.2	111.45	109.05	-2.40	-2.7
Low32	7680	8.3	19.79	16.75	-3.05	-4.1
Low32	7680	8.0	5.20	4.00	-1.20	-1.7
Low32	7680	8.0	5.18	4.08	-1.10	-1.5
Wai7	2468	9.5	20.86	20.91	0.06	0.2
Wai7	2468	10.3	30.74	29.74	-1.00	-3.3
Wai7	2468	10.0	31.20	28.58	-2.62	-8.9
Wai11	4310	8.2	16.86	15.63	-1.23	-3.0
Wai11	4310	8.2	17.16	15.72	-1.44	-3.5
Wai11	4310	6.9	13.56	12.03	-1.53	-4.4
Wai13	2546	10.6	16.68	15.77	-0.92	-2.9
Wai13	2546	10.6	16.63	14.72	-1.92	-6.0
Wai13	2546	10.6	12.28	13.39	1.10	3.5

COMPARISON WITH OTHER DATA

Study	**Inflow**	**Outflow**	**Length**	**Wetted Perimeter**	**Seep**
Kinzli	(ft3/s)	(ft3/s)	(ft)	(ft)	(ft/day)
	20.64	20.41	23097	55.3	0.02
	12.96	12.63	14567	31.7	0.06
	13.06	12.83	8694	30.2	0.07
	3.31	3.12	11024	23.2	0.07
	2.76	2.49	19357	18.5	0.06
	4.79	4.00	22047	20.3	0.15
	1.80	1.64	19258	18.7	0.04
	1.54	1.35	18799	18.0	0.05
	2.20	2.07	9416	11.7	0.10
Kilic	(ft3/s)	(ft3/s)	(ft)	(ft)	(ft/day)
	36.75	35.76	968	34.4	2.50
	40.68	34.78	3642	37.4	3.67
	41.01	40.03	4232	37.7	0.52
	39.04	38.39	984	34.1	1.65
	32.81	32.12	5249	35.1	0.32
USGS	(ft3/s)	(ft3/s)	(ft)	(ft)	(ft/day)
Koolau	20.4	20.2	1003	20	0.84

Koolau	25.0	29.2	1056	20	-16.82
Koolau	25.2	25.8	1056	20	-2.40
Koolau	44.3	43.6	2165	20	1.27
HC&S	(ft3/s)	(ft3/s)	(ft)	(ft)	(ft/day)
Hai30	2.78	3.59	3583	17.1	-1.12
Hai30	2.90	3.24	3583	17.1	-0.46
Hai30	2.83	3.70	3583	17.1	-1.19
Hai34	28.01	29.93	5092	17.5	-1.82
Hai34	49.11	50.92	5092	17.5	-1.72
Hai34	44.62	43.59	5092	17.5	0.98
Ham15	25.55	24.48	1401	16.3	3.97
Ham15	17.77	17.38	1401	16.3	1.43
Ham15	28.93	28.77	1401	16.3	0.60
Ham6	23.43	23.80	1450	16.2	-1.33
Ham6	55.84	55.17	1450	16.2	2.42
Ham6	53.05	52.79	1450	16.2	0.95
Kau31	19.63	11.30	3839	17.1	10.71
Kau31	7.88	6.32	3839	17.1	2.00
Kau4	48.93	47.07	3416	17.5	2.64
Kau4	49.05	48.04	3416	17.5	1.43
Kau4	52.01	50.42	3416	17.5	2.26
Low13	75.84	71.96	3950	18.5	4.49
Low13	98.83	95.94	3950	18.5	3.34
Low13	111.45	109.05	3950	18.5	2.78
Low32	19.79	16.75	6946	19.0	1.95
Low32	5.20	4.00	6946	19.0	0.77
Low32	5.18	4.08	6946	19.0	0.70
Wai11	16.86	15.63	4364	11.2	2.13
Wai11	17.16	15.72	4364	11.2	2.50
Wai11	13.50	11.82	4364	11.2	2.91
Wai13	16.68	15.77	2533	17.5	1.75
Wai13	16.63	14.72	2533	17.5	3.67
Wai13	12.28	13.39	2533	17.5	-2.11

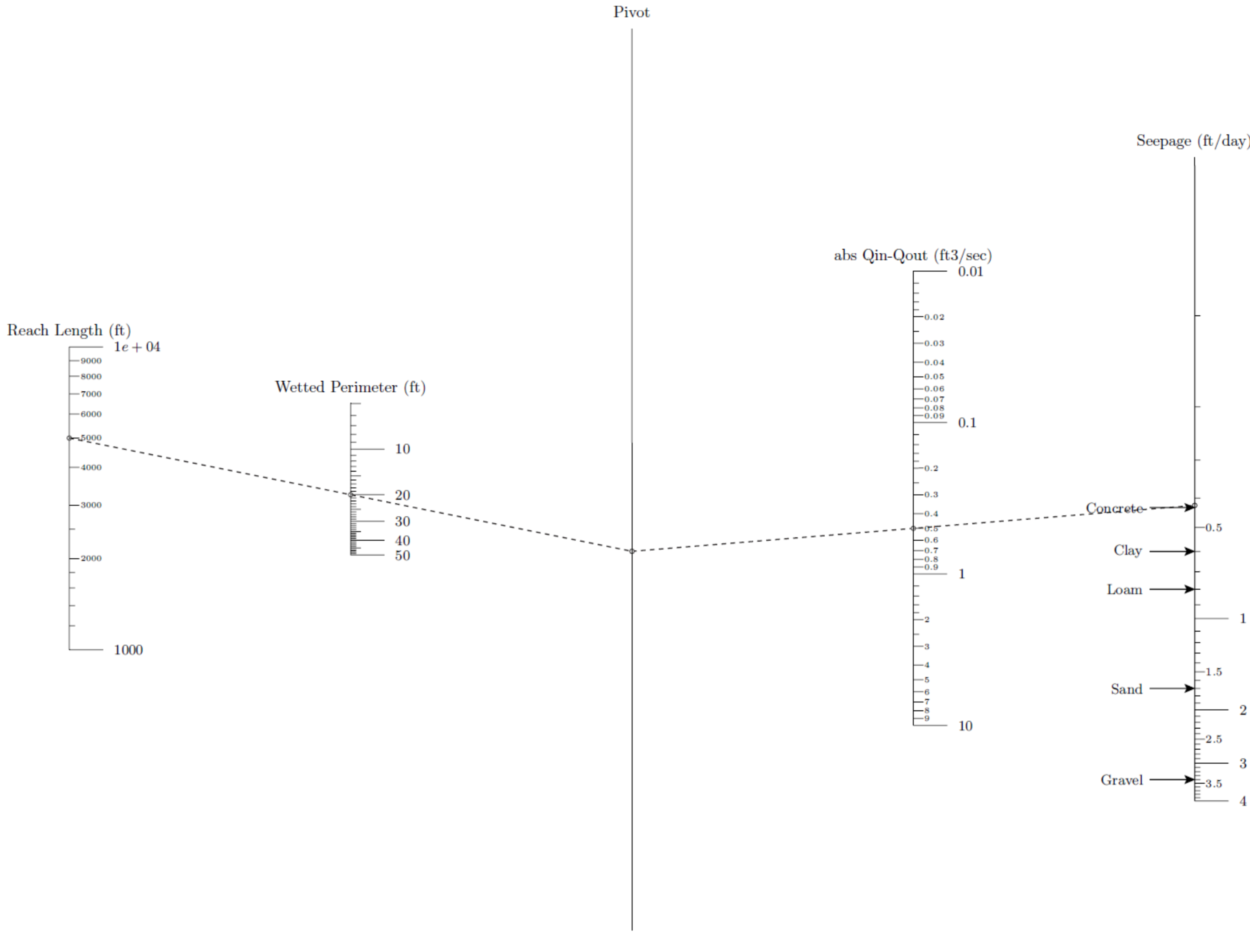
March 2013 – Final experiments and data collection

1. Verify IQ Plus synching and alignment procedures
2. Verify IQ Plus portable deployment method repeatability
3. Determine Inflow-Outflow error associated with reach length
4. Conduct “timed float” assessment to determine inflow/outflow lag time
5. Determine cross-section survey error through repeat surveys
6. Re-survey measured IQ points, recalculate Q with improved cross-section data
7. Determine wetted perimeters of measured ditch points (too variable, estimate)
8. Conduct velocity indexing measurements for one reach to see if improved inflow/outflow measurement is attainable under HC&S conditions (not calculated).

9. Calculate Manning’s n from velocity measurements and compare with visual ratings (not calculated)
10. Verify drip irrigation pipe flow using ultrasonic travel time flow meter (Optisonic 6400) : Operator unavailable, no measurements made, observation of inline meters: ~85k gph Do not have field size or irrigation system size this volume was delivered to.

September 2012 – Findings and Conclusions

1. Seepage estimates obtained from inflow/outflow measurements > instrument error (~1%)
2. Short reaches with short wetted perimeter yields small wetted surface area for seepage
3. Constantly surging flows further complicate measurement
4. Final values seepage obtained are 2 to 1000 times theoretical maximum
5. Best estimate by extrapolating theoretical seepage with accurate ditch lengths and wetted perimeter values and combine with maximum values obtained from unlined ponds (0.13 ft/day)



Seepage (ft/day) = abs Qin-Qout(ft3/sec) x 84600 / Length(ft) x Wetted Perimeter(ft), created with Pynomo, JWIII