Briefing on Kona Ground Water

State Commission on Water Resource Management

November 16, 2011

Topics

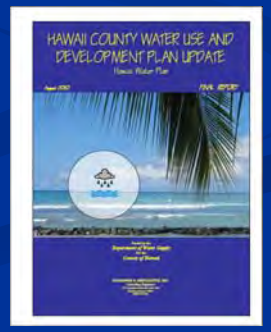
Current Conditions

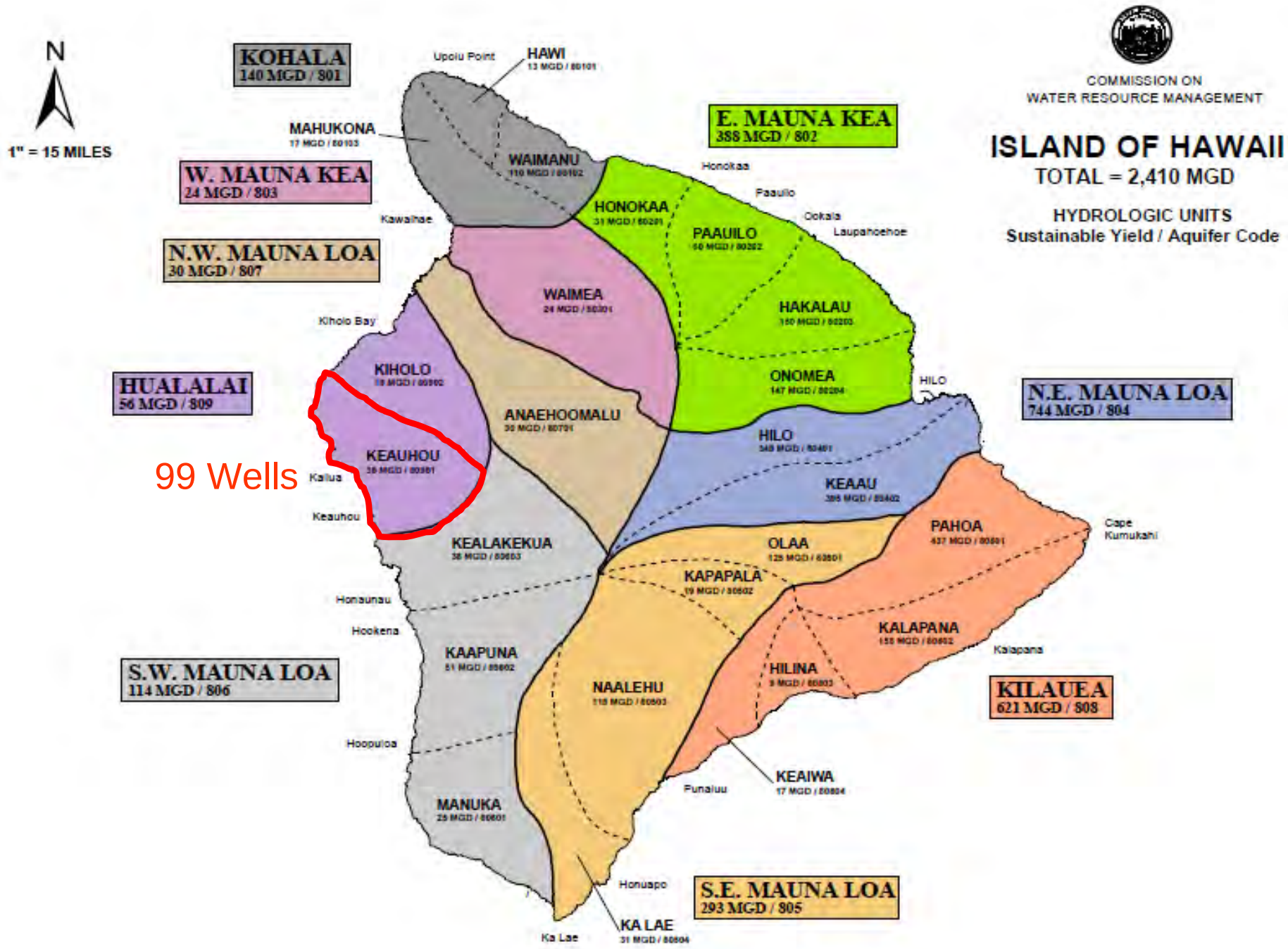
Updates

- 2011 USGS Recharge
- 2011 Rainfall Atlas

Future Conditions

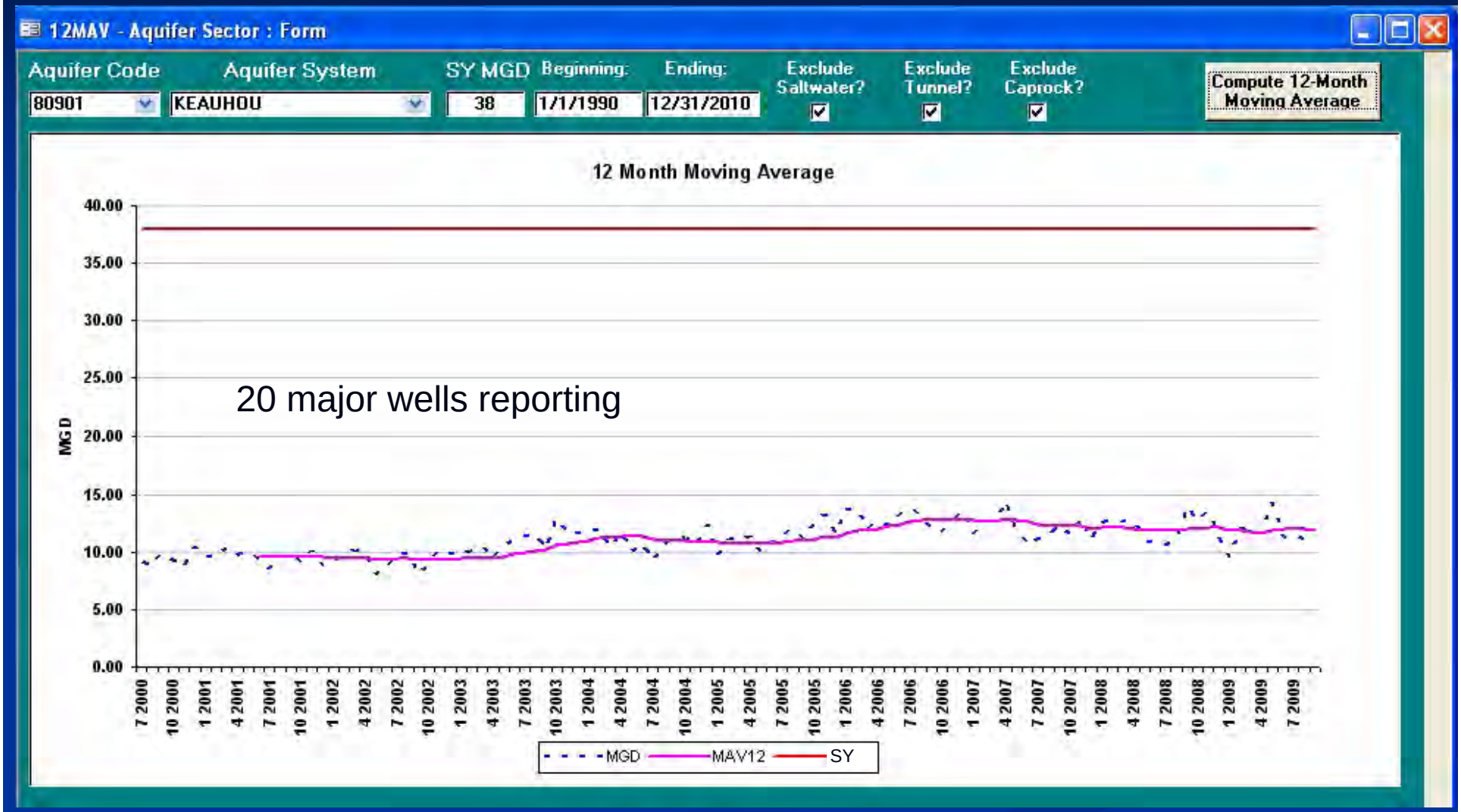
- Monitoring Program
- Hawaii WUDP Adoption

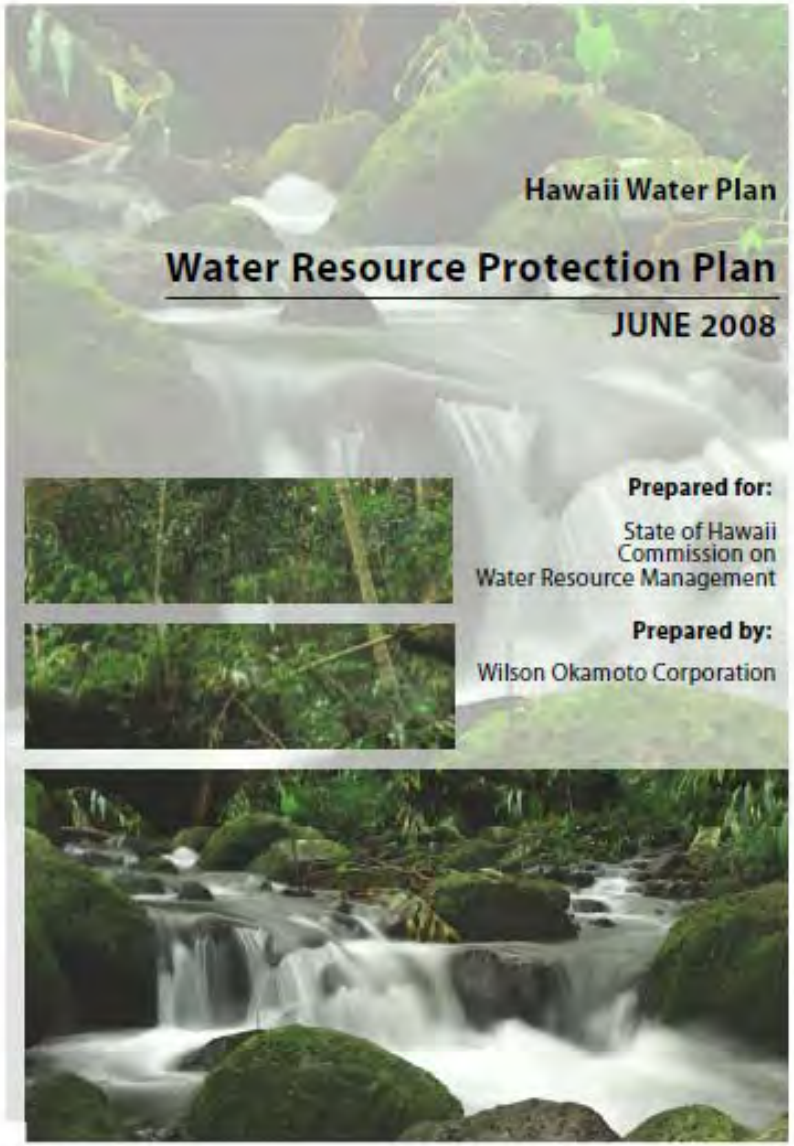



N
1" = 15 MILES
COMMISSION ON
WATER RESOURCE MANAGEMENT
ISLAND OF HAWAII
TOTAL = 2,410 MGD
HYDROLOGIC UNITS
Sustainable Yield / Aquifer Code
KOHALA
140 MGD / 801
W. MAUNA KEA
24 MGD / 803
N.W. MAUNA LOA
30 MGD / 807
HUALALAI
56 MGD / 809
S.W. MAUNA LOA
114 MGD / 806
E. MAUNA KEA
388 MGD / 802
N.E. MAUNA LOA
744 MGD / 804
KILAUEA
621 MGD / 808
S.E. MAUNA LOA
293 MGD / 805
99 Wells
Upolu Point
HAWI
MAHUKONA
WAIMANU
Kawaihae
HONOKAA
Honokaa
Paauilo
Ookala
Laupahoehoe
PAAUILO
HAKALAU
WAIMEA
Kiholo Bay
KIHOLO
ONOMEA
HILO
ANAEHOOMALU
KEAUHOU
Kailua
Keauhou
KEAAU
PAHOA
Cape Kumukahi
KEALAKEKUA
OLAA
KAPAPALA
Honaunau
Hookena
KALAPANA
Kalapana
KAAPUNA
HILINA
NAALEHU
Hoopuloa
KEAIWA
Punaluu
MANUKA
Honuapo
KA LAE
Ka Lae

Kona Wells (Basal vs. High-Level)

Keauhou Ground Water Pumpage




Hawaii Water Plan
Water Resource Protection Plan
JUNE 2008
Prepared for:
State of Hawaii
Commission on
Water Resource Management
Prepared by:
Wilson Okamoto Corporation

Water Code and Sustainable Yields

Ground Water Protection Updates

"***Sustainable yield***" means the maximum rate at which water may be withdrawn from a water source without impairing the utility or quality of the water source as determined by the commission. **(HRS §174C-3 Definitions)**

- CWRM discretion and decision
- Can vary depending on circumstances (examples; Ewa Caprock individual well chloride limits, well infrastructure limitations - Lanai, Pearl Harbor, Iao?)
- 2008 WRPP developed ranges of SY, selecting the minimum SYs where data was sparse or alternative SYs where data monitoring/analysis justified

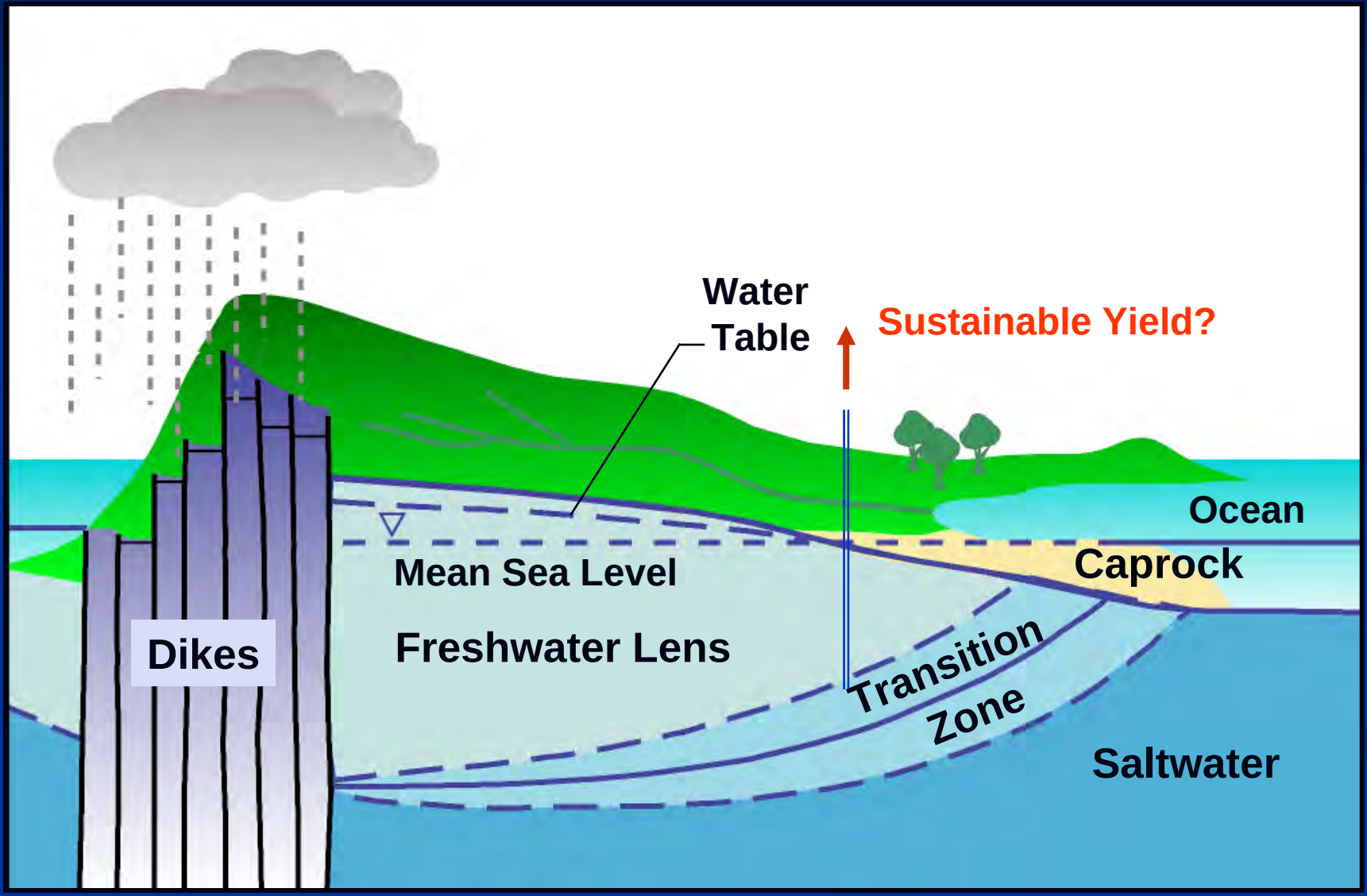
2008 WRPP Big Island SY

Aquifer Sector	Aquifer System	RAM (1990)	RAM (2008)	RAM + Updated Recharge	RAM 2	*SY Range*[1]	Previously Adopted SY (2007)[2]	Sustainable Yield (2008)	Alternate 2008 SY Selection Criteria
Hawaii									
Kohala	Hawi	27	27	13/29	~	*13-29*	27	**13**	
Kohala	Waimanu	110	110	~	~	*110*	110	**110**	
Kohala	Mahukona	17	17	~	~	*17*	17	**17**	
E. Mauna Kea	Honokaa	31	31	~	~	*31*	31	**31**	
E. Mauna Kea	Paauilo	60	60	~	~	*60*	60	**60**	
E. Mauna Kea	Hakalau	150	150	~	~	*150*	150	**150**	
E. Mauna Kea	Onomea	147	147	~	~	*147*	147	**147**	
W. Mauna Kea	Waimea	24	24	~	~	*24*	24	**24**	
NE. Mauna Loa	Hilo	347	349	~	~	*349*	347	**349**	
NE. Mauna Loa	Keaau	393	395	~	~	*395*	393	**395**	
SE. Mauna Loa	Olaa	124	125	~	~	*125*	124	**125**	
SE. Mauna Loa	Kapapala	19	19	~	~	*19*	19	**19**	
SE. Mauna Loa	Naalehu	117	118	~	~	*118*	117	**118**	
SE. Mauna Loa	Ka Lae	31	31	~	~	*31*	31	**31**	
SW. Mauna Loa	Manuka	42	42	25	~	*25-42*	42	**25**	
SW. Mauna Loa	Kaapuna	50	51	58	~	*51-58*	50	**51**	
SW. Mauna Loa	Kealakekua	38	38	38	~	*38*	38	**38**	
NW. Mauna Loa	Anaehoomalu	30	30	~	~	*30*	30	**30**	
Kilauea	Pahoa	435	437	~	~	*437*	435	**437**	
Kilauea	Kalapana	157	158	~	~	*158*	157	**158**	
Kilauea	Hilina	9	9	~	~	*9*	9	**9**	
Kilauea	Keaiwa	17	17	~	~	*17*	17	**17**	
Hualalai	Keauhou	38	38	38	~	*38*	38	**38**	
Hualalai	Kiholo	18	18	~	~	*18*	18	**18**	

Comparison of Predicted Sustainable Yields Considered by the CWRM

Sustainable Yield in Million Gallons Per Day (mgd)

Conceptual Hydrologic Model



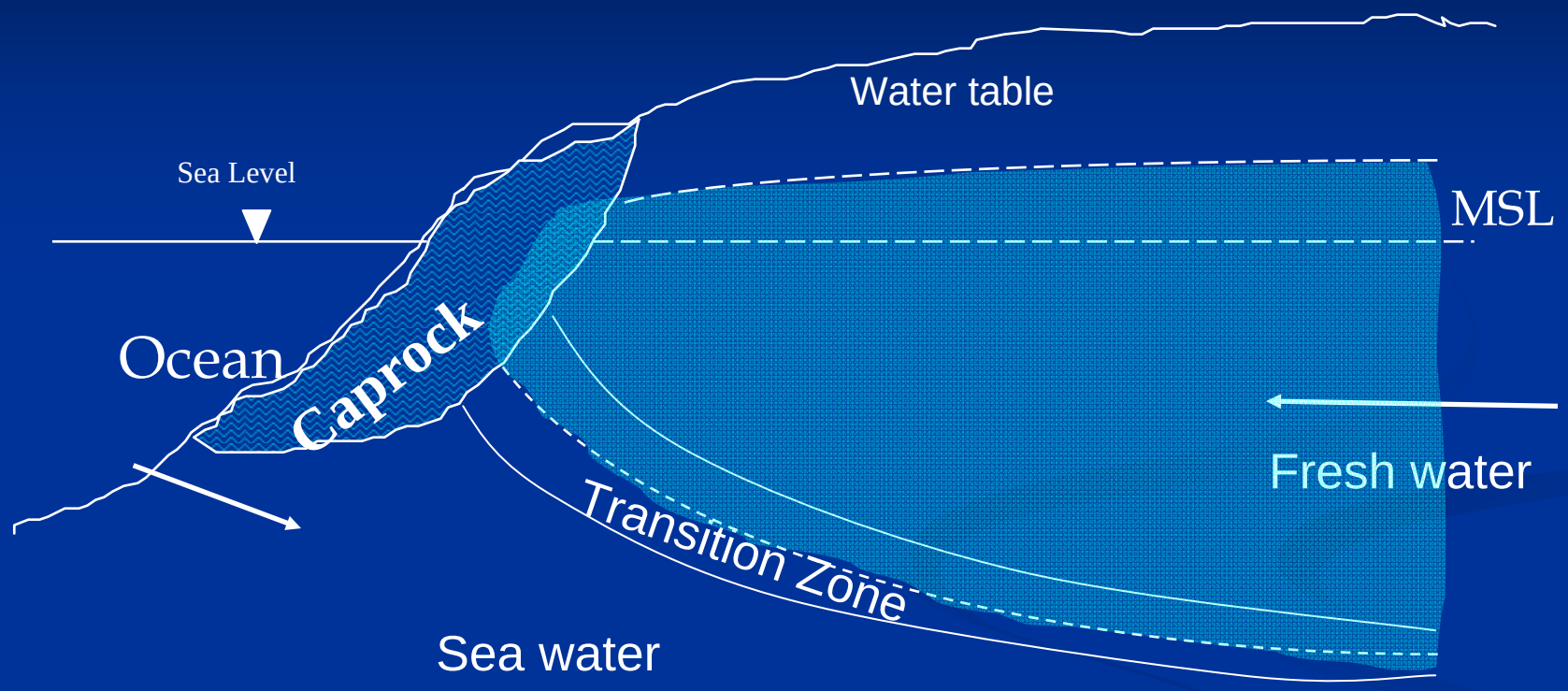
- How does CWRM estimate Sustainable Yields?
  - Use best public information available
  - RAM
  - RAM2
  - Numerical Models and other public studies

What is RAM?

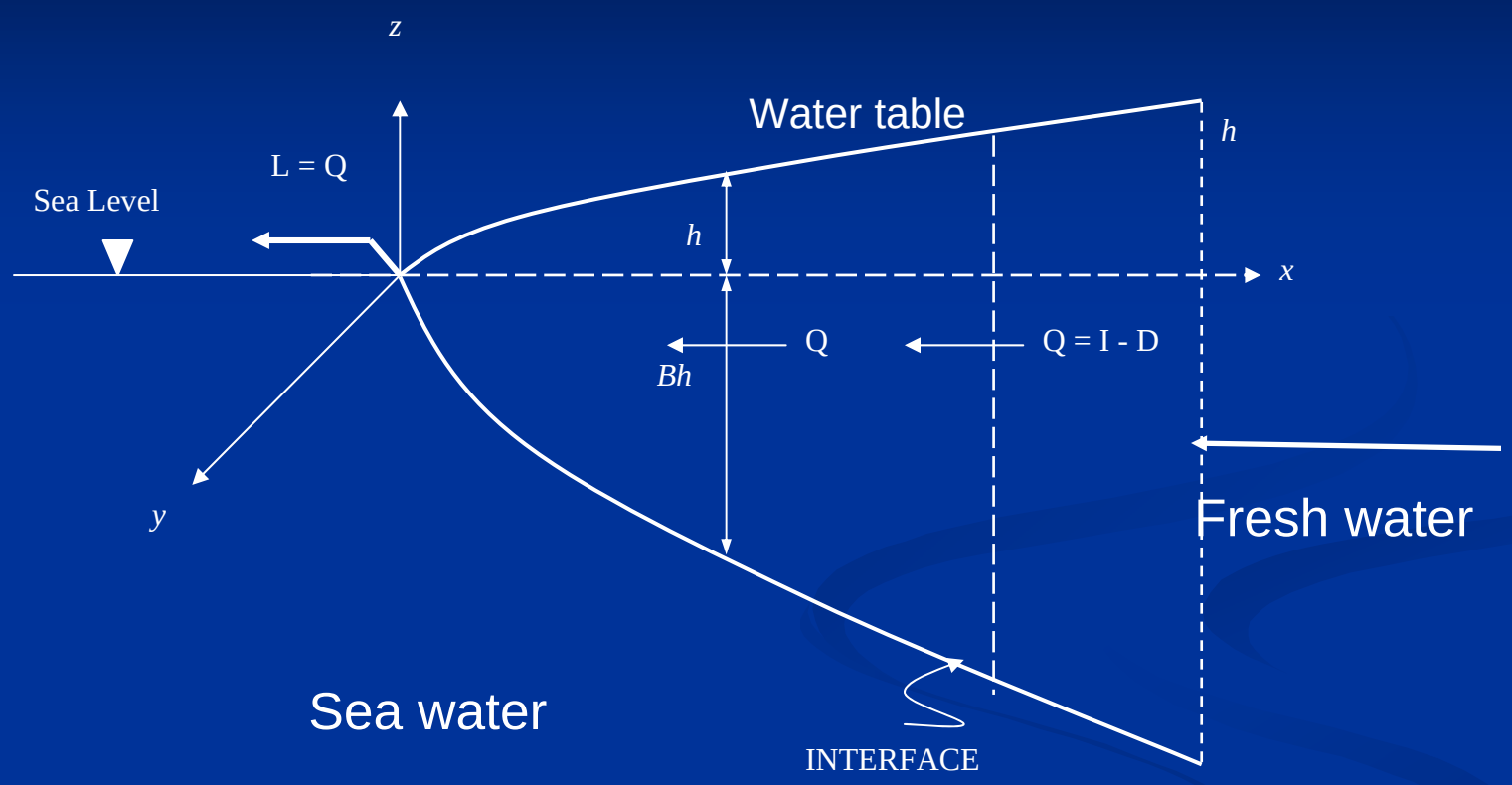
Robust Analytical Model (RAM)

(Mink, J.F. 1981.Determination of Sustainable Yields, in Groundwater in Hawaii – A Century of Progress, Water Resources Research Center, University of Hawaii)

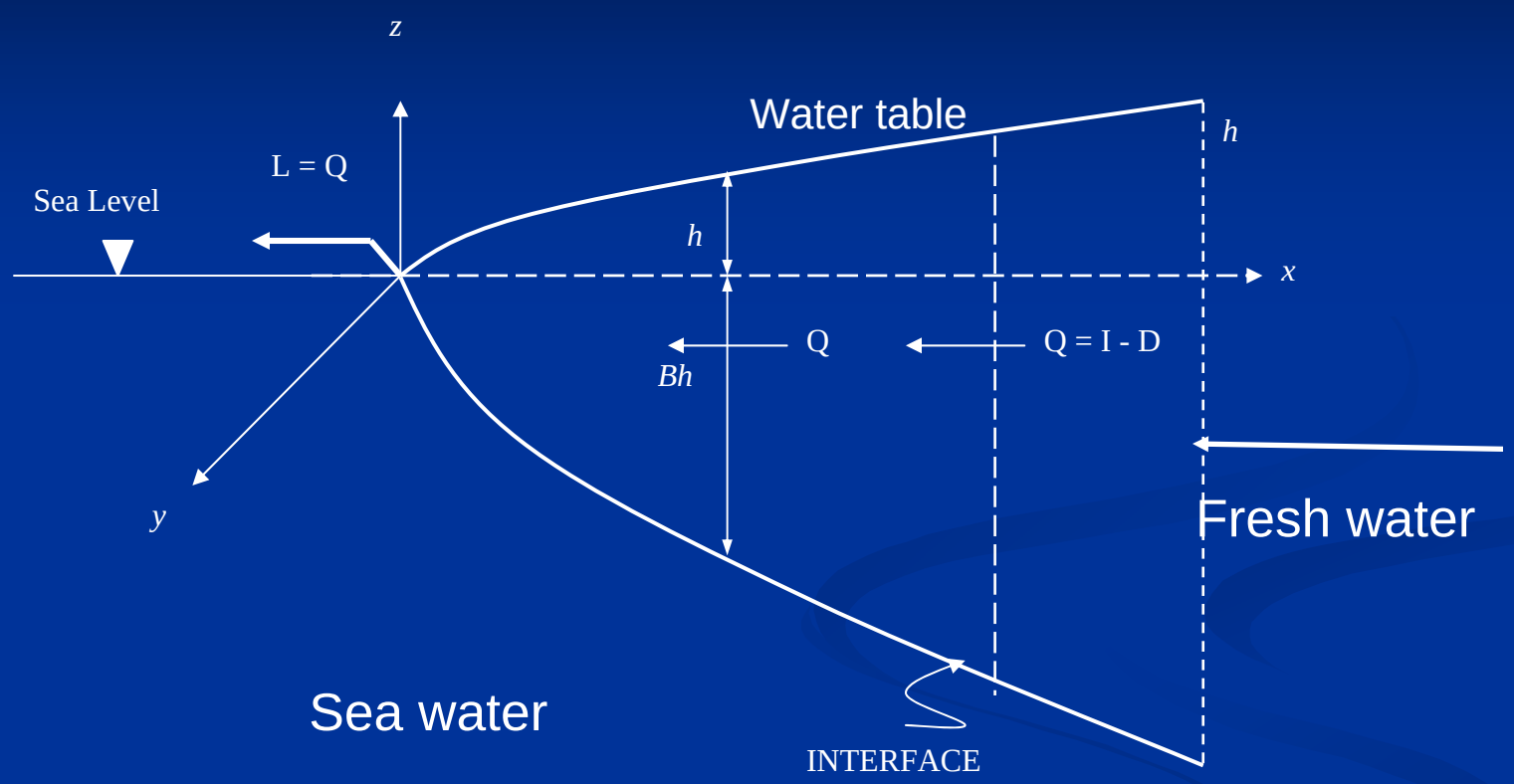
Conceptual RAM Model



Conceptual RAM Model



Conceptual RAM Model



By combining Darcy's Law, conservation of mass, and GH principle - RAM Model:

$$41SA\frac{dh}{dt} = I - D - ch^2$$

Solution:

$$h_{i+1} = h_0\sqrt{\frac{I-D}{D}}\left[\frac{[\sqrt{I-D}+\frac{h_i}{h_0}\sqrt{I}]\cdot\exp\left\{\frac{2\sqrt{(I-D)I}\,(t_{i+1}-t_i)}{V_0}\right\}-\sqrt{I-D}+\frac{h_i}{h_0}\sqrt{I}}{[\sqrt{I-D}+\frac{h_i}{h_0}\sqrt{I}]\cdot\exp\left\{\frac{2\sqrt{(I-D)I}\,(t_{i+1}-t_i)}{V_0}\right\}+\sqrt{I-D}-\frac{h_i}{h_0}\sqrt{I}}\right]$$

John Mink's Robust Analytical Model (RAM)

(Mink, J.F. 1981.Determination of Sustainable Yields, in:Groundwater in Hawaii – A Century of Progress, Water Resources Research Center, University of Hawaii)

$$D = I\{1 - (h/H)^2\}$$

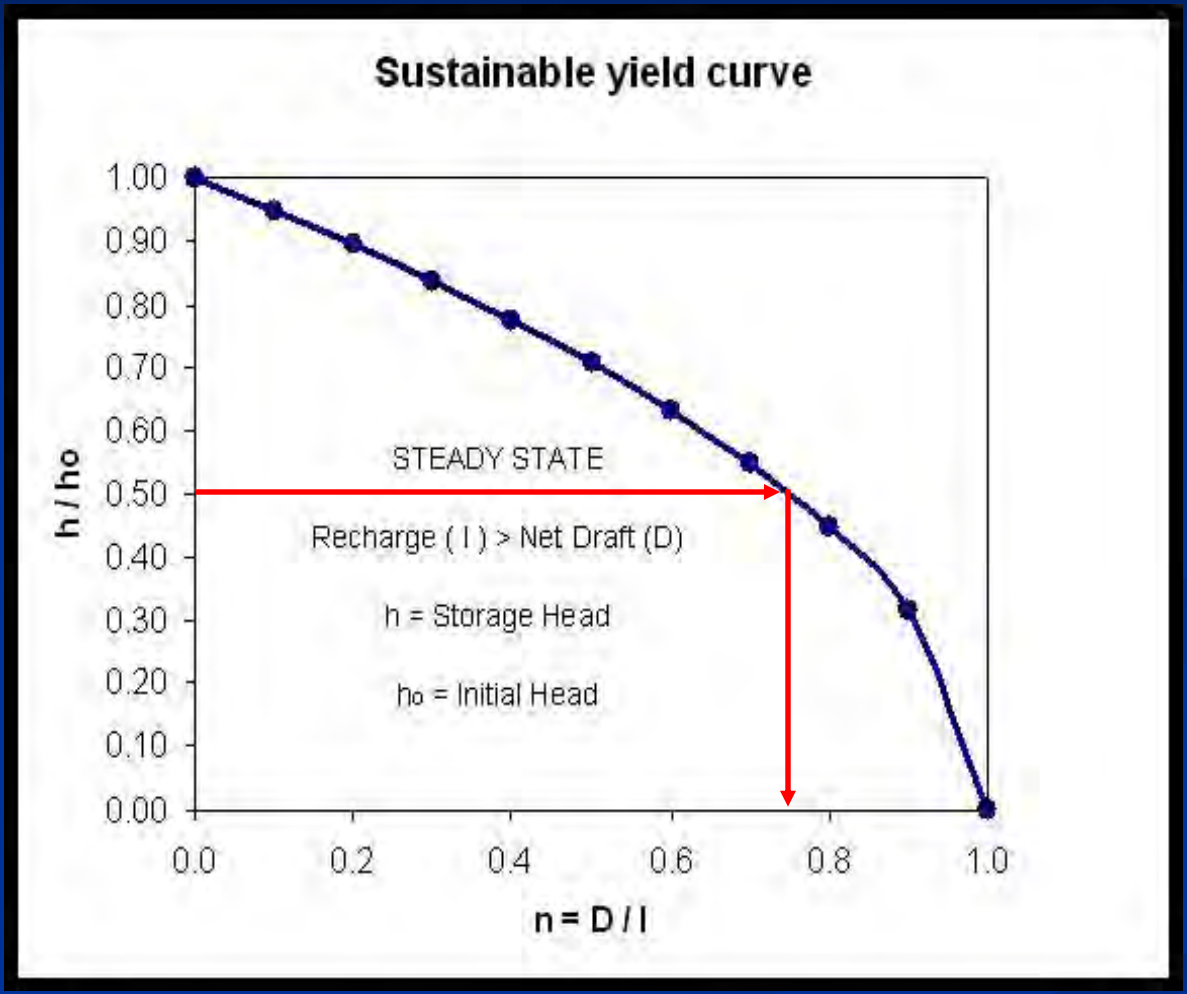
D = allowable draft (i.e. sustainable yield)
I = Recharge
H = original head before pumping (important calibration point)
h = equilibrium head

Limitations

- Assumes uniform distribution (optimized) pumpage
- Difficult, if not impossible, to define original & equilibrium head
- Does not directly assess changes in chlorides or water levels at a specific well

John Mink's Robust Analytical Model (RAM)

(Mink, J.F. 1981.Determination of Sustainable Yields, in:Groundwater in Hawaii – A Century of Progress, Water Resources Research Center, University of Hawaii)



John Mink's Robust Analytical Model (RAM)

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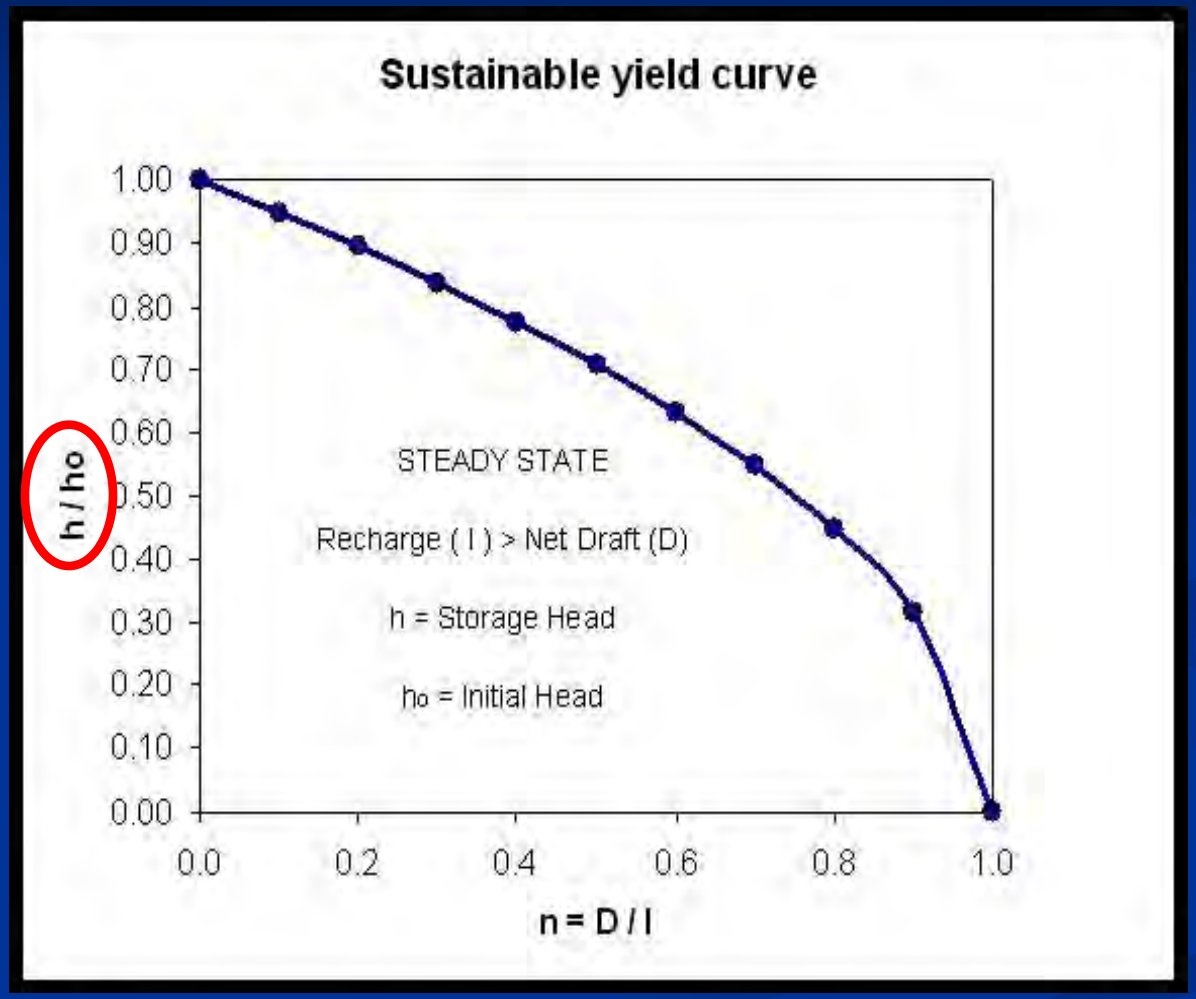


John Mink's Robust Analytical Model (RAM)

(Mink, J.F. 1981.Determination of Sustainable Yields, in:Groundwater in Hawaii – A Century of Progress, Water Resources Research Center, University of Hawaii)

Table 2. Relationships Between Initial Head and Minimum Equilibrium Head of Hawaii Basal Aquifers, Established by CWRM (1990)

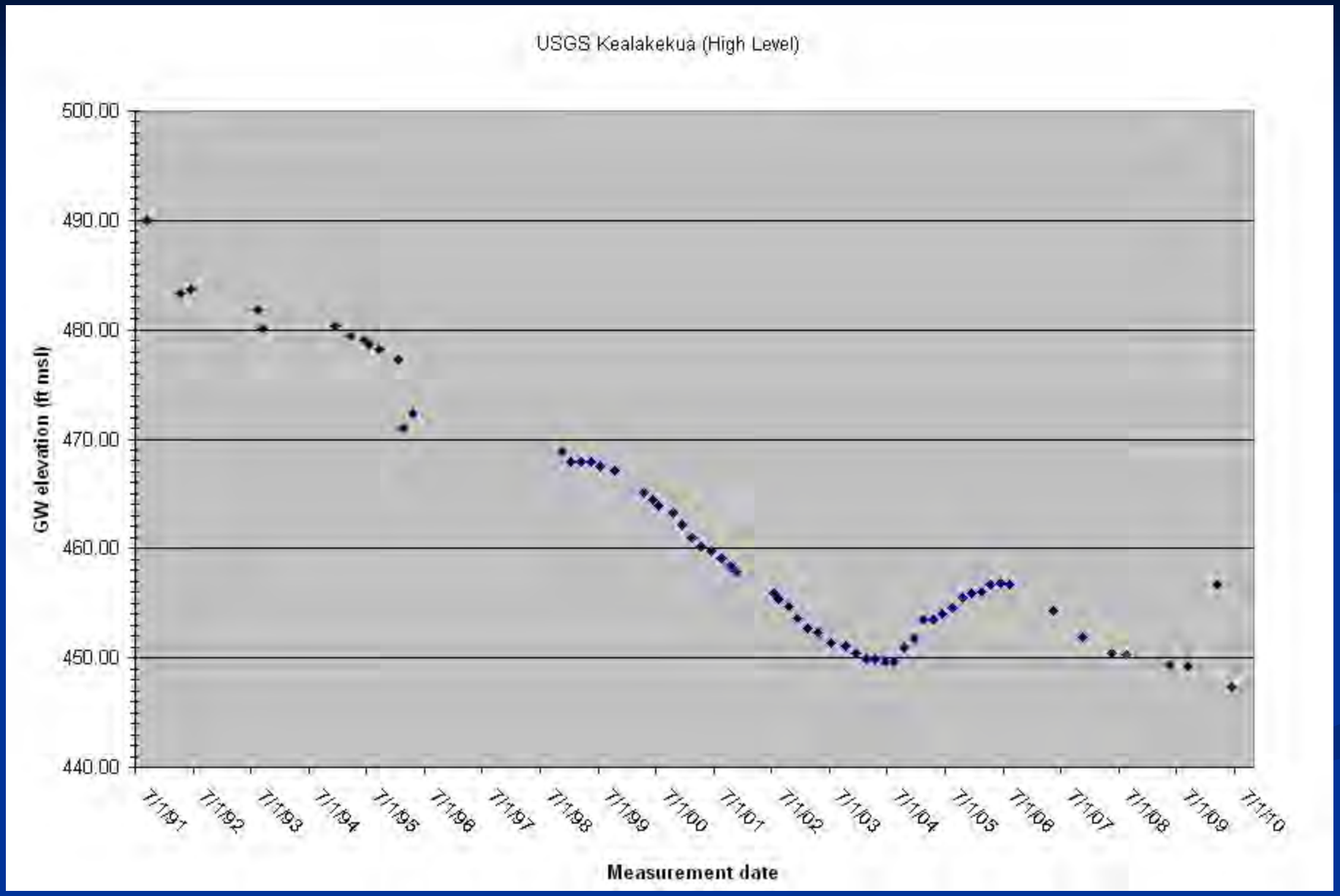
Range of Initial Head, h_0 (ft)	Ratio of Minimum Equilibrium Head and Initial Head, h_e/h_0		
4–10	0.75	44	SY=%Recharge
11–15	0.70	51	
16–20	0.65	58	
21–25	0.60	64	
> 26	0.50	75	

2008 WRPP Big Island SY

Aquifer Sector	Aquifer System	RAM SY - 1990 (mgd)	D/I = 1990 pg B-3	1990 Recharge	Revised Recharge	Revised Recharge SY	2008 SY Range
Hawaii							
Kohala	Hawi	27	0.44	62	29.9/65.4	13-29	13 - 29
Kohala	Waimanu	110	0.75	147	~	~	110
Kohala	Mahukona	17	0.44	38	~	~	17
E. Mauna Kea	Honokaa	31	0.44	71	~	~	31
E. Mauna Kea	Paauilo	60	0.44	136	~	~	60
E. Mauna Kea	Hakalau	150	0.44	341	~	~	150
E. Mauna Kea	Onomea	147	0.44	335	~	~	147
W. Mauna Kea	Waimea	24	0.44	54	~	~	24
NE. Mauna Loa	Hilo	347	0.44	793	~	~	349
NE. Mauna Loa	Keaau	393	0.44	898	~	~	395
SE. Mauna Loa	Olaa	124	0.44	284	~	~	125
SE. Mauna Loa	Kapapala	19	0.44	44	~	~	19
SE. Mauna Loa	Naalehu	117	0.44	268	~	~	118
SE. Mauna Loa	Ka Lae	31	0.44	71	~	~	31
SW. Mauna Loa	Manuka	42	0.44	96	56	25	25 - 42
SW. Mauna Loa	Kaapuna	50	0.44	115	133	58	51 - 58
SW. Mauna Loa	Kealakekua	38	0.44	86	87	38	38
NW. Mauna Loa	Anaehoomalu	30	0.44	69	~	~	30
Kilauea	Pahoa	435	0.44	994	~	~	437
Kilauea	Kalapana	157	0.44	359	~	~	158
Kilauea	Hilina	9	0.44	20	~	~	9
Kilauea	Keaiwa	17	0.44	39	~	~	17
Hualalai	Keauhou	38	0.44	87	86	38	38
Hualalai	Kiholo	18	0.44	42	~	~	18

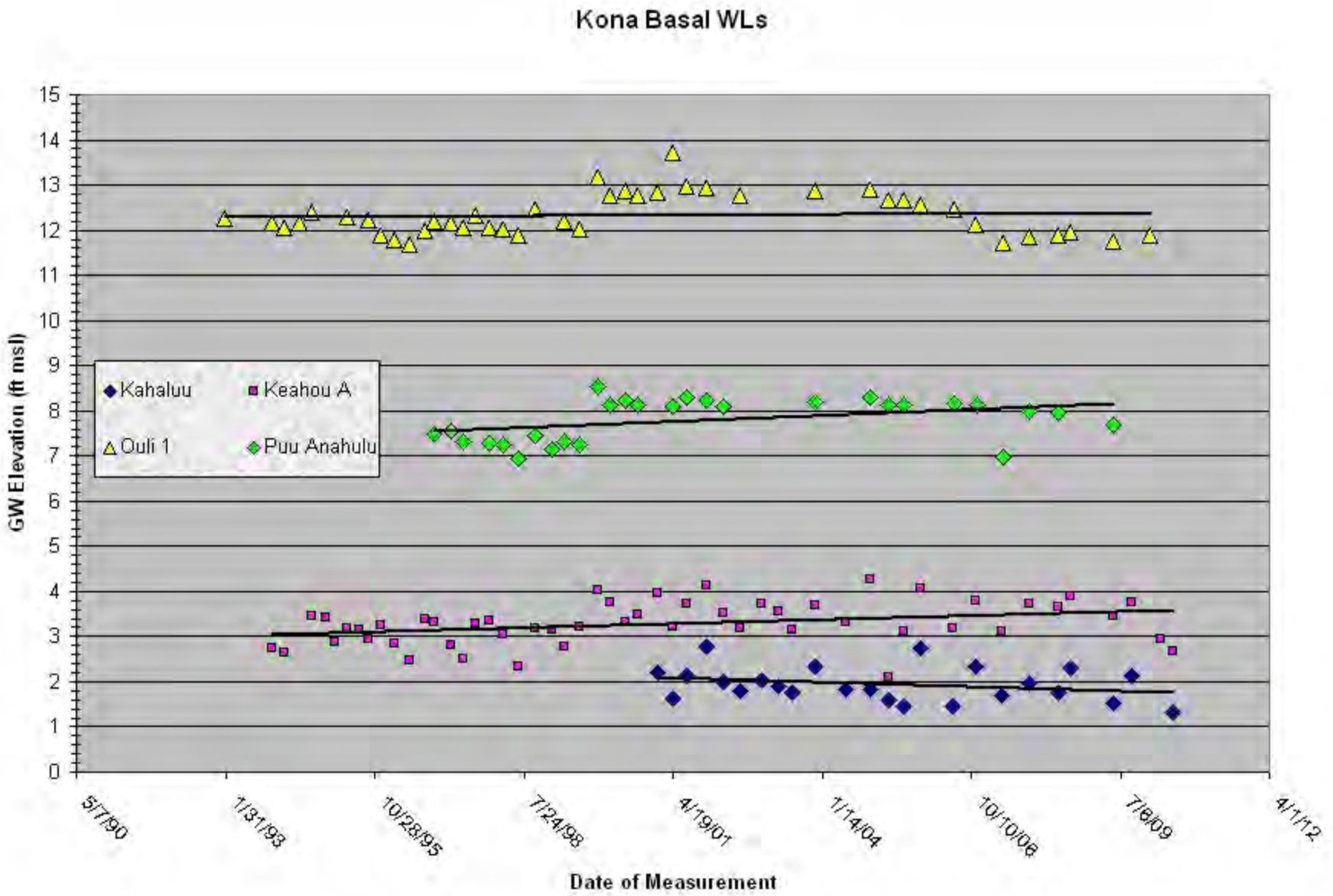
Observed Water Level Behavior

Observed Water Level Behavior

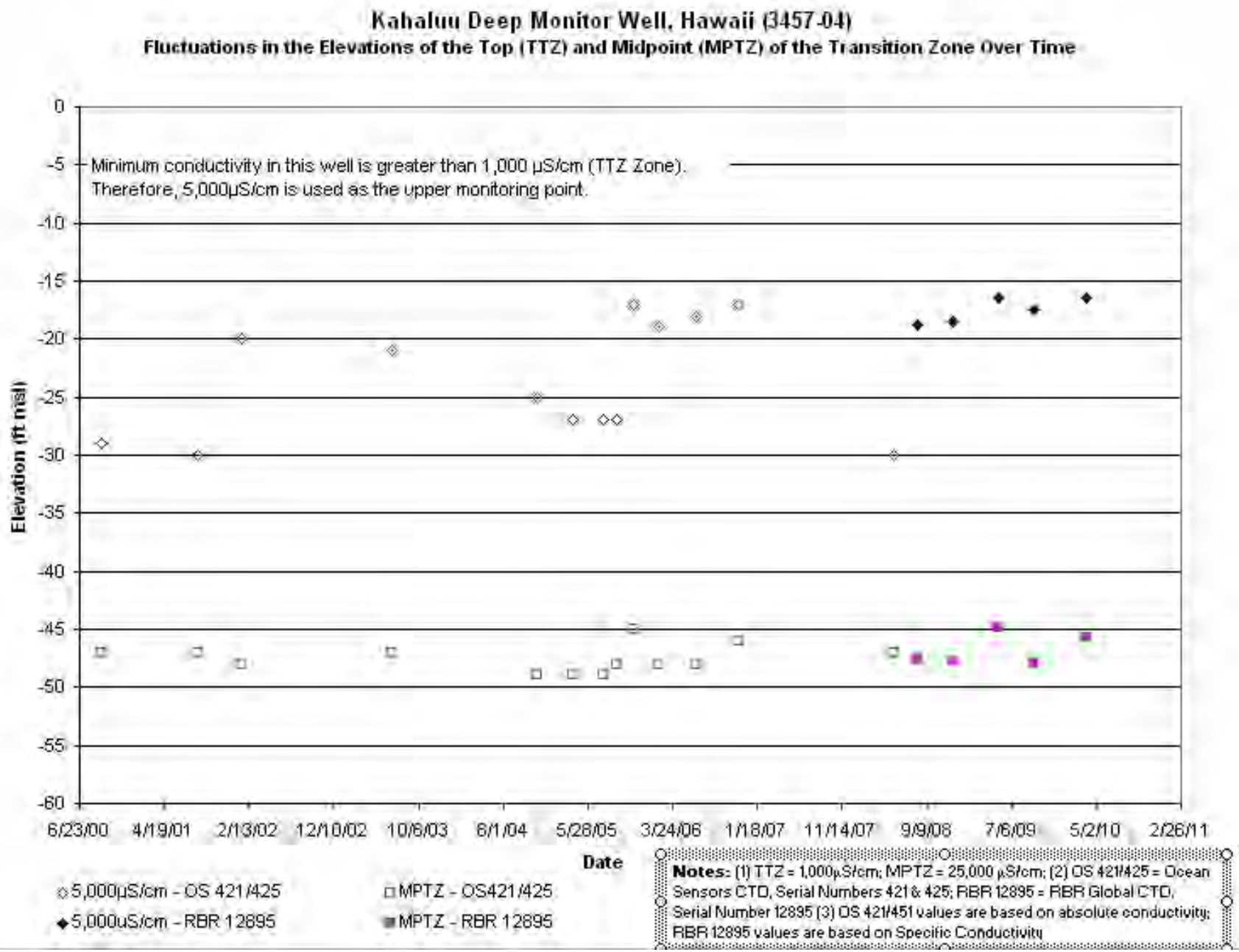


Observed Water Level Behavior

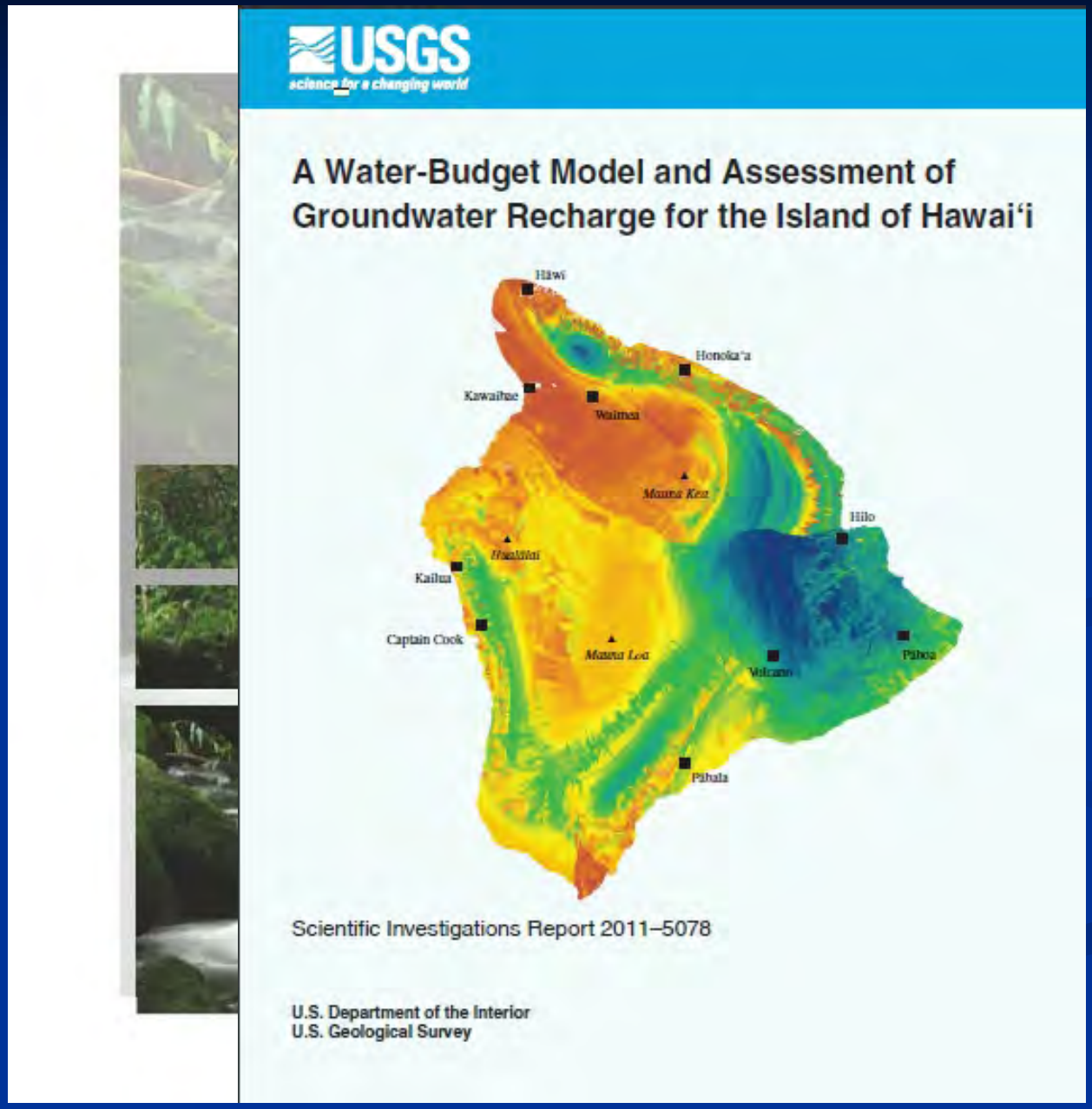
Observed Water Level Behavior



Observed Water Level Behavior



Big Island Recharge Update



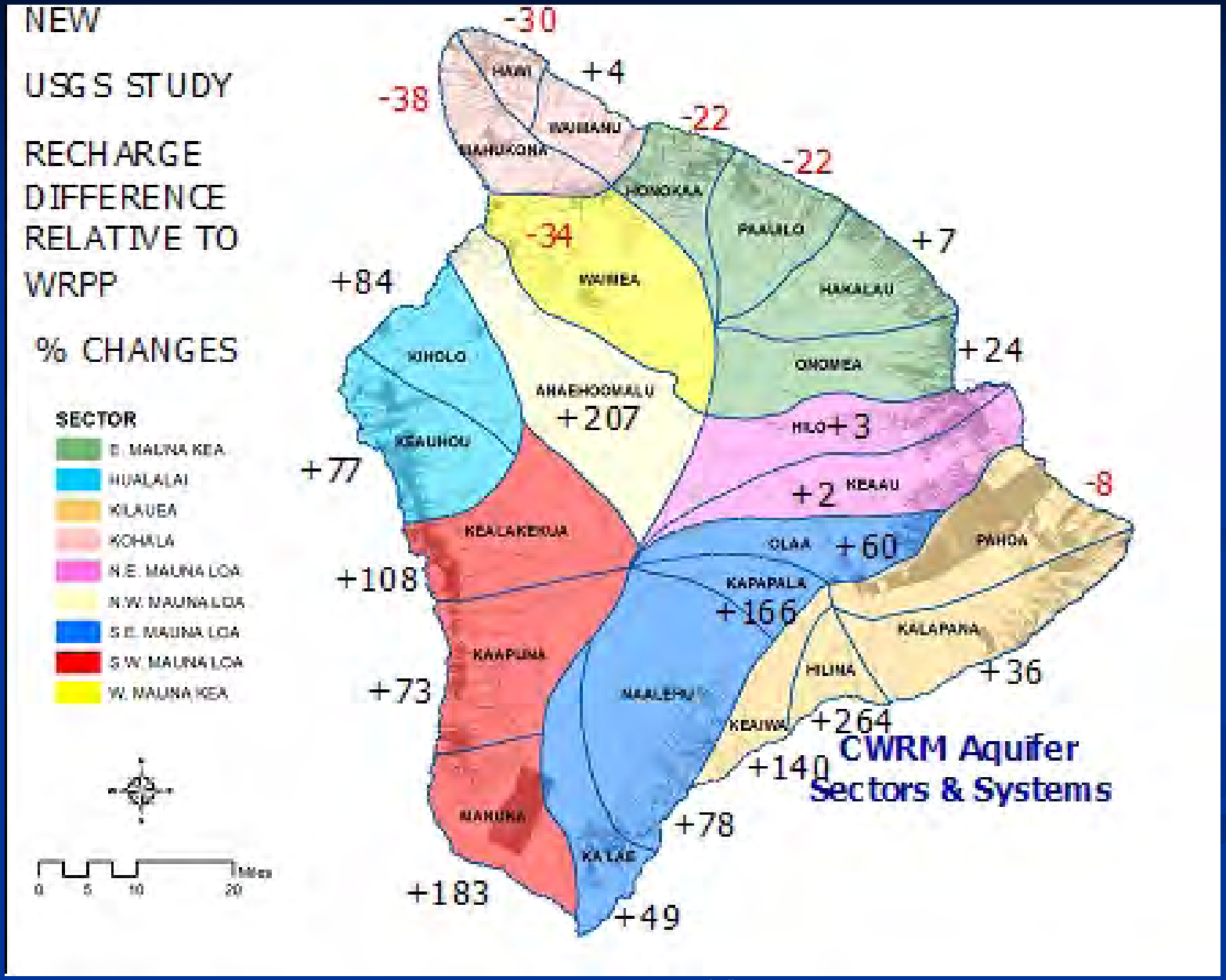
USGS
science for a changing world

A Water-Budget Model and Assessment of Groundwater Recharge for the Island of Hawai'i

Scientific Investigations Report 2011–5078

U.S. Department of the Interior
U.S. Geological Survey

Big Island Recharge Update



Effect on WRPP Big Island SY

Aquifer Sector	Aquifer System	RAM SY - 1990 (mgd)	D/I = 1990 pg B-3	1990 Recharge	Revised Recharge	Revised Recharge SY	USGS 2011 Revised Recharge Baseline	USGS 2011 Revised Recharge Baseline SY	2008 SY Range	2011 SY Range
Hawaii										
Kohala	Hawi	27	0.44	62	29.9/65.4	13-29	21.09	9	13 - 29	9 - 29
Kohala	Waimanu	110	0.75	147	~	~	153.09	115	110	110 - 115
Kohala	Mahukona	17	0.44	38	~	~	23.22	10	17	10 - 17
E. Mauna Kea	Honokaa	31	0.44	71	~	~	63.33	28	31	28 - 31
E. Mauna Kea	Paauilo	60	0.44	136	~	~	120.86	53	60	53 - 60
E. Mauna Kea	Hakalau	150	0.44	341	~	~	364.81	161	150	150 - 161
E. Mauna Kea	Onomea	147	0.44	335	~	~	417.08	184	147	147 - 184
W. Mauna Kea	Waimea	24	0.44	54	~	~	35.62	16	24	16 - 24
NE. Mauna Loa	Hilo	347	0.44	793	~	~	815.16	359	349	349 - 359
NE. Mauna Loa	Keaau	393	0.44	898	~	~	914.71	402	395	395 - 402
SE. Mauna Loa	Olaa	124	0.44	284	~	~	454.01	200	125	125 - 200
SE. Mauna Loa	Kapapala	19	0.44	44	~	~	116.81	51	19	19 - 51
SE. Mauna Loa	Naalehu	117	0.44	268	~	~	476.19	210	118	118 - 210
SE. Mauna Loa	Ka Lae	31	0.44	71	~	~	106.61	47	31	31 - 47
SW. Mauna Loa	Manuka	42	0.44	96	56	25	160.11	70	25 - 42	25 - 70
SW. Mauna Loa	Kaapuna	50	0.44	115	133	58	197.47	87	51 - 58	51 - 58
SW. Mauna Loa	Kealakekua	38	0.44	86	87	38	179.58	79	38	38 - 79
NW. Mauna Loa	Anaehoomalu	30	0.44	69	~	~	181.69	80	30	30 - 80
Kilauea	Pahoa	435	0.44	994	~	~	910.93	401	437	401 - 437
Kilauea	Kalapana	157	0.44	359	~	~	487.76	215	158	158 - 215
Kilauea	Hilina	9	0.44	20	~	~	72.95	32	9	9 - 32
Kilauea	Keaiwa	17	0.44	39	~	~	93.61	41	17	17 - 41
Hualalai	Keauhou	38	0.44	87	86	38	151.62	67	38	38 - 67
Hualalai	Kiholo	18	0.44	42	~	~	76.19	34	18	18 - 34

Effect on WRPP Big Island SY

Aquifer Sector	Aquifer System	RAM SY - 1990 (mgd)	D/I = 1990 pg B-3	1990 Recharge	Revised Recharge	Revised Recharge SY	USGS 2011 Revised Recharge Baseline	USGS 2011 Revised Recharge Baseline SY	2008 SY Range	2011 SY Range
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Kohala	Waimanu	110	0.75	147	~	~	153.09	115	110	110 - 115
Kohala	Mahukona	17	0.44	38	~	~	23.22	10	17	10 - 17
E. Mauna Kea	Honokaa	31	0.44	71	~	~	63.33	28	31	28 - 31
E. Mauna Kea	Paauilo	60	0.44	136	~	~	120.86	53	60	53 - 60
E. Mauna Kea	Hakalau	150	0.44	341	~	~	364.81	161	150	150 - 161
E. Mauna Kea	Onomea	147	0.44	335	~	~	417.08	184	147	147 - 184
W. Mauna Kea	Waimea	24	0.44	54	~	~	35.62	16	24	16 - 24
NE. Mauna Loa	Hilo	347	0.44	793	~	~	815.16	359	349	349 - 359
NE. Mauna Loa	Keaau	393	0.44	898	~	~	914.71	402	395	395 - 402
SE. Mauna Loa	Olaa	124	0.44	284	~	~	454.01	200	125	125 - 200
SE. Mauna Loa	Kapapala	19	0.44	44	~	~	116.81	51	19	19 - 51
SE. Mauna Loa	Naalehu	117	0.44	268	~	~	476.19	210	118	118 - 210
SE. Mauna Loa	Ka Lae	31	0.44	71	~	~	106.61	47	31	31 - 47
SW. Mauna Loa	Manuka	42	0.44	96	56	25	160.11	70	25 - 42	25 - 70
SW. Mauna Loa	Kaapuna	50	0.44	115	133	58	197.47	87	51 - 58	51 - 58
SW. Mauna Loa	Kealakekua	38	0.44	86	87	38	179.58	79	38	38 - 79
NW. Mauna Loa	Anaehoomalu	30	0.44	69	~	~	181.69	80	30	30 - 80
Kilauea	Pahoa	435	0.44	994	~	~	910.93	401	437	401 - 437
Kilauea	Kalapana	157	0.44	359	~	~	487.76	215	158	158 - 215
Kilauea	Hilina	9	0.44	20	~	~	72.95	32	9	9 - 32
Kilauea	Keaiwa	17	0.44	39	~	~	93.61	41	17	17 - 41
Hualalai	Keauhou	38	0.44	87	86	38	151.62	67	38	38 - 67
Hualalai	Kiholo	18	0.44	42	~	~	76.19	34	18	18 - 34

Online Rainfall Atlas Update

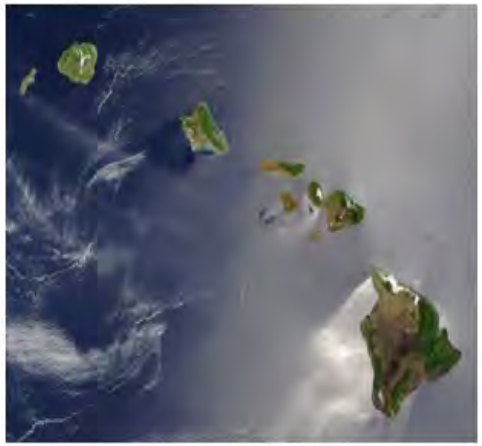
Rainfall Atlas of Hawai'i

Geography Department - University of Hawai'i at Mānoa

HOME | INTERACTIVE MAP | DOWNLOADS | HISTORY | METHODS | RAINFALL | ACKNOWLEDGMENTS | PEOPLE

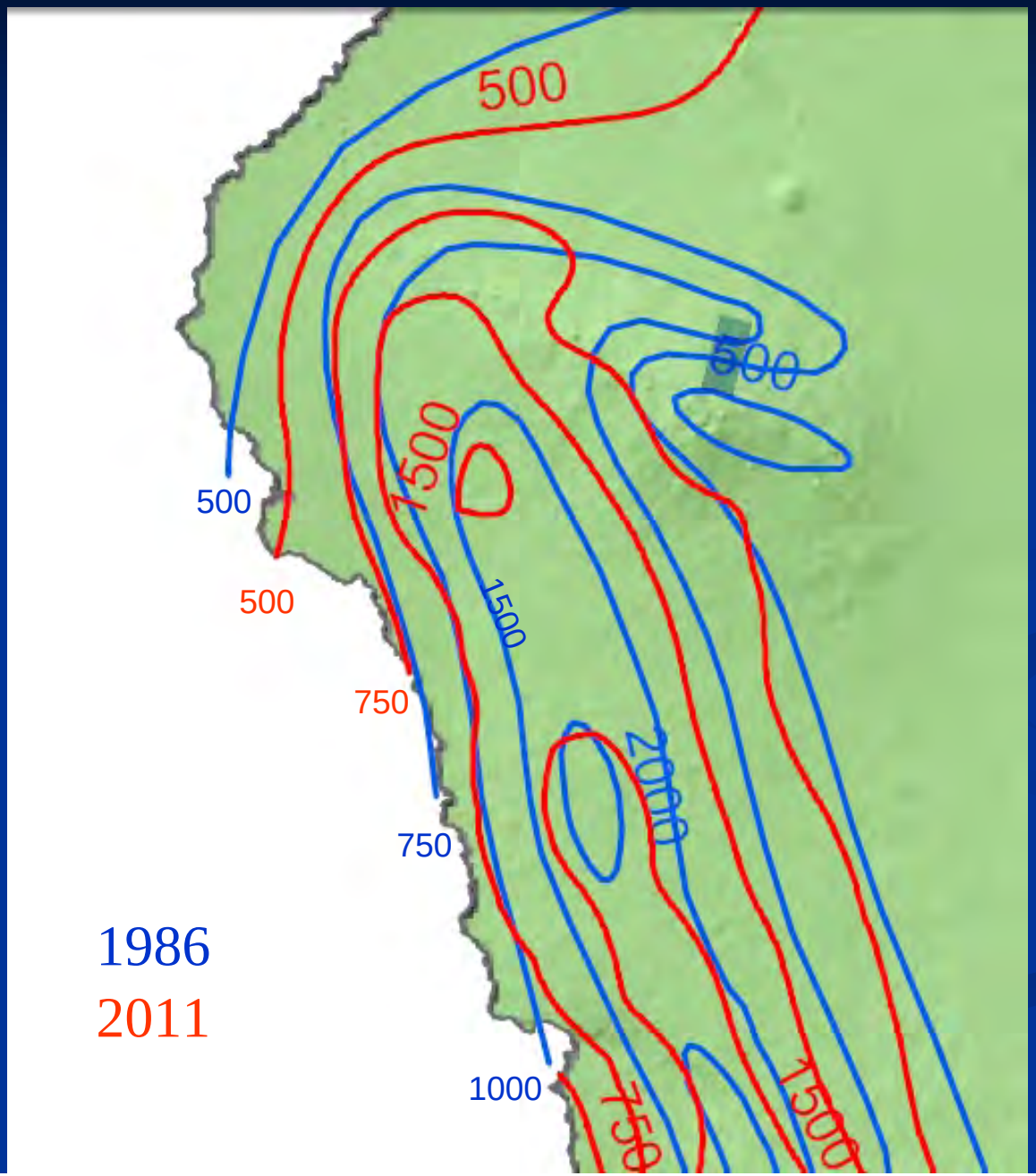
What is the Rainfall Atlas of Hawai'i?

The Hawaiian Islands have one of the most diverse rainfall patterns on earth. The mountainous terrain, persistent trade winds, heating and cooling of the land, and the regular presence of a stable atmospheric layer at an elevation of around 7,000 ft. interact to produce areas of uplift in distinct spatial patterns anchored to the topography. The resulting clouds and rainfall produced by this uplift lead to dramatic differences in mean rainfall over short distances. Knowledge of the mean rainfall patterns is critically important for a variety of resource management issues, including ground water and surface water development and protection, controlling and eradicating invasive species, protecting and restoring native ecosystems, and planning for the effects of global warming.



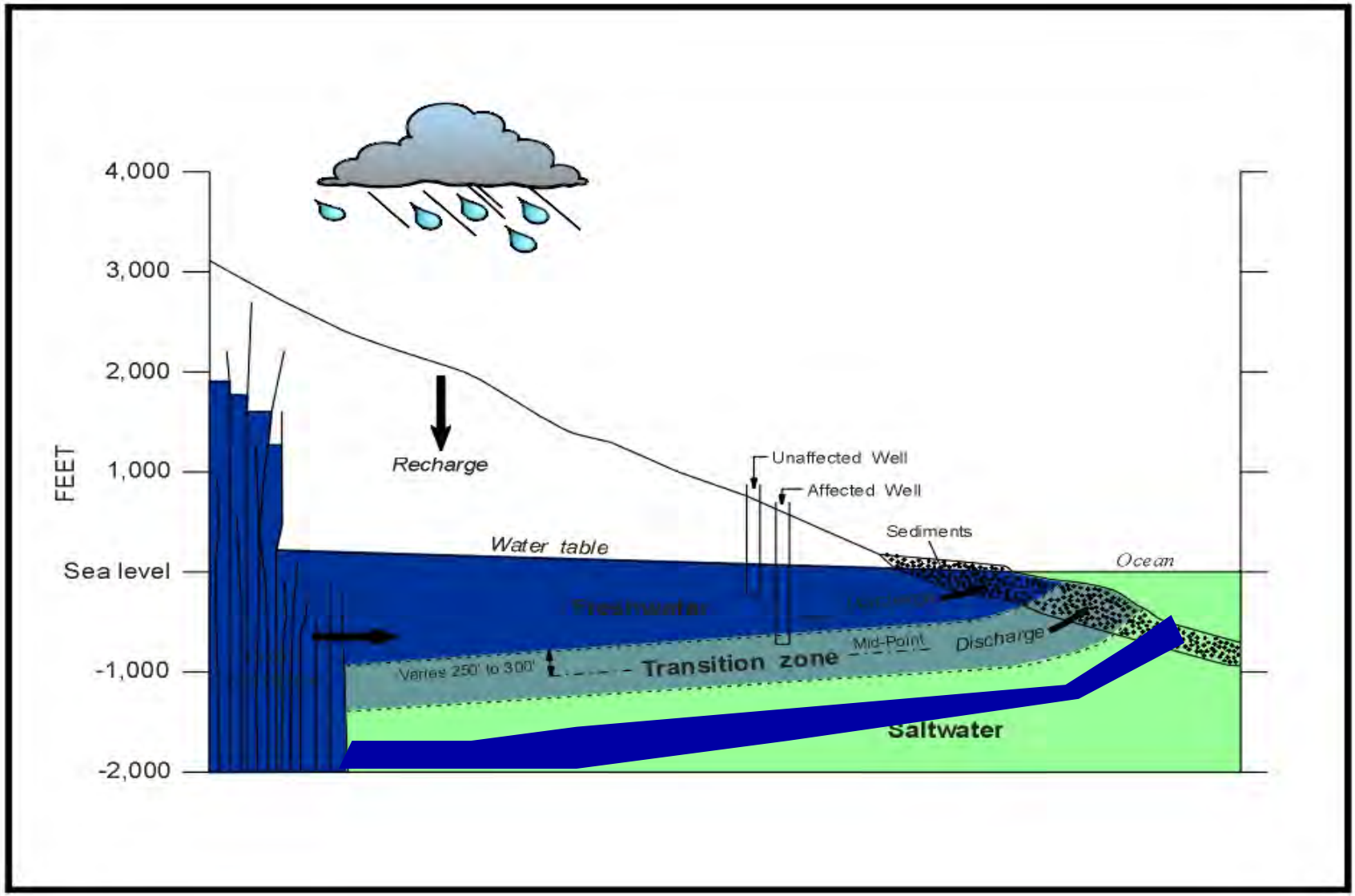
MODIS Image of Hawai'i, NASA Earth Observatory

Online Rainfall Atlas Update



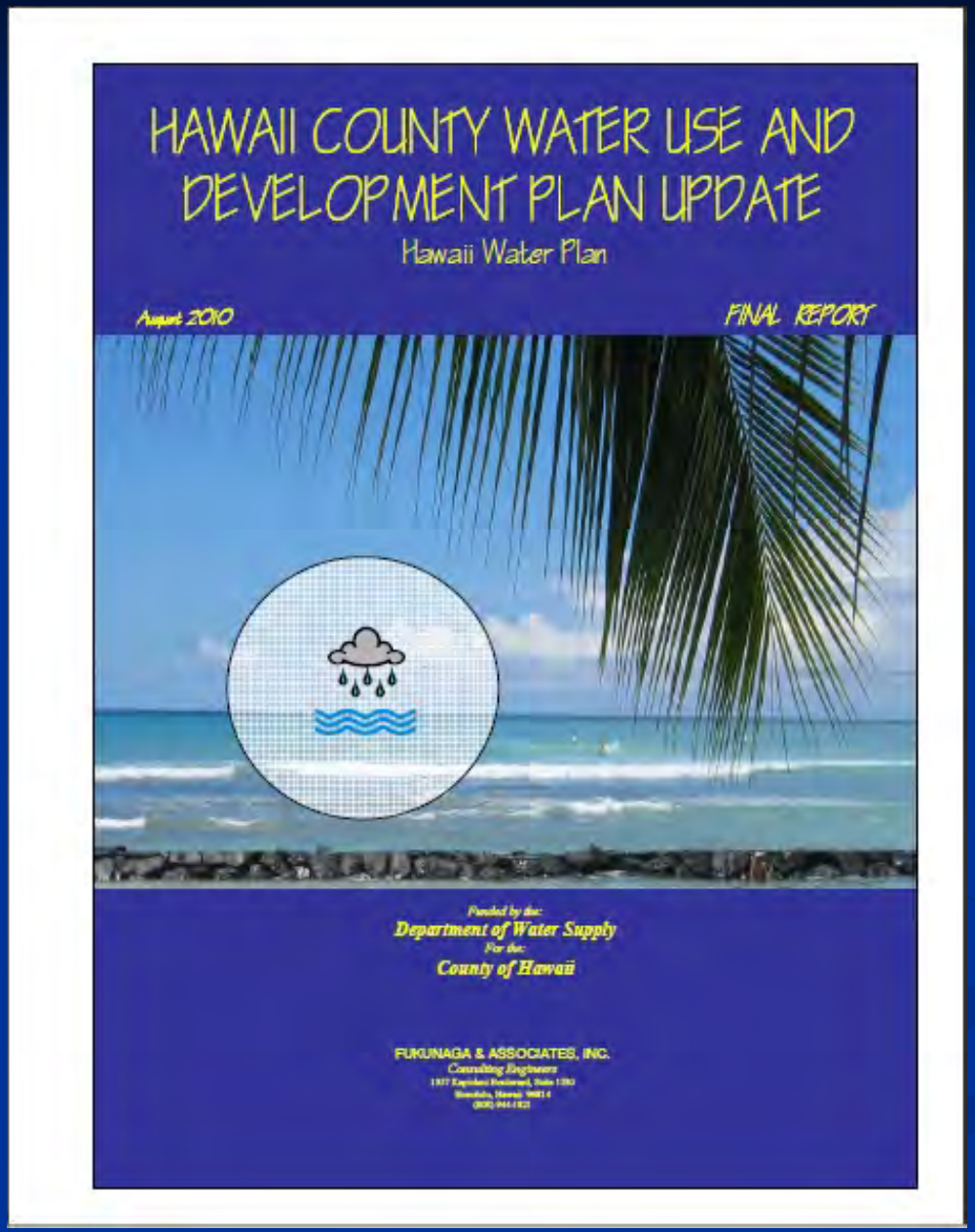
Kona Ground Water Monitoring Update

Kona Ground Water Monitoring Update



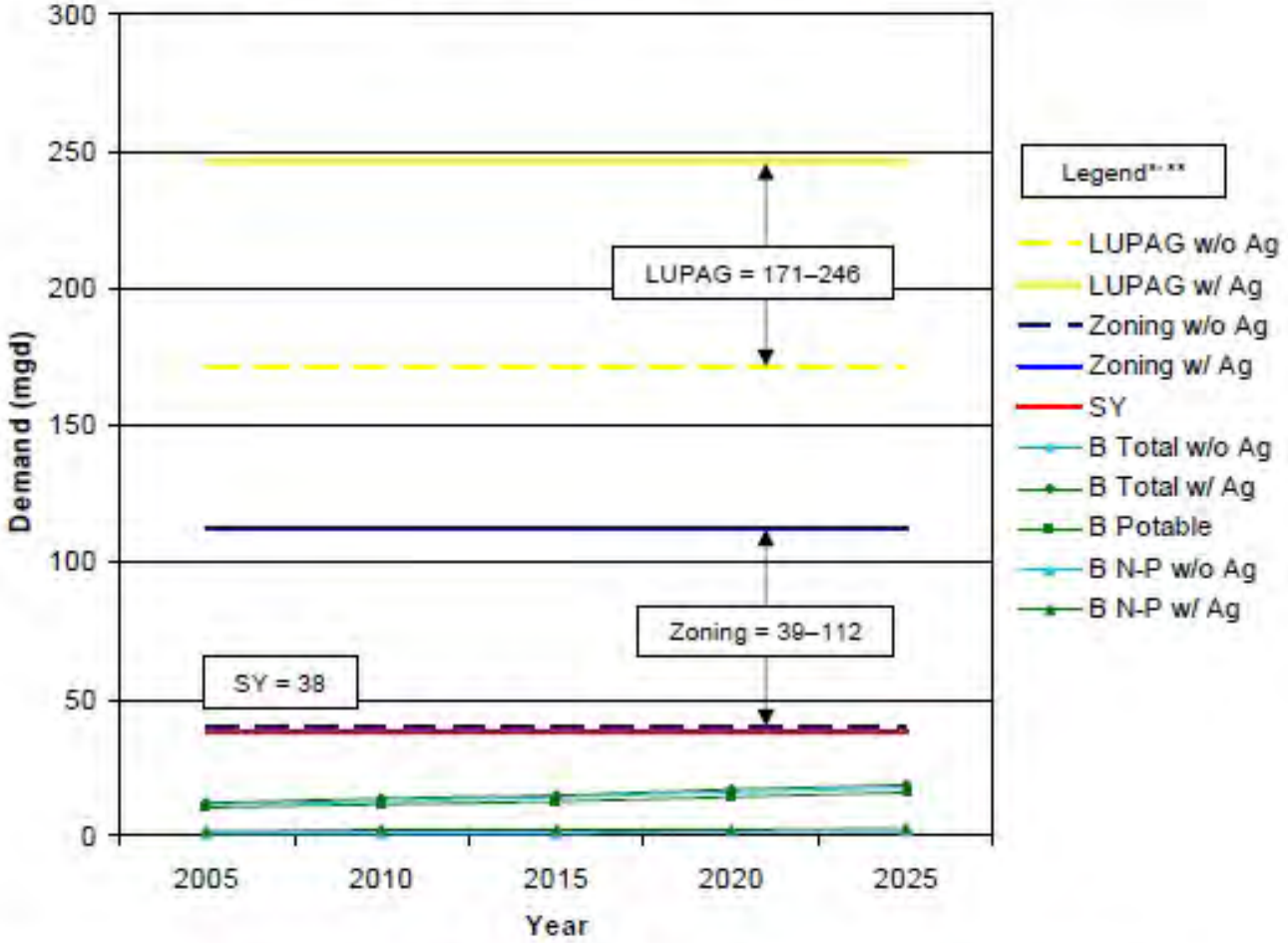
Kona Ground Water Monitoring Update

2011 Hawaii WUDP Update



2011 Hawaii WUDP Update

Figure 809-9a: Medium Growth Rate B Water Demand Projections and Full Build-Out – Keauhou Aquifer System Area [80901]



* Demand scenarios without and with agricultural demands represent the potential minimum and maximum agricultural demand, respectively, with the expectation that the actual demand will fall somewhere in between.
** The LUPAG and Zoning scenarios represent demand from full build-out to the maximum density allowed and are not associated with a timeline. The B scenario represents the 5-year incremental demand based on Growth Rate B population projections, with "Potable" representing the potable component, "N-P" representing the nonpotable component and "Total" representing the sum of the two.

2011 Hawaii WUDP Update

Table 809-17a: Medium Growth Rate B Water Demand Projection by Category – Keauhou Aquifer System Area [80901]

Water Use Category	2005 (mgd)	2010 (mgd)	2015 (mgd)	2020 (mgd)	2025 (mgd)
Total without Ag*	11.3	12.6	14.1	15.7	17.5
Total with Ag*	12.0	13.4	15.0	16.7	18.6
Domestic	0.4	0.4	0.4	0.5	0.5
Industrial	0.1	0.1	0.1	0.1	0.1
Irrigation	1.0	1.1	1.2	1.3	1.5
Agriculture	0.7	0.8	0.9	1.0	1.1
Military	0.0	0.0	0.0	0.0	0.0
Municipal	9.9	11.1	12.3	13.8	15.3
Potable	10.3	11.5	12.8	14.3	15.9
Nonpotable w/o Ag*	1.0	1.2	1.3	1.4	1.6
Nonpotable w/ Ag*	1.7	2.0	2.2	2.4	2.7
DWS	9.4	10.5	11.7	13.1	14.6

* Demand scenarios without and with agricultural demands represent the potential minimum and maximum agricultural demand, respectively, with the expectation that the actual demand will fall somewhere in between.

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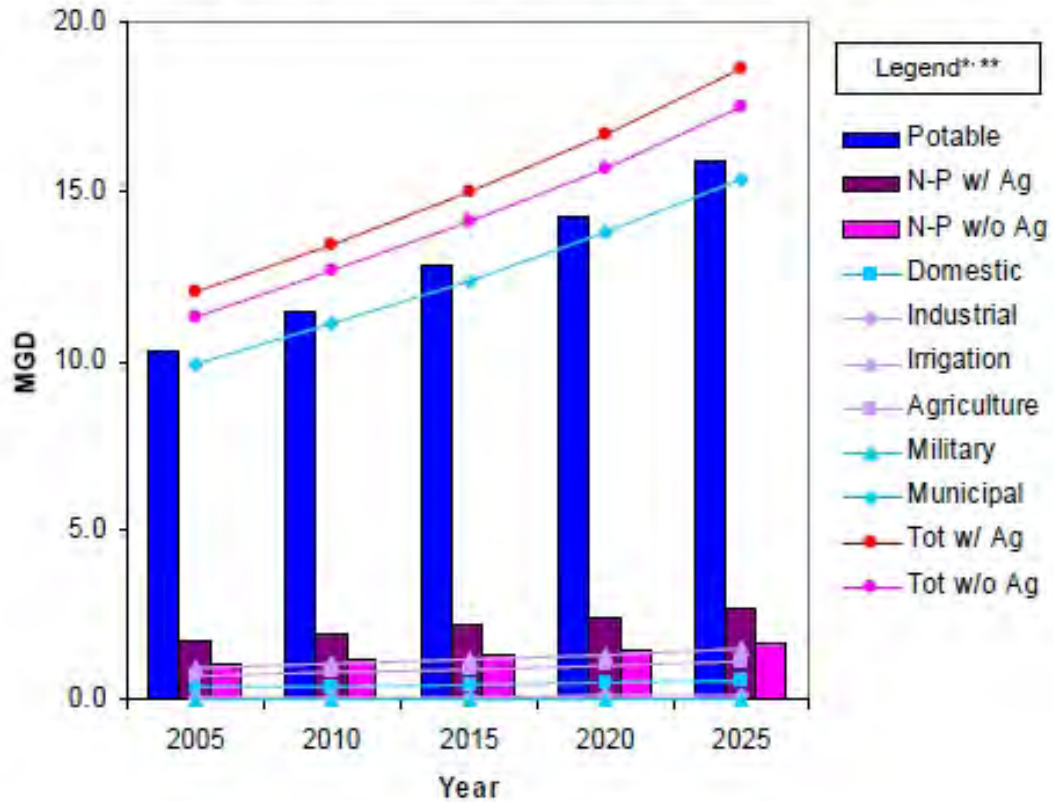
Figure 809-10a: Medium Growth Rate B Water Demand Projection by Category – Keauhou Aquifer System Area [80901]



* Demand scenarios without and with agricultural demands represent the potential minimum and maximum agricultural demand, respectively, with the expectation that the actual demand will fall somewhere in between.
** "N-P" represents the nonpotable component of the demand.

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- Hawaii WUDP adopted by county ordinance Feb ’11
- CWRM Public hearing Aug ‘11
- National Park Service comments
- Staff response
- CWRM action Dec ’11

Kona Ground Water Issues

- Current SY estimates appear conservative, but latest hydrological information means the current SY range does not consider best information available.
- Need to increase monitoring network for better management. Selecting alternative SY to minimum SY estimates require this to happen.
- Hawaii WUDP is ready for Commission action next month (December ''11) and provides best estimate for future demands on the resource up to 2025.