

A Hydrologic Model for Water Level in the Maya Reservoirs of Central Tikal

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GSA 2012 – Florea - Location





The Peten comprises a series of nearhorizontal Cretaceous limestone, largely breccia. These limestone strata dip slightly into the Peten Basin. To the north and the south of Tikal are ranges of hills that mark the southern margin of basinward dipping strata, or faults, or both. Elevations range between 200 and 300 m with a water table that is at least 100 m below the surface. Surface waters are present to the south at a series of lakes, including Lake Peten Itza.



GSA 2012 – Florea - Climate



NIVELES DE INSOLACION O HELIOFANIA EN PROMEDIO DE HORAS DE BRILLO SOLAR ANUAL LINITE DEPARTAMENTAL SOHELIA PROMEDID ANUAL (Dimensional= horas de brillo solar) LIMITE DE CUENCAY CODIGO LAS ISOMELIAS SE BASAN EN OBSERVACIONES EN LA RED METEOROLOGICA NACIONAL. PARA SU FLAROPACIÓN FUERON UTILIZADAS 25 ESTACIÓNES CLIMATOLOGICAS. DE ELLAS 20 SON ESTACIONES PRINCIPALES Y SESTACIONES AUXILIARES, LOS DATOS ANALIZADOS CORRESPONDEN AL PERIODO 1571-2002.

2400

W CARIBE

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GSA 2012 – Florea – Tikal Precipitation 2001–2010





GSA 2012 – Florea – Tikal Evaporation 2001–2010









GSA 2012 – Florea - Reservoirs

Detailed topographic data collected at Tikal and analyzed within ArcGIS reveal the contributing watersheds to each of the three reservoirs near the Central Acropolis and Great Plaza (Temple II shown in the above photo). The geometry and surface area of these reservoirs and watersheds form the basis for the hydrologic model. Previous studies of the watersheds demonstrate significant modification by the Maya to increase runoff efficiency. For example, clay liners 8-12 cm thick were used as a barrier to infiltration.



GSA 2012 – Florea – Conceptual Model

The three reservoirs are separated by clay-lined earthen dams. Previous investigations by archaeologists alternatively suggest that the reservoirs served as permanent lakes or hydrated wetlands. At least one investigation noted groundwater flow into the Temple Reservoir. Some studies indicate that overflow from the central reservoirs complemented irrigation needs. All studies agree that the reservoirs were used for drinking water. The nature and organization of this problem is a natural for a 'linked reservoir model' where both the reservoir volume and throughput are variable in time. In a linked-reservoir model all components of flux are accounted for in a series of mass-balance equations. Changes in mass manifest as changes in reservoir volume.

W2

1 - Temple

W1

R1

- 2 Palace
- 3 Hidden

Blue - PrecipitationYellow - OverflowWhite - EvapotranspirationRed - PumpingGreen - Overland FlowBlack - Seepage

R2

Orange - Groudwater recharge

W3



GSA 2012 – Florea – Model Design

0.46 % 0.1 m 0.0000001 m/s 11,520 m^2	Palace Reservoir Shape = depe Rth b	ning wedge 0.46 %	Hidden reserve	voir Shape = half d		T=	Daily average	temperatu	ure, I = Avera	ee daily solar in	rolation P =	Dailyana																				
0.46 % 0.1 m 0.00000001 m/s 11,520 m^2	Palace Reservoir Shape = depe Rth b	ning wedge 0.46 %	Hidden reserve	voir Shape = half o		T =	Daily average	temperati	ure, I = Avera	ge daily solar in	colation R =	- Daily area																				
0.46 % 0.1 m 0.00000001 m/s 11,520 m^2	Shape = depe Rth b	ening wedge 0.46 %		Shape = half o							solution, r =	 Daily prec 	cipitation, H = r	eservoir depth	i, SA =reserve	ir surface are	ea, WP = rese	rvoir wetted p	erimeter, alp	ha = Penman'	alpha,											
0.46 % 0.1 m 0.00000001 m/s 11,520 m^2	Rth b	0.46 %			one	rho	= water densi	ty, HL= Lat	tent heat of f	fusion, E = Daily	evaporation	n, L= Leaka	ge, L' = Specific	leakage, Q = I	Pumping rate	, Q' = Specific	: pump rate, l	R = Surface rec	harge, R' = S	pecific rechage												
0.1 m 0.00000001 m/s 11,520 m^2	ь			Rth	0.46 %	dH	= Change in re	servoir he	sight.																							
0.00000001 m/s 11,520 m^2		0.1 m	1	b	0.1 m																											
11,520 m^2	K	0.00000001 m/s		к	0.00000001 m/s	*Su	urface Area is I	imited to	greater than	100 m^2 to pre	vent model	I instability	6																			
	SA @ max D	12,721 m^2		SA @ max D	3,780 m^2	*K 1	values are ada	pted from	n a layered cl	lay (Bear, 1972)																						
9.4 m	Av Max R D	10 m		Max R D	4 m	*St	arting depth is	s given as	blue shaded	area in PNAS 2	012 article, p	potential o	verflow in Ter	nple Reservoir	r is directed t	o recharge in	Palace Rese	rvoir														
41,294 m^2	W	46,454 m^2		w	25,462 m^2	*Ru	unoff is given b	by daily pr	recip - Evap *	Efficiency (Li e	: al., 2004) *	*Temple R	eservoir has ad	ditional sprin	g input of 7.5	I/hr (PNAS 2	2012)															
8.82 degrees	m	20.67 degrees		m	4.66 degre	tes Nur	mber of depen	idants L	liters per dep	iendant per day																						
			<u> </u>				1200		4.000																							
Climate D	ata	Temple Reserv	/oir	Pa	lace Reservoir		Hidder	Reservoir	r		Connect	tions			Wat	er flux within	Temple Rese				War	ter flux within	Palace Reserv	oir			Wate	r flux within H	lidden Reservo	ir		
T (C) E (m)	P (m)	H (m) SA (m^2)	WP (m^2)	H (m)	SA (m^2) WP	(m^2)	H (m) SA	(m^2)	WP (m^2)	Temple Over Pa	lace Over H	Hidden Ove	a.		L' (m)		Q. (m)	R (m^3)	K' (m)	L (m^3)	L' (m)	Q (m^3)	Q. (m)	R (m^3)	K' (m)	L (m^3)	L' (m)	Q (m^3)	Q. (m)	R (m^3)	K' (m)	dH (m) - Temple
22.49 0.013	0.029	9.400 1.15E+04	4 1.17E+04	10.000	6.362+03 1.3	36E+04	2.000 9	.45E+U2	9.48E+02	0.00	0.00	0.0	U	568.09	0.0493	1.60		298.92	0.03	704.84	0.1108	1.60	0.0003	336.06	0.05	9.83	0.0104	1.60	0.0017	184.20	0.19	-0.00
22.38 0.0127	0.028	9.392 1.150+04	1.166+04	9.957	6.335+03 1.3	356+04	2.199 1	.146+03	1.150+03	0.00	0.00	0.0	0	500.08	0.0493	1.60	0.0001	285.34	0.02	698.80	0.1103	1.60	0.0003	320.79	0.05	15.06	0.0114	1.60	0.0014	1/5.83	0.15	-0.00
22.29 0.0124	0.027	9.363 1.150+04	1.100+04	9.915	6.302403 1.3	000	2.355 1	.310+03	1.510+05	0.00	0.00	0.0	0	564.95	0.0492	1.60		2/1.//		692.57	0.1098	1.60		305.53	0.05	10.04	0.0122	1.00		107.47	0.15	-0.01
22.20 0.0121	0.026	9.371 1.140+04		9,805	6.276+03 1.3	046+04	2,483 1	.400+03	1.400+03	0.00	0.00	0.0	0	562.89	0.0492	1.60		258.23		685.97	0.1093	1.60	0.0003	290.29	0.05	10.02	0.0129	1.60		159.11	0.11	-0.01
22.12 0.0119	0.025	9.330 1.140104	1.100004	9.615	6.246403 1.3	25+04	2.592 1	705+03	1.395403	0.00	0.00	0.0	0	500.52	0.0491	1.60		244.71	0.02	675.07	0.1088	1.60	0.0003	275.08	0.04	22.40	0.0135	1.60	0.0010	142.46	0.09	-0.01
22.00 0.0117	0.024	9.345 1.146+04	1 1 15E+04	9,709	6 195+03 1.5	225+04	2,000 1	91E+03	1.915+03	0.00	0.00	0.0	0	554.86	0.0490	1.60		217.79		664.41	0.1082	1.60	0.0003	235.51	0.04	25.60	0.0144	1.60	0.0009	134.17	0.08	-0.01
21.00 0.0115	0.022	9 308 1 135+04	1 1 145+04	9.652	6 145+03 1 3	R1F+04	2,837 1	90E+03	1.915+03	0.00	0.00	0.0	0	551 58	0.0488	1.60		204 39		656.67	0.1070	1.60		229.73	0.04	28.05	0.0148	1.60	0.0003	125.92	0.07	-0.02
21.90 0.0114	0.021	9.288 1.12F+04	1 1.14E+04	9.593	6.10E+03 1.3	30F+04	2,898 1	98E+03	1.99E+03	0.00	0.00	0.0	n	548.01	0.0487	1.60		191.07		648.66	0.1063	1.60		214 74	0.04	29.91		1.60	0.0008		0.05	-0.02
21.86 0.0113	0.021	9.266 1.12E+04	1.13E+04	9.532	6.06E+03 1.3	30E+04	2.952 2	.06E+03	2.07E+03	0.00	0.00	0.0	n	544.16	0.0486	1.60		177.81		640.39	0.1056	1.60	0.0003	199.82	0.03	31.60	0.0154	1.60	0.0008	109.52	0.05	-0.02
21.83 0.0113	0.020	9.243 1.11E+04	1.13E+04	9,468	6.02E+03 1.7	29E+04	2.998 2	.12E+03	2.13E+03	0.00	0.00	0.0	0	540.03	0.0485	1.60	0.0001	164.62	0.01	631.87	0.1049	1.60	0.0003	184.98	0.03	33.11	0.0156	1.60	0.0008	101.39	0.05	-0.02
21.81 0.0113	0.019	9.217 1.11E+04	1.12E+04	9,402	5.98E+03 1.2	28E+04	3.038 2	.18E+03	2.19E+03	0.00	0.00	0.0	0	535.62	0.0484	1.60			0.01	623.12	0.1042	1.60	0.0003	170.24	0.03	34,46	0.0158	1.60		93.31	0.04	-0.02
21.79 0.0113	0.019	9.191 1.10E+04	4 1.11E+04	9.334	5.94E+03 1.2	27E+04	3.072 2	.23E+03	2.24E+03	0.00	0.00	0.0	0	530.95	0.0482	1.60	0.0001	138.50	0.01	614.14	0.1034	1.60	0.0003	155.60	0.03	35.64	0.0160	1.60	0.0007	85.29	0.04	-0.02
21.78 0.0114	0.018	9.162 1.09E+04	1.11E+04	9.264	5.89E+03 1.2	26E+04	3,101 2	.27E+03	2.28E+03	0.00	0.00	0.0	0	526.03	0.0481	1.60	0.0001	125.57	0.01	604.93	0.1027	1.60	0.0003	141.06	0.02	36.65	0.0161	1.60	0.0007	77.32	0.03	-0.03
21.77 0.0115	0.017	9.132 1.09E+04	4 1.10E+04	9.192	5.85E+03 1.2	25E+04	3.125 2	.31E+03	2.31E+03	0.00	0.00	0.0	0	520.86	0.0479	1.60	0.0001	112.75	0.01	595.51	0.1019	1.60	0.0003	126.64	0.02	37.50	0.0163	1.60	0.0007	69.41	0.03	-0.03
21.77 0.0116	0.017	9.100 1.08E+04	1.09E+04	9.117	5.80E+03 1.2	24E+04	3.144 2	.34E+03	2.34E+03	0.00	0.00	0.0	0	515.44	0.0477	1.60	0.0001	100.04	0.01	585.89	0.1010	1.60	0.0003	112.34	0.02	38.19	0.0164	1.60	0.0007	61.57	0.03	-0.03
21.78 0.0117	0.016	9.067 1.07E+04	4 1.08E+04	9.041	5.75E+03 1.2	23E+04	3.159 2	.36E+03	2.36E+03	0.00	0.00	0.0	0	509.79	0.0476	1.60	0.0001	87.44	0.01	576.08	0.1002	1.60	0.0003	98.16	0.02	38.72	0.0164	1.60	0.0007	53.81	0.02	-0.03
21.79 0.0119	0.016	9.032 1.06E+04	1.08E+04	8.962	5.70E+03 1.2	22E+04	3.169 2	.37E+03	2.38E+03	0.00	0.00	0.0	0	503.92	0.0474	1.60	0.0002	74.96	0.01	566.08	0.0993	1.60	0.0003	84.13	0.01	39.10	0.0165	1.60	0.0007	46.11	0.02	-0.03
	1.125 In2 8.82 degreesi Climate D Climate D 12.249 0.013 22.249 0.013 22.230 0.0121 22.210 0.0121 22.220 0.0121 22.250 0.013 21.250 0.0114 21.250 0.0113 21.88 0.0113 21.89 0.0113 21.80 0.0113 21.70 0.0114 21.77 0.0115 21.77 0.0115 21.70 0.0114 21.77 0.0115 21.77 0.0115 21.79 0.0114	-1.229 III.2 W 6.82.06gress m Climate Data ym 2.28 0.021 0.028 2.2.29 0.024 0.027 2.2.29 0.024 0.027 2.2.10 0.026 0.025 2.2.10 0.026 0.025 2.1.80 0.0116 0.021 2.1.80 0.0116 0.021 2.1.80 0.0116 0.021 2.1.80 0.0116 0.021 2.1.80 0.0116 0.021 2.1.77 0.0116 0.027 2.1.77 0.0116 0.027 2.1.79 0.0116 0.027 2.1.79 0.0116 0.027 2.1.79 0.0116 0.027 2.1.79 0.0112 0.016 2.1.79 0.0115 0.017 2.1.79 0.0116 0.017 2.1.79 0.0119 0.016	Lizzy (i/2) W S2057 (dgres) M Climate Data P(m) 20.67 (dgres) M T(C) E(m) P(m) M M M 22.28 0012 0.020 9.392 1.55+0 22.29 00124 0.027 9.338 1.55+0 22.20 0.0124 0.025 9.338 1.35+0 22.00 0.015 0.023 9.338 1.35+0 21.00 0.015 0.023 9.338 1.35+0 21.80 0.0115 0.021 9.238 1.35+0 21.80 0.0115 0.021 9.238 1.35+0 21.80 0.0114 0.021 9.268 1.22+0 21.80 0.013 0.021 9.268 1.22+0 21.80 0.013 0.021 9.268 1.22+0 21.70 0.014 0.018 9.121 1.11+0 21.70 0.015 0.017 9.132 1.05+0 21.70 <	-1.229 IV -0.2057 IV 6.8.2 degrees m 20.67 degrees Cinuate Data Temple Reservoir T(C) E(m) P (m) 2.239 0.023 0.029 2.249 0.021 0.026 2.229 0.024 0.027 2.229 0.024 0.025 2.220 0.021 0.026 2.220 0.0124 0.027 2.238 1.154-04 1.154-04 2.240 0.0124 0.025 9.338 1.154-04 1.154-04 2.130 0.013 0.021 9.348 1.154-04 1.154-04 2.146 0.013 0.021 9.348 1.154-04 1.154-04 2.160 0.013 0.021 9.266 9.348 1.154-04 1.154-04 2.180 0.013 0.021 9.266 1.181 0.013 0.021 9.266 1.124-04 2.177	Close for 2 Dial Close for 2 Dial Dial 6.82 dept m 20.57 depted m Climate Data Temple Reservoir m TC() E(m) 9(m) 35(mc2) W(m2) P(m) 22.83 d0.77 0.89 9.99 115(mc1) P(m) 9.97 22.83 d0.77 0.83 1.34(mc1) 1.07(mc4) 9.97 22.29 d0.11 0.025 9.391 1.15(mc4) 1.15(mc4) 9.97 22.20 d0.11 0.025 9.391 1.34(mc4) 1.15(mc4) 9.78 1.15(mc4) 1.15(mc4) 9.78 22.20 d0.11 0.025 9.391 1.34(mc4) 1.15(mc4) 9.78 1.15(mc4) 1.15(mc4) 9.78 21.80 d0.13 0.021 9.391 1.34(mc4) 1.15(mc4) 9.592 2.14(mc4) 9.22 9.22 1.13(mc4) 1.15(mc4) 9.592 2.14(mc4) 9.22 9.23 1.14(mc4) 1.15(mc4) 9.592 2.14(mc4) 9.22 9.23 1.14(mc4)	Close m/s rs	Climate Data Temple Reservoir N 2021 Mi2 N 0000 Palace Reservoir Climate Data Temple Reservoir M 2021 Mi2 N 46.6 degrees N TC() E(m) P(m) 354 (m2) W(m2) W(m2) Palace Reservoir TC() E(m) P(m) 354 (m2) W(m2) W(m2) N(m2) 22.88 0.007 9.383 1.154 (rb) 1.164 (rb) 9.933 1.354 (rb) 22.29 0.015 0.025 9.391 1.344 (rb) 1.164 (rb) 9.938 1.354 (rb) 22.20 0.025 9.391 1.344 (rb) 1.164 (rb) 9.938 1.354 (rb) 22.10 0.025 9.391 1.344 (rb) 1.354 (rb) 1.354 (rb) 21.30 0.015 0.022 9.391 1.344 (rb) 1.354 (rb) 1.354 (rb) 21.80 0.015 0.021 9.391 1.344 (rb) 1.354 (rb) 1.354 (rb) 21.80 0.013 0.021 9.388	Climate Data Temple Reservoir PM 2.048 (P2) Monume description 1.000 (P2) 1.0000 (P2)	Close Pair Fair Pair Pair<	Climate Data Temple Reservoir Pailor Reservoir Pailor Reservoir Hidden Reservoir Reservoir	Climate Data Temple Reservoir Place Reservoir Place Reservoir Hidden Reservoir Hidden Reservoir Climate Data Temple Reservoir Place Reservoir Hidden Reservoir Rewei Reservoir <t< td=""><td>Clipper Part Part Part Part Part Part Part Par</td><td>Climate Data Temple Reservoir Palace Reservoir Hidden Reservoir Hidden Reservoir Hidden Reservoir Connections Climate Data Temple Reservoir Palace Reservoir Hidden Reservoir Hidden Reservoir Hidden Reservoir Connections Connections T(C) E(m) P(m) H(m) SA(mc2) WP(m2) Hidden Reservoir Hidden Reservoir Connections Connections 2248 0.025 9.371 1.1464 1.0564 9.285 0.274.00 0.00</td><td>Construction Construction M Construction Construction</td><td>Construction Construction Construction<</td><td>Contract Data Temple Reservoir Palace Reservoir High 5 Ad (m²) State Out 2 State O</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	Clipper Part Part Part Part Part Part Part Par	Climate Data Temple Reservoir Palace Reservoir Hidden Reservoir Hidden Reservoir Hidden Reservoir Connections Climate Data Temple Reservoir Palace Reservoir Hidden Reservoir Hidden Reservoir Hidden Reservoir Connections Connections T(C) E(m) P(m) H(m) SA(mc2) WP(m2) Hidden Reservoir Hidden Reservoir Connections Connections 2248 0.025 9.371 1.1464 1.0564 9.285 0.274.00 0.00	Construction Construction M Construction Construction	Construction Construction<	Contract Data Temple Reservoir Palace Reservoir High 5 Ad (m²) State Out 2 State O																

The linked-reservoir model was translated into Excel using a series of geometric parameters, hydraulic equations, and linking equations. Overland flow into the reservoir is computed using a combination of watershed area, runoff efficiency, and precipitation-evapotranspiration. Reservoir seepage is calculated using Darcy's Law and a mean water depth. Reservoir surface area was caluclated using a geometric conversion from water depth. The surface area at each time interval is used to compute changes in water depth resulting from mass flux. Minimum surface areas prevent model instability and maximum depth values trigger overflow. Individual runs were allowed to run for up to 1,000 iterations or until convergence reached 0.1%



GSA 2012 – Florea – Model Input

A	B C	D E	F G	H I	J	K	L	M	N	0	Р	Q	R	S	T U		V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1																																		
2	Temple Reservoir		Palace Reservoir	·	Hidden res	ervoir			T = Daily avera	ge tempera	ture, l = Aver	age daily solar i	solation, P	 Daily precipitation 	on, H = reservoir	depth, SA	A =reservoir :	surface are	a, WP = resen	voir wetted pe	rimeter, alp	ha = Penman's	alpha,											
3	Shape = cone		Shape = dep	ening wedge		Shape = half	cone		rho = water de	nsity, HL= L	atent heat of	fusion, E = Daily	evaporatio	n, L= Leakage, L' =	Specific leakage	, Q = Pun	nping rate, Q	(= Specific	pump rate, R	= Surface rech	iarge, R' = Sp	pecific rechage												
4	Runoff efficiency	0.46 %	Rth	0.46 %		Rth	0.46	i %	dH = Change in	n reservoir h	eight.																							
5	Liner Thickness	0.1 m	b	0.1 m		b	0.1	m																										
6	Hydro Conductivity	0.00000001 m/s	к	0.00000001 m/s		к	0.00000001	m/s	*Surface Area	is limited to	greater that	n 100 m^2 to pr	event mode	l instability.																				
7	Surface area @ max D	11,520 m^2	SA @ max D	12,721 m^2		SA @ max D	3,780	1 m^2	*K values are a	adapted fro	m a layered o	lay (Bear, 1972)																					
8	Max reservoir D	9.4 m	Av Max R D	10 m		Max R D	4	m	*Starting dept	h is given a	s blue shaded	area in PNAS 2	012 article,	potential overflo	w in Temple Res	ervoir is	directed to r	echarge in	Palace Reserv	voir														
9	Watershed area	41,294 m^2	W	46,454 m^2		W	25,462	m^2	Runoff is give	n by daily p	recip - Evap	 Efficiency (Li e 	rt al., 2004)	*Temple Reservoi	r has additional	spring in	put of 7.5 I/I	hr (PNAS 20	012)															
10	Average slope	8.82 degrees	m	20.67 degrees		m	4.66	degrees	Number of dep	pendants	Liters per de	pendant per da	1																					
11									1200		4.000																							
12																																		
13		Climate Da	ata	Ten, Ve Re	servoir	P	Palace Reservo	bir	Hide	den Reservo	ir 👘		Connec	tions			Waterf	lux within 1	Temple Resen	voir			Wa	ter flux within	Palace Reserve				Wat	er flux within H	Hidden Reserv			
14	DAY	T (C) E (m)	P (m)	H (m) SA 7	*2) WP (m*2)	H (m)	SA (m^2)	WP (m^2)	H (m)	SA (m^2)	WP (m^2)	Temple Over P	alace Over 1	didden Over	L (m'	3)	L' (m) (Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	dH (m) - Temple
15	1	22.49 0.013	0.029	9.400 1.15	04 1.17E+0	4 10.000	6.36E+03	1.36E+04	2.000	9.45E+02	9.48E+02	0.00	0.00	0.00	56	8.09	0.0493	1.60		298.92	0.03	704.84	0.1108	1.60	0.0003	336.06		9.83	0.0104	1.60	0.0017	184.20	0.19	-0.00
16	2	22.38 0.0127	0.028	9.392 1.158	1.16E+0	4 9.957	6.33E+03	1.35E+04	2.199	1.14E+03		0.00	0.00	0.00	Se	6.68	0.0493	1.60	0.0001	285.34	0.02	698.86	0.1103	1.60	0.0003	320.79	0.05	13.06	0.0114	1.60	0.0014	175.83	0.15	-0.00
17	3	22.29 0.0124	0.027	9.383 1.156	1.162+04	4 9.913	6.302+03	1.35E+04	2.355	1.31E+03	1.31E+03	0.00	0.00	0.00	56	4.95	0.0492	1.60		2/1.//		692.57	0.1098	1.60		305.53		16.04	0.0122	1.60		167.47	0.13	-0.01
10	4	22.20 0.0121	0.026	9.371 1.140		4 9.805	6.272+03	1.340+04	2.483	1.400+03	1.400+03	0.00	0.00	0.00	50		0.0492	1.60		258.23		685.97	0.1093	1.60	0.0003	290.29		18.82	0.0129	1.60		159.11	0.11	-0.01
20	6	22.12 0.0113	0.025	9.336 1.140	404 1.16 W	9.015	6.246403	1.336+04	2.592	1.390+03	1.392403	0.00	0.00	0.00	50	7.94	0.0491	1.60		244.71	0.02	675.07	0.1088	1.60	0.0003	275.08		22.40	0.0135	1.60	0.0010	142.46	0.09	-0.01
21	7	22.00 0.0116	0.024	9.345 1.140	404 1.15E+0	9.703	6 195+03	1.336+04	2.000	1.916+03	1.916+03	0.00	0.00	0.00	55	1.94	0.0490	1.60		217.79		664.41	0.1076	1.60	0.0003	239.91	0.04	25.00	0.0140	1.60	0.0009	134.17	0.08	-0.01
22	8	21.94 0.0115	0.022	9 308 1 136	+04 1.15E+0	4 9.652	6 14E+03	1.31E+04	2.837	1.905+03	1.91E+03	0.00	0.00	0.00	55	1 58	0.0488	1.60		204 39		656.67	0 1070	1.60		229 73	0.04	28.05	0.0148	1.60	0.0008	125.92	0.07	-0.02
23	9	21.90 0.0114	0.021	9,288 1,126	+04 1.14E+0	4	6.10E+03	1.30E+04	2,898	1.98E+03	1.99E+03	0.00	0.00	0.00	54		0.0487	1.60		191.07		648.66	0.1063	1.60		214 74		29.91		1.60	0.0008		0.06	-0.02
24	10	21.86 0.0113	0.021	9,266 1,128	+04 1.13E+0	4 9.55	6.06E+03	1.30E+04	2,952	2.06E+03	2.07E+03	0.00	0.00	0.00	54	4.16	0.0486	1.60		177.81		640.39	0.1056	1.60	0.0003	199.82		31.60	0.0154	1.60	0.0008	109.52	0.05	-0.02
25	11	21.83 0.0113	0.020	9.243 1.116	+04 1.13E+0	9.468	6.02E+03	1.29E+04	2,998	2.12E+03	2.13E+03	0.00	0.00	0.00	54	0.03	0.0485	1.60	0.0001	164.62	0.01	631.87	0.1049	1.60	0.0003	184.98		33.11	0.0156	1.60	0.0008	101.39	0.05	-0.02
26	12	21.81 0.0113	0.019	9.217 1.118	+04 1.12E+0	4 9.402	\$ \$E+03	1.28E+04	3.038	2.18E+03	2.19E+03	0.00	0.00	0.00	53	5.62	0.0484	1.60	0.0001		0.01	623.12	0.1042	1.60	0.0003	170.24	0.03	34,46	0.0158	1.60	0.0007	93.31	0.04	-0.02
27	13	21.79 0.0113	0.019	9.191 1.108	+04 1.11E+0	4 9.334	5.94 03	1.27E+04	3.072	2.23E+03	2.24E+03	0.00	0.00	0.00	53	0.95	0.0482	1.60	0.0001	138.50	0.01	614.14	0.1034	1.60	0.0003	155.60	0.03	35.64	0.0160	1.60	0.0007	85.29	0.04	-0.02
28	14	21.78 0.0114	0.018	9.162 1.098	+04 1.11E+0	4 9.264	5.89E+L	1.26E+04	3.101	2.27E+03	2.28E+03	0.00	0.00	0.00	52	6.03	0.0481	1.60	0.0001	125.57	0.01	604.93	0.1027	1.60	0.0003	141.06	0.02	36.65	0.0161	1.60	0.0007	77.32	0.03	-0.03
29	15	21.77 0.0115	0.017	9.132 1.098	+04 1.10E+0	4 9.192	5.85E+03	1.25E+04	3.125	2.31E+03	2.31E+03	0.00	0.00	0.00	52	0.86	0.0479	1.60	0.0001	112.75	0.01	595.51	0.1019	1.60	0.0003	126.64	0.02	37.50	0.0163	1.60	0.0007	69.41	0.03	-0.03
30	16	21.77 0.0116	0.017	9.100 1.088	+04 1.09E+0	4 9.117	5.80E+03	4E+04	3.144	2.34E+03	2.34E+03	0.00	0.00	0.00	51	5.44	0.0477	1.60	0.0001	100.04	0.01	585.89	0.1010	1.60	0.0003	112.34	0.02	38.19	0.0164	1.60	0.0007	61.57	0.03	-0.03
31	17	21.78 0.0117	0.016	9.067 1.078	+04 1.08E+0	4 9.041	5.75E+03	1.25. 04	3.159	2.36E+03	2.36E+03	0.00	0.00	0.00	50	9.79	0.0476	1.60	0.0001	87.44	0.01	576.08	0.1002	1.60	0.0003	98.16	0.02	38.72	0.0164	1.60	0.0007	53.81	0.02	-0.03
32	18	21.79 0.0119	0.016	9.032 1.068	+04 1.08E+0-	4 8.962	5.70E+03	1.22E+6	3.169	2.37E+03	2.38E+03	0.00	0.00	0.00	50	3.92	0.0474	1.60	0.0002	74.96	0.01	566.08	0.0993	1.60	0.0003	84.13	0.01	39.10	0.0165	1.60	0.0007	46.11	0.02	-0.03

Computes slope of reservoir basin using the surface area at maximum depth.

Average daily temperature, pan evaporation, and precipitation values from Tikal

A B C D E F G	Н	T
1		Т
2 Temple Reservoir Palace Reservoir		
3 Shape = cone Shape = depening	wedge	
4 Runoff efficiency 0.46 % Rth	0.46	9
S Liner Thickness 0.1 m b	0.1	F
6 Hydro Conductivity 0.00000001 m/s K 0.00	100001	
7 Surface area @ max D 11,520 m^2 SA @ max D	12,721	ſ
8 Max reservoir D 9.4 m Av Max R D	10	1
10 Australiana 0.02 destata	20.67	

GSA 2012 – Florea – Water Depth Computations

	B C	DE	F G	H I	J	K	L M	N	0	Р	Q	R	S	τι		V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
L																																	
2	Temple Reservoir		Palace Reservoir		Hidden reserv	oir		T = Daily a	verage tempera	ture, I = Aver	age daily solar in:	solation, P =	 Daily precipitation 	n, H = reservoi	depth, SA	k =reservoir	surface area	, WP = reserv	voir wetted p	perimeter, alg	oha = Penman'	s alpha,											
3	Shape = cone		Shape = depe	ening wedge	S	ihape = half co	ne	rho = wate	r density, HL= L	atent heat of	fusion, E = Daily	evaporation	n, L= Leakage, L' =	Specific leakag	e, Q = Pum	ping rate, C	Ω' = Specific p	ump rate, R	 Surface recl 	charge, R' = S	pecific rechage	9											
1	Runoff efficiency	0.46 %	Rth	0.46 %	R	tth	0.46 %	dH = Chan	ge in reservoir h	eight.																							
5	Liner Thickness	0.1 m	b	0.1 m	b		0.1 m																										
5	Hydro Conductivity	0.00000001 m/s	К	0.00000001 m/s	K	. 0	1.00000001 m/s	*Surface A	irea is limited to	greater tha	n 100 m^2 to pre	vent model	l instability.																				
7	Surface area @ max D	11,520 m^2	SA @ max D	12,721 m^2	S	A @ max D	3,780 m^2	*K values	are adapted fro	m a layered	day (Bear, 1972)																						
3	Max reservoir D	9.4 m	Av Max R D	10 m	N	/lax R D	4 m	*Starting of	lepth is given a	s blue shade	d area in PNAS 20	012 article, j	potential overflor	v in Temple Re	servoir is d	directed to	recharge in P	Palace Reserv	voir														
•	Watershed area	41,294 m^2	W	46,454 m^2	V	N	25,462 m^2	*Runoff is	given by daily p	recip - Evap	* Efficiency (Li et	: al., 2004) *	Temple Reservoi	r has additiona	spring inp	put of 7.5 l/	/hr (PNAS 20:	12)															
0	Average slope	8.82 degrees	m	20.67 degrees	n	n	4.66 degrees	Number of	f dependants	Liters per de	pendant per day																						
1								120	0	4.000																							
2																																	
3		Climate Da	ita	Temple Reserv	voir	Pala	ice Reservoir		Hidden Reserve	ir 👘		Connect	tions			Water	flux within Te	emple Reserv	/oir			Wate	er flux within	Palace Reserve	oir			Wate	r flux within H	idden Reservo	pir		
4	DAY	T (C) E (m)	P (m)	H (m) SA (m^2)	WP (m^2)	H (m) :	SA (m^2) WP (m	2) H (m)	SA (m^2)	WP (m^2)	Temple Over Pa	lace Over H	lidden Over	L (m	نغ) L	.' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	dH (m) - Temple
5	1	22.49 0.013	0.029	9.400 1.15E+04	4 1.17E+04	10.000	6.36E+03 1.36E	+04 2.00	0 9.45E+02	9.48E+02	0.00	0.00	0.00	5	58.09	0.0493	1.60		298.92	0.03	704.84	0.1108	1.60	0.0003	336.06	0.05	9.83	0.0104	1.60	0.0017	184.20	0.19	-0.00
6	2	22.38 0.0127	0.028	9.392 1.15E+04	4 1.16E+04	9.957	6.33E+03 1.35E	+04 2.19	9 1.14E+03	1.15E+03	0.00	0.00	0.00	5	56.68	0.0493	1.60	0.0001	285.34	0.02	698.86	0.1103	1.60	0.0003	320.79	0.05	13.06	0.0114	1.60	0.0014	175.83	0.15	-0.00
7	3	22.29 0.0124	0.027	9.383 1.15E+04	4 1.16E+04	9.913	6.30E+03 1.35E	+04 2.35	5 1.31E+03	1.31E+03	0.00	0.00	0.00	5	54.95	0.0492	1.60		271.77	0.02	692.57	0.1098	1.60	0.0003	305.53	0.05	16.04	0.0122	1.60	0.0012	167.47	0.13	-0.01
8	4	22.20 0.0121	0.026	9.371 1.14E+04	4 1.16E+04	9.865	6.27E+03 1.34E	+04 2.48	I3 1.46E+03	1.46E+03	0.00	0.00	0.00	5	52.89	0.0492	1.60	0.0001	258.23	0.02	685.97	0.1093	1.60	0.0003	290.29	0.05	18.82	0.0129	1.60	0.0011	159.11	0.11	-0.01
9	5	22.12 0.0119	0.025	9.358 1.14E+04	4 1.16E+04	9.815	6.24E+03 1.33E	+04 2.59	2 1.59E+03	1.59E+03	0.00	0.00	0.00	5		0.0491	1.60		244.71	0.02	679.07	0.1088	1.60	0.0003	275.08	0.04	21.40	0.0135	1.60	0.0010	150.78	0.09	-0.01
0	6	22.06 0.0117	0.024	9.343 1.14E+04	4 1.15E+04	9.763	6.21E+03 1.33E	+04 2.68	16 1.70E+03	1.71E+03	0.00	0.00	0.00	5	57.84	0.0490	1.60		231.22	0.02	671.88	0.1082	1.60	0.0003	259.91	0.04	23.80	0.0140	1.60	0.0009	142.46	0.08	-0.01
1	7	22.00 0.0116	0.023	9.326 1.13E+04	4 1.15E+04	9.709	6.18E+03 1.32E	+04 2.76	i6 1.81E+03	1.81E+03	0.00	0.00	0.00	5	54.86	0.0489	1.60		217.78	0.02	664.41	0.1076	1.60	0.0003	244.79	0.04	26.01	0.0144	1.60	0.0009	134.17	0.07	-0.01
2	8	21.94 0.0115	0.022	9.308 1.13E+04	4 1.14E+04	9.652	6.14E+03 1.31E	+04 2.83	17 1.90E+03	1.91E+03	0.00	0.00	0.00	5	51.58	0.0488	1.60		204.39	0.02	656.67	0.1070	1.60	0.0003	229.73	0.04	28.05	0.0148	1.60	0.0008	125.92	0.07	-0.02
3	9	21.90 0.0114	0.021	9.288 1.12E+04	4 1.14E+04	9.593	6.10E+03 1.30E	+04 2.89	1.98E+03	1.99E+03	0.00	0.00	0.00	5	8.01	0.0487	1.60		191.07	0.02	648.66	0.1063	1.60	0.0003	214.74	0.04	29.91		1.60	0.0008	117.70	0.06	-0.02
4	10	21.86 0.0113	0.021	9.266 1.12E+04	4 1.13E+04	9.532	6.06E+03 1.30E	+04 2.95	2 2.06E+03	2.07E+03	0.00	0.00	0.00	5	14.16	0.0486	1.60		177.81		640.39	0.1056	1.60	0.0003	199.82	0.03	31.60	0.0154	1.60	0.0008	109.52	0.05	-0.02
5	11	21.83 0.0113	0.020	9.243 1.11E+04	4 1.13E+04	9.468	6.02E+03 1.29E	+04 2.99	8 2.12E+03	2.13E+03	0.00	0.00	0.00	5	0.03	0.0485	1.60		164.62	0.01	631.87	0.1049	1.60	0.0003	184.98	0.03	33.11	0.0156	1.60	0.0008	101.39	0.05	-0.02
6	12	21.81 0.0113	0.019	9.217 1.11E+04	4 1.12E+04	9.402	5.98E+03 1.28E	+04 3.03	18 2.18E+03	2.19E+03	0.00	0.00	0.00	5	85.62	0.0484	1.60				623.12	0.1042	1.60	0.0003	170.24	0.03	34.46	0.0158	1.60		93.31	0.04	-0.02
/	13	21.79 0.0113	0.019	9.191 1.10E+04	4 1.11E+04	9.334	5.94E+03 1.27E	+04 3.07	2 2.23E+03	2.24E+03	0.00	0.00	0.00	5	\$0.95	0.0482	1.60		138.50	0.01	614.14	0.1034	1.60	0.0003	155.60	0.03	35.64	0.0160	1.60	0.0007	85.29	0.04	-0.02
8	14	21.78 0.0114	0.018	9.162 1.09E+04	4 1.11E+04	9.264	5.89E+03 1.26E	+04 3.10	2.27E+03	2.28E+03	0.00	0.00	0.00	5	26.03	0.0481	1.60		125.57		604.93	0.1027	1.60		141.06	0.02	36.65	0.0161	1.60		77.32	0.03	-0.03
9	15	21.77 0.0115	0.017	9.132 1.09E+04	4 1.10E+04	9.192	5.85E+03 1.25E	+04 3.12	5 2.31E+03	2.31E+03	0.00	0.00	0.00	5	0.86	0.0479	1.60		112.75	0.01	595.51	0.1019	1.60	0.0003	126.64	0.02	37.50	0.0163	1.60	0.0007	69.41	0.03	-0.03
0	16	21.77 0.0116	0.017	9.100 1.08E+04	4 1.09E+04	9.117	5.80E+03 1.24E	+04 3.14	14 2.34E+03	2.34E+03	0.00	0.00	0.00	5	15.44	0.0477	1.60		100.04		585.89	0.1010	1.60		112.34	0.02	38.19	0.0164	1.60		61.57	0.03	-0.03
1	17	21.78 0.0117	0.016	9.067 1.07E+04	4 1.08E+04	9.041	5.75E+03 1.23E	+04 3.15	9 2.36E+03	2.36E+03	0.00	0.00	0.00	5	19.79	0.0476	1.60	0.0001	87.44	0.01	576.08	0.1002	1.60	0.0003	98.16	0.02	38.72	0.0164	1.60	0.0007	53.81	0.02	-0.03
2	18	21.79 0.0119	0.016	9.032 1.06E+04	4 1.08E+04	8.962	5.70E+03 1.22E	+04 3.16	i9 2.37E+03	2.38E+03	0.00	0.00	0.00	5	J3.92	0.0474	1.60	0.0002	74.96	0.01	566.08	0.0993	1.60	0.0003	84.13	0.01	39.10	0.0165	1.60	0.0007	46.11	0.02	-0.03

	Computed water level, surface
Computes new WL	area, and wetted perimeter
	H=IF(H+AM<0,0,IF(H+AM>\$D\$8,\$D\$8,H+AM))
	I=IF(Pi*((H/TAN((\$D\$10*Pi)/180))^2)<100,100,Pi*((H/TAN((\$D\$10*Pi)/180))^2))
	J=2*(K/SIN(\$H\$10*Pi/180))*240
Computes new SA 🍝	K=IF(K+AN<0,0,IF(K+AN>\$H\$8,\$H\$8,K+AN))
	L=IF(((K/TAN((\$H\$10*Pi)/180)))*240<100,100,((K/TAN((\$H\$10*Pi)/180)))*240)
	M=2*(K/SIN(\$H\$10*Pi/180))*240
	N=IF(N+AO<0,0,IF(N+AO>\$L\$8,\$L\$8,N+AO))
	O=IF(((Pi*((N/TAN((\$L\$10*Pi)/180))^2))/2)<100,100,(Pi*((N/TAN((\$L\$10*Pi)/180))^2))/2)
Computes new WP 4	P=Pi*((N)/TAN((\$L\$10*Pi)/180))*((N)/SIN((\$L\$10*Pi)/180))/2+(N*SIN(\$L\$10*Pi)/180)*N



GSA 2012 – Florea – Linking Reservoirs

A	B C	D E	F G	H I	J	K	L	M	N	0	Р	Q	R	S	Т	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1																																		
2	Temple Reservoir		Palace Reservoi	r	Hidden rese	rvoir			T = Daily avera	ige tempera	ture, I = Avera	age daily solar i	nsolation, P	= Daily precipita	tion, H = r	eservoir depth,	SA =reservoi	surface are	a, WP = reser	voir wetted pe	erimeter, alp	ha = Penman's	alpha,											
3	Shape = cone		Shape = dep	pening wedge		Shape = half	cone		rho = water de	ensity, HL= L	atent heat of	fusion, E = Daily	/ evaporatio	on, L= Leakage, I	= Specific	leakage, Q = Pu	umping rate, I	Ω' = Specific	pump rate, R	= Surface rech	harge, R' = Sp	ecific rechage												
4	Runoff efficiency	0.46 %	Rth	0.46 %		Rth	0.46	%	dH = Change in	n reservoir h	eight.																							
5	Liner Thickness	0.1 m	b	0.1 m		b	0.1	m																										
6	Hydro Conductivity	0.00000001 m/s	к	0.00000001 m/s		к	0.0000001	m/s	*Surface Area	is limited to	greater than	100 m^2 to pr	event mode	el instability.																				
7	Surface area @ max D	11,520 m^2	SA @ max D	12,721 m^2		SA @ max D	3,780	m^2	*K values are a	adapted fro	m a layered c	lay (Bear, 1972)																					
8	Max reservoir D	9.4 m	Av Max R D	10 m		Max R D	4	m	*Starting dept	th is given a	s blue shaded	area in PNAS 2	012 article,	, potential over	low in Ter	nple Reservoir i	is directed to	recharge in	Palace Reserve	voir														
9	Watershed area	41,294 m^2	W	46,454 m^2		W	25,462	m^2	*Runoff is give	en by daily p	recip - Evap *	* Efficiency (Li e	rt al., 2004)	*Temple Reser	roir has ad	ditional spring	input of 7.5 (/hr (PNAS 20	012)															
10	Average slope	8.82 degrees	m	20.67 degrees		m	4.66	degrees	Number of dep	pendants	Liters per dep	pendant per da	y																					
11									1200		4.000																							
12																																		
13		Climate Da	ata	Temple Reserv	voir	P.	alace Reservoi	r	Hide	den Reservo	ir		Conne	ctions			Water	flux within 1	Temple Resen	voir			Wa	ter flux within	Palace Reserve	oir			Wat	ter flux within H	Hidden Reservo	bir		
14	DAY	T (C) E (m)	P (m)	H (m) SA (m^2)	WP (m^2)	H (m)	SA (m^2)	WP (m^2)	H (m)	SA (m^2)	WP (m^2)	Temple Over P	alace Over	Hidden Over		L (m^3)	L' (m)		Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	dH (m) - Temple
15	1	22.49 0.013	0.029	9.400 1.15E+04	4 1.17E+04		6.36E+03	1.36E+04	2.000	9.45E+02	9.48E+02	0.00	0.00	0.00		568.09	0.0493	1.60		298.92		704.84	0.1108	1.60		336.06		9.83	0.0104	1.60		184.20	0.19	-0.00
16	2	22.38 0.0127	0.028	9.392 1.15E+04	4 1.16E+04	9.957	6.33E+03	1.35E+04	2.199	1.14E+03		0.00	0.00	0.00		566.68	0.0493	1.60		285.34		698.86	0.1103	1.60	0.0003	320.79		13.06	0.0114	1.60	0.0014	175.83	0.15	-0.00
17	3	22.29 0.0124	0.027	9.383 1.15E+04	4 1.16E+04	9.913	6.30E+03	1.35E+04	2.355	1.31E+03	1.31E+03	0.00	0.00	0.00		564.95		1.60		271.77		692.57	0.1098	1.60		305.53		16.04		1.60		167.47	0.13	-0.01
18	4	22.20 0.0121	0.026	9.371 1.14E+04	4 1.16E+04	9.865	6.27E+03	1.34E+04	2.483	1.46E+03	1.46E+03	0.00	0.00	0.00		562.89	0.0492	1.60		258.23		685.97	0.1093	1.60	0.0003	290.29		18.82	0.0129	1.60			0.11	-0.01
19	5	22.12 0.0119	0.025	9.358 1.14E+04	4 1.16E+04	9.815	6.24E+03		2.592	1.59E+03	1.59E+03	0.00	0.00	0.00		560.52	0.0491	1.60		244.71		679.07	0.1088	1.60	0.0003	275.08	0.04	21.40		1.60		150.78	0.09	-0.01
20	6	22.06 0.0117	0.024	9.343 1.14E+04	4 1.15E+04	9.763	6.21E+03		2.686	1.70E+03	1.71E+03	0.00	0.00	0.00		557.84	0.0490	1.60				6/1.88	0.1082	1.60	0.0003	259.91	0.04	23.80	0.0140	1.60	0.0009	142.46	0.08	-0.01
21		22.00 0.0116	0.023	9.326 1.13E+04	4 1.15E+04	9.709	6.18E+03		2.766	1.81E+03	1.816+03	0.00	0.00	0.00		554.86	0.0489	1.60	0.0001	217.78	0.02	664.41	0.1076	1.60	0.0003	244.79	0.04	26.01	0.0144	1.60	0.0009	134.17	0.07	-0.01
22	8	21.94 0.0115	0.022	9.308 1.13E+04	4 1.14E+04	9.652	6.14E+03	1.31E+04	2.837	1.90E+03	1.91E+03	0.00	0.00	0.00		551.58	0.0488	1.60	0.0001	204.39	0.02	656.67	0.1070	1.60	0.0003	229.73	0.04	28.05	0.0148	1.60	0.0008	125.92	0.07	-0.02
23	9	21.90 0.0114	0.021	9.288 1.126+04	4 1.146+04	9.593	6.102+03	1.300+04	2.898	1.986+03	1.992+03	0.00	0.00	0.00		548.01	0.0487	1.60	0.0001		0.02	648.66	0.1063	1.60	0.0003	214.74	0.04	29.91	0.0151	1.60	0.0008	117.70	0.06	-0.02
24	10	21.80 0.0113	0.021	9.200 1.120+04	4 1.135+04	9.552	6.002+03	1.300+04	2.952	2.000+03	2.072+03	0.00	0.00	0.00		544.10	0.0485	1.00	0.0001	164.63	0.02	621.97	0.1050	1.60	0.0003	199.82	0.03	31.00	0.0154	1.60	0.0008	109.52	0.05	-0.02
25	12	21.85 0.0113	0.020	9.243 1.116+04	4 1.13E+04 4 1.12E+04	9,400	5.022403	1.295+04	2.550	2.120703	2.132+03	0.00	0.00	0.00		540.03	0.0485	1.00		164.02		622.12	0.1049	1.60		170.24		24.46	0.0150	1.60	0.0003	02.21	0.05	-0.02
27	12	21.01 0.0113	0.019	9.101 1.105.00	4 1.120+04	0.324	5.562+03		3.030	2.100+03	2.150+03	0.00	0.00	0.00		535.02	0.0483	1.00		139.50		614.14	0.1042	1.00	0.0003	155.60		25.64	0.0150	1.00		95.31	0.04	-0.02
29	10	21.75 0.0113	0.019	9.151 1.100+04	4 1.112+04	9.354	5.946703	1.275+04	3.072	2.235403	2.246+03	0.00	0.00	0.00		526.03	0.0482	1.00	0.0001	136.50	0.01	604.02	0.1034	1.60		141.06	0.03	35.04	0.0160	1.60	0.0007	77.22	0.04	-0.02
20	15	21.78 0.0114	0.017	0.122 1.095+04	4 1.1105+04	0.102	5,852+03		3.101	2.270+03	2.200403	0.00	0.00	0.00		520.05	0.0481	1.00		112 75	0.01	505 51	0.1027	1.00	0.0003	126.64		30.05	0.0161	1.00		60.41	0.03	-0.03
30	16	21.77 0.0115	0.017	9 100 1 08F+04	4 1.09F+04	9.117	5.80E+03	1.24E+04	3 144	2 34F+03	2 34E+03	0.00	0.00	0.00		515.44	0.0475	1.60	0.0001	100.04	0.01	585.89	0.1019	1.60	0.0003	112 34	0.02	38.19	0.0164	1.60	0.0007	61.57	0.03	-0.03
31	17	21.78 0.0117	0.016	9.067 1.075+0/	1 08E+04	9.041	5 755+03	1.235+04	3 159	2.365+03	2.365+03	0.00	0.00	0.00		509.79	0.0476	1.60		87.44	0.01	576.08	0.1002	1.60	0.0003	98.16		38.72	0.0164	1.60		53.81	0.03	-0.03
32	18	21.79 0.0119	0.016	9.032 1.05E±04	4 1.08E±04	8 962	5 70E+03	1.22E+04	3 169	2 37E+03	2.38F+03	0.00	0.00	0.00		503.92	0.0476	1.60	0.0002	74.96	0.01	566.08	0.0993	1.60	0.0003	84 13	0.01	39.10	0.0165	1.60	0.0007	46.11	0.02	-0.03
	10	21/75 0.0115	0.010	3.032 1.002404	1.001104	0.502	51132403	21222404	3,103	2.072403	2.002403	0.00	0.00	0.00		505.52	0.0474	1.00	010002	24,50	0.01	500100	0.0995	1.00	0.0003	04.13	0.01	33/10	010105	1.00	0.0007		0.02	-0.03

Volume of reservoir overflow

Q=IF(H=\$D\$8,AM*\$D\$7,0) R=IF(K=\$H\$8,AN*\$H\$7,0) S=IF(N=\$L\$8,AO*\$L\$7,0)



GSA 2012 – Florea – Flux Computations

	B C	D E	F G	H I	J	K	L	М	N	0	Р	Q	R	S T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1																																	
2	Temple Reservoir		Palace Reservoir		Hidden rese	rvoir			T = Daily avera	age temperat	ure, I = Avera	ge daily solar ins	olation, P = [Daily precipitation	H = reservoir dep	th, SA =resen	oir surface ar	rea, WP = reser	voir wetted per	rimeter, alp	pha = Penman's	alpha,											
3	Shape = cone		Shape = dep	ening wedge		Shape = half	cone		rho = water di	ensity, HL= La	itent heat of	fusion, E = Daily e	vaporation,	L= Leakage, L' = S	pecific leakage, Q	Pumping rat	e, Q' = Specifi	ic pump rate, R	I = Surface rech	arge, R' = S	pecific rechage												
4	Runoff efficiency	0.46 %	Rth	0.46 %		Rth	0.46 %	6	dH = Change i	n reservoir h	eight.																						
5	Liner Thickness	0.1 m	b	0.1 m		ь	0.1 m	n																									
6	Hydro Conductivity	0.00000001 m/s	к	0.00000001 m/s		к	0.00000001 m	n/s	*Surface Area	is limited to	greater than	100 m^2 to pres	rent model i	nstability.																			
7	Surface area @ max D	11,520 m^2	SA @ max D	12,721 m^2		SA @ max D	3,780 m	n^2	*K values are	adapted from	n a layered o	lay (Bear, 1972)																					
8	Max reservoir D	9.4 m	Av Max R D	10 m		Max R D	4 m	n	*Starting dep	th is given as	blue shaded	area in PNAS 20	12 article, po	otential overflow	in Temple Reserv	ir is directed	to recharge i	n Palace Reser	voir														
9	Watershed area	41,294 m^2	W	46,454 m^2		W	25,462 m	n^2	Runoff is giv	en by daily p	recip - Evap '	Efficiency (Li et	al., 2004) *T	emple Reservoir	has additional spri	ng input of 7.	5 I/hr (PNAS	2012)															
10	Average slope	8.82 degrees	m	20.67 degrees		m	4.66 d	legrees	Number of de	pendants	Liters per de	endant per day																					
11									1200		4.000																						
12																																	
13		Climate Da	ita	Temple Reserv	/oir	Pi	alace Reservoir		Hid	iden Reservo	ir 👘		Connectio	ons		Wa	ter flux within	n Temple Reser	voir			Wat	ter flux within	Palace Reservoi	H			Wat	er flux within h	lidden Reservo	ir		
14	DAY	T (C) E (m)	P (m)	H (m) SA (m^2)	WP (m^2)	H (m)	SA (m^2)	WP (m^2)	H (m)	SA (m^2)	WP (m^2)	Temple Over Pal	ace Over Hic	iden Over	L (m^3)	L' (m)		Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	dH (m) - Temple
15	1	22.49 0.013	0.029	9.400 1.15E+04	1.17E+04	10.000	6.36E+03	1.36E+04	2.000	9.45E+02	9.48E+02	0.00	0.00	0.00	568.09	0.0493	1.60		298.92		704.84	0.1108	1.60		336.06		9.83	0.0104	1.60		184.20	0.19	-0.00
16	2	22.38 0.0127	0.028	9.392 1.15E+04	1.16E+04	9.957	6.33E+03	1.35E+04	2.199	1.14E+03		0.00	0.00	0.00	566.68		1.60		285.34		698.86	0.1103	1.60		320.79		13.06	0.0114	1.60	0.0014	175.83	0.15	-0.00
17	3	22.29 0.0124	0.027	9.383 1.15E+04	1.16E+04	9.913	6.30E+03	1.35E+04	2.355	1.31E+03	1.31E+03	0.00	0.00	0.00	564.95		1.60		271.77		692.57	0.1098	1.60		305.53		16.04		1.60		167.47	0.13	-0.01
18	4	22.20 0.0121	0.026	9.371 1.14E+04	1.16E+04	9.865	6.27E+03	1.34E+04	2.483	1.46E+03	1.46E+03	0.00	0.00	0.00	562.85	0.0492	1.60		258.23		685.97	0.1093	1.60	0.0003	290.29		18.82	0.0129	1.60			0.11	-0.01
19	5	22.12 0.0119	0.025	9.358 1.14E+04	1.16E+04	9.815	6.24E+03		2.592	1.59E+03	1.59E+03	0.00	0.00	0.00	560.57	0.0491	1.60		244.71		679.07	0.1088	1.60	0.0003	275.08	0.04	21.40	0.0135	1.60		150.78	0.09	-0.01
20	6	22.06 0.0117	0.024	9.343 1.14E+04	1.15E+04	9.763	6.21E+03		2.686	1.70E+03	1.71E+03	0.00	0.00	0.00	557.84	0.0490	1.60				6/1.88	0.1082	1.60				23.80	0.0140	1.60	0.0009	142.46	0.08	-0.01
21	7	22.00 0.0116	0.023	9.326 1.13E+04	1.15E+04	9.709	6.18E+03	1.32E+04	2.766	1.81E+03	1.81E+03	0.00	0.00	0.00	554.80		1.60		217.78		664.41	0.1076	1.60	0.0003	244.79	0.04	26.01	0.0144	1.60	0.0009	134.17	0.07	-0.01
22	8	21.94 0.0115	0.022	9.308 1.13E+04	1.14E+04	9.652	6.14E+03		2.837	1.90E+03	1.91E+03	0.00	0.00	0.00	551.58	0.0488	1.60		204.39		656.67	0.1070	1.60		229.73	0.04	28.05	0.0148	1.60	0.0008	125.92	0.07	-0.02
23	9	21.90 0.0114	0.021	9.288 1.126+04	4 1.14E+04	9.593	6.102+03	1.30E+04	2.898	1.986+03	1.99E+03	0.00	0.00	0.00	548.0.	0.0481	1.60	0.0001	191.07	0.02	648.66	0.1063	1.60	0.0003	214.74	0.04	29.91	0.0151	1.60	0.0008		0.06	-0.02
24	10	21.86 0.0113	0.021	9.266 1.12E+04	1.13E+04	9.532	6.06E+03	1.30E+04	2.952	2.06E+03	2.07E+03	0.00	0.00	0.00	544.18	0.0486	1.60	0.0001	1/7.81	0.02	640.39	0.1056	1.60	0.0003	199.82	0.03	31.60	0.0154	1.60	0.0008	109.52	0.05	-0.02
25	11	21.83 0.0113	0.020	9.243 1.11E+04	1.13E+04	9.468	6.02E+03	1.295+04	2.998	2.12E+03	2.13E+03	0.00	0.00	0.00	540.03	0.048:	1.60	0.0001	104.02	0.01	631.87	0.1049	1.60	0.0003	184.98	0.03	33.11	0.0156	1.60	0.0008	101.39	0.05	-0.02
20	12	21.81 0.0113	0.019	9.217 1.110+04	1.120+04	9,402	5.982+03	1.280+04	3.038	2.100+03	2.196+03	0.00	0.00	0.00	535.04	0.0484	1.00	0.0001	151.51	0.01	023.12	0.1042	1.00	0.0003	170.24	0.03	34,40	0.0158	1.00	0.0007	93.31	0.04	-0.02
27	13	21.79 0.0113	0.019	9.191 1.100+04	+ 1.11E+04	9.334	5.948+03		3.072	2.235+03	2.246+03	0.00	0.00	0.00	530.9	0.0482	1.60	0.0001	138.50	0.01	614.14	0.1034	1.60	0.0003	155.60	0.03	35.64	0.0160	1.60	0.0007	85.29	0.04	-0.02
20	14	21.78 0.0114	0.018	9.102 1.092+04	+ 1.11E+04	9.204	5.692+03	1.200+04	3.101	2.276+03	2.280+03	0.00	0.00	0.00	520.03	0.0481	1.00	0.0001	125.57	0.01	604.93	0.1027	1.00	0.0003	141.00	0.02	30.05	0.0161	1.00	0.0007	11.32	0.03	-0.03
20	15	21.77 0.0115	0.017	5.152 1.09E+04	1.1005+04	9.192	5.652+03		3.125	2.312+03	2.510+03	0.00	0.00	0.00	520.80	0.0475			102.04		595.51	0.1019	1.60		120.04		37.50	0.0163	1.60		05/41	0.03	-0.03
21	10	21.77 0.0110	0.017	9.100 1.082+04	1.095+04	9.117	5.002+03	1.240404	3.144	2.340+03	2.346+03	0.00	0.00	0.00	515.44	0.0471	1.60	0.0001	97.44	0.01	575.09	0 010	1.60	0.0003	02.16	0.02	30.19	0.0164	1.60	0.0007	61.57	0.03	-0.03
31	10	21.78 0.0117	0.016	0.007 1.07E+04	1.085+04	9.041	5.752+03		3.159	2.302+03	2.302+03	0.00	0.00	0.00	509.75	0.0476	1.60		37.44		576.08		1.60		98.10		38.72	0.0164	1.60		33.81	0.02	-0.03
54	10	21.79 0.0119	0.016	9.052 1.060+04	+ 1.085+04	0.902	5.702403	1.220404	5,109	2.372+03	2.360403	0.00	0.00	0.00	505.94	0.0474	1.60	0.0002	74.90	0.01	500.08		1.60	0.0003	04.15	0.01	39.10	0.0165	1.60	0.0007	40.11	0.02	-0.03

Darcy's Law

WL Change

Pump rate

WL Change

Recharge

WL Change

Computed seepage from base of reservoir, pumping rate, and recharge

U = (\$D\$6*J*(H*0.6)*(1/\$D\$5))*86400 $V = U/((|I+|_{i+1})*0.6)$ W = \$N\$11/3*(\$P\$11/1000) $X = W/((|I+|_{i+1})*0.6)$ Y = IF((((G-E))<0,0,((G-E)*\$D\$4*\$D\$9))+(7.5/1000)*24 $Z = Y/((|I+|_{i+1})*0.6)$



GSA 2012 – Florea – Mass Balance Computation

	B C	D E	F G	H I	J	K	L	M	N	0	Р	Q	R	S	T I	J	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
1																																		
2	Temple Reservoir	1	Palace Reservoir		Hidden reser	rvoir			T = Daily aver	age temperat	ure, I = Aver	age daily solar in	solation, P =	Daily precipitat	on, H = reservo	r depth, !	SA =reservoir	surface area	a, WP = reserv	voir wetted per	rimeter, alp	ha = Penman'	s alpha,											
3	Shape = cone		Shape = dep	ening wedge		Shape = half	cone		rho = water d	ensity, HL= La	itent heat of	f fusion, E = Daily	evaporation,	, L= Leakage, L'	Specific leakag	je, Q = Pu	imping rate, C	χ' = Specific ;	pump rate, R	 Surface recharge 	arge, R' = Sp	pecific rechage	5											
4	Runoff efficiency	0.46 %	Rth	0.46 %		Rth	0.46 %	5	dH = Change i	n reservoir h	eight.																							
5	Liner Thickness	0.1 m	b	0.1 m		b	0.1 m	1																										
6	Hydro Conductivity	0.00000001 m/s	к	0.00000001 m/s		к	0.00000001 m	∿s	*Surface Area	is limited to	greater tha	n 100 m^2 to pre	event model	instability.																				
7	Surface area @ max D	11,520 m^2	SA @ max D	12,721 m^2		SA @ max D	3,780 m	1^2	*K values are	adapted from	n a layered (clay (Bear, 1972)																						
8	Max reservoir D	9.4 m	Av Max R D	10 m		Max R D	4 m	1	*Starting dep	th is given as	blue shade	d area in PNAS 2	012 article, p	otential overflo	w in Temple Re	servoir is	s directed to i	recharge in I	Palace Reserv	voir														
9	Watershed area	41,294 m^2	W	46,454 m^2		W	25,462 m	1^2	Runoff is giv	en by daily p	recip - Evap	* Efficiency (Li e	t al., 2004) *1	Femple Reservo	ir has additiona	I spring i	input of 7.5 l/	hr (PNAS 20	12)															
10	Average slope	8.82 degrees	m	20.67 degrees		m	4.66 d	egrees	Number of de	pendants	Liters per de	pendant per day																						
11									1200		4.000																							
12																																		
13		Climate Da	ita	Temple Reserv	roir	Pa	alace Reservoir		Hic	iden Reservo	ir		Connecti	ions			Water	flux within T	emple Reserv	<i>i</i> oir			Wat	er flux within	Palace Reserve	hir			Wat	er flux within H	lidden Reservi	air		
14	DAY	T (C) E (m)	P (m)	H (m) SA (m^2)	WP (m^2)	H (m)	SA (m^2)	WP (m^2)	H (m)	SA (m^2)	WP (m^2)	Temple Over Pa	lace Over Hi	idden Over	L (n	r^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	L (m^3)	L' (m)	Q (m^3)	Q' (m)	R (m^3)	R' (m)	dH (m) - Temple
15	1	22.49 0.013	0.029	9.400 1.15E+04	1.17E+04	10.000	6.36E+03	1.36E+04	2.000	9.45E+02	9.48E+02	0.00	0.00	0.00	-	68.09	0.0493	1.60		298.92	0.03	704.84	0.1108	1.60	0.0003	336.06		9.83	0.0104	1.60	0.0017	184.20	0.19	-0.00
16	2	22.38 0.0127	0.028	9.392 1.15E+04	1.16E+04	9.957	6.33E+03	1.35E+04	2.199	1.14E+03	1.15E+03	0.00	0.00	0.00	5	66.68	0.0493	1.60		285.34	0.02	698.86	0.1103	1.60		320.79		13.06	0.0114	1.60	0.0014	175.83	0.15	-0.00
17	3	22.29 0.0124	0.027	9.383 1.15E+04	1.16E+04	9.913	6.30E+03	1.35E+04	2.355	1.31E+03	1.31E+03	0.00	0.00	0.00	-	64.95	0.0492	1.60		271.77	0.02	692.57	0.1098	1.60	0.0003	305.53		16.04		1.60	0.0012	167.47	0.13	-0.01
18	4	22.20 0.0121	0.026	9.371 1.14E+04	1.16E+04	9.865	6.27E+03	1.34E+04	2.483	1.46E+03	1.46E+03	0.00	0.00	0.00	5	62.89	0.0492	1.60		258.23		685.97	0.1093	1.60	0.0003	290.29		18.82	0.0129	1.60	0.0011		0.11	-0.01
19	5	22.12 0.0119	0.025	9.358 1.14E+04	1.16E+04	9.815	6.24E+03	1.33E+04	2.592	1.59E+03	1.59E+03	0.00	0.00	0.00		60.52	0.0491	1.60		244.71	0.02	679.07	0.1088	1.60	0.0003	275.08		21.40		1.60	0.0010	150.78	0.09	-0.01
20	6	22.06 0.0117	0.024	9.343 1.14E+04	1.15E+04	9.763	6.21E+03	1.33E+04	2.686	1.70E+03	1.71E+03	0.00	0.00	0.00		57.84	0.0490	1.60				671.88	0.1082	1.60	0.0003	259.91	0.04	23.80	0.0140	1.60	0.0009	142.46	0.08	-0.01
21	7	22.00 0.0116	0.023	9.326 1.13E+04	1.15E+04	9.709	6.18E+03	1.32E+04	2.766	1.81E+03	1.81E+03	0.00	0.00	0.00		54.86	0.0489	1.60		217.78		664.41	0.1076	1.60	0.0003	244.79		26.01	0.0144	1.60	0.0009	134.17	0.07	-0.01
22	8	21.94 0.0115	0.022	9.308 1.13E+04	1.14E+04	9.652	6.14E+03	1.31E+04	2.837	1.90E+03	1.91E+03	0.00	0.00	0.00		51.58	0.0488	1.60		204.39		656.67	0.1070	1.60	0.0003	229.73	0.04	28.05	0.0148	1.60	0.0008	125.92	0.07	-0.02
23	9	21.90 0.0114	0.021	9.288 1.12E+04	1.14E+04	9.593	6.10E+03	1.30E+04	2.898	1.98E+03	1.99E+03	0.00	0.00	0.00		48.01	0.0487	1.60		191.07		648.66	0.1063	1.60	0.0003	214.74	0.04	29.91		1.60	0.0008		0.06	-0.02
24	10	21.86 0.0113	0.021	9.266 1.12E+04	1.13E+04	9.532	6.06E+03	1.30E+04	2.952	2.06E+03	2.07E+03	0.00	0.00	0.00		44.16	0.0486	1.60		1/7.81		640.39	0.1056	1.60		199.82		31.60	0.0154	1.60	0.0008		0.05	-0.02
25	11	21.83 0.0113	0.020	9.243 1.11E+04	1.13E+04	9.468	6.02E+03	1.29E+04	2.998	2.12E+03	2.13E+03	0.00	0.00	0.00		40.03	0.0485	1.60		164.62		631.87	0.1049	1.60	0.0003	184.98		33.11	0.0156	1.60	0.0008	101.39	0.05	-0.02
26	12	21.81 0.0113	0.019	9.217 1.11E+04	1.12E+04	9.402	5.98E+03	1.28E+04	3.038	2.18E+03	2.19E+03	0.00	0.00	0.00		35.62	0.0484	1.60			0.01	623.12	0.1042	1.60	0.0003	170.24		34.46	0.0158	1.60	0.0007	93.31	0.04	-0.02
27	13	21.79 0.0113	0.019	9.191 1.10E+04	1.11E+04	9.334	5.94E+03		3.072	2.23E+03	2.24E+03	0.00	0.00	0.00		30.95	0.0482	1.60		138.50		614.14	0.1034	1.60	0.0003	155.60		35.64	0.0160	1.60		85.29	0.04	-0.02
28	14	21.78 0.0114	0.018	9.162 1.09E+04	1.11E+04	9.264	5.89E+03	1.26E+04	3.101	2.27E+03	2.28E+03	0.00	0.00	0.00		26.03	0.0481	1.60			0.01	604.93	0.1027	1.60	0.0003	141.06		36.65	0.0161	1.60	0.0007	11.32	0.03	-0.03
29	15	21.77 0.0115	0.017	9.132 1.09E+04	1.10E+04	9.192	5.85E+03		3.125	2.31E+03	2.31E+03	0.00	0.00	0.00		20.85	0.0479	1.60	0.0001	112.75	0.01	595.51	0.1019	1.60	0.0003	126.64	0.02	37.50	0.0163	1.60	0.0007	09.41	0.03	-0.03
30	16	21.77 0.0116	0.017	9.100 1.08E+04		9.117	5.80E+03	1.24E+04	3.144	2.34E+03	2.34E+03	0.00	0.00	0.00		15.44	0.0477	1.60	0.0001	100.04	0.01	585.89	0.1010	1.60	0.0003	112.34	0.02	38.19	0.0164	1.60	0.0007	61.57	0.03	-0.03
31	17	21.78 0.0117	0.016	9.067 1.07E+04	1.08E+04	9.041	5.75E+03	1.23E+04	3.159	2.36E+03	2.36E+03	0.00	0.00	0.00		09.79	0.0476	1.60	0.0001	87.44	0.01	576.08	0.1002	1.60	0.0003	98.16	0.02	38.72	0.0164	1.60	0.0007	55.81	0.02	-0.03
34	18	21.79 0.0119	0.016	9.032 1.06E+04	1.08E+04	8.962	5.70E+03	1.22E+04	3.169	2.3/E+03	2.38E+03	0.00	0.00	0.00		03.92	0.0474	1.60	0:0002	74.95	0.01	566.08	0.0993	1.60	0.0003	84.13	0.01	39.10	0.0165	1.60	0.0007	46.11	0.02	-0.03

Preip + Runoff – Evapotrans – Leakage - Pumping

P + R - ET - L - Q

Change in water height in reservoir

AM=G+Z-E-V-X AN=G+AF-E-AD-AB AO=G+AL-E-AH-AJ AP=IF(S<0,0,S*1000)

GSA 2012 – Florea – Results (Average Climate Data)

Reservoir Water Level - Communication Between Reservoirs





GSA 2012 – Florea – Results (El Nino Years)











GSA 2012 – Florea – Results (La Nina Years)







The modeled water levels reveal an interesting trend for the available climate years, water levels in the reservoir end lower than they began.

This trend is even visible using thicker liners with lower conductivity and high values of runoff efficiency.

These trends are also visible in both El Nino (2007, 2009) years with lower precipitation and greater evaporation and La Nina (2008, 2010) years with greater precipitation and lower evaporation.



The results pose an interesting divergence from recent publications (e.g., *Scarborough et al, 2012; Gallopin, 1990*) that present data to support water-filled reservoirs with overflow utilized for irrigation.

Results in this model are more suggestive of hydrated wetlands with periods of desiccation during the dry season and highly variable water depths during the wet season.

This second notion is more in line with *Jaccob (1995)* who argues that the reservoirs were in fact "marshy areas of perennial wetness."



If correct, this model suggests a few possible climate implications:

1) Annual precipitation may have been, on average, greater that modern available data during the Classic Maya period. If, for example, annual rainfall were to meet or exceed the level of the 2008 and 2010 La Nina years, water levels would remain elevated, particularly in the Temple and Palace Reservoirs. Significantly more precipitation could induce occasional overflow.

Interestingly *Gallopin (1990)* assumes an 150 cm/yr in his conceptual model.

2001 Precipitation data (180 cm) - 69% R-eff, 12 cm liner, 1e-9 m/s K





2) A modest reduction in annual precipitation (~20%) over an multi-year period, largely from a reduced number of tropical cyclones, could result in long-periods of limited reservoir hydration and therefore significant stress upon domestic and agricultural water use.

This second possibility has been long suspect in the collapse of the Classic Maya at Tikal and elsewhere with recent supporting data from stable isotopes (e.g., *Medina-Elizalde and Rohling, 2012*).

Science 335, 956 (2012); M. Medina-Elizalde and E.J. Rohling

- A. Stalagmite Chaac δ^{18} O record
- B. Lake Chichancanab Pyrgophorus coronatus δ¹⁸O record
- C. Lake Punta Laguna ostracod
 Cytheridella ilosvayi δ¹⁸O Record
- Lake Chichancanab sediment density record





GSA 2012 – Florea – Final Point

Finally, these results imply the need for more detailed numerical modeling.

While an interesting exercise, we have reached the limits of a simple spreadsheet-based model.





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