An assessment of In-Situ Physiochemical Water Quality Parameters in Streams of The Chiquibul Ecosystem and Bald Hills

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AN ASSESSMENT OF IN-SITU PHYSIOCHEMICAL WATER QUALITY PARAMETERS IN STREAMS OF THE CHIQUIBUL FOREST AND BALD HILLS

The assessment of the 2023 in-situ water quality data was conducted by Friends for Conservation and Development in 2023. The data collection and analysis undertaken by the BRIM Technician and the FCD Research Unit was financed in part by the Protected Areas Conservation Trust (PACT), U.S Department of the Interior-International Technical Assistance Program (USDOI-ITAP) and Fortis Belize.

This study would not have been possible without the arduous work of the field staff; namely FCD Rangers Ellsworth Sutherland and George Pott who were based at Cooma Cairn Ranger Outpost.

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To Bulridge Company Limited, we are thankful for providing access through the gates in the Mountain Pine Ridge which facilitated the field work and collection of data.

Introduction:

The Chiquibul ecosystem comprised of the Caracol Archaeological Reserve, Chiquibul National Park, and Chiquibul Forest Reserve, a key biodiversity area is an integral part of the largest remaining tract of tropical forest in Central America: the Selva Maya (Bridgewater et al. 2006). The Chiquibul ecosystem forms the headwaters of the Greater Belize River Watershed (GBRW), which is the largest and, perhaps, the most important source of water for the country (Briggs et al. 2013). The two main sub-drainage systems of the GBRW include the Macal and the Mopan Rivers. In the Macal River Sub-Watershed, there are abundant streams, that support more than 130,000 Belizeans. The Mopan River Sub-Watershed supports more than 100,000 Guatemalans in approximately 180 communities of the Peten (BERDS 2005; The Nature Conservancy 2006). In the Macal Sub-Watershed, there exists abundant surface drainage (small streams), while the Mopan Sub-Watershed has a large subterranean component (Meadows and Meerman 1999). The GBRW is crucial for water security in Belize; therefore, water quality monitoring becomes of great importance.

Climate change and increased anthropogenic activities are leading causes of change in the hydrological cycle; the degradation of the quality of water has become a crucial issue for sustainability. In the Chiquibul Forest, anthropogenic activities affecting the quality of the water include hydroelectric dam, illegal gold panning and gold mining (in the Southern Chiquibul sub-basin), and the ongoing paved construction of the Caracol road. The Chalillo Hydroelectric dam created a reservoir extending 20 km upstream of the Macal and Raspaculo Rivers, inundating approximately 1,133.12 hectares of forested and riparian ecosystems (Meadows and Meerman 1999). In the Southern Chiquibul Sub-basin, direct habitat alteration, sediment/siltation, and altered flow regime, are stresses caused by gold panning (Guerra 2022). The impact on water quality by the construction of the Caracol highway is not fully understood, but is evident by the increase load of sedimentations in the water column and physical obstruction of water flow. It is, therefore, important to monitor the water quality in these headwaters to guide management and conservation efforts of this natural resource. Under the Friends for Conservation and Development's Biodiversity Research, Inventory and Monitoring (BRIM) Framework (Arevalo 2019), the quality monitoring of the Aquatic Systems, aligns with Belize's Department of the Environment (DoE) National Water Quality Monitoring Program and Protocols.

The objective of this report was to assess the water quality of the CF for the 2023 period and compare it with the baseline established in 2021.

Methodology:

Study Site:

The water quality, data collection for 2022 was carried out in the streams of the Chiquibul ecosystem (*Map 1*), which is composed of three protected areas; the Caracol Archeological Reserve, the Chiquibul Forest Reserve and the Chiquibul National Park. The Chiquibul ecosystem is located between the western slopes of the Maya Mountains, reaching a maximum elevation of 1,124 m, and extending to the western border with Guatemala. The region has a subtropical climate with a marked dry season between February to May and a rainy season coinciding with the hurricane season starting from July to November (Salas and Meerman 2008). Riparian areas in the Chiquibul ecosystem receive, on average 2,000–3,000 mm of rainfall per year and undergo frequent flood events during the rainy

season. Average minimum and maximum temperatures are 20.58C and 31.38C inland, and 17.78C and 25.38C in the mountains (Britt et al. 2014).

The eastern section of the Mountain Pine Ridge Forest Reserve (MPRFR), generally referred to as the Bald Hills area, serves as a buffer zone to the eastern section of the Chiquibul National Park. The area occupies a ridge that defines the upper boundary of the headwaters for four main river systems. The eastern and north-eastern portion of Bald Hills drains into the Sibun River and Cave's Branch Creek (a main tributary of the Sibun River), respectively. The northern side of Bald Hills drains into Roaring River and the southern side drains into the Macal River; both river systems are tributaries of the Belize River. The Macal River supports a series of dams and reservoirs. This study focuses on the southern section of the Bald Hills area, which constitutes the headwaters of the Macal River.

Water quality data collection protocols

Before initiating water quality sampling, the YSI instruments were calibrated following established protocols by, and with assistance from, the Department of the Environment, Ministry of Sustainable Development and Climate Change in Belmopan.

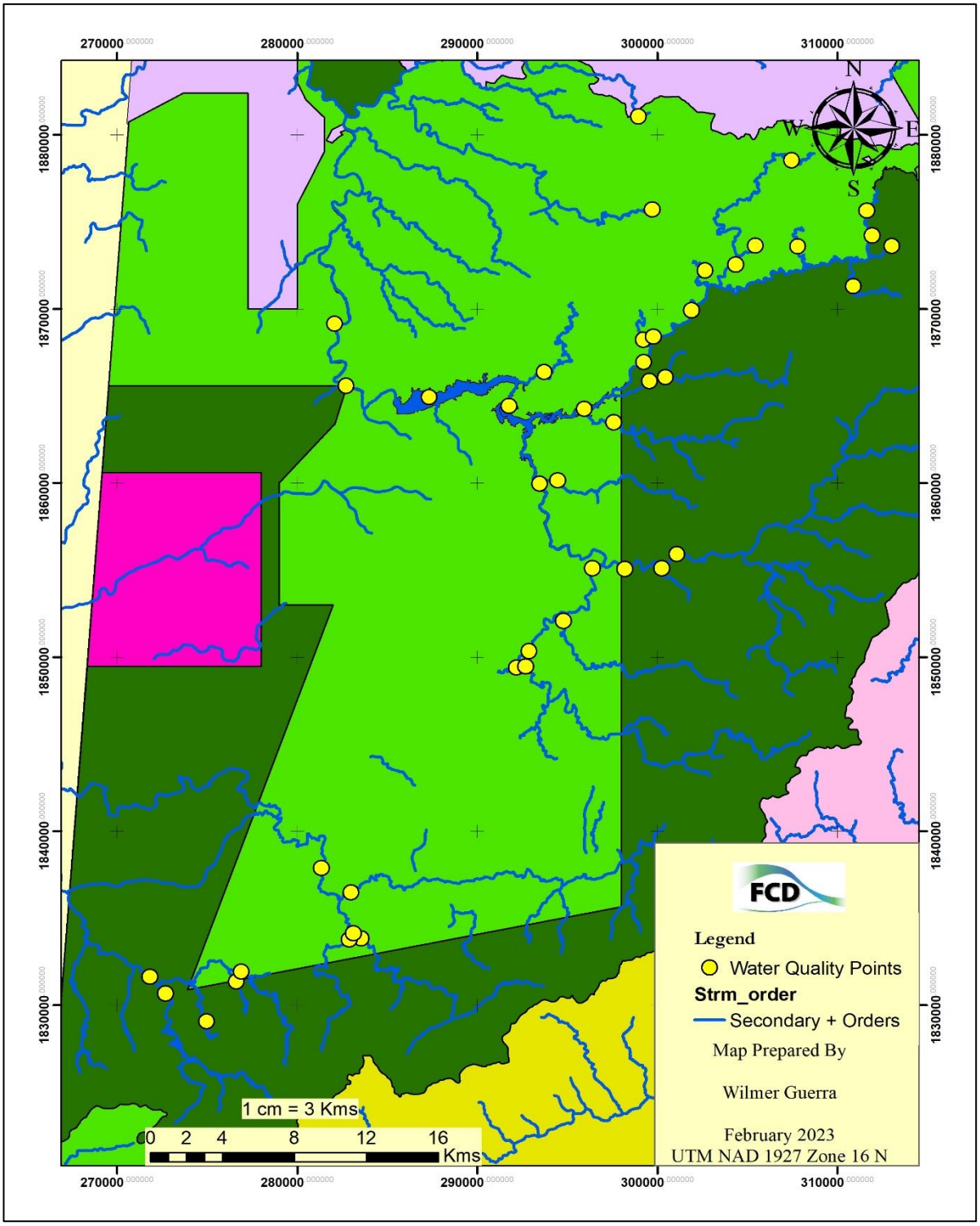
A total of 32 sampling sites (see table 1) were surveyed during both the dry season (May-July 2023) and the wet season (October-November 2023) in the Chiquibul ecosystem and 12 in the Bald Hills Region of the MPRFR. Using the YSI Multi-Parameter Instrument, the team measured and documented in-situ readings for temperature, pH, conductivity, Dissolved Oxygen, Total Dissolved Solids, salinity and nitrates.

Data collection procedures followed the DoE in-situ water sampling standards, as established by the National Water Quality Monitoring Program and Protocols. The probes were submerged at depths of about 30 cm below the water surface and in the direction of the current. The instrument was allowed to stabilize at the predetermined depth, usually between thirty seconds to one minute, after which the readings were documented in data sheets.

Data Analysis

The recorded data was entered into the IBM SPSS (Statistical Package for the Social Science) Statistics Program. Although the name reflects its original use in the field of social sciences, SPSS use has since expanded into other data markets. Descriptive statistical analysis was performed on the collected physiochemical water quality data. Whisker Box Plots were constructed for each water quality parameter. Two-Way-Anova for each measured parameter (Temperature, Salinity, pH, Dissolved Oxygen, Specific Conductance, and Nitrates) was done to measure the significance in variance based on 1.) surveying year (2021 and 2022) and 2.) between localities (Macal, Raspaculo, Chiquibul, Monkey Tail and Southern Chiquibul.)

For comparison purposed with previous assessments (Arevalo, 2021) the data was categorized at two scales: spatial and temporal. At the spatial scale, sites were aggregated into sub-basins: Macal River (n = 11), Raspaculo River (n = 5), Monkey Tail (n = 4), Chiquibul River (n = 5), Southern Chiquibul River (n = 7) and Bald Hills (n=12). For the temporal scale, statistics were calculated based on sampling year (2021 and 2022).



Map 1: *Showing the geo-locations of the physiochemical water quality sampling points in the Chiquibul ecosystem and the Bald Hills Region, 2022-2023.*

Results:

The results of the 2023 water quality survey, compared to those of 2021 and 2022, provide valuable data for effectively monitoring water quality in the Chiquibul ecosystem. While there was no significant variance between the mean temperature values for the entire survey (cumulatively for all subbasins) within the different surveying years, 2021 displayed a higher overall mean temperature value with 24.5°C, while 2022 had the lower mean temperature values. The results indicate that for the 2023 water quality survey the Monkey Tail Subbasin displayed higher mean temperature (26.4°C) when compared to all other subbasins, while the Bald Hills subbasin displayed the lowest mean temperature values (20.5°C) for that surveying year. The mean cumulative temperature value (for all three years) was highest in the Macal River with 25.83°C. The mean temperature value in the Monkey Tail subbasin, was significantly higher in 2021 than in 2022 (f value= 9.611; p value= 0.008). Comparison of mean temperature values, indicates significant statistical variance between the Bald Hills Subbasin (F-value =27.116; p-value =0.001) and all other subbasins, except with the Southern Chiquibul Subbasin (F-value = 27.116; p-value =0.079).

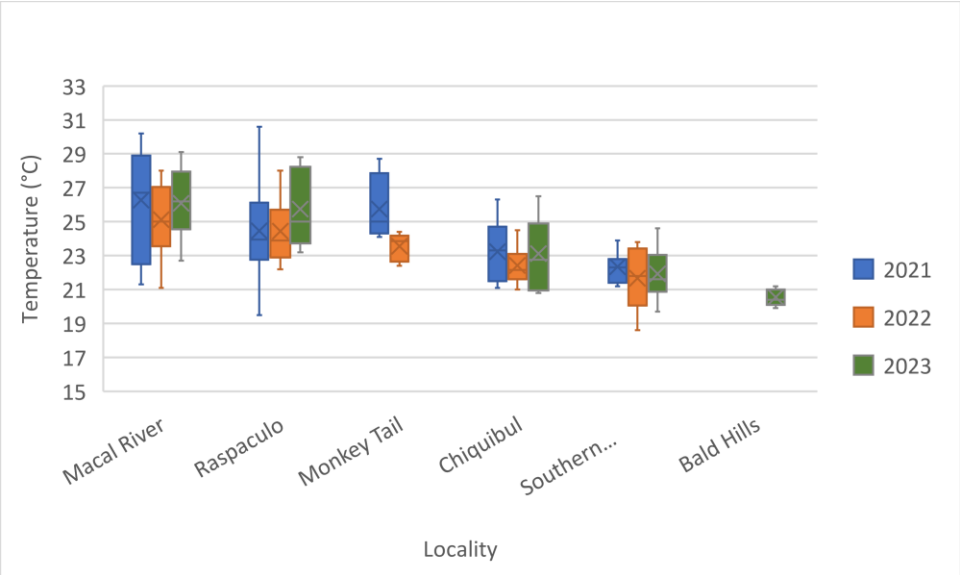


Figure 1: Showing recorded temperature in streams of the Chiquibul ecosystem measured during the 2021, 2022 and 2023 surveys and in the Bald Hills Region Measured in 2023. Southern Chiquibul= Southern Chiquibul River.

The results indicate that there was no statistical difference in Dissolved Oxygen (%/L) saturations between all the subbasins. The Monkey Tail had significant statistical variance between the surveying years (f-value = 6.90; p-value = 0.02) with the mean DO values being higher in 2022 than 2021. The Southern Chiquibul River had the highest Dissolved Oxygen (%/L) value for the 2023 survey with 101.41 %/L while the Chiquibul river had the lowest DO value with 99.51 %/L. The Bald Hills subbasin had less variability in the gathered Dissolved Oxygen data between its points where the Chiquibul River had more variability between its points than any other subbasin. The cumulative mean Dissolved Oxygen Values ranged from 96.9 %/L in the Macal River to 106.2 %/L in the Monkey Tail river.

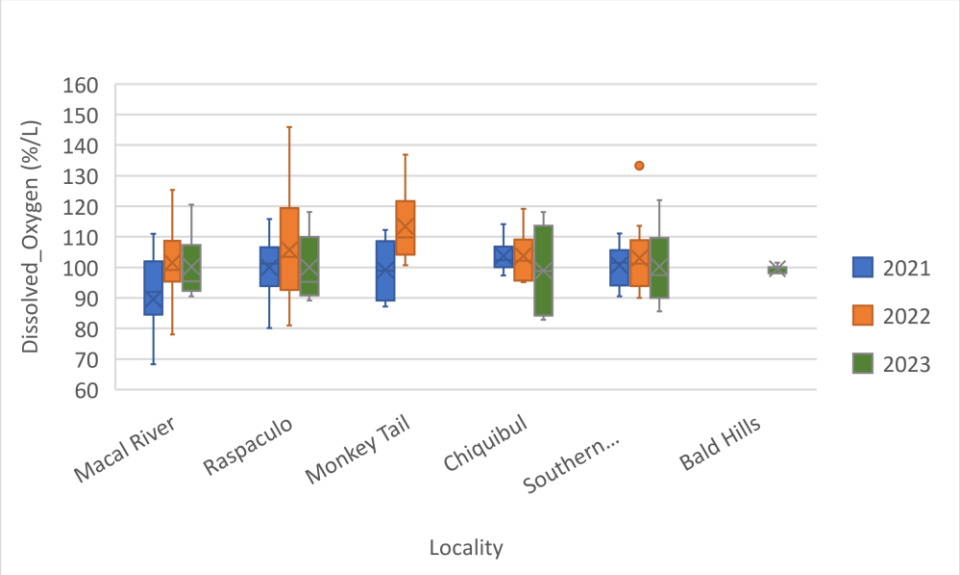


Figure *2: showing Dissolved Oxygen (%/L) readings in streams of the Chiquibul Forest measured during the 2021, 2022 and 2023 surveys and in the Bald Hills Region Measured in 2023. Southern Chiquibul= Southern Chiquibul River.*

Mean Salinity in the Chiquibul and Bald Hills watershed subbasins ranged from 0.02 ppt in the Bald Hills Subbasin to 0.1 ppt in the Chiquibul River Subbasin during the 2023 surveys. The cumulative salinity values for the three years of survey in the Chiquibul Forest ranged from 0.03 ppt in Monkey Tail river to 0.07 ppt in the Raspaculo river. There was no statistical difference in mean salinity values between the Subbasins or between the different surveying years. The Raspaculo River Subbasin had the most variance in salinity values while the Monkey Tail subbasin has less variability in the salinity values collected in its different sampling points.

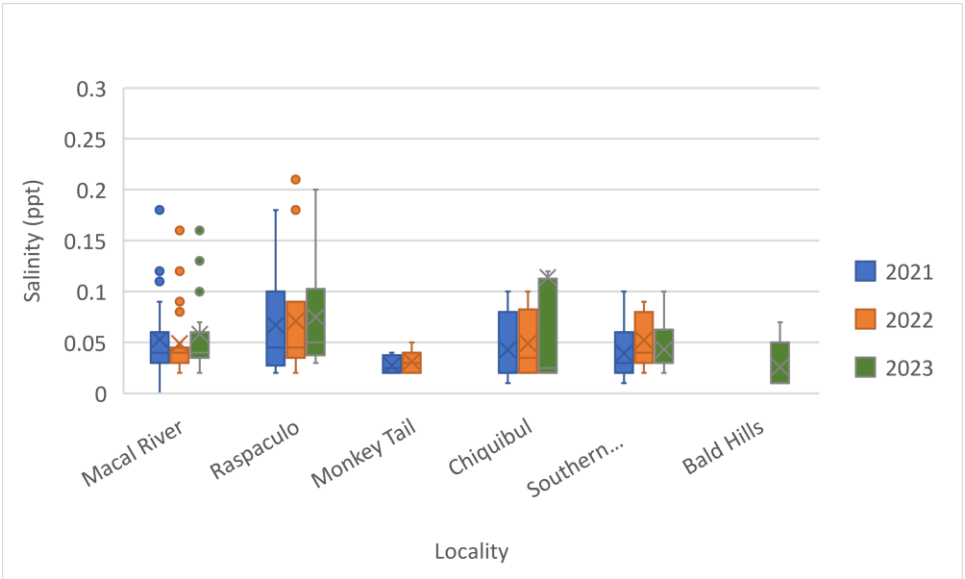


Figure 3: Salinity (ppt) in streams of the Chiquibul Forest measured during the 2021, 2022 and 2023 surveys and in the Bald Hills Region Measured in 2023. Southern Chiquibul= Southern Chiquibul River.

The mean cumulative Specific Conductance (SPC; µS/cm) indicated significant variance between the Raspaculo River subbasin and the Monkey Tail Subbasin (f-value=; p-value=0.007) and between the Raspaculo River Subbasin and the Southern Chiquibul river subbasin (f-value=; p-value=0.021). The mean Specific Conductance values ranged from 58.9 µS/cm in the Bald Hills Region of the Mountain Pine Ridge Forest Reserve to the 162.2 µS/cm in the Raspaculo River Subbasin for the 2023 survey. The Raspaculo River Subbasin displayed the highest mean SPC values (and highest variability) during the 2023 water quality survey. The mean cumulative (three years of survey) SPC value was also highest in the Raspaculo River subbasin while the Monkey Tail had the lowest with 66.60 µS/cm.

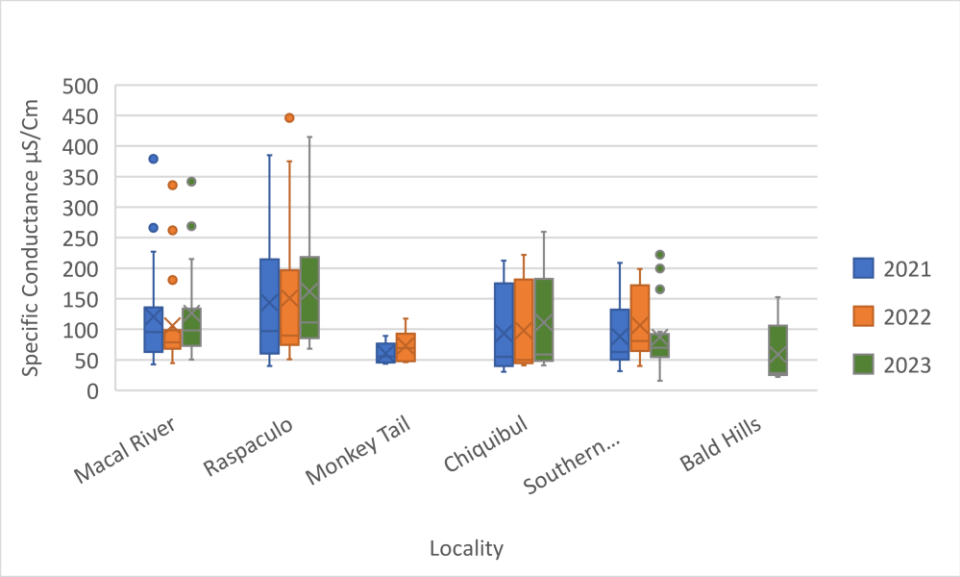


Figure 4: Conductivity in streams of the Chiquibul Forest measured during the 2021, 2022 and 2023 surveys and in the Bald Hills Region Measured in 2023. Southern Chiquibul= Southern Chiquibul River.

The mean amalgamated pH values for each locality ranged from 6.89 in the Bald Hills Region of the Mountain Pine Ridge to 7.89 in the Macal River subbasin. The total accumulated mean pH value for the Chiquibul ecosystem over three years of survey is 7.57. The only statistically significant variance between the subbasins is between the Bald Hills subbasin and Monkey Tail subbasin (f-value=2.642; p-value=0.024) with the monkey tail had higher pH values. The mean pH value in the Monkey Tail subbasin was 7.89.

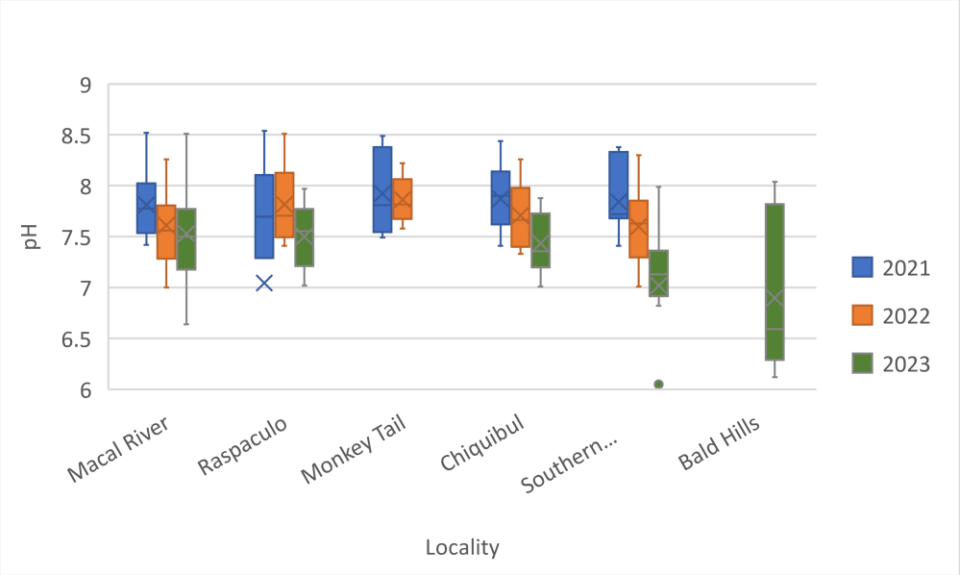


Figure 5: pH in streams of the Chiquibul Forest measured during the 2021, 2022 and 2023 surveys and in the Bald Hills Region Measured in 2023. Southern Chiquibul= Southern Chiquibul River.

The results indicate significant variance in the mean TDS values between the Monkey Tail and the Raspaculo subbasin (f-value=3.186; p-value=0.007) and between Southern Chiquibul River and Raspaculo Subbasins (f-value=3.816; p-value=0.035). The Raspaculo River Subbasin had the highest mean cumulative TDS value with 98.84 mg/L while the Bald Hills had the lowest mean TDS value with 38.53 mg/L. There was no significant statistical variance in TDS values between any other subbasins.

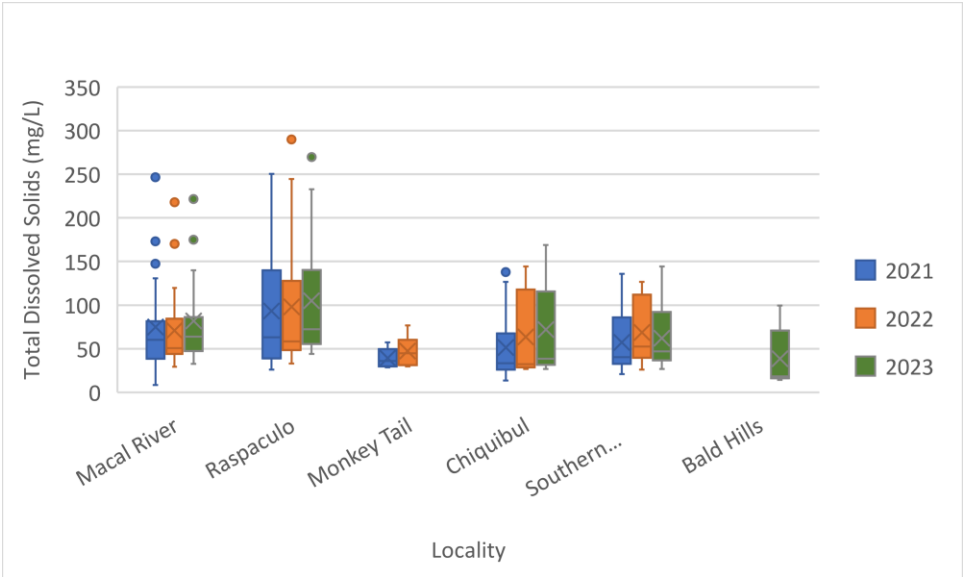


Figure 6: TDS in streams of the Chiquibul Forest measured during the 2021, 2022 and 2023 surveys and in the Bald Hills Region Measured in 2023. Southern Chiquibul= Southern Chiquibul River.

Discussion:

The results of the 2023 water quality survey, compared to those of 2021 and 2022, provide valuable data for effectively monitoring water quality in the Chiquibul ecosystem. The mean temperature values were higher in 2021, followed by 2023 and 2022 respectively. One of the primary factors that could have contributed to the increased freshwater temperatures in 2021 was the extended dry conditions in Belize for that specific year. In 2021, the dry conditions persisted longer than usual, which led to concerns about water availability and its impact on agriculture and natural ecosystems in the region. Increased precipitation on freshwater temperature influences the surface water temperature, depending on factors such as the season, the amount of rainfall, and the size and depth of the water body. Furthermore, in 2022, Belize experienced significant rainfall, with notable events such as Hurricane Lisa contributing to the annual total rainfall. The hurricane caused extensive flooding and added a substantial amount to the year's precipitation. The overall rainfall for 2022 varied across the country, ranging from 60 inches (1524 mm) in the northern regions to up to 160 inches (4064 mm) in the southern part. With this increased water flow due to precipitation there is a decrease in surface water temperature which could be attributed as the reason for lower temperatures in 2022 (Blake 2023).

The Macal River subbasin had the highest temperature values for the three years which could be a result of the almost stagnant waters in the Chalillo Lake reservoir due to the altered flow regime caused by the controlled water release at the dam. With the flooding of the Macal river to create the reservoir, there was an obvious increase in stream width, clearing of riparian forest that prevents it from forming a closed canopy over the water way. This allows for direct sunlight to hit the surface water, a contributing factor to higher surface water temperatures in the Macal River compared to the other sub-basins with fast flowing waters, narrow channels, and in which the water way is shaded by the closed riparian forest canopy like in Bald Hills and the Southern Chiquibul Watershed. Bald hills, with an elevation higher than all other sub-basins has lower temperatures which is expected because generally, as altitude increases, air temperature decreases due to the lower atmospheric pressure and thinner air. This cooling effect typically results in colder water temperatures in these high-altitude streams.

Mean Dissolved Oxygen (DO) levels were lower in the areas of higher temperature like in the Macal River but higher in rapidly moving water, such as that in the mountain streams of the Southern Chiquibul River and the Bald Hills region. Dissolved Oxygen occurs inversely with the water temperature values. The concentration of dissolved oxygen in surface water is dependent on temperature and has both a seasonal and a daily cycle; where it peaks during the day and decreases during the night (Arevalo 2021). Aquatic plants and algae produce oxygen through photosynthesis during the day, increasing DO levels. Conversely, respiration by aquatic organisms and microbial decomposition of organic matter consume oxygen and can decrease DO levels, especially at night or in areas with high organic content (Masters 2008). The Bald Hills region had less variability on its data which indicates DO values are more consistent and less spread out from the mean temperature value.

The physiochemical parameters of water quality influence and have direct impact on the existence and response of each other. For instance, salinity and temperature both affect the solubility of oxygen; where, as salinity levels increase, the amount of dissolved oxygen in the water decreases (Verberk et al. 2011). Salinity, the total concentration of all dissolved salts in water, is a strong

contributor to conductivity; these electrolytes form ionic particles as they dissolve, each with a positive and negative charge. Salinity, therefore, is a strong contributor to conductivity. Conductivity is also affected by temperature; temperature affects conductivity by increasing ionic mobility as well as the solubility of many salts and minerals. The TDS, which is all solids, usually mineral salts, that are dissolved in water and the electrical conductivity are also in a close connection. The more salts are dissolved in the water, the higher is the value of the electric conductivity. The Bald Hills region of the MPFR has 0.02 ppt mean salinity value, which is suitable for most freshwater organisms, that are adapted to low salinity conditions and is unlikely to cause any form of stress to freshwater fish, invertebrates, and plants, making it conducive to maintaining biodiversity and healthy ecosystems. Mean salinity values in all subbasins in the CF (2021-2023) also fell within normal ranges for the three surveying years.

Significantly elevated electrical conductivity can indicate that pollution has entered the river. A measure of electrical conductivity cannot tell you what the pollutant is, but it can help identify that there is a problem that may harm invertebrates and/or fish. Freshwater is usually between 0 and 1,500 uS/cm. The Raspaculo river had a SPC value, slightly above this range, which represented the highest TDS mean value and could be caused by the stagnation of water due to the water catchment reservoir of the Chalillo Lake. The dam altered the natural flow regime of the Macal and Raspaculo Rivers. Changes in water flow can affect aquatic habitats through the delayed sediment transportation and flow, and the natural hydrological cycle. Furthermore, stagnant water in reservoirs can lead to reduced water quality, including lower levels of dissolved oxygen and higher concentrations of pollutants. It is therefore imperative for continued water quality monitoring in these areas of the Chiquibul ecosystem. In the three years of the Survey, the mean pH values of the waters in the Chiquibul ecosystem were all within normal ranges, representing optimal pH ranges for Cichlid, which is one of the most common type of freshwater fishes in the area.

Conclusion and Recommendations:

The results of measured water quality physiochemical parameters of the headwaters in the Chiquibul ecosystem were for the most part consistent with a healthy aquatic system. The Raspaculo and the Macal River, while still healthy water systems, did present data that are consistent with environmental impacts caused by the Chalillo reservoir. Water Quality monitoring, especially in these ecologically sensitive areas, is of utmost importance to determine if conservation efforts are sufficient to address, and to determine if intervention is necessary to mitigate, these impacts and protect the ecological integrity of the Raspaculo River and the surrounding Chiquibul region. Overall, the Chiquibul boasts a healthy aquatic system that maintains a balance of these water quality parameters, supporting diverse and productive ecosystems. Regular monitoring and management are essential to maintain these conditions and address any deviations that may indicate environmental stress or degradation.

- The continuation of the in-situ surveys of the physical and chemical parameters of water quality on a yearly basis. Monitoring is especially important in the Macal and Raspaculo Rivers as these are areas where known anthropogenic activities are occurring, which place at risk the quality of the aquatic systems.

- There is a need for a correlation between the physiochemical results and results of the freshwater macroinvertebrate surveys, which is to be done in 2024.

- A data sharing protocols between FCD and Fortis Belize is recommended. Fortis Belize collects water quality readings on a yearly basis on the entire watershed. A correlative study to assess both the headwater and those downstream (past the dams) can possibly provide further insight into the causative reasons for our results, especially the elevated nitrates.

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Appendix:

Appendix 1: *Table Showing Grids and Localities of Water Quality Sample Points in the Chiquibul ecosystem, 2021-2023.*

X	Y	ID	Locality	Subbasin
298188	1855061	CWQ_001	Upper Raspaculo River	Raspaculo
300240	1855104	CWQ_002	Upper Raspaculo River	Raspaculo
296382	1855113	CWQ_003	Raspaculo	Raspaculo
301095	1855919	CWQ_004	Upper Raspaculo River	Raspaculo
294455	1860142	CWQ_005	Cut Log Creek	Raspaculo
293717	1866378	CWQ_006	Pheobe Canyon	Macal River
292177	1849404	CWQ_007	Monkey Tail River - Creek	Monkey Tail
292679	1849452	CWQ_008	Monkey Tail River - Creek	Monkey Tail
292879	1850354	CWQ_009	Monkey Tail River	Monkey Tail
294773	1852080	CWQ_010	Monkey Tail River	Monkey Tail
299226	1868239	CWQ_011	MPR_Creek	Macal River
299778	1868407	CWQ_012	Macal River	Macal River
299240	1866951	CWQ_013	Macal River	Macal River
297583	1863495	CWQ_016	Scarlet Creek	Macal River
271811	1831643	CWQ_017	Rio Blanco	Southern Chiquibul
272685	1830682	CWQ_018	Rio Blanco	Southern Chiquibul
274966	1829082	CWQ_019	Ceibo Chico	Southern Chiquibul
276625	1831366	CWQ_020	Mal Pago Creek	Southern Chiquibul
276901	1831941	CWQ_021	Ceibo Grande	Southern Chiquibul
281332	1837891	CWQ_022	Natural Arch	Chiquibul River
282995	1836489	CWQ_023	Chiquibul Crossing	Chiquibul River
283562	1833830	CWQ_024	Smokey Branch	Chiquibul River
282895	1833785	CWQ_025	Smokey Branch	Chiquibul River
283111	1834141	CWQ_026	Smokey Branch	Chiquibul River
282724	1865591	CWQ_027	Guacamallo	Macal River
295944	1864255	CWQ_028	Macal-Scarlet Creek	Macal River
293459	1859957	CWQ_029	Raspa-Cut Log Creek	Macal River
291744	1864415	CWQ_030	3 Stroke Camp	Macal River
287330	1864938	CWQ_031	Bailarina	Macal River
282079	1869153	CWQ_032	Vietnam Camp	Macal River
274482	1830714	CWQ_033	Ceibo Chico	Southern Chiquibul
273426	1827877	CWQ_034	Rio Blanco	Southern Chiquibul

Appendix 2: *Table Showing Grids and Localities of Water Quality Sample Points in the Bald Hills Region of MPRFR, 2023.*

X	Y	ID	Name of tributary
302647	1872206	BBWQ01	Upper Macal
301893	1869923	BBWQ02	Upper Macal
304355	1872563	BBWQ03	Upper Macal
305447	1873626	BBWQ04	Upper Macal
307453	1878536	BBWQ05	Upper Macal
307800	1873586	BBWQ06	Upper Macal
310888	1871313	BBWQ07	Upper Macal
311920	1874231	BBWQ08	Upper Macal
313032	1873616	BBWQ09	Upper Macal
298960	1881061	BBWQ10	Privassion
299716	1875717	BBWQ11	Rio On
311634	1875643	BBWQ12	Upper Macal

Appendix 3: *Univariate analysis of Variance*

3.1 Between-Subjects Factors

Locality	1	Macal	44
	2	RaspaCulo	20
	3	Monkey Tail	16
	4	Chiquibul River	20
	5	Southern Chiquibul Rive R	30
	6	Bald Hills	12

3.2 Descriptive Statistic

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Temperature	Macal River	64	25.8344	2.39226	0.29903	25.2368	26.4319	21.10	30.20
	Raspaculo	30	24.8767	2.50237	0.45687	23.9423	25.8111	19.50	30.60
	Monkey Tail	16	24.6500	1.78064	0.44516	23.7012	25.5988	22.40	28.70
	Chiquibul	31	22.9290	1.64827	0.29604	22.3244	23.5336	20.80	26.50
	Southern Chiquibul River	45	21.9844	1.36364	0.20328	21.5748	22.3941	18.60	24.60
	Bald Hills	7	20.5429	0.49281	0.18626	20.0871	20.9986	19.90	21.20
	Total	193	24.0311	2.60358	0.18741	23.6614	24.4007	18.60	30.60
Dissolved Oxygen	Macal River	64	96.9670	15.75600	1.96950	93.0313	100.9028	10.09	125.30
	Raspaculo	30	101.9367	13.66058	2.49407	96.8357	107.0376	80.10	145.90
	Monkey Tail	16	106.2125	12.82762	3.20690	99.3771	113.0479	87.20	136.90
	Chiquibul	31	102.1774	10.09266	1.81270	98.4754	105.8794	82.90	119.20
	Southern Chiquibul River	45	101.2644	9.88624	1.47375	98.2943	104.2346	85.60	133.30
	Bald Hills	7	99.5714	1.19543	0.45183	98.4658	100.6770	98.10	101.50

	Total	193	100.4393	12.98766	0.93487	98.5954	102.2833	10.09	145.90
Salinity	Macal River	64	0.0533	0.03784	0.00473	0.0438	0.0627	0.00	0.18
	Raspaculo	30	0.0710	0.05967	0.01090	0.0487	0.0933	0.02	0.21
	Monkey Tail	16	0.0294	0.01063	0.00266	0.0237	0.0350	0.02	0.05
	Chiquibul	31	0.0677	0.12222	0.02195	0.0229	0.1126	0.01	0.70
	Southern Chiquibul River	45	0.0447	0.02564	0.00382	0.0370	0.0524	0.01	0.10
	Bald Hills	7	0.0257	0.02440	0.00922	0.0032	0.0483	0.01	0.07
	Total	193	0.0534	0.06079	0.00438	0.0447	0.0620	0.00	0.70
SPC	Macal River	64	117.6672	78.06323	9.75790	98.1676	137.1668	42.20	378.80
	Raspaculo	30	152.1900	124.65740	22.75922	105.6422	198.7378	40.00	445.80
	Monkey Tail	16	66.6000	22.76603	5.69151	54.4688	78.7312	43.60	117.50
	Chiquibul	31	100.5323	72.96876	13.10558	73.7671	127.2974	30.30	259.50
	Southern Chiquibul River	45	93.4756	55.00543	8.19972	76.9501	110.0010	15.70	222.00
	Bald Hills	7	58.8714	50.85881	19.22283	11.8349	105.9080	21.90	152.50
	Total	193	108.2746	81.35575	5.85612	96.7240	119.8252	15.70	445.80
pH	Macal River	63	7.6557	0.39815	0.05016	7.5554	7.7560	6.64	8.52
	Raspaculo	30	7.4530	1.40075	0.25574	6.9300	7.9760	0.34	8.54
	Monkey Tail	16	7.8938	0.32348	0.08087	7.7214	8.0661	7.49	8.49
	Chiquibul	31	7.6787	0.35395	0.06357	7.5489	7.8085	7.01	8.44
	Southern Chiquibul River	45	7.4731	0.60318	0.08992	7.2919	7.6543	4.97	8.38
	Bald Hills	7	6.8957	0.77921	0.29451	6.1751	7.6164	6.12	8.04
	Total	192	7.5771	0.71711	0.05175	7.4750	7.6792	0.34	8.54
TDS	Macal River	64	75.8828	51.56527	6.44566	63.0022	88.7634	8.40	246.35
	Raspaculo	30	98.8433	81.10004	14.80677	68.5601	129.1266	26.00	289.90
	Monkey Tail	16	43.3063	14.74392	3.68598	35.4498	51.1627	28.60	76.70
	Chiquibul	31	62.0323	47.33774	8.50211	44.6686	79.3959	13.75	169.00
	Southern Chiquibul River	45	62.5200	35.16847	5.24261	51.9542	73.0858	20.80	144.30
	Bald Hills	7	38.5357	33.47072	12.65074	7.5805	69.4910	14.30	99.45

3.3 Sig. Values for one Way Anova, by Year														
	Temperature		Dissolved Oxygen		Salinity		Conductivity		pH		Total Dissolved Solids		Nitrates	
	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Macal	1.431	0.247	89.35	0.111	0.297	0.744	0.38	0.686	3.062	0.54	0.247	0.782	7.764	0.009
Raspaculo	0.886	0.993	0.731	0.404	0.021	0.888	0.015	0.903	0.141	0.712	0.015	0.903	0.337	0.573
Monkey Tail	9.611	0.008	6.903	0.02	0.481	0.499	1.177	0.296	0.13	0.724	1.234	0.285	10.401	0.01
Chiquibul	0.73	0.491	0.747	0.483	1.069	0.357	0.162	0.851	5.172	0.012	0.488	0.619	15.665	0.001
Southern Chiquibul	0.904	0.413	0.327	0.723	0.946	0.396	0.578	0.565	11.02	0.001	0.351	0.706	6.091	0.025

3.4 Tukey HSD Multiple Comparisons

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Temperature	Macal River	Raspaculo	0.95771	0.44444	0.264	-0.3221	2.2375
		Monkey Tail	1.18438	0.56143	0.287	-0.4323	2.8010
		Chiquibul	2.90534*	0.43954	0.000	1.6397	4.1710
		Southern Chiquibul River	3.84993*	0.39077	0.000	2.7247	4.9751
		Bald Hills	5.29152*	0.79964	0.000	2.9890	7.5941
	Raspaculo	Macal River	-0.95771	0.44444	0.264	-2.2375	0.3221
		Monkey Tail	0.22667	0.62181	0.999	-1.5638	2.0172
		Chiquibul	1.94763*	0.51443	0.003	0.4663	3.4289
		Southern Chiquibul River	2.89222*	0.47344	0.000	1.5289	4.2555
		Bald Hills	4.33381*	0.84313	0.000	1.9060	6.7616
	Monkey Tail	Macal River	-1.18438	0.56143	0.287	-2.8010	0.4323
		Raspaculo	-0.22667	0.62181	0.999	-2.0172	1.5638
		Chiquibul	1.72097	0.61832	0.065	-0.0595	3.5014
		Southern Chiquibul River	2.66556*	0.58466	0.000	0.9820	4.3491

		Bald Hills	4.10714*	0.91024	0.000	1.4861	6.7282
	Chiquibul	Macal River	-2.90534*	0.43954	0.000	-4.1710	-1.6397
		Raspaculo	-1.94763*	0.51443	0.003	-3.4289	-0.4663
		Monkey Tail	-1.72097	0.61832	0.065	-3.5014	0.0595
		Southern Chiquibul River	0.94459	0.46884	0.338	-0.4054	2.2946
		Bald Hills	2.38618	0.84055	0.056	-0.0342	4.8065
	Southern Chiquibul River	Macal River	-3.84993*	0.39077	0.000	-4.9751	-2.7247
		Raspaculo	-2.89222*	0.47344	0.000	-4.2555	-1.5289
		Monkey Tail	-2.66556*	0.58466	0.000	-4.3491	-0.9820
		Chiquibul	-0.94459	0.46884	0.338	-2.2946	0.4054
		Bald Hills	1.44159	0.81611	0.490	-0.9084	3.7916
	Bald Hills	Macal River	-5.29152*	0.79964	0.000	-7.5941	-2.9890
		Raspaculo	-4.33381*	0.84313	0.000	-6.7616	-1.9060
		Monkey Tail	-4.10714*	0.91024	0.000	-6.7282	-1.4861
		Chiquibul	-2.38618	0.84055	0.056	-4.8065	0.0342
		Southern Chiquibul River	-1.44159	0.81611	0.490	-3.7916	0.9084
Dissolved_Oxygen	Macal River	Raspaculo	-4.96964	2.84357	0.502	-13.1577	3.2184
		Monkey Tail	-9.24547	3.59208	0.109	-19.5889	1.0979
		Chiquibul	-5.21039	2.81217	0.435	-13.3080	2.8873
		Southern Chiquibul River	-4.29741	2.50016	0.521	-11.4966	2.9018
		Bald Hills	-2.60440	5.11612	0.996	-17.3363	12.1275
	Raspaculo	Macal River	4.96964	2.84357	0.502	-3.2184	13.1577
		Monkey Tail	-4.27583	3.97841	0.891	-15.7317	7.1800
		Chiquibul	-0.24075	3.29135	1.000	-9.7182	9.2367
		Southern Chiquibul River	0.67222	3.02911	1.000	-8.0501	9.3945
		Bald Hills	2.36524	5.39439	0.998	-13.1679	17.8984
	Monkey Tail	Macal River	9.24547	3.59208	0.109	-1.0979	19.5889
		Raspaculo	4.27583	3.97841	0.891	-7.1800	15.7317
		Chiquibul	4.03508	3.95602	0.911	-7.3563	15.4265

		Southern Chiquibul River	4.94806	3.74067	0.772	-5.8232	15.7193
		Bald Hills	6.64107	5.82379	0.864	-10.1285	23.4107
	Chiquibul	Macal River	5.21039	2.81217	0.435	-2.8873	13.3080
		Raspaculo	0.24075	3.29135	1.000	-9.2367	9.7182
		Monkey Tail	-4.03508	3.95602	0.911	-15.4265	7.3563
		Southern Chiquibul River	0.91297	2.99965	1.000	-7.7245	9.5505
		Bald Hills	2.60599	5.37790	0.997	-12.8797	18.0917
	Southern Chiquibul River	Macal River	4.29741	2.50016	0.521	-2.9018	11.4966
		Raspaculo	-0.67222	3.02911	1.000	-9.3945	8.0501
		Monkey Tail	-4.94806	3.74067	0.772	-15.7193	5.8232
		Chiquibul	-0.91297	2.99965	1.000	-9.5505	7.7245
		Bald Hills	1.69302	5.22152	1.000	-13.3424	16.7284
	Bald Hills	Macal River	2.60440	5.11612	0.996	-12.1275	17.3363
		Raspaculo	-2.36524	5.39439	0.998	-17.8984	13.1679
		Monkey Tail	-6.64107	5.82379	0.864	-23.4107	10.1285
		Chiquibul	-2.60599	5.37790	0.997	-18.0917	12.8797
		Southern Chiquibul River	-1.69302	5.22152	1.000	-16.7284	13.3424
Salinity	Macal River	Raspaculo	-0.01772	0.01330	0.767	-0.0560	0.0206
		Monkey Tail	0.02391	0.01680	0.713	-0.0245	0.0723
		Chiquibul	-0.01446	0.01315	0.881	-0.0523	0.0234
		Southern Chiquibul River	0.00861	0.01170	0.977	-0.0251	0.0423
		Bald Hills	0.02757	0.02393	0.859	-0.0413	0.0965
	Raspaculo	Macal River	0.01772	0.01330	0.767	-0.0206	0.0560
		Monkey Tail	0.04163	0.01861	0.226	-0.0120	0.0952
		Chiquibul	0.00326	0.01540	1.000	-0.0411	0.0476
		Southern Chiquibul River	0.02633	0.01417	0.431	-0.0145	0.0671
		Bald Hills	0.04529	0.02523	0.472	-0.0274	0.1179
	Monkey Tail	Macal River	-0.02391	0.01680	0.713	-0.0723	0.0245
		Raspaculo	-0.04163	0.01861	0.226	-0.0952	0.0120

		Chiquibul	-0.03837	0.01851	0.306	-0.0917	0.0149
		Southern Chiquibul River	-0.01529	0.01750	0.952	-0.0657	0.0351
		Bald Hills	0.00366	0.02724	1.000	-0.0748	0.0821
	Chiquibul	Macal River	0.01446	0.01315	0.881	-0.0234	0.0523
		Raspaculo	-0.00326	0.01540	1.000	-0.0476	0.0411
		Monkey Tail	0.03837	0.01851	0.306	-0.0149	0.0917
		Southern Chiquibul River	0.02308	0.01403	0.570	-0.0173	0.0635
		Bald Hills	0.04203	0.02516	0.553	-0.0304	0.1145
	Southern Chiquibul River	Macal River	-0.00861	0.01170	0.977	-0.0423	0.0251
		Raspaculo	-0.02633	0.01417	0.431	-0.0671	0.0145
		Monkey Tail	0.01529	0.01750	0.952	-0.0351	0.0657
		Chiquibul	-0.02308	0.01403	0.570	-0.0635	0.0173
		Bald Hills	0.01895	0.02443	0.971	-0.0514	0.0893
	Bald Hills	Macal River	-0.02757	0.02393	0.859	-0.0965	0.0413
		Raspaculo	-0.04529	0.02523	0.472	-0.1179	0.0274
		Monkey Tail	-0.00366	0.02724	1.000	-0.0821	0.0748
		Chiquibul	-0.04203	0.02516	0.553	-0.1145	0.0304
		Southern Chiquibul River	-0.01895	0.02443	0.971	-0.0893	0.0514
SPC	Macal River	Raspaculo	-34.52281	17.35704	0.353	-84.5025	15.4568
		Monkey Tail	51.06719	21.92590	0.188	-12.0685	114.2029
		Chiquibul	17.13493	17.16538	0.918	-32.2928	66.5627
		Southern Chiquibul River	24.19163	15.26088	0.609	-19.7521	68.1354
		Bald Hills	58.79576	31.22861	0.416	-31.1271	148.7186
	Raspaculo	Macal River	34.52281	17.35704	0.353	-15.4568	84.5025
		Monkey Tail	85.59000*	24.28403	0.007	15.6641	155.5159
		Chiquibul	51.65774	20.09028	0.110	-6.1923	109.5077
		Southern Chiquibul River	58.71444*	18.48954	0.021	5.4738	111.9551
		Bald Hills	93.31857	32.92711	0.057	-1.4951	188.1323
	Monkey Tail	Macal River	-51.06719	21.92590	0.188	-114.2029	12.0685

		Raspaculo	-85.59000*	24.28403	0.007	-155.5159	-15.6641
		Chiquibul	-33.93226	24.14741	0.724	-103.4648	35.6003
		Southern Chiquibul River	-26.87556	22.83290	0.847	-92.6229	38.8718
		Bald Hills	7.72857	35.54818	1.000	-94.6325	110.0896
	Chiquibul	Macal River	-17.13493	17.16538	0.918	-66.5627	32.2928
		Raspaculo	-51.65774	20.09028	0.110	-109.5077	6.1923
		Monkey Tail	33.93226	24.14741	0.724	-35.6003	103.4648
		Southern Chiquibul River	7.05670	18.30974	0.999	-45.6662	59.7796
		Bald Hills	41.66083	32.82649	0.801	-52.8631	136.1848
	Southern Chiquibul River	Macal River	-24.19163	15.26088	0.609	-68.1354	19.7521
		Raspaculo	-58.71444*	18.48954	0.021	-111.9551	-5.4738
		Monkey Tail	26.87556	22.83290	0.847	-38.8718	92.6229
		Chiquibul	-7.05670	18.30974	0.999	-59.7796	45.6662
		Bald Hills	34.60413	31.87197	0.887	-57.1713	126.3795
	Bald Hills	Macal River	-58.79576	31.22861	0.416	-148.7186	31.1271
		Raspaculo	-93.31857	32.92711	0.057	-188.1323	1.4951
		Monkey Tail	-7.72857	35.54818	1.000	-110.0896	94.6325
		Chiquibul	-41.66083	32.82649	0.801	-136.1848	52.8631
		Southern Chiquibul River	-34.60413	31.87197	0.887	-126.3795	57.1713
pH	Macal River	Raspaculo	0.20271	0.15576	0.784	-0.2458	0.6513
		Monkey Tail	-0.23804	0.19658	0.831	-0.8041	0.3280
		Chiquibul	-0.02300	0.15405	1.000	-0.4666	0.4206
		Southern Chiquibul River	0.18260	0.13705	0.767	-0.2121	0.5773
		Bald Hills	0.76000	0.27976	0.077	-0.0456	1.5656
	Raspaculo	Macal River	-0.20271	0.15576	0.784	-0.6513	0.2458
		Monkey Tail	-0.44075	0.21737	0.331	-1.0667	0.1852
		Chiquibul	-0.22571	0.17983	0.809	-0.7436	0.2922
		Southern Chiquibul River	-0.02011	0.16551	1.000	-0.4967	0.4565
		Bald Hills	0.55729	0.29474	0.411	-0.2915	1.4060

	Monkey Tail	Macal River	0.23804	0.19658	0.831	-0.3280	0.8041
		Raspaculo	0.44075	0.21737	0.331	-0.1852	1.0667
		Chiquibul	0.21504	0.21615	0.919	-0.4074	0.8375
		Southern Chiquibul River	0.42064	0.20438	0.314	-0.1679	1.0092
		Bald Hills	.99804*	0.31820	0.024	0.0817	1.9144
	Chiquibul	Macal River	0.02300	0.15405	1.000	-0.4206	0.4666
		Raspaculo	0.22571	0.17983	0.809	-0.2922	0.7436
		Monkey Tail	-0.21504	0.21615	0.919	-0.8375	0.4074
		Southern Chiquibul River	0.20560	0.16390	0.809	-0.2664	0.6776
		Bald Hills	0.78300	0.29384	0.087	-0.0632	1.6292
	Southern Chiquibul River	Macal River	-0.18260	0.13705	0.767	-0.5773	0.2121
		Raspaculo	0.02011	0.16551	1.000	-0.4565	0.4967
		Monkey Tail	-0.42064	0.20438	0.314	-1.0092	0.1679
		Chiquibul	-0.20560	0.16390	0.809	-0.6776	0.2664
		Bald Hills	0.57740	0.28530	0.333	-0.2442	1.3990
	Bald Hills	Macal River	-0.76000	0.27976	0.077	-1.5656	0.0456
		Raspaculo	-0.55729	0.29474	0.411	-1.4060	0.2915
		Monkey Tail	-.99804*	0.31820	0.024	-1.9144	-0.0817
		Chiquibul	-0.78300	0.29384	0.087	-1.6292	0.0632
		Southern Chiquibul River	-0.57740	0.28530	0.333	-1.3990	0.2442
TDS	Macal River	Raspaculo	-22.96052	11.32502	0.331	-55.5709	9.6499
		Monkey Tail	32.57656	14.30608	0.209	-8.6178	73.7709
		Chiquibul	13.85055	11.19996	0.818	-18.3998	46.1009
		Southern Chiquibul River	13.36281	9.95732	0.761	-15.3093	42.0349
		Bald Hills	37.34710	20.37585	0.447	-21.3252	96.0194
	Raspaculo	Macal River	22.96052	11.32502	0.331	-9.6499	55.5709
		Monkey Tail	55.53708*	15.84469	0.007	9.9123	101.1619
		Chiquibul	36.81108	13.10838	0.061	-0.9345	74.5567
		Southern Chiquibul River	36.32333*	12.06394	0.035	1.5852	71.0615

		Bald Hills	60.30762	21.48408	0.061	-1.5558	122.1711
	Monkey Tail	Macal River	-32.57656	14.30608	0.209	-73.7709	8.6178
		Raspaculo	-55.53708*	15.84469	0.007	-101.1619	-9.9123
		Chiquibul	-18.72601	15.75555	0.842	-64.0942	26.6421
		Southern Chiquibul River	-19.21375	14.89787	0.790	-62.1122	23.6847
		Bald Hills	4.77054	23.19425	1.000	-62.0174	71.5584
	Chiquibul	Macal River	-13.85055	11.19996	0.818	-46.1009	18.3998
		Raspaculo	-36.81108	13.10838	0.061	-74.5567	0.9345
		Monkey Tail	18.72601	15.75555	0.842	-26.6421	64.0942
		Southern Chiquibul River	-0.48774	11.94662	1.000	-34.8881	33.9126
		Bald Hills	23.49654	21.41842	0.882	-38.1778	85.1709
	Southern Chiquibul River	Macal River	-13.36281	9.95732	0.761	-42.0349	15.3093
		Raspaculo	-36.32333*	12.06394	0.035	-71.0615	-1.5852
		Monkey Tail	19.21375	14.89787	0.790	-23.6847	62.1122
		Chiquibul	0.48774	11.94662	1.000	-33.9126	34.8881
		Bald Hills	23.98429	20.79562	0.858	-35.8968	83.8653
	Bald Hills	Macal River	-37.34710	20.37585	0.447	-96.0194	21.3252
		Raspaculo	-60.30762	21.48408	0.061	-122.1711	1.5558
		Monkey Tail	-4.77054	23.19425	1.000	-71.5584	62.0174
		Chiquibul	-23.49654	21.41842	0.882	-85.1709	38.1778
		Southern Chiquibul River	-23.98429	20.79562	0.858	-83.8653	35.8968
*. The mean difference is significant at the 0.05 level.							