Droughts in Iguaçu River: a big impact in the hydroelectric power in Brazil

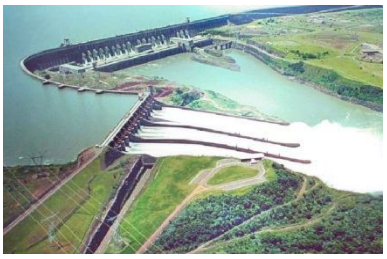
OBJECTIVE

The main objective of this project is to correlate the droughts in Iguaçu River (located in the Paraná basin of Brazil) with the supply of energy from hydroelectric power plants using the ArcGIS tools.

HYDROLOGY DESCRIPTION OF THE REGION UNDER STUDY

Hydroelectric power plants produce over 90% of the electrical energy consumed in Brazil. The main hydroelectric power plant is Itaipu Dam and it is built on the Paraná River dividing Brazil and Paraguay. The dam is the largest operating hydroelectric facility in terms of annual energy generation, generating 91.6 TWh in 2009. This dam supplies 25% of the annual energy consumed in Brazil and 75% of Paraguay's electric power needs. Paraná River is the second largest river in Brazil with 4,880 km long. Paraná River flows southward and forms a natural boundary between Paraguay and Brazil until the confluence with the Iguaçu River. Shortly upstream from this confluence, the river is dammed by the Itaipu Dam.





Iguaçu River has an average flow rate of 1,746 m³/s. The name "Iguaçu" comes from the Guarani or Tupi (indigene dialect) words "big water". The Iguaçu River originates in the Serra do Mar coastal mountains of the Brazilian state of Paraná. For 1,205 kilometres (749 mi), the Iguaçu flows west through Paraná State, Brazil. Downriver from the confluence the Iguaçu River forms the boundary between Brazil and Argentina's Misiones Province. Continuing west, the river drops off a plateau, forming the Iguaçu Falls. The falls are within national parks in both Brazil and Argentina. It empties into the Paraná River at the point where the borders of Argentina, Brazil, and Paraguay join, an area known as the Triple Frontier.

The Iguaçu Falls currently has the second-greatest average annual flow of any waterfall in the world, after Niagara, with an average rate of 1,746 m³/s (61,660 cu ft). Its maximum recorded flow was

12,800 m³/s (452,000 cu ft/s). By comparison, the average flow of Niagara Falls is 2,400 m³/s (85,000 cu ft), with a maximum recorded flow of 8,300 m³/s (293,000 cu ft/s). On November 11 of 2011, Iguaçu Falls was announced as one of the seven winners of the New Seven Wonders of Nature by the New Seven Wonders of the World Foundation.

PROPOSED METHOD

This project will use data to provide digital information to the flow rate of the Iguaçu River and the supply of energy of hydroelectric power plants located in this river. The hydroelectric power plants that are going to be evaluated are: Foz do Areia (installed capacity 1,676 MW), Salto Osório (installed capacity 1,078 MW), Segredo (installed capacity 1,260 MW), Salto Santiago (installed capacity 1,420 MW), and Salto Caxias (installed capacity 1,240 MW).

- Coordinates of Salto Osório: 25°32′06″S 53°00′33″W
- Coordinates of Foz do Areia: 26°00′34″S 51°40′00″W
- Coordinates of Segredo: 25°47′30″S 52°06′88″W
- Coordinates of Salto Santiago: 25°37′04″S 52°36′48″W
- Coordinates of Salto Caxias: 25°32′66″S 53°29′54″W

The analysis that are going to described on this report relates to the year of 2006, where a big drought during the months of May, June, July and August caused the Iguaçu River to become diminished, reducing the amount of water flowing and consequently having an impact in the generation and supply of energy to this region.

DATA SOURCE

The sources used to carry out this project are from Brazilian water and electric agencies.

The data used in this project is public knowledge.

- **Data River Flow, Watershed, Subwatershed, Flowlines:**

http://hidroweb.ana.gov.br/HidroWeb.asp?TocItem=4100

- **Tables with hydroelectric power plants series of flow and generation:**

http://www.ons.org.br/operacao/vazoes_naturais.aspx

- **Precipitation data series:**

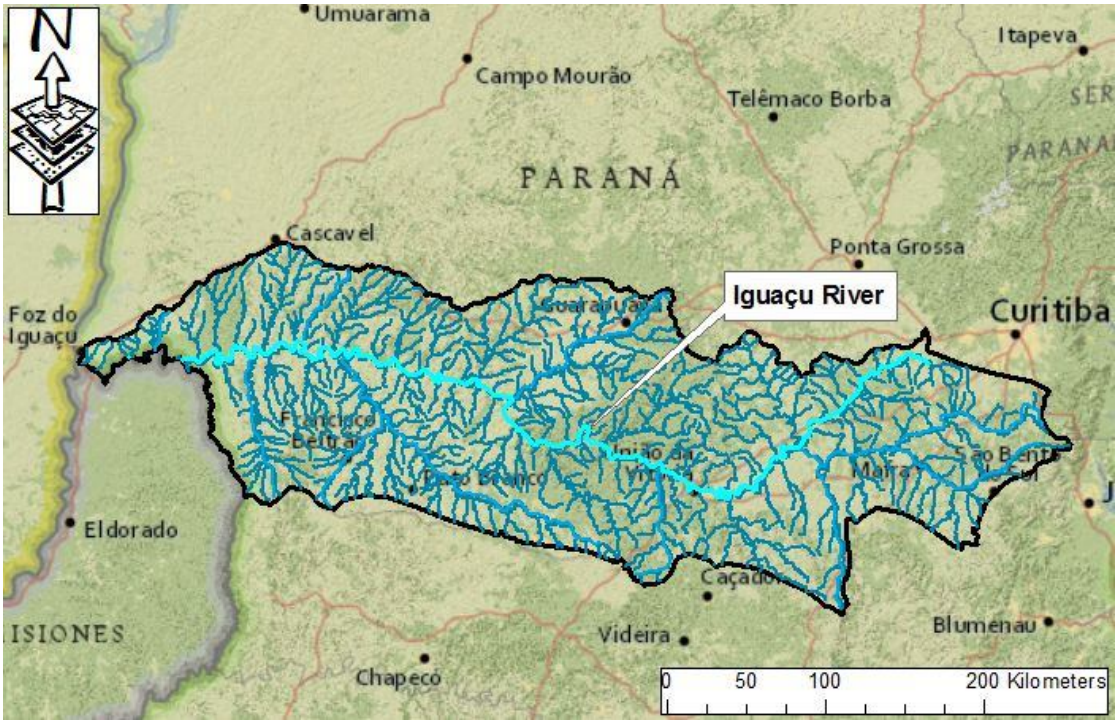
http://www.cprm.gov.br/publique/cgi/cgilua.exe/sys/start.htm?infoid=1351&sid=9

USING GIS TOOLS TO ILLUSTRATE THE WATERSHED AND THE AREA UNDER STUDY

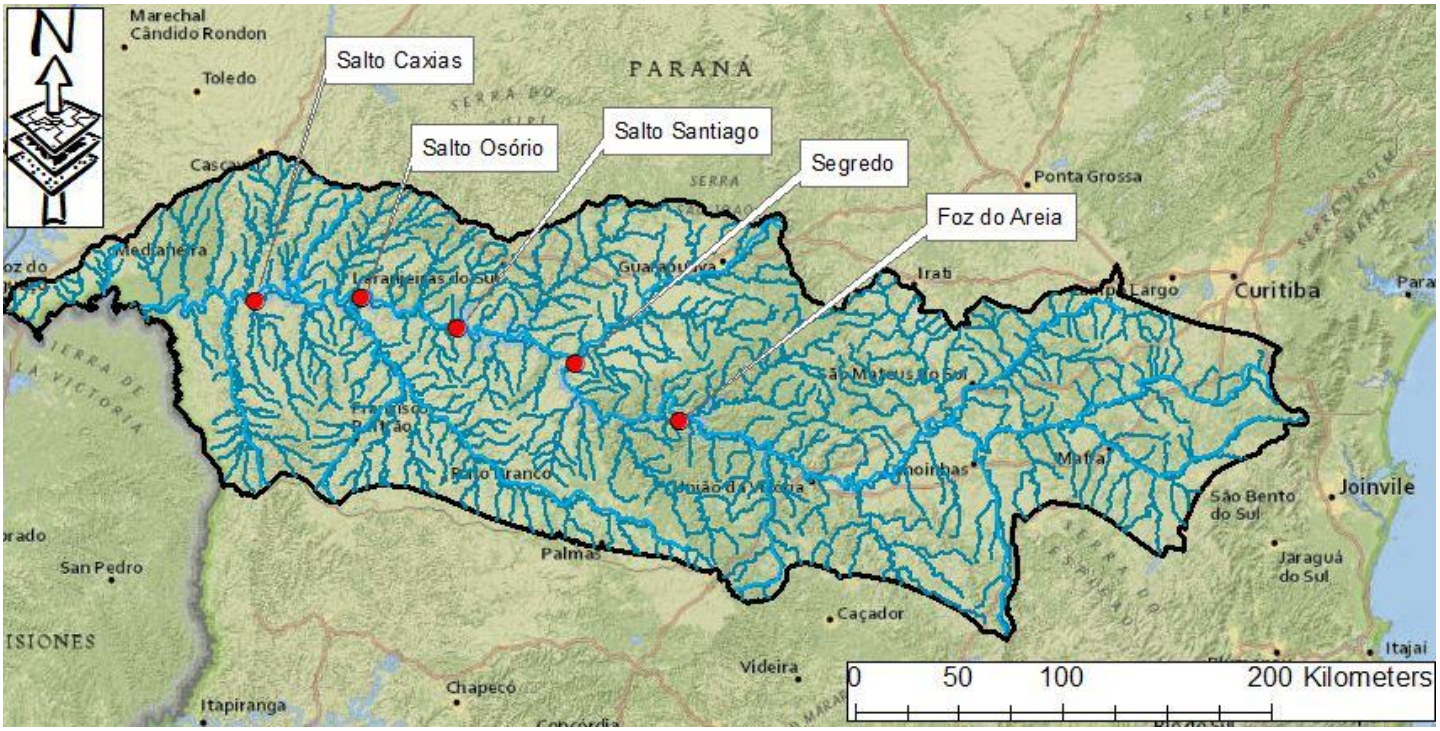
Paraná Watershed and Base Map

Subwatershed of Paraná Basin – Iguaçu Subwatershed will be the case study for this project.

Creating a Iguaçu Basin Boundary and flowlines within the area of study (select by location)



Locating the hydroelectric power plants of study in the subwatershed (Creating a feature class out of the coordinate points)



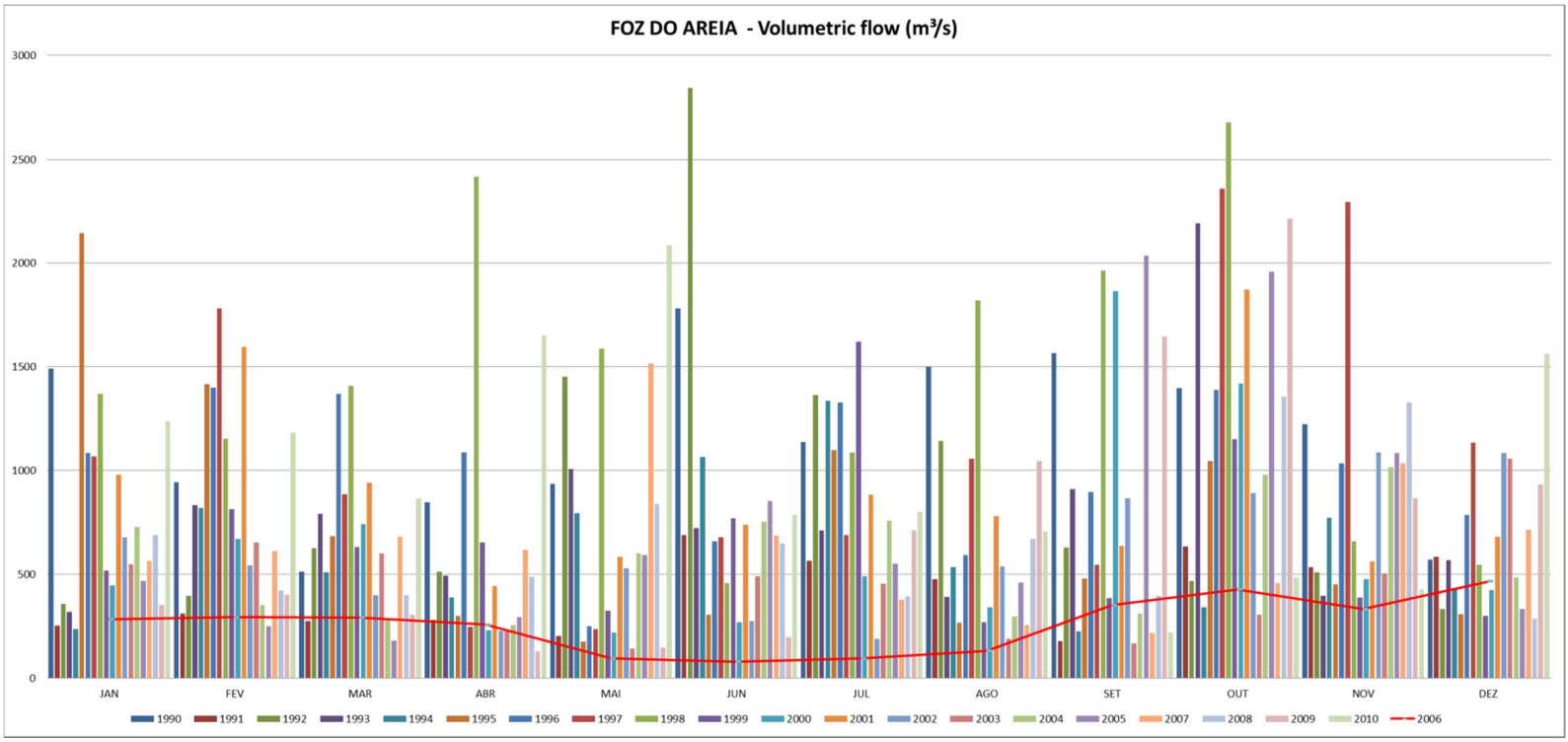
DATA ANALYSIS

Average flow rates of the River from 1990 through 2010, were analyzed. The precipitation data from this period made this study accurate. Flow rates and the precipitation data were exported to the ArcGIS Base data. Using ArcGIS Interpolation tool to the subwatershed precipitation was helpful to understand the drought season of the year 2006. The data analysis is presented in the next pages of this report.

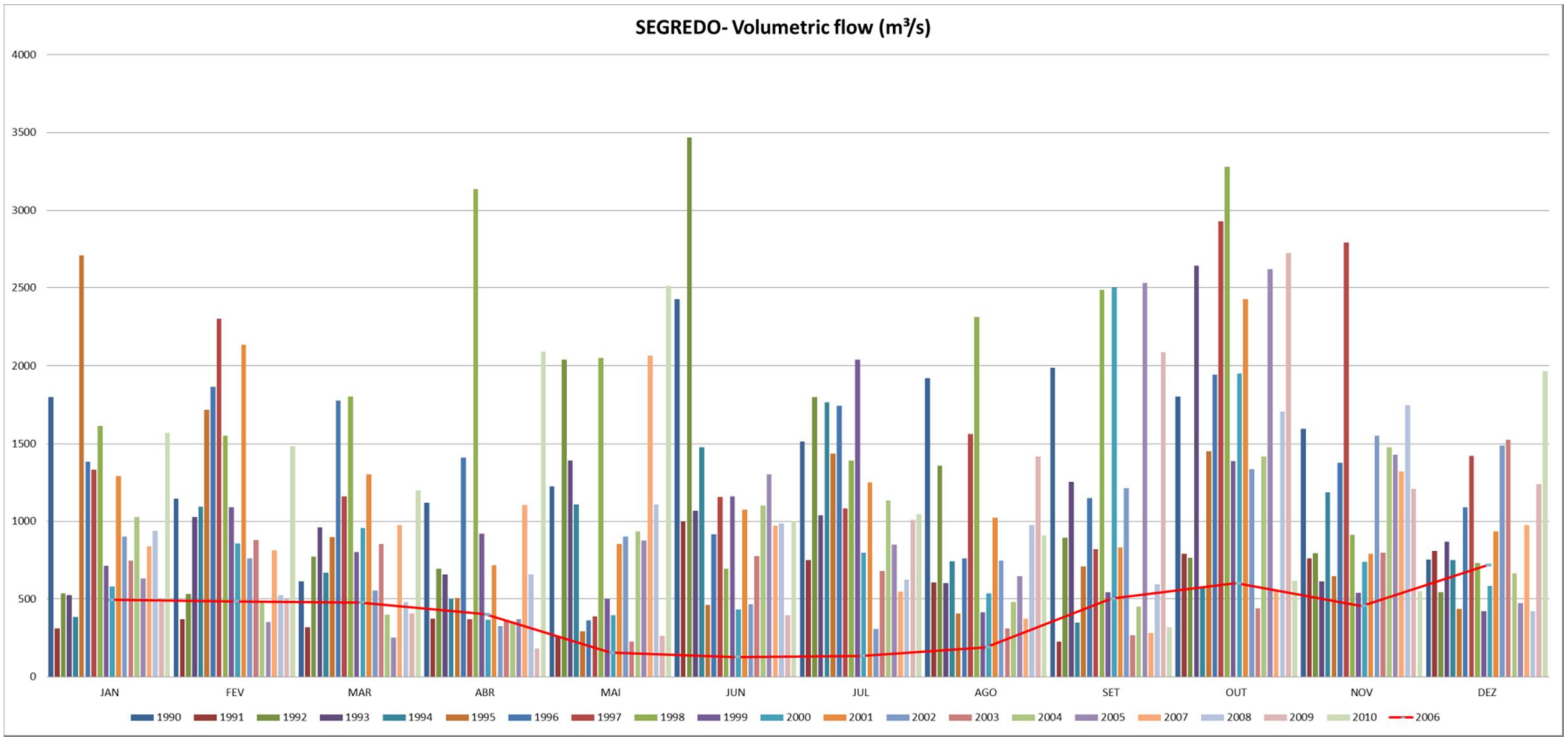
Flow rate data analysis (1990_2010):

This project analyzed the Flow rate data (monthly average) to study and understand the big drought that occurred in 2006. The graphs showed below represent this study. The flow rate values for the year 2006 are illustrated with a red line. The remaining years from the series 1990 through 2010 are represented as bar graphs. Furthermore, each of the graphs below represents one of the hydroelectric plants that are under study in this project (Foz do Areia, Segredo, Salto Osório, Salto Caxias, and Salto Santiago).
The data used to build these graphs can be found in the appendix of this report.

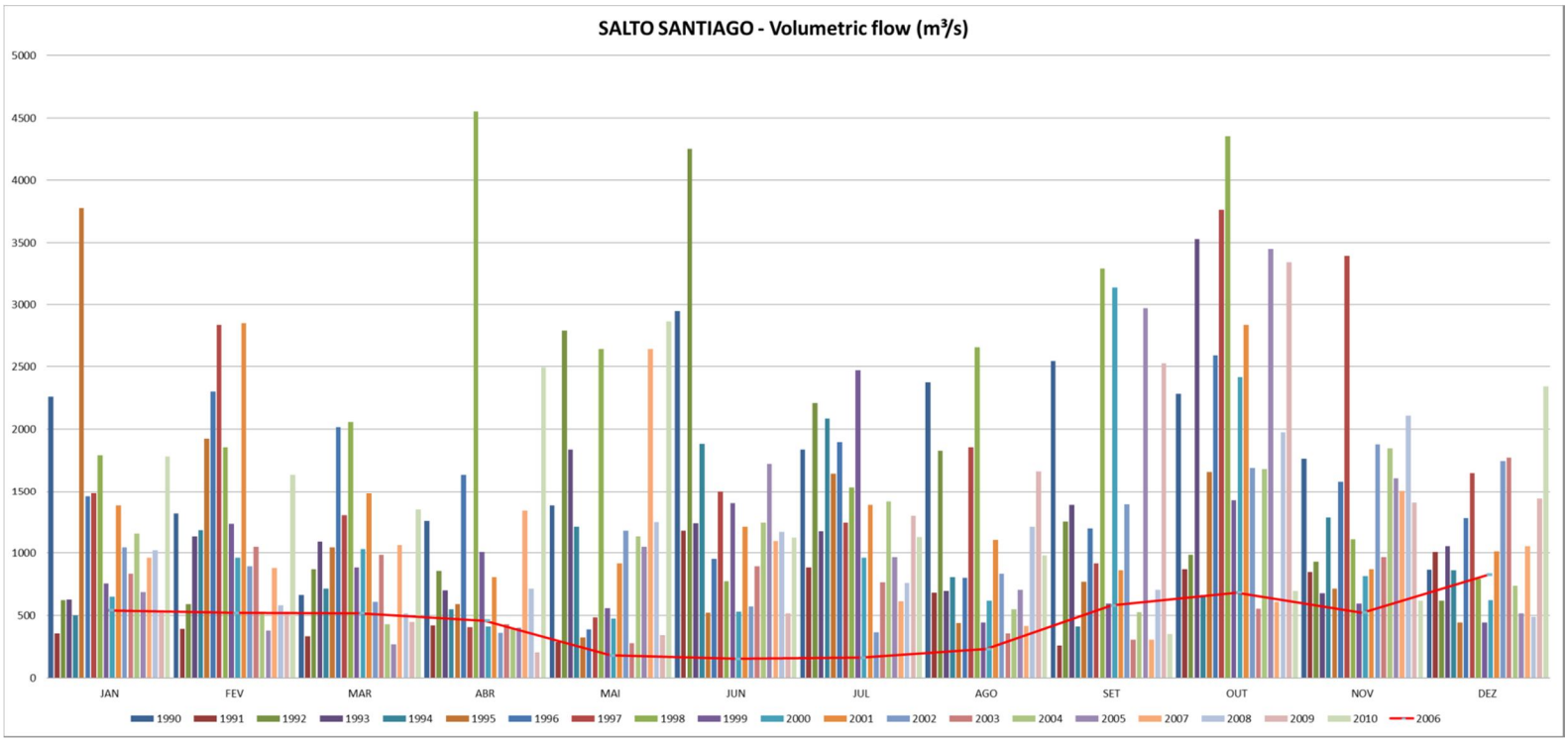
- ✓ Hydroelectric Plant Foz do Areia:



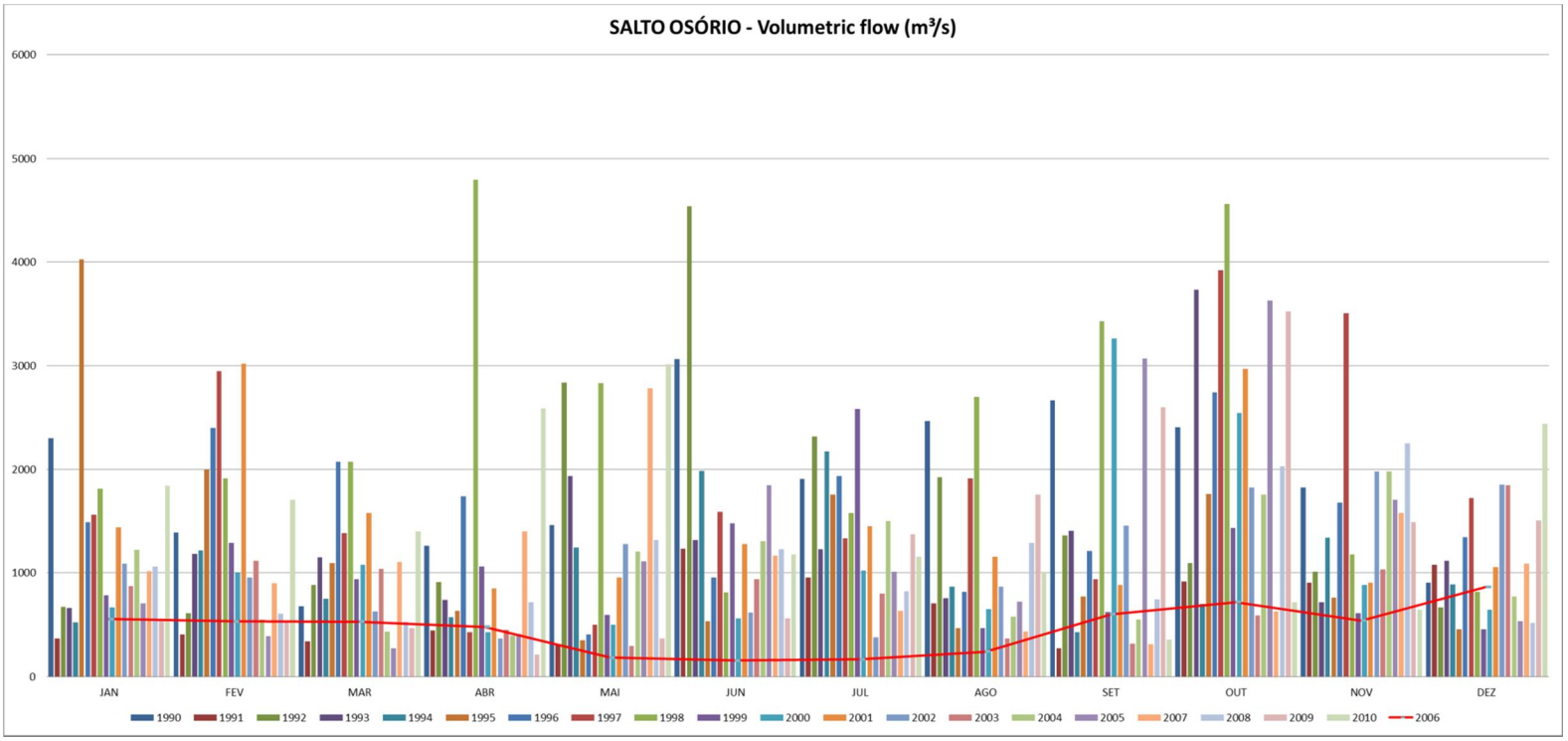
✓ Hydroelectric Plant Segredo:



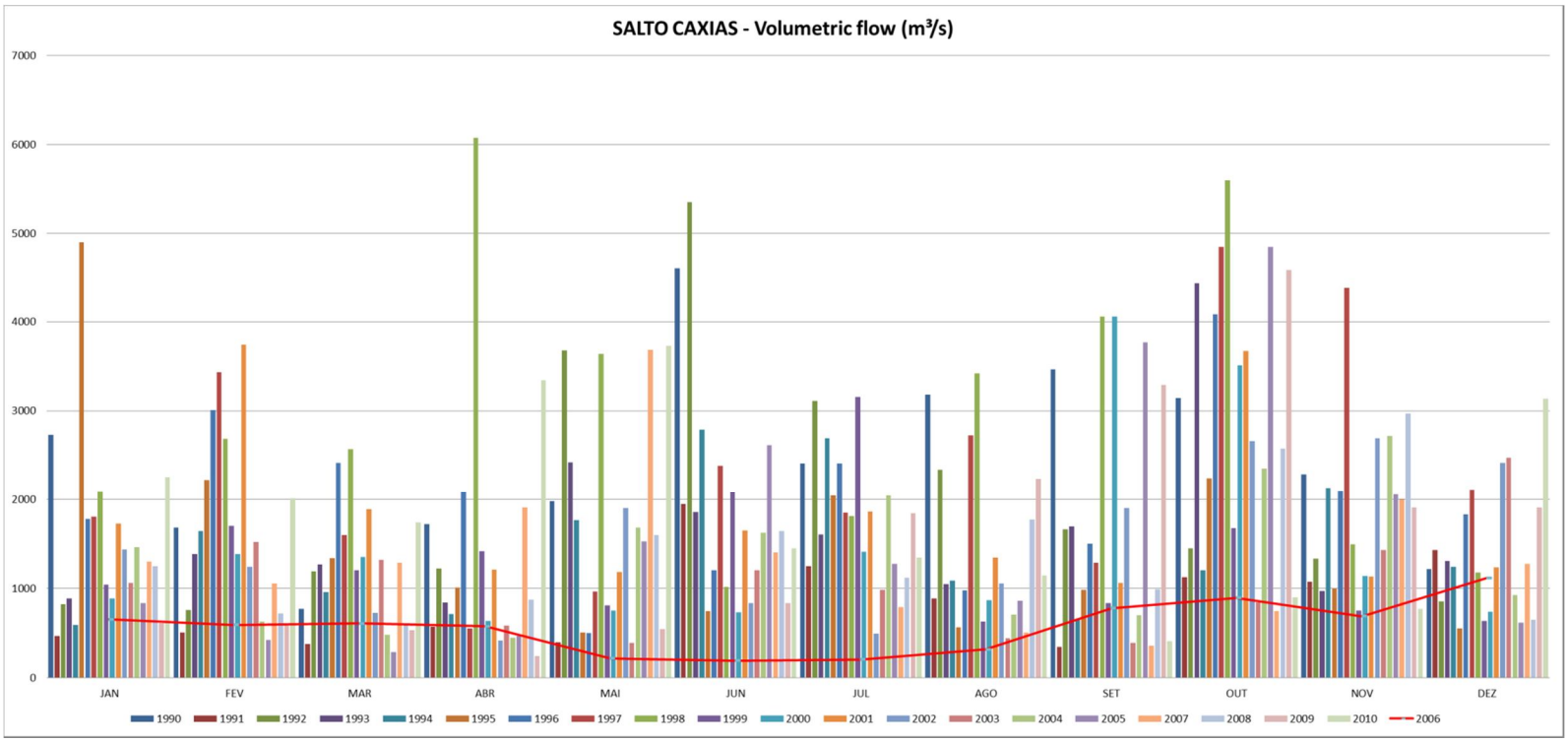
✓ Hydroelectric Plant Salto Santiago:



✓ Hydroelectric Plant Salto Osório:

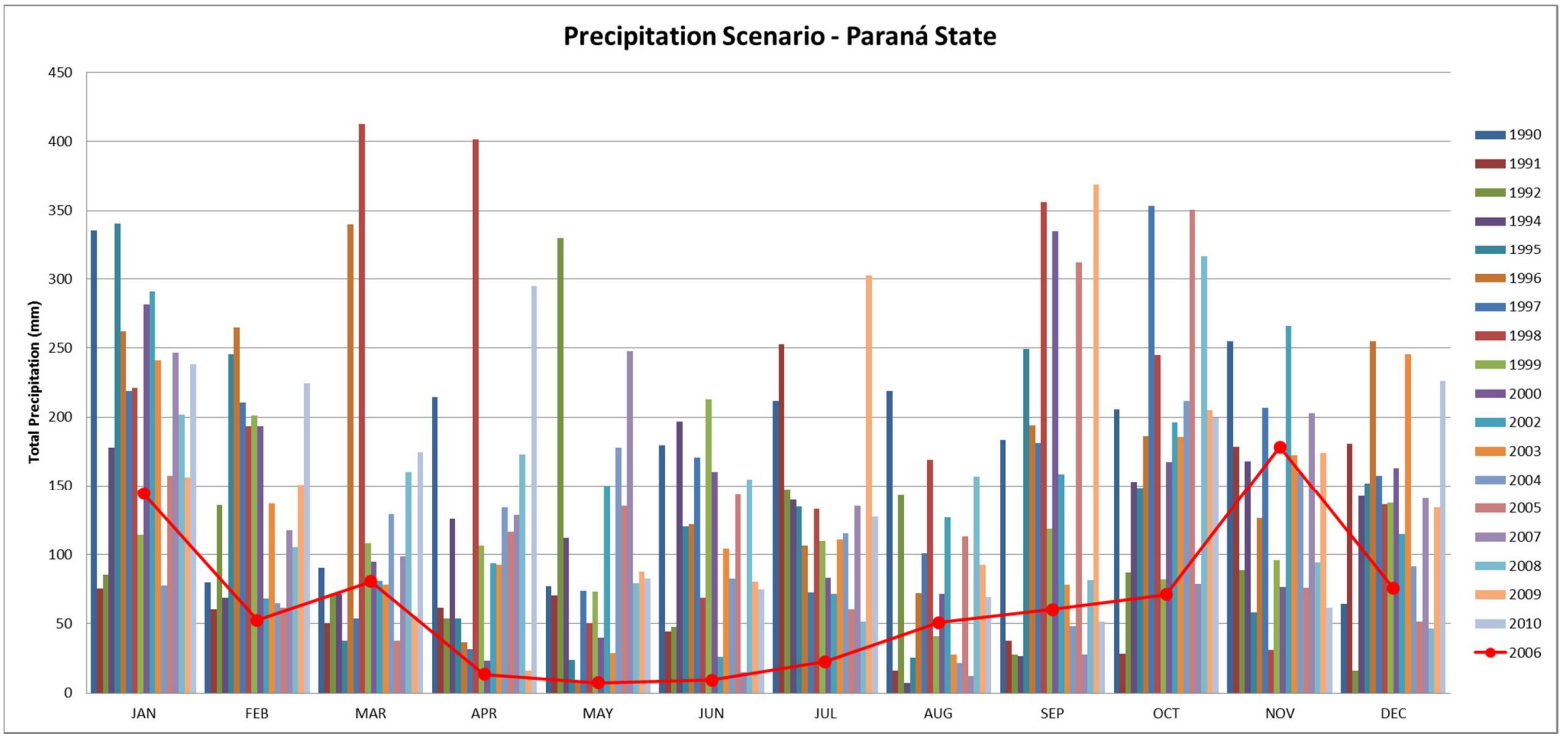


✓ Hydroelectric Plant Salto Caxias:



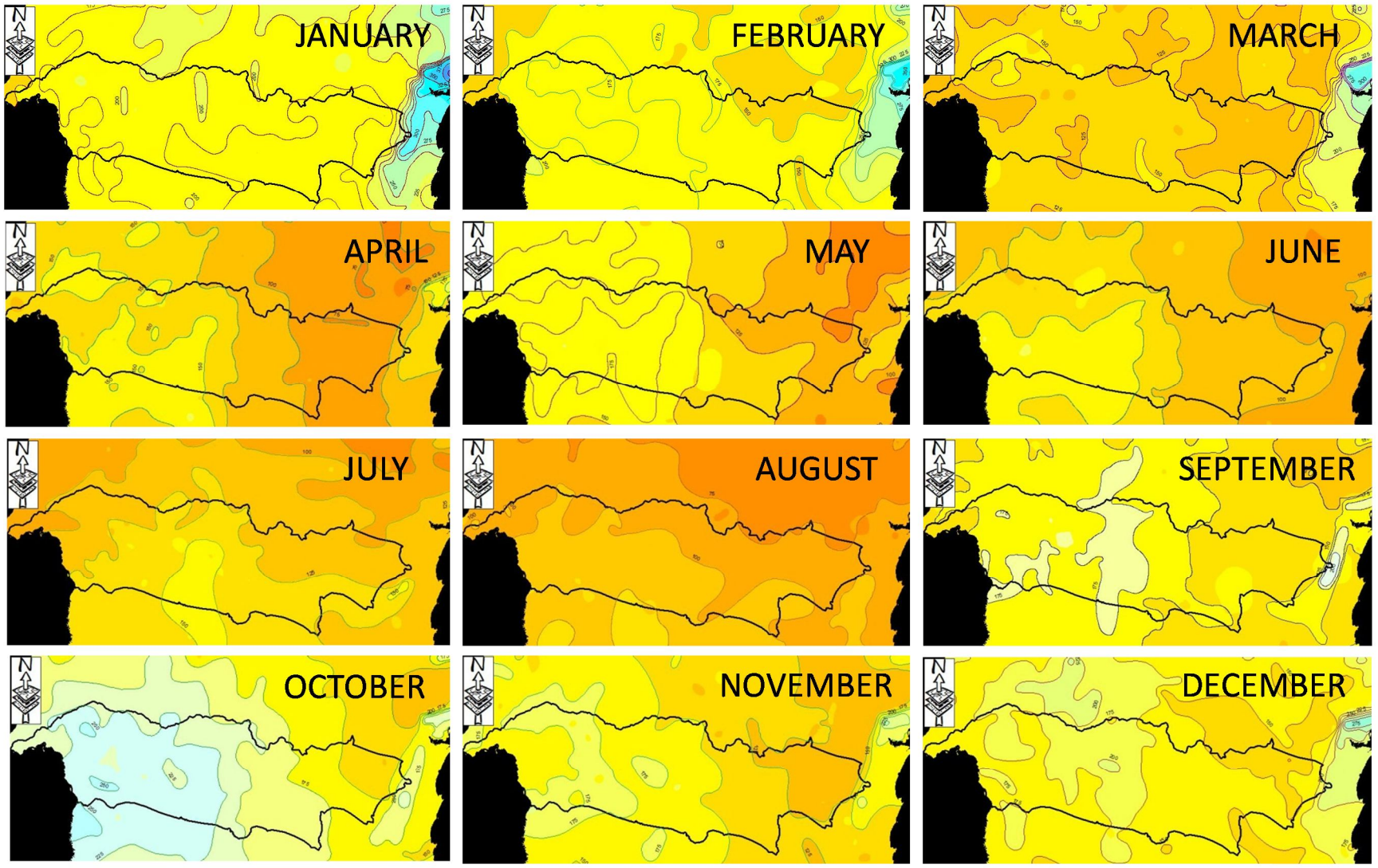
Precipitation data analysis (1990_2010):

A similar study was made for the monthly total precipitation data. This project analyzed the monthly total precipitation of Paraná State to study and understand the big drought that occurred in 2006. The graph showed below represents this study. The total precipitation values for the year 2006 are illustrated with a red line. The remaining years from the series 1990 through 2010 are represented as bar graphs.
The data used to build this graph can be found in the appendix of this report.



Precipitation data analysis using ArcGIS tools (1990_2010):

To make this study even more complete, the Interpolation tool from ArcGIS was utilized to study the precipitation of Iguaçu Subwatershed. The Spline method was used and the result can be found in the pictures below. The interpolation method was made for each month using a raster file. As result, we can understand how the average monthly precipitation values of Paraná State are predicted using an ArcGIS image.


JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Total Precipitation (average - 1990 2010)
125 mm
150mm
175mm
200mm
225mm
250mm
300mm
325mm
350mm
400mm

CONCLUSION

It was clear after developing this project that the ArcGIS could be very useful to demonstrate graphically and predict the impact of a drought year to the distribution of energy.

Hydroelectric power plants produce over 90% of the electrical energy consumed in Brazil. The five hydroelectric studied in this project distribute the energy to Paraná State and more that 30% are distributed to other regions in Brazil.

The energy in Brazil is interconnected and controlled by the National Interconnected System (SIN). The National Interconnected System, which covers almost the entire country, allows different regions to exchange power among them. This system is very useful for linking energy generators, being mostly hydroelectric plants located far from consumers and dependent on regional rainfall, have ups and downs in their productivity. The subsystems of the SIN are all interconnected, so enjoy the best seasonal rivers and exchanging surplus electricity during the flood period in each region. Hence, the during the drought season of 2006, the Paraná State had their energy supplied by other region of Brazil.

The table below represents the energy distribution by source in the Paraná State.

Source	Plant quantity	Potência (kW)	%
Wind Power Plant	2	2.502	0,01
Small Hydroelectric Power Plants	31	230.996	1,30
Hydroelectric Power Plants	20	16.415.821	92,42
Thermoelectric Power Plants	63	1.112.368	6,26
Total	**148**	**17.761.687**	**100**

As we can see, most of the energy comes from Hydroelectric Power Plants. Once again the drought in the year 2006 had a big impact in the energy distribution of Paraná State. The energy came from other States and from the Thermoelectric Plants. GIS tools can be really helpful to manage the exchange energy among the Brazilian regions and to predict a dry season if you have a data set updated.

APPENDIX

✓ Monthly average Flow rate (m^3/s) - Foz do Areia

FOZ DO AREIA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1931	710	398	382	195	1241	1383	895	415	1119	851	415	637	720
1932	547	756	756	1445	979	844	482	437	606	772	534	876	753
1933	277	370	292	174	178	133	156	115	251	554	321	170	249
1934	273	649	473	529	362	201	175	165	206	489	196	555	356
1935	296	258	477	218	125	287	354	817	1142	3415	1041	575	750
1936	1152	392	267	169	235	1321	353	953	1008	858	783	484	665
1937	494	397	770	691	377	288	191	336	289	1221	1126	509	557
1938	494	1097	352	413	899	1520	2104	541	503	478	423	334	763
1939	369	448	760	451	563	456	481	217	516	315	1004	1803	615
1940	628	432	248	403	491	239	191	292	254	271	238	353	337
1941	635	1097	498	321	437	580	375	967	542	616	684	748	625
1942	378	1078	706	802	610	816	815	568	443	474	227	200	593
1943	243	416	299	169	162	612	436	794	660	748	483	263	440
1944	520	296	847	304	142	115	101	87	233	153	483	455	311
1945	128	268	468	193	132	231	953	255	220	376	269	296	316
1946	621	2198	1809	671	439	635	1156	534	539	924	633	674	903
1947	555	994	764	322	255	660	493	832	1552	1554	539	607	761
1948	513	740	661	491	650	472	343	1280	438	504	697	209	583
1949	277	150	280	659	391	606	246	257	312	289	207	187	322
1950	639	523	939	314	359	273	270	185	293	1292	536	460	507
1951	511	1101	1178	344	175	172	201	102	104	890	897	636	526
1952	316	275	207	164	92	414	290	171	758	1217	914	405	435
1953	465	503	366	279	216	259	178	153	466	848	1272	518	460
1954	862	512	681	413	1794	1380	819	418	578	1181	464	277	782
1955	242	220	359	551	885	1741	2105	795	799	277	201	295	706
1956	447	593	276	605	1119	530	473	702	578	401	228	181	511
1957	310	784	371	319	282	514	2039	3182	3036	1226	1010	553	1136
1958	376	296	655	337	200	410	307	534	1044	561	523	638	490
1959	468	545	311	293	399	401	271	322	633	334	187	149	359
1960	200	351	305	385	335	418	313	958	807	834	1021	461	532
1961	438	381	1087	617	508	543	302	161	955	1076	1612	616	691
1962	372	491	815	347	242	280	220	169	587	1123	539	233	452
1963	369	766	728	571	185	150	106	102	139	1100	1343	747	526
1964	246	427	329	436	596	557	679	773	947	479	271	305	504
1965	273	407	445	238	1511	539	1462	748	662	1345	949	1085	805
1966	703	1395	943	336	306	453	585	272	766	1027	1034	776	716
1967	667	869	1116	542	218	515	382	383	438	332	382	639	540
1968	465	393	225	253	167	159	186	141	164	199	479	335	264
1969	459	541	565	1207	686	1334	979	325	343	743	920	504	717
1970	478	444	337	288	505	1063	1277	352	469	831	343	858	604
1971	2224	788	845	802	1121	1506	1037	526	392	624	217	199	857
1972	406	960	888	509	184	456	561	956	1942	1765	780	762	847
1973	670	660	491	484	769	909	1260	1073	1896	1348	754	434	896
1974	806	819	802	418	225	439	656	449	650	276	326	225	508
1975	447	350	490	286	208	242	290	728	885	1765	757	1892	695
1976	1072	748	774	669	500	1556	574	1198	867	545	855	673	836

1977	828	1002	746	751	284	318	328	424	372	1048	705	676	624
1978	271	211	372	173	132	180	470	542	637	337	463	435	352
1979	303	164	249	241	1539	406	350	486	859	1639	1590	1105	744
1980	627	569	929	439	405	330	952	955	1580	833	605	1033	771
1981	1341	679	287	262	217	182	119	149	221	539	602	853	454
1982	330	544	368	182	193	719	1846	657	342	1088	2165	1477	826
1983	790	817	1238	683	2010	2169	5150	1658	1158	1332	739	588	1528
1984	434	255	354	417	631	1102	601	1747	779	595	1037	645	716
1985	274	595	392	781	296	179	191	110	183	143	256	82	290
1986	166	430	433	390	405	346	144	276	438	512	570	903	418
1987	848	773	277	311	1814	1386	666	439	321	544	344	229	663
1988	287	410	417	265	1580	1229	401	179	216	439	312	197	494
1989	824	1259	690	705	940	280	459	898	1736	714	322	201	752
1990	1490	943	512	847	934	1781	1137	1498	1565	1396	1222	571	1158
1991	253	311	275	279	203	689	564	476	177	634	535	585	415
1992	357	396	626	512	1452	2845	1363	1143	628	468	509	334	886
1993	320	833	791	493	1006	722	710	391	911	2194	396	568	778
1994	236	820	510	389	795	1064	1337	535	224	342	772	433	621
1995	2148	1415	683	299	174	304	1097	267	480	1045	452	307	723
1996	1085	1399	1370	1086	249	659	1327	593	897	1389	1034	787	990
1997	1069	1781	885	248	237	678	688	1056	546	2362	2296	1134	1082
1998	1370	1153	1407	2418	1587	458	1088	1818	1963	2679	660	545	1429
1999	519	814	632	654	325	770	1620	268	385	1151	388	299	652
2000	445	669	743	231	219	269	490	342	1863	1420	477	425	633
2001	979	1596	942	443	585	740	882	780	637	1872	562	682	892
2002	677	543	399	229	528	276	189	537	866	892	1088	1084	609
2003	547	652	602	229	142	491	454	189	168	304	504	1056	445
2004	727	351	289	256	602	753	759	296	312	978	1015	486	569
2005	467	251	182	293	593	852	552	461	2036	1957	1083	332	755
2006	284	294	292	257	95	80	95	132	352	428	332	466	259
2007	564	612	681	618	1516	686	376	255	218	458	1034	715	644
2008	690	422	399	488	838	647	393	669	397	1356	1329	287	660
2009	351	401	306	128	147	197	711	1047	1647	2218	865	931	746
2010	1238	1181	866	1651	2089	785	800	707	220	485	427	1563	1001
MIN	128	150	182	128	92	80	95	87	104	143	187	82	249
MED	590	664	597	478	590	665	705	596	717	929	698	585	651
MAX	2224	2198	1809	2418	2089	2845	5150	3182	3036	3415	2296	1892	1528

✓ Monthly average Flow rate (m^3/s) - Segredo

SEGREDO

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1931	905	489	460	253	1608	1744	1158	519	1352	1029	518	761	900
1932	679	943	1029	1832	1262	1162	673	580	847	1122	671	1033	986
1933	341	442	370	214	229	158	189	131	297	663	405	212	304
1934	344	785	587	687	476	266	225	207	265	611	247	682	449
1935	356	302	586	288	167	450	528	1118	1466	3962	1271	738	936
1936	1446	488	326	210	328	1844	512	1246	1252	1047	926	583	851
1937	640	499	927	832	478	365	245	414	371	1472	1446	655	695

1938	620	1376	448	521	1194	1904	2530	681	617	578	518	395	949
1939	448	546	933	559	748	584	654	281	645	408	1320	2180	776
1940	819	551	323	580	650	333	256	349	314	322	313	452	439
1941	760	1400	658	455	630	799	526	1284	718	782	913	944	822
1942	521	1249	884	1062	787	1029	1039	737	561	599	297	241	751
1943	285	475	354	209	191	782	552	959	797	927	631	332	541
1944	610	354	967	377	169	139	121	101	269	183	589	537	368
1945	158	322	551	231	154	272	1116	320	277	457	358	413	386
1946	849	2650	2076	808	574	872	1496	674	639	1244	828	942	1138
1947	726	1244	903	461	350	968	677	1043	1950	1819	684	749	965
1948	626	953	812	586	864	611	455	1433	535	716	908	274	731
1949	320	182	334	784	519	775	306	313	362	370	256	237	397
1950	807	707	1165	406	497	352	383	249	391	1682	736	576	663
1951	676	1327	1483	431	224	231	258	133	130	1212	1210	844	680
1952	413	350	252	248	120	579	391	229	1012	1604	1208	534	578
1953	560	660	469	405	341	381	253	208	742	1198	1576	751	629
1954	1208	702	808	550	2162	1716	1086	546	870	1554	641	398	1020
1955	343	294	445	701	1184	2174	2464	1054	1008	355	282	353	888
1956	565	684	343	902	1402	730	619	984	796	516	276	204	668
1957	400	922	441	381	345	744	2388	3648	3526	1462	1122	691	1339
1958	464	328	732	393	228	486	381	693	1394	770	719	864	621
1959	608	714	415	402	520	581	375	459	794	460	259	195	482
1960	239	451	365	479	421	555	393	1194	1076	1146	1314	571	684
1961	504	450	1444	838	720	725	386	207	1207	1337	1900	804	877
1962	484	729	1013	425	297	367	284	209	730	1446	697	366	587
1963	480	951	879	696	246	197	131	124	184	1400	1714	971	664
1964	331	517	439	680	795	780	882	1084	1202	640	352	427	677
1965	354	525	561	324	1818	704	1782	961	851	1752	1320	1405	1030
1966	895	1750	1170	409	354	590	741	357	939	1376	1282	951	901
1967	850	1050	1371	658	269	646	480	503	596	459	503	726	676
1968	561	453	280	339	246	207	241	180	188	336	624	436	341
1969	764	708	696	1467	878	1698	1281	468	449	1066	1153	643	939
1970	623	556	461	401	622	1358	1654	461	596	1062	446	1069	776
1971	2736	1052	1060	1013	1448	1898	1360	684	560	840	301	285	1103
1972	537	1228	1141	677	242	625	789	1218	2394	2218	992	986	1087
1973	928	930	652	624	997	1189	1622	1370	2342	1738	1024	561	1165
1974	976	1013	955	500	286	602	804	573	840	387	487	388	651
1975	628	560	625	368	270	346	396	872	1146	2082	1033	2138	872
1976	1293	899	883	809	617	1820	741	1465	1099	702	1107	882	1026
1977	1013	1215	914	862	336	452	417	532	489	1186	860	788	755
1978	317	241	406	195	148	213	655	648	736	390	595	527	423
1979	378	223	311	308	1962	523	446	681	1090	2066	1914	1364	939
1980	860	720	1124	560	631	483	1251	1240	1930	1095	834	1369	1008
1981	1698	1031	447	465	397	342	220	223	293	743	858	1258	665
1982	499	703	458	226	241	1084	2456	922	465	1478	2742	1868	1095
1983	1098	1099	1734	1038	2642	2644	6066	2014	1474	1702	1158	755	1952
1984	565	369	499	623	855	1516	794	2214	1025	786	1402	914	964
1985	379	773	529	1134	440	262	293	175	237	192	357	106	406
1986	211	579	577	546	674	611	224	388	636	692	755	1080	581
1987	990	1034	378	447	2388	1816	960	581	396	709	516	357	881

1988	385	529	537	376	2124	1608	558	242	250	504	370	260	645
1989	1124	1678	937	900	1284	379	612	1186	2284	1088	517	309	1025
1990	1798	1145	613	1119	1228	2426	1516	1922	1988	1804	1596	754	1492
1991	312	369	319	374	255	998	749	605	227	791	759	810	547
1992	535	532	773	694	2038	3470	1800	1362	892	764	792	545	1183
1993	523	1024	960	658	1396	1065	1038	604	1258	2640	614	868	1054
1994	386	1093	667	502	1108	1480	1766	742	347	568	1185	751	883
1995	2706	1720	897	506	291	462	1440	406	710	1452	645	438	973
1996	1387	1864	1778	1414	363	914	1744	761	1149	1942	1378	1088	1315
1997	1334	2300	1157	369	390	1156	1080	1562	821	2930	2794	1423	1443
1998	1615	1554	1804	3136	2050	693	1395	2310	2484	3282	910	732	1830
1999	714	1090	800	920	504	1160	2040	414	542	1391	541	421	878
2000	580	855	955	368	395	431	796	537	2498	1952	739	582	891
2001	1296	2134	1306	718	853	1073	1255	1021	829	2424	789	935	1219
2002	900	761	555	327	902	465	306	746	1216	1340	1554	1490	880
2003	746	878	853	359	227	774	680	311	267	441	797	1528	655
2004	1025	481	399	356	932	1098	1134	481	452	1420	1480	665	827
2005	630	350	251	370	876	1304	848	647	2530	2618	1430	472	1027
2006	495	485	478	403	155	128	136	190	502	601	455	717	395
2007	837	812	974	1102	2066	970	546	372	280	554	1323	973	901
2008	936	525	479	657	1106	984	623	976	596	1709	1748	422	897
2009	480	498	406	183	265	397	1006	1419	2087	2722	1213	1245	993
2010	1570	1487	1203	2089	2512	1000	1045	908	320	618	552	1967	1273
MIN	158	182	251	183	120	128	121	101	130	183	247	106	304
MED	763	849	757	635	787	896	921	773	924	1196	919	765	849
MAX	2736	2650	2076	3136	2642	3470	6066	3648	3526	3962	2794	2180	1952

✓ Monthly average Flow rate (m^3/s) - Salto Santiago

SALTO SANTIAGO

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1931	1030	548	507	297	2109	2193	1346	587	1463	1118	581	809	1049
1932	755	1049	1239	2390	1467	1507	845	687	1052	1611	742	1088	1203
1933	392	478	431	253	275	187	219	151	327	710	468	251	345
1934	381	854	658	799	575	325	273	250	312	702	296	747	514
1935	398	329	631	352	215	607	689	1389	1796	4945	1391	833	1131
1936	1639	556	367	249	412	3019	659	1468	1389	1151	989	626	1044
1937	728	565	999	896	552	429	293	454	430	1582	1753	761	787
1938	695	1548	517	590	1429	2442	3166	780	682	631	577	430	1124
1939	487	599	1023	638	877	674	802	343	727	481	1632	2648	911
1940	949	639	379	735	778	424	323	383	364	355	373	535	520
1941	821	1692	780	576	805	986	659	1653	860	902	1100	1073	992
1942	632	1315	1009	1259	923	1179	1200	869	649	687	361	270	863
1943	310	491	390	248	216	905	647	1059	879	1035	741	388	609
1944	650	392	996	429	199	168	150	116	294	210	655	576	403
1945	192	367	588	261	181	309	1178	374	327	514	433	436	430
1946	888	2971	2169	893	718	1041	1955	766	729	1510	1021	1189	1321
1947	883	1289	993	593	417	1107	807	1169	2262	1929	767	875	1091
1948	694	966	846	655	902	699	506	1471	621	865	1110	336	806

1949	347	201	381	876	686	878	373	343	405	435	291	250	456
1950	906	839	1338	492	604	431	499	288	425	1925	833	613	766
1951	715	1396	1654	515	269	260	306	165	153	1243	1348	966	749
1952	446	414	292	299	147	708	471	290	1136	2098	1367	583	688
1953	596	671	518	482	385	469	309	237	948	1469	1826	780	724
1954	1321	736	861	569	2572	2031	1191	621	966	1742	752	482	1154
1955	414	325	487	761	1319	2880	2979	1277	1144	431	320	372	1059
1956	577	771	412	1241	1619	902	748	1139	944	613	326	219	793
1957	424	1043	506	415	394	1044	2969	4190	4514	1694	1372	766	1611
1958	505	343	767	452	252	494	469	808	1762	940	873	926	716
1959	687	932	477	446	554	703	436	550	813	511	304	223	553
1960	256	473	379	507	456	651	446	1300	1279	1323	1506	605	765
1961	537	480	1586	897	837	793	446	241	1213	1565	2003	927	960
1962	591	975	1145	504	327	477	344	256	881	1900	890	420	726
1963	559	1019	895	759	307	263	169	151	195	1555	2444	1029	779
1964	411	615	474	879	874	846	989	1406	1356	836	467	523	806
1965	435	670	683	447	2198	812	2014	1013	1046	2190	1559	1841	1242
1966	1072	2024	1282	480	394	629	872	436	1070	1553	1453	973	1020
1967	973	1129	1467	724	308	729	566	557	693	503	613	893	763
1968	582	504	306	363	283	218	276	193	201	362	671	504	372
1969	1137	798	773	1606	959	1911	1346	502	515	1191	1215	680	1053
1970	674	580	473	415	694	1459	1885	479	640	1187	495	1068	837
1971	2946	1124	1101	1147	1805	2270	1621	753	684	906	383	347	1257
1972	617	1340	1231	765	296	749	960	1707	3092	2512	1084	1067	1285
1973	1271	1207	833	728	1243	1597	1710	1656	2557	2100	1228	647	1398
1974	1103	1136	1046	581	358	714	907	706	967	479	611	529	761
1975	744	699	714	440	328	458	458	973	1312	2480	1188	2406	1017
1976	1426	1046	924	942	706	2076	894	1664	1281	869	1359	1053	1187
1977	1168	1264	963	901	370	551	484	598	575	1258	945	900	831
1978	359	282	436	238	174	245	913	829	873	445	693	589	506
1979	398	266	335	365	2225	585	487	780	1186	2411	2331	1473	1070
1980	998	804	1239	613	761	576	1376	1339	2276	1343	950	1533	1151
1981	1910	1189	524	589	495	435	304	274	324	846	981	1746	801
1982	630	731	570	268	268	1301	3197	1077	546	1954	3832	2390	1397
1983	1251	1258	2087	1351	3912	3443	8252	2344	2036	2248	1453	901	2545
1984	656	465	615	721	971	1937	891	2525	1206	900	1615	1149	1138
1985	428	959	600	1386	531	304	320	200	276	233	376	121	478
1986	246	710	683	645	916	760	259	468	775	790	774	1183	684
1987	1066	1216	430	556	3447	2237	1140	674	439	807	664	442	1093
1988	427	570	579	448	2448	1869	672	261	264	515	400	278	728
1989	1310	1973	1052	1001	1482	442	732	1446	2944	1373	632	369	1230
1990	2262	1316	663	1257	1384	2948	1835	2374	2545	2284	1763	867	1792
1991	357	392	333	422	287	1177	884	681	258	870	850	1009	627
1992	623	592	869	855	2789	4252	2211	1827	1253	987	932	616	1484
1993	628	1133	1094	701	1837	1238	1175	695	1388	3530	676	1053	1262
1994	500	1183	713	548	1212	1884	2086	807	410	663	1284	861	1013
1995	3781	1926	1047	590	325	519	1645	438	770	1656	714	444	1155
1996	1456	2301	2018	1637	386	952	1898	800	1197	2594	1581	1282	1509
1997	1488	2838	1304	407	485	1502	1246	1857	916	3766	3389	1649	1737
1998	1791	1856	2057	4552	2642	773	1534	2657	3287	4353	1110	794	2284

1999	758	1233	887	1008	559	1402	2470	443	597	1422	597	444	985
2000	649	961	1034	410	475	530	963	618	3133	2418	818	624	1053
2001	1384	2851	1482	808	918	1213	1387	1107	864	2838	869	1012	1394
2002	1044	893	609	359	1180	571	363	835	1392	1691	1880	1746	1047
2003	834	1051	984	427	279	893	766	354	306	552	967	1773	766
2004	1156	529	429	388	1134	1244	1412	550	524	1681	1847	739	969
2005	689	379	270	403	1049	1722	966	705	2968	3443	1609	518	1227
2006	541	520	518	457	179	152	162	231	579	684	522	827	448
2007	964	880	1065	1339	2641	1097	614	415	307	609	1506	1057	1041
2008	1025	583	515	713	1247	1172	761	1211	705	1975	2108	489	1042
2009	520	530	449	206	342	517	1300	1661	2525	3339	1407	1436	1186
2010	1784	1636	1347	2497	2864	1124	1127	980	349	696	617	2342	1447
MIN	192	201	270	206	147	152	150	116	153	210	291	121	345
MED	873	968	842	749	955	1090	1103	899	1092	1434	1081	878	997
MAX	3781	2971	2169	4552	3912	4252	8252	4190	4514	4945	3832	2648	2545

✓ Monthly average Flow rate (m³/s) - Salto Osório

SALTO OSORIO

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1931	1075	572	529	310	2201	2289	1405	613	1527	1167	606	844	1095
1932	788	1095	1294	2495	1531	1572	882	717	1098	1681	774	1135	1255
1933	409	499	449	264	287	196	229	158	341	741	488	262	360
1934	398	891	687	834	600	339	285	261	325	733	309	780	537
1935	416	343	659	367	224	634	719	1449	1875	5161	1452	870	1181
1936	1710	580	383	260	430	3151	688	1532	1450	1201	1032	654	1089
1937	760	590	1043	935	576	448	306	473	449	1651	1830	794	821
1938	726	1615	540	616	1491	2548	3304	814	711	658	603	449	1173
1939	508	625	1068	666	915	704	837	358	758	502	1703	2763	951
1940	990	667	396	767	812	443	337	399	380	370	389	552	542
1941	858	1763	818	603	836	1030	691	1723	897	948	1137	1123	1036
1942	666	1367	1045	1322	967	1221	1254	911	676	723	379	283	901
1943	318	514	409	261	217	946	671	1105	917	1082	781	406	636
1944	676	408	1035	456	209	175	157	119	308	218	675	611	421
1945	201	372	620	275	190	316	1229	395	339	537	452	457	449
1946	899	3079	2290	951	742	1082	2040	799	772	1557	1083	1235	1377
1947	926	1322	1060	618	436	1148	838	1221	2329	2045	809	908	1138
1948	724	1001	893	687	925	747	518	1540	649	880	1184	355	842
1949	362	210	395	911	720	913	394	355	424	456	304	257	475
1950	942	875	1396	521	628	452	522	302	436	2000	879	643	800
1951	736	1447	1740	545	282	266	326	173	159	1273	1415	1019	782
1952	466	428	297	314	150	734	491	304	1170	2205	1469	625	721
1953	611	695	535	527	414	511	326	243	998	1490	1966	824	762
1954	1386	782	887	580	2694	2163	1247	654	981	1819	816	506	1210
1955	437	336	493	784	1372	3040	3128	1344	1214	450	336	380	1110
1956	571	798	424	1311	1708	964	796	1268	981	643	341	226	836
1957	422	1069	516	421	412	1031	3038	4402	4769	1788	1429	801	1675
1958	521	348	778	466	257	505	471	836	1818	993	902	955	738
1959	710	992	502	464	587	738	471	569	840	539	326	237	581

1960	270	502	407	540	481	684	485	1361	1385	1393	1610	641	813
1961	562	495	1687	969	897	847	481	257	1234	1620	2113	994	1013
1962	618	1020	1205	537	347	499	362	269	895	2001	946	465	764
1963	563	1086	950	816	324	277	179	159	191	1616	2566	1111	820
1964	443	634	498	946	935	908	1050	1474	1441	909	497	571	859
1965	470	745	739	462	2339	869	2086	1075	1036	2336	1648	1889	1308
1966	1138	2091	1353	508	415	631	927	453	1110	1623	1531	1008	1066
1967	1011	1146	1512	755	327	767	615	592	739	528	637	945	798
1968	608	535	320	380	316	243	301	217	222	400	723	525	399
1969	1198	820	798	1638	995	2001	1424	550	534	1278	1287	749	1106
1970	716	607	503	445	719	1496	2001	526	680	1257	547	1098	883
1971	3094	1176	1129	1189	1898	2367	1724	801	735	969	427	390	1325
1972	675	1366	1289	835	327	808	1030	1794	3212	2659	1130	1124	1354
1973	1354	1292	876	745	1278	1642	1790	1690	2647	2223	1295	670	1459
1974	1124	1170	1091	606	373	745	937	730	1030	500	646	574	794
1975	782	766	754	463	343	489	479	997	1333	2625	1250	2486	1064
1976	1466	1093	940	985	719	2170	924	1716	1346	914	1434	1109	1235
1977	1209	1304	983	929	386	581	511	618	597	1295	990	939	862
1978	376	292	442	247	181	251	966	885	910	463	707	611	528
1979	416	276	354	376	2305	630	506	820	1246	2810	2516	1556	1151
1980	1048	849	1299	625	795	590	1407	1374	2385	1418	1000	1572	1197
1981	1995	1242	557	599	543	468	333	288	332	895	1024	1877	846
1982	694	740	595	281	272	1354	3407	1138	576	2046	4014	2543	1472
1983	1319	1303	2195	1431	4102	3657	8473	2482	2129	2381	1542	936	2663
1984	683	509	627	766	1010	2005	942	2587	1261	962	1688	1234	1190
1985	464	990	643	1452	581	336	359	220	293	240	388	126	508
1986	254	742	728	677	991	847	279	493	807	822	795	1219	721
1987	1104	1276	466	583	3701	2351	1208	707	457	838	718	482	1158
1988	446	595	612	469	2546	1968	723	280	270	514	419	276	760
1989	1316	2072	1100	1029	1567	465	735	1546	3067	1465	678	391	1286
1990	2299	1382	678	1259	1454	3062	1910	2469	2667	2408	1824	902	1860
1991	367	408	339	445	308	1227	954	706	272	915	905	1074	660
1992	673	610	883	907	2838	4544	2317	1927	1358	1089	1006	666	1568
1993	658	1182	1145	737	1936	1314	1225	755	1398	3732	718	1112	1326
1994	521	1214	749	573	1242	1987	2174	865	427	697	1335	884	1056
1995	4023	1998	1093	633	349	535	1750	466	770	1757	758	457	1216
1996	1482	2399	2074	1733	408	954	1937	816	1207	2744	1670	1342	1564
1997	1557	2950	1380	429	500	1585	1331	1912	939	3922	3504	1713	1810
1998	1815	1913	2075	4799	2832	811	1571	2699	3426	4565	1175	813	2375
1999	779	1283	936	1058	596	1473	2582	469	623	1426	611	454	1024
2000	667	1001	1075	428	501	559	1018	648	3264	2543	879	643	1102
2001	1436	3021	1574	850	953	1271	1443	1151	883	2971	906	1054	1459
2002	1087	953	628	368	1273	614	381	866	1448	1825	1979	1855	1106
2003	868	1113	1035	451	296	935	796	369	316	590	1028	1850	804
2004	1218	547	436	395	1202	1302	1496	578	549	1751	1983	768	1019
2005	706	391	273	411	1105	1849	1009	722	3071	3625	1698	535	1283
2006	553	533	528	479	184	157	167	242	601	717	541	864	464
2007	1011	898	1103	1397	2785	1162	634	432	313	625	1573	1083	1085
2008	1058	604	527	718	1310	1225	820	1286	746	2030	2252	516	1091
2009	531	537	466	211	365	560	1366	1747	2599	3525	1484	1501	1241

2010	1841	1697	1394	2589	3013	1173	1153	1011	358	718	641	2437	1502
MIN	201	210	273	211	150	157	157	119	159	218	304	126	360
MED	910	1008	878	784	1003	1144	1153	941	1137	1509	1139	920	1044
MAX	4023	3079	2290	4799	4102	4544	8473	4402	4769	5161	4014	2763	2663

✓ Monthly average Flow rate (m³/s) - Salto Caxias

SALTO CAXIAS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
1931	1353	701	654	434	2930	2994	1811	781	1792	1373	773	993	1382
1932	966	1345	1747	3315	1991	2182	1224	955	1521	2449	976	1292	1664
1933	530	589	583	349	380	248	283	197	421	866	617	353	451
1934	503	1058	851	1081	792	461	388	346	439	929	411	953	684
1935	522	411	790	517	316	946	1047	1952	2488	6325	1813	1140	1522
1936	2105	751	497	351	620	4689	1072	1981	1770	1436	1186	785	1437
1937	977	756	1208	1104	754	568	402	594	587	1905	2371	1051	1023
1938	945	1948	714	786	1938	3341	4147	1072	866	788	730	541	1485
1939	625	772	1291	833	1214	915	1118	494	989	669	2279	3466	1222
1940	1371	856	530	1120	1076	626	465	491	473	467	533	728	728
1941	999	2173	1082	885	1129	1411	948	2286	1177	1203	1509	1671	1373
1942	890	1721	1285	1763	1398	1510	1457	1047	861	962	480	394	1147
1943	390	622	508	326	406	1392	915	1300	1093	1332	1000	519	817
1944	814	508	1173	601	302	228	200	148	345	263	800	709	508
1945	283	474	736	377	253	416	1418	550	435	662	606	639	571
1946	1239	3770	2723	1249	1097	1432	2687	1049	915	1967	1342	1545	1751
1947	1147	1562	1282	864	680	1547	1057	1540	2920	2447	1017	1089	1429
1948	849	1310	1130	865	1195	939	741	1955	870	1288	1569	470	1098
1949	507	276	576	1266	1003	1269	532	511	588	631	403	361	660
1950	1151	1083	1679	711	885	601	730	415	530	2401	1137	797	1010
1951	942	1720	2200	725	386	336	404	212	204	1527	1717	1215	966
1952	590	536	379	405	215	964	655	409	1400	2767	1803	778	908
1953	743	854	657	626	516	644	460	348	1316	2015	2460	1034	973
1954	1711	989	1068	708	3301	3098	1753	847	1435	2449	1088	818	1605
1955	630	435	614	1039	1745	3934	3833	1749	1471	580	423	471	1410
1956	726	992	550	1901	2205	1352	1086	1649	1324	853	417	266	1110
1957	535	1434	638	497	518	1269	3732	5934	5804	2145	1662	930	2092
1958	593	386	862	588	300	700	610	1123	2479	1386	1168	1331	961
1959	866	1304	665	678	799	1016	649	779	1010	716	441	387	776
1960	361	595	455	592	555	816	592	1790	1788	1917	2006	788	1021
1961	668	588	2260	1203	1110	970	577	317	1640	2288	2506	1238	1280
1962	794	1299	1452	649	521	691	504	380	1250	2497	1205	588	986
1963	653	1302	1209	985	634	411	251	219	246	2092	3459	1447	1076
1964	568	800	601	1209	1268	1057	1228	1848	1778	1212	660	698	1077
1965	572	890	871	570	2795	1189	2777	1442	1493	3307	2272	2615	1733
1966	1488	2638	1759	768	507	855	1289	643	1434	2134	1904	1258	1390
1967	1240	1354	1966	920	404	904	769	840	975	690	801	1106	997
1968	673	594	357	442	419	302	413	278	264	544	929	769	499
1969	1827	1021	1036	2165	1345	2763	1775	708	693	1926	1638	883	1482
1970	823	709	602	547	849	1812	2582	674	894	1785	708	1444	1119

1971	3707	1396	1293	1457	2492	3119	2304	1092	903	1192	535	454	1662
1972	759	1543	1475	1099	410	1148	1349	2469	4190	3327	1344	1301	1701
1973	1860	1803	1133	896	1852	2122	2203	2228	3296	2820	1651	818	1890
1974	1364	1385	1249	722	535	1105	1175	875	1398	636	920	862	1019
1975	1115	1019	904	581	439	665	696	1251	1755	3485	1676	2935	1377
1976	1780	1327	1052	1116	840	2621	1102	2061	1627	1170	1774	1270	1478
1977	1370	1426	1119	1032	440	738	656	847	790	1565	1309	1191	1040
1978	465	334	468	264	195	292	1310	1104	1156	587	958	799	661
1979	493	327	436	552	3376	901	751	1224	1605	3655	3483	1925	1561
1980	1395	1085	1535	721	970	701	1637	1730	2727	1661	1383	1979	1460
1981	2323	1555	709	807	796	661	435	350	404	1046	1437	2629	1096
1982	912	902	706	323	330	1849	4428	1442	746	2539	5443	3161	1898
1983	1534	1485	3212	1850	5798	4451	10798	3011	2792	2928	1984	1253	3425
1984	974	732	881	1134	1293	2733	1193	3201	1589	1286	2101	1588	1559
1985	575	1240	752	1731	783	488	485	402	387	374	602	208	669
1986	356	1086	974	1093	1529	1337	450	859	1342	1178	1011	1482	1058
1987	1308	1794	609	842	5037	3023	1633	852	551	1095	1138	630	1543
1988	553	682	676	575	3217	2518	912	350	329	609	519	326	939
1989	1679	2589	1316	1166	1893	584	981	2022	3993	1979	945	498	1637
1990	2728	1680	771	1719	1977	4598	2410	3184	3463	3140	2286	1212	2431
1991	468	503	376	573	396	1945	1246	886	347	1124	1072	1425	863
1992	824	759	1189	1221	3680	5357	3113	2337	1662	1444	1328	857	1981
1993	884	1385	1264	844	2421	1856	1603	1046	1695	4434	967	1308	1642
1994	592	1638	959	710	1763	2789	2694	1086	659	1200	2132	1238	1455
1995	4904	2222	1337	1010	503	742	2043	563	986	2237	995	549	1508
1996	1773	3010	2413	2086	497	1199	2405	978	1501	4082	2100	1827	1989
1997	1802	3432	1597	548	965	2383	1848	2724	1285	4853	4378	2108	2327
1998	2090	2685	2566	6077	3636	1016	1806	3423	4060	5599	1495	1175	2969
1999	1039	1697	1202	1413	812	2076	3158	626	836	1672	748	633	1326
2000	889	1382	1351	638	754	729	1407	869	4061	3508	1137	741	1456
2001	1727	3741	1887	1207	1184	1648	1858	1342	1060	3674	1133	1237	1808
2002	1431	1239	726	413	1899	837	496	1055	1897	2657	2689	2415	1480
2003	1058	1517	1315	583	390	1203	982	441	391	841	1430	2470	1052
2004	1461	630	481	448	1678	1619	2037	708	700	2347	2717	923	1312
2005	832	425	289	465	1526	2614	1274	863	3766	4853	2051	614	1631
2006	651	592	606	574	216	191	204	318	778	893	688	1117	569
2007	1301	1053	1287	1906	3685	1404	791	503	355	744	1998	1272	1358
2008	1249	721	589	871	1598	1639	1116	1770	987	2577	2967	650	1394
2009	610	601	533	241	542	832	1843	2233	3288	4580	1903	1906	1593
2010	2252	2009	1740	3339	3728	1446	1341	1146	406	898	773	3133	1851
MIN	283	276	289	241	195	191	200	148	204	263	403	208	451
MED	1128	1247	1078	1011	1335	1525	1484	1217	1447	1946	1475	1171	1339
MAX	4904	3770	3212	6077	5798	5357	10798	5934	5804	6325	5443	3466	3425

✓ Monthly Total Precipitation - Iguaçu subwatershed

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1990	335.6	80.1	90.1	214.7	76.9	179.6	211.4	218.8	183.6	205.8	255.1	64.6
1991	75.5	60.2	50.5	61.4	70.6	44.3	252.6	16.4	37.8	28.6	178.4	180.4
1992	85.2	135.8	70.5	53.7	330.2	47.7	147.4	142.9	27.8	87	88.5	15.9
1994	178.1	68.7	71.8	126	112.1	196.6	139.8	7.4	26.6	152.7	168	142.7
1995	340.7	245.7	37.7	53.7	23.8	120	134.7	25.6	249.2	148.7	58.4	151.9
1996	262.2	264.9	339.9	36.5	7.2	122.1	106.7	72.1	194.1	186.1	126.5	255
1997	219.1	210.7	53.6	31.4	73.9	170.6	72.8	101	181.1	353.7	206.7	157.6
1998	221.2	193.5	412.7	401.8	50.4	68.8	133.2	168.8	356	244.8	31.2	136.3
1999	114.1	201.2	107.9	106.2	73.2	212.9	109.7	40.8	118.4	82.2	95.8	137.7
2000	281.4	193.3	95	23.6	39.9	160.4	82.9	71.6	335	167.4	76.4	162.7
2002	290.8	68.1	80.9	93.5	150	26.1	71.5	127	158.3	196	265.8	115
2003	241	136.7	78.1	92.6	28.9	104.2	111	27.8	78.2	185.9	172.5	245.6
2004	77.8	64.8	128.9	134.1	177.9	82.7	115.2	21.9	48.3	211.8	159.6	91.4
2005	157.2	61.3	37.8	116.4	135	143.5	60.7	113	312.1	350.8	76.2	51.4
2006	144.1	52.6	80.6	13.4	7.3	9.4	22.6	50.8	60.4	71.1	178.3	75.5
2007	246.7	117.3	98.6	128.8	247.6	14.9	135.3	12.1	27.9	79	202.6	140.8
2008	201.8	105.5	160.3	172.9	79.3	154.4	51.8	157.1	81.3	316.5	94.5	46.8
2009	156.2	150.7	55.6	16.3	87.6	80.5	302.5	92.6	369.2	204.8	173.9	134
2010	238.1	224.3	174.5	294.6	82.8	74.9	127.7	69.3	51.6	199.3	61.5	225.8