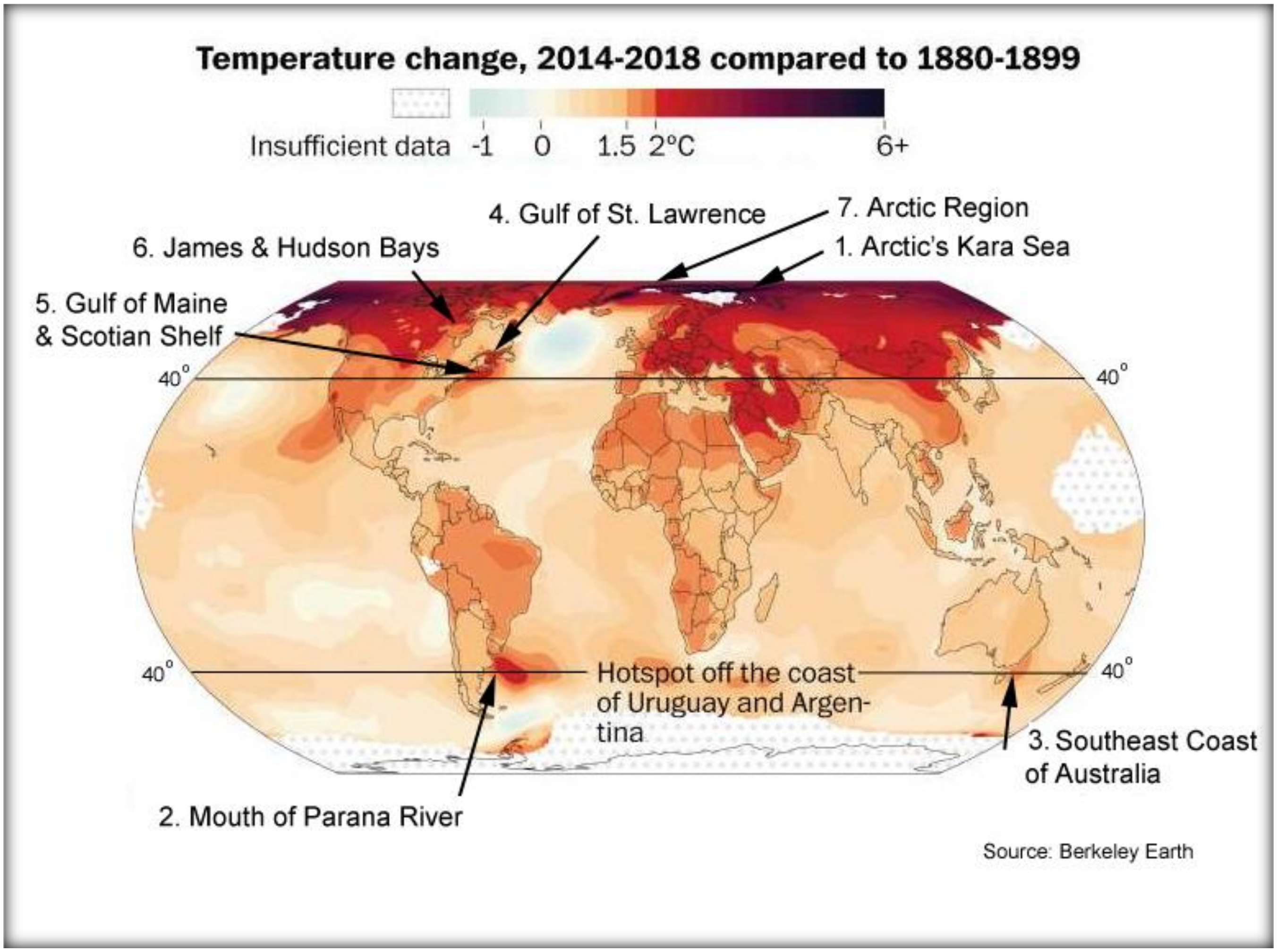
HEAT POLLUTION

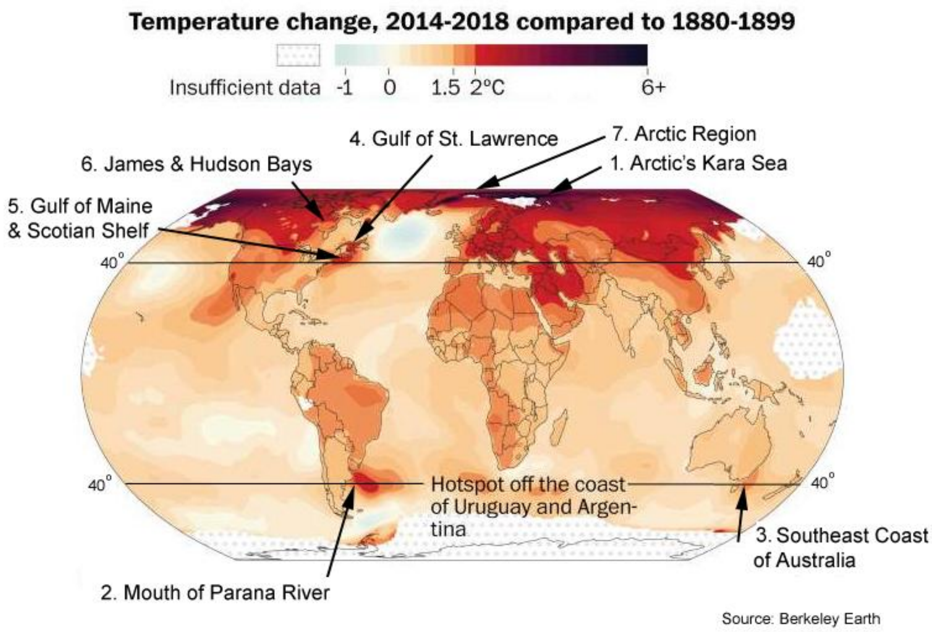
From Reservoir Hydroelectric Dams
Is Warming Our Oceans and Climate



Condensed Version
By Stephen M. Kasprzak
October 2019

HEAT POLLUTION
From Reservoir Hydroelectric Dams Is Warming Our Oceans and Climate

There is plenty of evidence linking hot spots in the world's estuaries and coastal seas to heat pollution from reservoir hydroelectric dams discharging near 40° latitude or higher.



Reservoir hydroelectric power stations are designed to change the natural hydrological cycle and store (steal) the river flow (kinetic energy) of the spring run–off as potential energy. This stored water is typically released as kinetic energy during the winter when river flows are naturally at their lowest and electrical demand is at its highest.

The transfer of heat from the turbines to the falling water generating the electricity is one form of heat pollution. The water is the fuel and coolant keeping the turbines from overheating and seizing up.

Additional heat pollution occurs upstream of the turbines by solar energy warming and causing thermal stratification of the waters in these large reservoirs.

Further heat pollution occurs downstream of the dam, as both winter and summer temperatures of the surface layer in the estuaries and coastal waters have increased; *"in winter due to an increase in upwelling of deeper warmer water, and in summer due to slower surface currents which will allow the surface layer to absorb more heat during the passage through the system."* ([12])

HOT SPOT #1 IS ARCTIC'S COASTAL KARA SEA

The discharged waters from reservoir power stations in both the northern and southern temperate and polar zones are warm mega water faucets regulated by man to maximize the generation of electricity to meet winter power demands.

For example, *"The Vilyuy Dam is a large dam and hydroelectric power station on the Vilyuy River, the longest tributary to the Lena River, which discharges into the Arctic's coastal Laptev Sea, which borders the Kara Sea. The reservoir started filling in 1969 and was full by 1973. It is 280 miles long with a total capacity of 35.9 km³.* In comparison, the water volume of Maine's largest lake, Moosehead, is 5.19 cubic kilometers (km³).

*The large reservoir formed by the dam has caused the winter temperature of the Vilyuy River to increase by 5 to 6 C (9 to 10.8°F) . . . "*Wikipedia

The Yenisei River flows into the Kara Sea and the magnitude of the river regulation scheme by Russia on the Yenisei River and its tributary, the Angara River, is illustrated below. The Yenisei is the 10th largest river in the world.

The Sajano/Sjusjenskaja and Kransojarsk power stations are the 10th and 11th largest in the world with annual capacities of 6,400 and 6,000 MW, respectively. The generating capacity of the other 5 power stations is 12,014 MW, which makes a total capacity of 24,414 MW for these 7 dams. Maine's total annual capacity is 753 MW.

THE VOLUME OF WARM DISCHARGE WATERS FROM THESE LARGE RESERVOIR DAMS IS SO LARGE THAT IT IMPACTS RIVER AND AIR TEMPERATURES MILES DOWNSTREAM

For example, "*the Krasnoyarsk Dam significantly influences the local climate; normally the river would freeze over in the bitterly-cold Siberian winter, but because the dam releases unfrozen water year-round, the river never freezes in the 200 kilometres (120 mi) to 300 kilometres (190 mi) stretch of river immediately downstream from the dam. ([1]) ([2]). In winter, the frigid air interacts with the warm river water to produce fog, which shrouds Krasnoyarsk and other downstream areas*."([2]) ([3])

The discharge waters of the Krasnoyarsk Dam are a man-made Gulf Stream warming both the waters and regional air as much as 190 miles downstream.

Russia has built two other dams on the Yenisei River, which flows into Kara Sea, and four more on the Angara River, a tributary to the Yenisei. The cumulative impact of the warm discharged waters from these seven dams has warmed the Kara Sea and the radiant heat from the surface of the Kara has warmed the air temperature at an alarming rate.

"According to Roshydromet (Russia's state agency on meteorology and environmental monitoring) the Kara Sea has experienced the most dramatic boost in air temperatures over the last 30 years. Since 1998 the average temperatures in the area have increased by as much as 4.95°Celcius degrees, 9°F." ([4])

We have built world-wide over 50,000 dams in the past 70 years, all of which cause similar warming impacts.

In 1950, there were only 5,000 large dams in the world. A large dam is defined by International Commission on Large Dams (ICOLD) as one measuring 15 meters (about 50 feet) from foundation to crest and by mid-1990's, there were more than 40,000. ([5]) Today, it is estimated that there are 57,000 large dams.

ICOLD defines a major reservoir hydroelectric dam as either higher than 150 meters or reservoir storage of at least 25 km^3 or annual electrical generation capacity of at least 1,000 megawatts (MW).

"In 1950, 10 behemoths met these criteria; by 1995 the number had soared to 305. The leading builder of major dams is the US, followed by ex-USSR, Canada, Brazil and Japan in the World's Major Dams and Hydro Plants by T.W. Mermet 1995." ([5])

HOT SPOT #2 IS LOCATED IN SOUTH ATLANTIC OCEAN

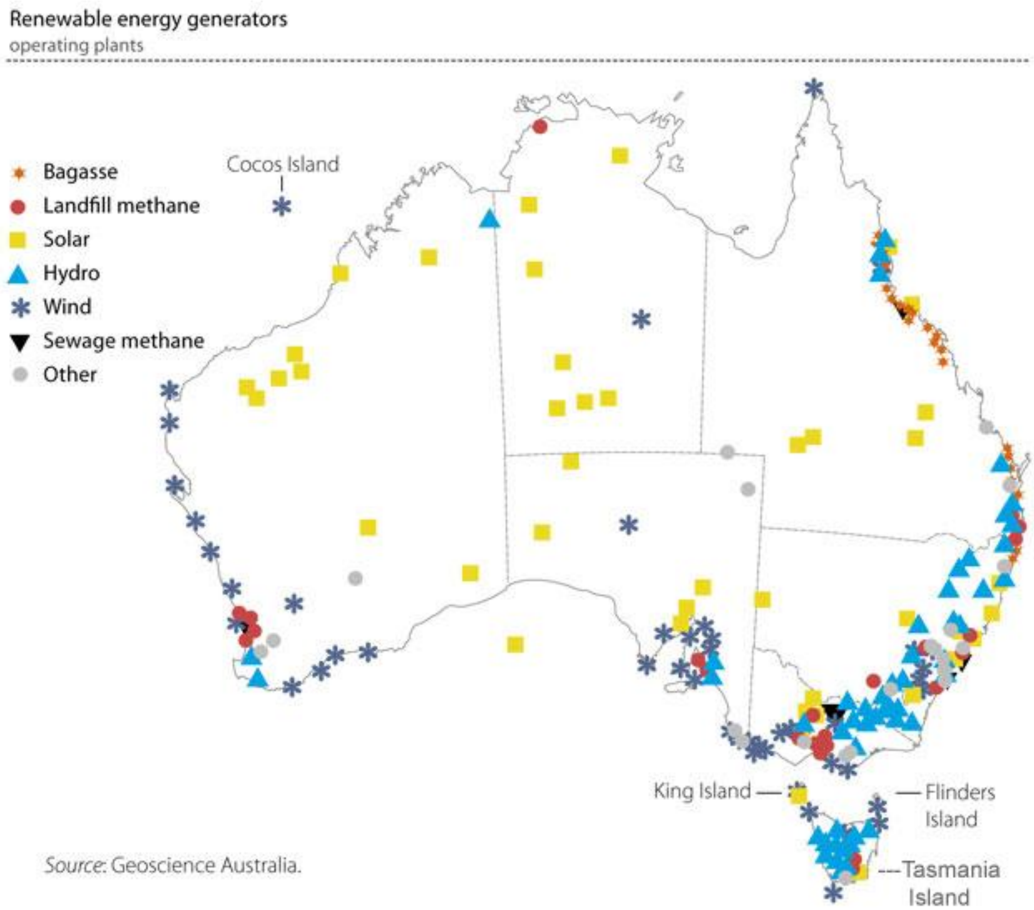
Hot Spot #2 is located off the mouth of the Parana River, which is the 12th largest river in the world. The Itaipu and Yacyreta Hydroelectric Dams are the 2nd and 29th largest hydropower stations in the world with annual capacities of 14,000 and 3,100 MW, respectively. The heat pollution from these dams appears to be the driving force in creating this hot zone.

Another part of the heat pollution from these reservoir dams is their large surface areas which are subject to warming by solar energy. The surface area of the Itaipu and Yacyreta Reservoirs are 521 and 618 square miles respectively, or a total of 1,139 square miles.

Itaipu Dam on Parana River between Brazil and Paraguay

HOT SPOT #3 IS LOCATED OFF OF AUSTRALIA'S SOUTHEAST COAST

Australia generates about 8,000 MW of electricity per year and the reservoir power stations are concentrated on Australia's and Tasmania's rivers, which discharge into the southeast coastal seas of Australia (see map below).



The largest power station is called the Snowy Mountains Hydroelectric Scheme, and as the title implies, the hydropower is being generated with stored (stolen) waters from the natural spring run-off.

Although the amount of hydropower being generated in Australia is only a fraction of the hydropower schemes described in Hot Spots #1 and #2, it is still enough to warm the southeastern coastal waters of Australia.

HOT SPOT #4 IS THE GULF OF ST. LAWRENCE

As early as 1964, Dr. Hans Neu, a Canadian oceanographer, warned the Provincial Government of Quebec of heat pollution from its hydroelectric dams when he wrote:

> *"The installation of the Manicouagan power scheme, which changes the natural run-off of the "group" of rivers, will alter the Gaspe' Current, modifying the seasonal salt and temperature balance not only of the estuary, but probably also of the Gulf of St. Lawrence," . . . and . . . "Whether these changes were or are beneficial is undecided, though the possibility exists that their consequences may be likened to large-scale heat pollution with ecological implications. Thus, to avoid such consequences, future modification of this type should be carefully studied."* (Emphasis by SMK) (9)

The passage of time has proven Dr. Neu's predictions to be true as documented by Hot Spot #4 in the Gulf of St. Lawrence.

Before the Daniel Johnson Dam was built in 1970, the Manicouagan River, seen in the lower right hand corner of the photo below typically had low monthly winter flows of about 7,000 cubic feet per second (ft^3/sec,) which would not generate much electricity. However, the natural spring run-off was 105,000 ft^3/sec or 15 times greater.

Hydro-Quebec designed, built and operates this reservoir hydroelectric dam to steal the river flow (kinetic energy) of the spring run-off and to store the water as potential energy. This is the 4th largest reservoir in the world.

These stolen waters are released months later as discharged heated river flow (man-made kinetic energy) to fuel the power station at flows 10 to 20 times greater than during the near dormant natural river flows of summer and winter.

Daniel Johnson Dam and Manic-5 Generating Station on the Manicouagan River in Quebec (Source: Hydro-Quebec)

HOT SPOT #5 IS GULF OF MAINE AND SCOTIAN SHELF

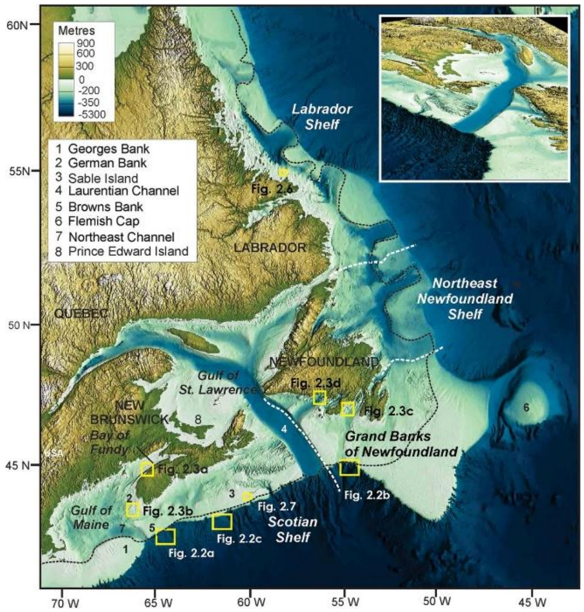
In 1976, Dr. Neu warned that the large scale heat pollution with its ecological implications from the Manicouagan power scheme would also extend to the St. Lawrence's coastal zone, which includes the Scotian Shelf and Gulf of Maine.

Dr. Neu reinforced his earlier 1964 conclusions in a 1976 Report (11) in which he explains how the St. Lawrence Estuary, Gulf and coastal zone would be weakened as the seasonal spring run-off was significantly reduced:

> *"Fresh water from the drainage of rivers plays a prominent role in the generation of large-scale motions in the coastal environment. In the St. Lawrence system, it initiates a circulation in which huge quantities of sea water are transported from the ocean into the Gulf and up the Estuary, a distance of more than 1500 km (932 miles). As the seasonal flow of fresh water is modified for power production, the strength of this circulation is altered and with it upwelling, mixing, flushing of the system and near-coast water masses, and the composition of the water with respect to salinity and temperature. The changes must result in climatic modifications which influence the heat budget and therefore the ice conditions.*

A reduction in upwelling during spring and summer has decreased the nutrient supply and this, in addition to the change in the composition of the water in the upper layer, must have affected the reproduction of many species. ***It can, therefore, be concluded that seasonal discharge regulation, as implemented in the St. Lawrence for power production since the turn of the century, has imposed large-scale modifications upon the ecosystem of the Estuary, Gulf and coastal zone. This applies to any other system in which similar conditions prevail****."*
Emphasis by SMK

Again, the passage of time has proven Dr. Neu's warnings to be true as documented by Hot Spot #5.



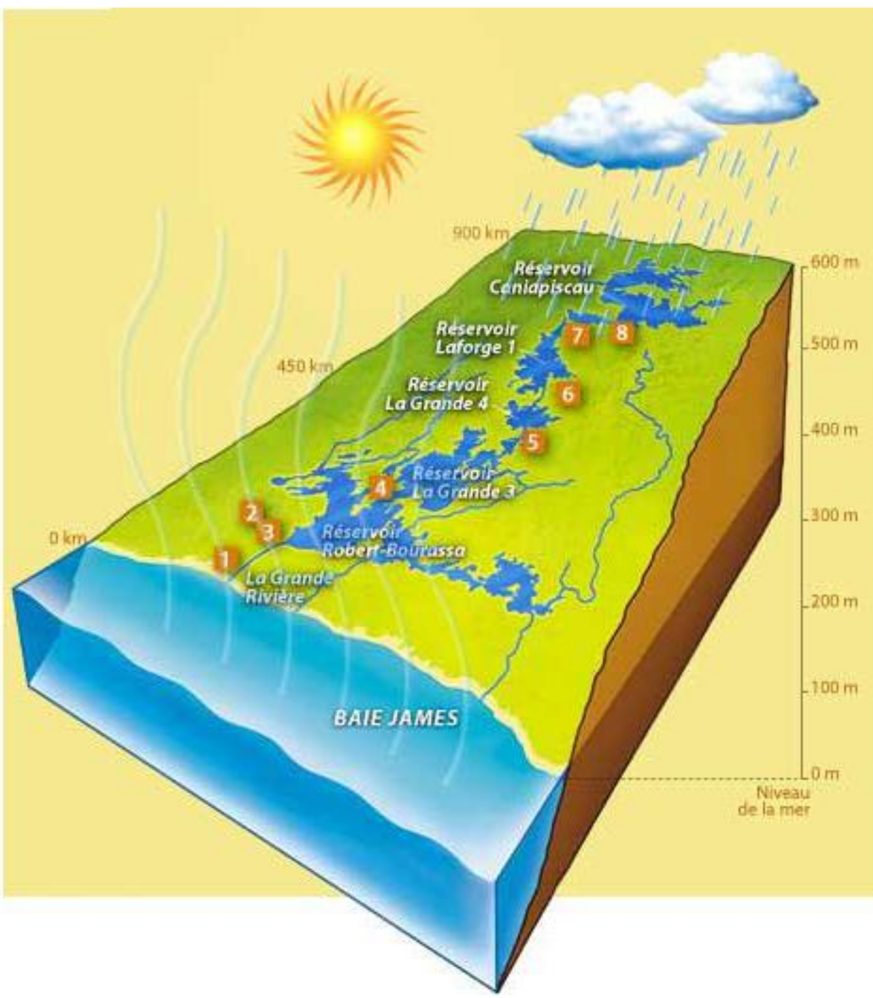
Source: SHAW, TODD, LI, MOSHER & KOSTYLEV
Geological Survey of Canada (Atlantic), Bedford Institute of Oceanography

HOT SPOT #6 IS JAMES AND HUDSON BAYS

Hotspot #6 has been warmed by a series of reservoir and power stations known as LaGrande Power Scheme.

Hydrological Cycle - LaGrande Complex *"At the LaGrande complex, water flows through the turbines of eight generating stations no less than seven times. This means that the same water generates electricity seven times before emptying into James Bay."* (Hydro-Quebec)

It also means the water is warmed seven times as it fuels the generation of electricity and keeps the turbines from overheating.



	Capacity (mw)
8 **Brisay** 535,5 m	469
7 **Laforge-2** 481,1 m	319
6 **Laforge-1** 439,0 m	878
5 **La Grande-4** 377,0 m	2,779
4 **La Grande-3** 256,0 m	2,418
3 **La Grande-2-A**	2,106
2 **Robert-Bourassa** 175,3 m	5,616
1 **La Grande-1** 32,0 m	1,436
	16,021

The magnitude of the large scale motions and ecological implications from the LaGrande Power Scheme is colossal according to the following data from LaGrande River by Harper:

"In Quebec, peak electricity consumption occurs during the winter when river flows are naturally at their lowest because water is locked up in snow and ice. To meet the demand for electricity during cold weather, dams and diversions have increased the winter flow on the LaGrande River by eight times (from 18,000 to 141,000 cubic feet per second) in order to store water for the following winter and have eradicated the spring flow (flow reduced from 176,000 to 53,000 cubic feet per second)." LaGrande River by Harper

The LaGrande Power Scheme has increased the winter flow by 123,000 cubic feet per second and reduced the spring flow by the same amount. The average flow of Niagara Falls is approximately 64,000 cubic feet per second. This is equivalent to eliminating, during the spring months, two Niagara Falls flowing into the shallow waters of James Bay and then increasing the flow by two Niagara Falls in the winter months.

In a 1982 Report, Dr. Neu made the following observations and warning:

> *"Reducing the flow of fresh water during spring and summer and increasing it during the winter changes the seasonal composition of the water in the surface layer and the seasonal strength of the density current.*
>
> *As this trend continues, the cyclic variation will be reversed, the surface saline becoming saltier in spring and summer and fresher in the winter. This represents a fundamental change in the seasonal salinity patterns of the coastal region and continental shelf.*
>
> *There is a definite possibility that both winter and summer temperatures of the surface layer will increase; in winter due to an increase in upwelling of deeper warmer water, and in summer due to slower surface currents which will allow the surface layer to absorb more heat during the passage through the system. It can be assumed therefore that fresh water regulation modifies the climate of the coastal region to be more continental-like in the summer and more maritime-like in the winter."* Emphasis by SMK ([12])

HOT SPOT #7 IS THE ARCTIC REGION

The concentration of reservoir hydroelectric dams on Canadian and Russian rivers is a major force warming the Arctic region.

> *"The Chuckchi, East Siberia, Laptev, Kara and Barents Seas are shallow coastal seas bordering the Arctic Ocean. These marginal seas occupy 36 percent of the area of the Arctic Ocean, yet they contain only 2 percent of its water volume."* and *"The Kara Sea lies on the Siberian Shelf; thus about 40 percent of it is less than 160 feet deep and only 2 percent is over 1,600 feet deep." (Britannica)*

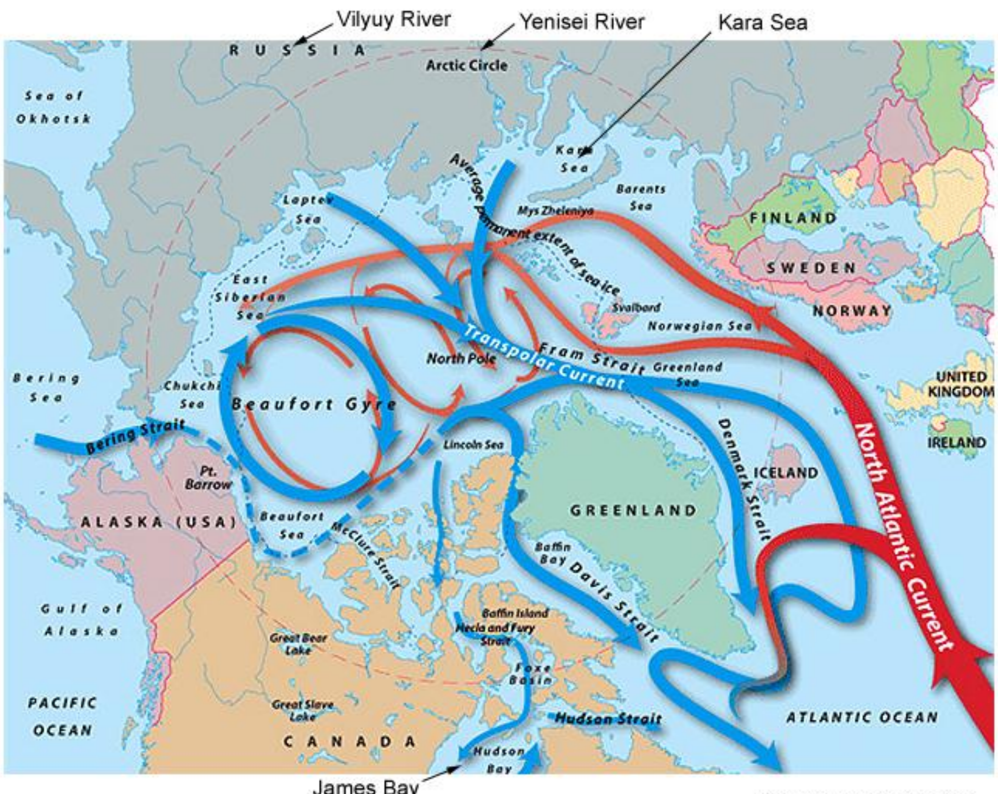
These shallow seas are very susceptible to warming from discharged waters of major reservoir dams, which have been built on the huge rivers in Siberia. They are operated to change seasonal fresh water flows in order to optimize power generation in the winter. Their warm discharge waters have heated up the shallow coastal seas of the Arctic Ocean and the *Warm entry current* (on above map), which has accelerated the melting of Greenland's ice sheet.

The warm discharge waters from dams flowing into the shallow waters of James Bay, Labrador Sea and Gulf of St. Lawrence have warmed both the *Cold exit current* and Labrador Current. This has resulted in a warmer Gulf Stream flowing into the Norwegian Sea and Arctic Ocean.

THE ARCTIC OCEAN IS A VERY LARGE ESTUARINE ECOSYSTEM

> *"An estuary is a partially enclosed body of water, and its surrounding coastal habitats, where salt water from the ocean typically mixes with fresh water from rivers or streams."* NOAA

According to Dr. Neu's studies, the intensity of the estuarine circulation is directly correlated by the fresh water inflow. The volume of sea water brought into circulation in the Arctic Ocean is controlled by the amount of fresh water being discharged into the Arctic's coastal seas.



Source: HydroQuebec

Large reductions in spring and summer outflows from Canadian and Russian rivers leads to multiple factors affecting the strength of the *Transpolar Current (*on map above) through Fram Strait and the Canadian Archipelago. A weaker Transpolar Current changes the natural freshwater balance and thermohaline circulation of the global ocean and results in a warmer Gulf Stream flowing into the *North Atlantic Current* (on map above).

The acceleration in the melting of the Arctic ice has been documented and corresponds with the proliferation of reservoir hydroelectric dams by Russia and Canada.

> *"Submarine sonar data obtained since 1958 have revealed that the average ice draft in the Arctic Ocean in the 1990's decreased by over 1 m (about 3 feet) and that ice volume was 40 percent lower than during the period 1958-76."The greatest ice draft reduction occurred in the central and eastern Arctic, where both the ice concentration and the duration of the ice-covered season also decreased." Britannica.com*

DID PROVINCIAL GOVERNMENT OF QUEBEC CENSOR DR. NEU'S STUDIES?

It appears that Dr. Neu's 1964 "Study On Mixing and Circulation in the St. Lawrence Estuary Up to 1964" was not allowed to be released by the Provincial Government of Quebec until after Dennis Johnson Dam (part of Manicouagan Power Scheme) went online in 1970. They then allowed only a limited circulation, and Dr. Neu's work was simply labeled "unpublished manuscript." A copy of the Study is available in Research Collection at http://friendsofsebago.org.

In this Study he wrote the following two conclusions:

> *"The most important conclusion is the intensity of the estuarine circulation in the St. Lawrence Estuary can be characterized solely by the fresh water inflow. The volume of sea water brought into circulation is controlled by the amount of fresh water being discharged into the system. (Emphasis* by SMK)
>
> *From this it follows that modifications to the fresh water run-off (e.g. hydropower developments and water diversions) alter the flow regime and with it the salinity and temperature structure of the system."*

If we stop burning all the fossil fuels in the world, we would greatly eliminate carbon pollution. Although this is crucial for success against combating climate change it will not mitigate continued heat pollution from the world-wide proliferation of reservoir hydroelectric dams over the past 70 years.

The reservoirs of these dams are heat sinks with massive amounts of evaporation from the river's ecosystem. These evaporated waters no longer outflow into the coastal seas powering strong and deep ocean upwelling currents. For example, *"The massive amount of water evaporated from the reservoirs behind Hoover and other dams on the Colorado River equals one-third of the river's natural flow."* ([5])

Typically, these large reservoir hydroelectric dams have stored (stolen) 50 to 70 percent of the spring run-off to maximize power generation in the winter. This long-term storage greatly reduces the natural forces of the spring runoff and further weakens these upwelling currents.

The long-term storage of the spring run-off and the massive amount of evaporation from the stored waters have produced a double whammy, which has weakened deep ocean upwelling currents and starved the fisheries.

WEAKER UPWELLING CURRENTS IN SPRING AND SUMMER ARE STARVING FISHERIES AND WARMING CLIMATE

The following excerpts were written by Dr. Neu in his 1982 Report ([12]):

> *"The most outstanding feature in the encounter between fresh water and salt water is the formation of a current which oceanographers refer to as haline circulation and engineers as density current."*

and

> *"Obviously, the two-layer current system acts like a large natural pump which constantly transports large quantities of deep ocean water onto the continental shelf and then into the embayment's and estuaries.*

Historically, before reservoir dams, both the natural flowing rivers and the upwelling of large quantities of deep ocean water transported dissolved silica and other essential nutrients to the coastal waters and were the major source of nutrients to the estuaries.([13])

"Just as for the winds in the atmosphere, the magnitude of the current is proportional to the pressure difference. Hence, in times where more fresh water enters the ocean, the longitudinal gradient seaward increases and with it the strength of the current system. From this it follows that in estuaries the density current varies with the seasonal run-off, being at a minimum during the low discharges in winter and at its peak during the large discharges in spring and summer. In coastal waters which are some distance away from the fresh water source (i.e. the Grand Banks, the Scotian Shelf and Georges Bank) there can be delays of from several months to almost a year before the freshwater peak arrives." Emphasis by SMK

CONCLUSIONS

If the world stops burning fossil fuels tomorrow, it will not mitigate the continued heat pollution generated by the 50,000 plus large dams built in the past 70 years.

Not only do these dams and their flow regulation cause coastal and ocean hotspots, but their impacts on ocean density or haline circulation, affect deep ocean currents. All of these changes impact world climate and the marine ecosystem from phytoplankton to copepods to cod and right whales.

Reservoir hydroelectrical dams represent a fundamental change in the seasonal delivery of essential nutrients to the coastal regions and continental shelf via riverine and upwelling currents. This has led not only to the starvation of the fisheries, but also to the failure of the populations to rebound after the implementations of fishing moratoriums. ([14])

"Run off has been transferred from the biologically active to the biologically inactive period of the year. This is analogous to stopping the rain during the growing season and irrigating during the winter, when no growth occurs." ([12])

The hydro dams and flow regulations alter nutrient delivery and availability by current mixing to the marine ecosystems. Like the importance of oxygen producing biota of the rain forests, the phytoplankton of the oceans are equally critical in their role for CO^2 removal, oxygen production, and mediating ocean acidity and are the very base (core) of the food chain. Without the delivery of sufficient nutrients, this ecosystem is profoundly compromised.

There exists striking evidence of a direct cause and effect relationship for ocean hotspots due to the presence of large dams and their flow regulation on rivers discharging near 40° latitude or higher. Given all the people and countries of the earth who stand to suffer great losses due to climate change, it is vital that we investigate **all** the causes of global warming. The consequences of dams and flow regulation on the oceans should be at the top of the list. (deserve the highest priority)

Large and Major Reservoir Hydroelectric Generating Stations Discharging into Estuary and Gulf of St. Lawrence River

Owner	Name	Capacity in Megawatts	(MW) Head (FT)	Commissioned	Watershed
Hydro-Quebec	Rapids Blanc	204	33	1934-35	St. Maurice
Hydro-Quebec	Bersimis-1	1,178	267	1956	Betsiamites
Hydro-Quebec	Bersimis-2	869	116	1959	Betsiamites
Hydro-Quebec	Jean-Lesage (Manic-2)	1,145	70	1965-67	Manicouagan
Hydro-Quebec	Outardes-4	785	121	1969	Outardes
Hydro-Quebec	Outardes-3	1,023	144	1969	Outardes
Hydro-Quebec	Outardes-2	523	82	1978	Outardes
Hydro-Quebec	Manic-5	1,596	142	1970	Manicouagan
Hydro-Quebec	Rene-Levesque (Manic-3)	1,244	94	1975-76	Manicouagan
Hydro-Quebec	Manic-5-PA	1,064	145	1989	Manicouagan
Hydro-Quebec	Sainte-Marguerite	882	330	2003	Saint-Marguerite
Hydro-Quebec	Touinstouc	526	152	2005	Touinstouc
Hydro-Quebec	Peribonka	405	68	2007-08	Peribonka
Hydro-Quebec	Romaine-2	640	156	2014	Romaine
Hydro-Quebec	Romaine-1	270	63	2015-16	Romaine
Hydro-Quebec	Romaine-3	395	119	2017	Romaine
		12,749			

Large and Major Reservoir Hydroelectric Generating Stations Discharging Into James Bay and Hudson Bay

Owner	Name	Capacity in Megawatts MW	Commissioned	Watershed
Manitoba Hydro	Kelsey	287	1957	Nelson
Manitoba Hydro	Kettle	1,220	1970	Nelson
Manitoba-Hydro	Lang-Spruce	980	1977	Nelson
Hydro Quebec	Robert-Bourassa	5,616	1979-81	LaGrande
Hydro Quebec	LaGrande-3	2,417	1982-84	LaGrande
Hydro Quebec	LaGrande-4	2,779	1984-86	LaGrande
Manitoba-Hydro	Limestone	1,350	1990	Nelson
Hydro-Quebec	Brisay	469	1993	Caniapiscau
Hydro Quebec	LaGrande-2-A	2,106	1991-92	LaGrande
Hydro Quebec	Laforge-1	878	1993-94	Laforge
Hydro Quebec	LaGrande-1	1,463	1994-95	LaGrande
Hydro Quebec	Laforge-2	319	1996	Laforge
Hydro Quebec	Eastmain-1	507	2006	Eastmain
Hydro Quebec	Eastmain-1-A	829	2011-12	Eastmain
		21,220		

APPENDIX 1

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