

Summit on Fraser River Sockeye Salmon



Contaminants in sewage

Ken Ashley, Ph.D.

March 31, 2010

Wosk Centre for Dialogue

Simon Fraser University

Vancouver BC

Outline

Emerging concerns in wastewater

Removal efficiencies at WWTPs

Effect on smolt migration?

PCB and PBDE trends in SoG sediment cores

Effects of WWTP discharges on Fraser River water quality

Emerging concerns in wastewater

Endocrine disruptors – Bisphenol A, Triclosan

Personal care products – musks, insect repellants

POPs – PCBs, Toxaphene, PBDEs (fire retardant)

Pharmaceuticals

VIAGRA
(sildenafil citrate) tablets

PROZAC
fluoxetine hydrochloride

Nanoparticles – nanosilver, nanotitanium, nanocarbon

Silver nanoparticles from Samsung's SilverCare washing machine will soon have to be registered with EPA as a pesticide.



For example: Triclosan

Products Containing Triclosan (incomplete list)

Liquid Hand/Face Soaps: Dial, Softsoap, Clearasil, Clean & Clear, pHisoderm, DermaKleen

Toothpastes & Mouthwashes: Colgate Total, Reach Antibacterial Toothbrushes, Breeze Triclosan Mouthwash



Deodorants: Old Spice High Endurance Stick Deodorant, Right Guard Sport Deodorant

Cosmetics: Supre Cafe Bronzer, TotalSkinCare Makeup Kit, Garden Botanika Powder Foundation, Mavala Lip Base, Jason Natural Cosmetics, Blemish Cover Stick, Movate Skin Lightening Cream HQ, Paul Mitchell Detangler Comb, Revlon ColorStay LipShine Lipcolor, Dazzle

Shaving Products: Gillette Complete Skin Care MultiGel Aerosol Shave Gel, Murad Acne Complex Kit, Diabet-x Cream, T.Taio sponges and wipes, Aveeno Therapeutic Shave Gel

Dish Soaps/Household Cleaners: Dawn, Ajax, mop heads

What are Endocrine Disruptors?

Chemicals in the environment that mimic hormones in the body and can have potential impact on fish, wildlife and humans at ultra-low concentrations (i.e., nanograms per litre)

- **Parts per trillion** = 1 second in 30,000 years.

List of Identified Endocrine Disrupting Chemicals (2007)

17 B-estradiol (normal female hormone)

Ethinylestradiol (birth control pills)

Surfactants such as nonylphenol and nonylphenol ethoxylates

Triclosan (antimicrobial agent in household products)

Removal efficiencies at WWTPs

Over half of the frequently detected EDCs were reduced by 95% or more by Activated Sludge plants




Less than 10% of the EDCs were reduced by 95% at the Trickling Filter plants

Primary treatment

Primary treatment is a mainly mechanical process that removes between 30 and 40 per cent of BOD and 50 per cent of the TSS. Iona Island and Lions Gate Wastewater Treatment Plants both provide primary treatment to the wastewater before the effluent - the remaining water - is released into the surrounding marine environment.

Secondary treatment

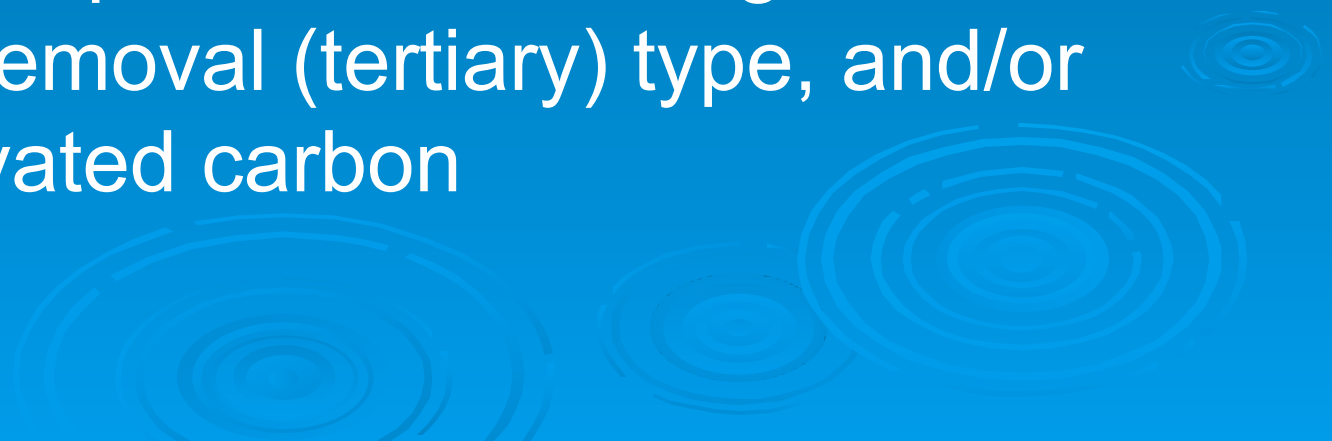
Secondary treatment is a biological process that removes up to 90 per cent of BOD and the TSS. Lulu Island, Annacis Island and Northwest Langley Wastewater Treatment Plants provide secondary treatment to the wastewater before the effluent - the remaining water - is released into the **Fraser River**.



Removal efficiencies at WWTPs

Recent reviews (2007) in Europe and USA indicate that trickling filter plants are ineffective at removing a wide range of emerging contaminants

Most effective plants were Biological Nutrient Removal (tertiary) type, and/or using activated carbon



Effect of WWTP design: 2007 study in England

Activated sludge WWTPs have higher removal efficiencies for most EDCs than most trickling filter plants

Higher removal efficiency in AS WWTPs is due to (1) longer hydraulic contact time (2) longer solids contact time and (3) more diverse microbial community:

Activated Sludge WWTP ~ 5-20 hr HRT

Trickling Filter WWTP ~ 30 minute HRT

Biologically Aerated Filter ~ 15 – 60 minute HRT

Effect of WWTP design: 2007 USA study by Metcalf and Eddy Inc.

Highest (>90%) EDC removals were observed in:

AS plants with sludge age of 5 to 10 days and

AS plants with a nitrification/denitrification step

TF plants with additional tertiary biological step

Note: Annacis/Lulu design (TF/SC) is not effective at removing EDCs (~ only 30% removal of estrone)

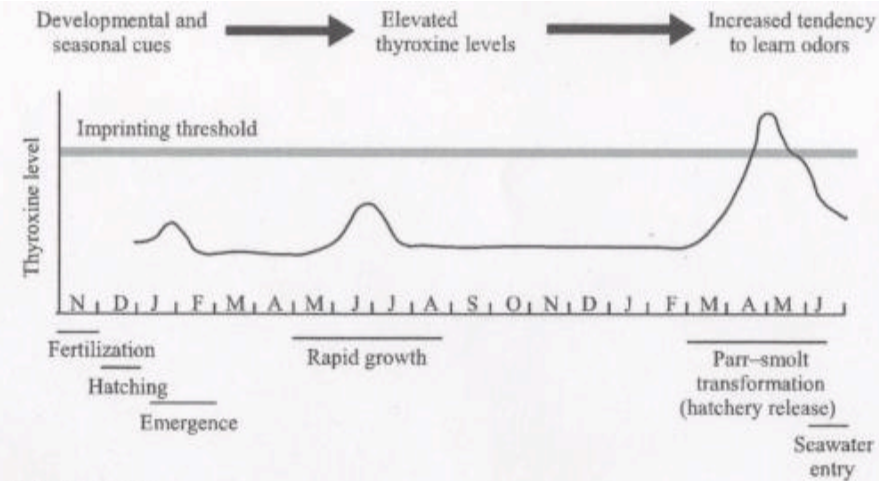
Effects on salmon migration?

- In streams juvenile salmon detect the unique odour of their natal streams – **olfactory imprinting**
- This was confirmed by the classic morpholine experiments of Hasler, and lab experiments of Hara.
- Evidence suggests that juvenile salmon ‘imprint’ odours of their streams on the way when the ocean during the **parr-smolt transformation period (PST)**.

-During this period, they have elevated concentrations of the hormone 'thyroxine' in their plasma

-thyroxine is believed to regulate neurogenesis, and surges of hormones likely influence neural development in the salmon olfactory system, and facilitate olfactory imprinting





(B) Wild salmon

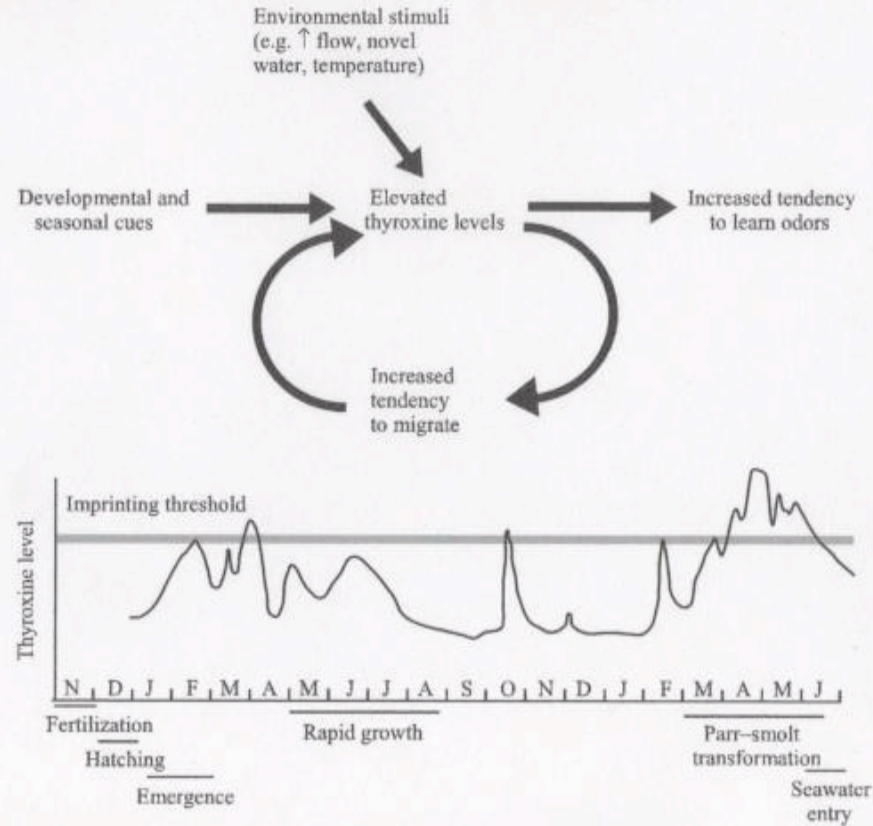


Fig. 2. Hypothetical relationship between thyroxine levels, olfactory imprinting and migration in (A) hatchery-reared and (B) wild coho salmon. Thyroxine data for hatchery fish from Dickhoff and Sullivan (1987). Thyroxine levels for wild salmon are purely hypothetical to illustrate the model.

PCB and PBDE trends in SoG sediment cores

Johannesen et al., 2008. Marine Environmental Research 66:S112-S120.

Strait of Georgia.

(Fig. 2) in October 2003 and retrieved in April 2004. Each trap

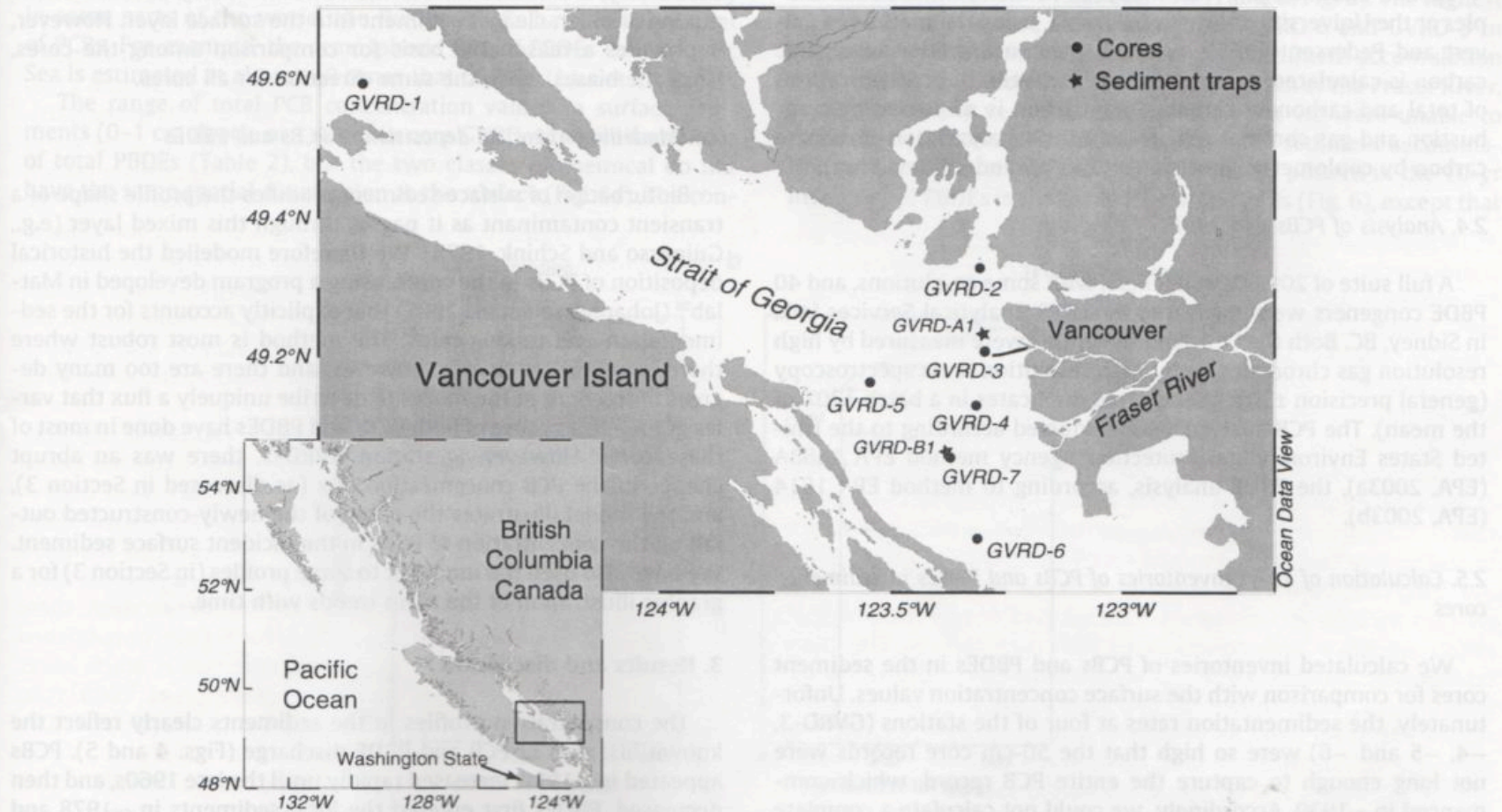
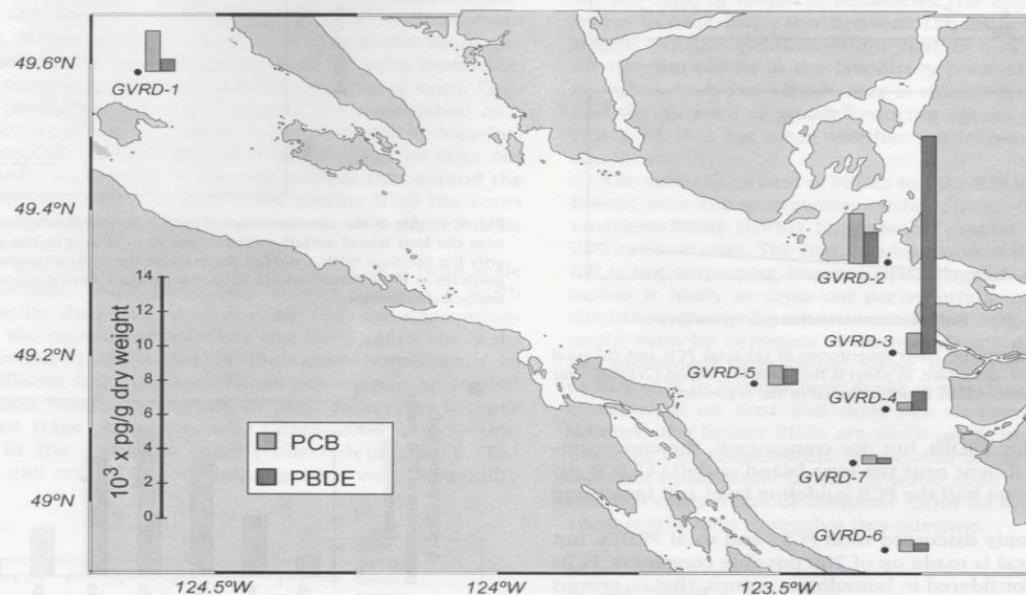


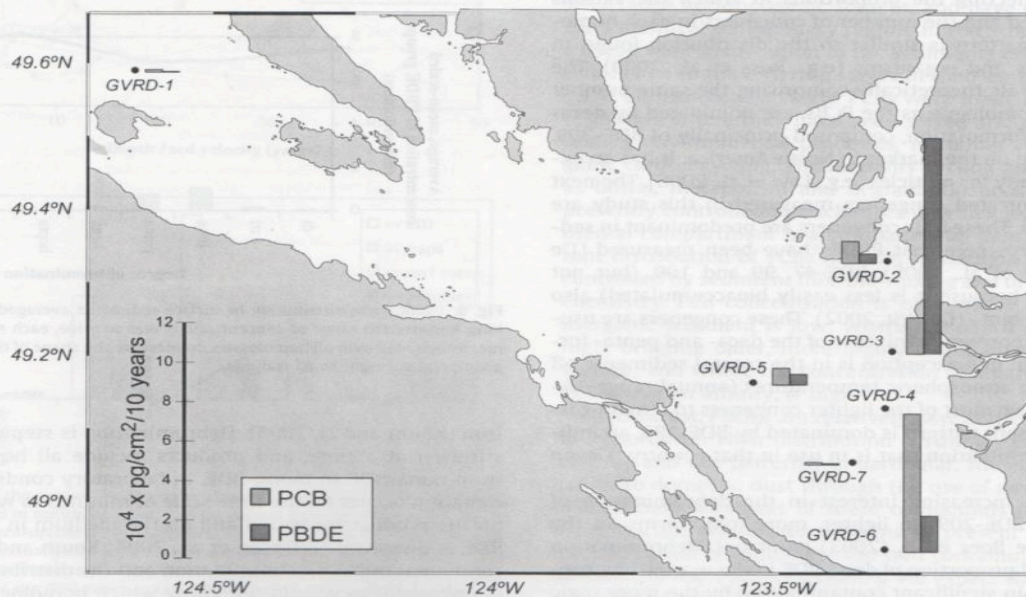
Fig. 2. Sediment core sampling locations (GVRD-1 to GVRD-7) and locations of sediment trap moorings (GVRD-A1, GVRD-B1) in the Strait of Georgia. The black line immediately to the east of station GVRD-3 represents the location of the Iona Island outfall pipe.

PBDE use is curtailed, and environmental cycling begins to domi-

to decrease, in the absence of a new source. There are no sediment



(a) Surface concentration



(a) 10-year inventory

Fig. 6. Distribution of total PCBs and total PBDEs in Strait of Georgia sediments: (a) surface concentration, (b) 10-yr inventory, as described in text.

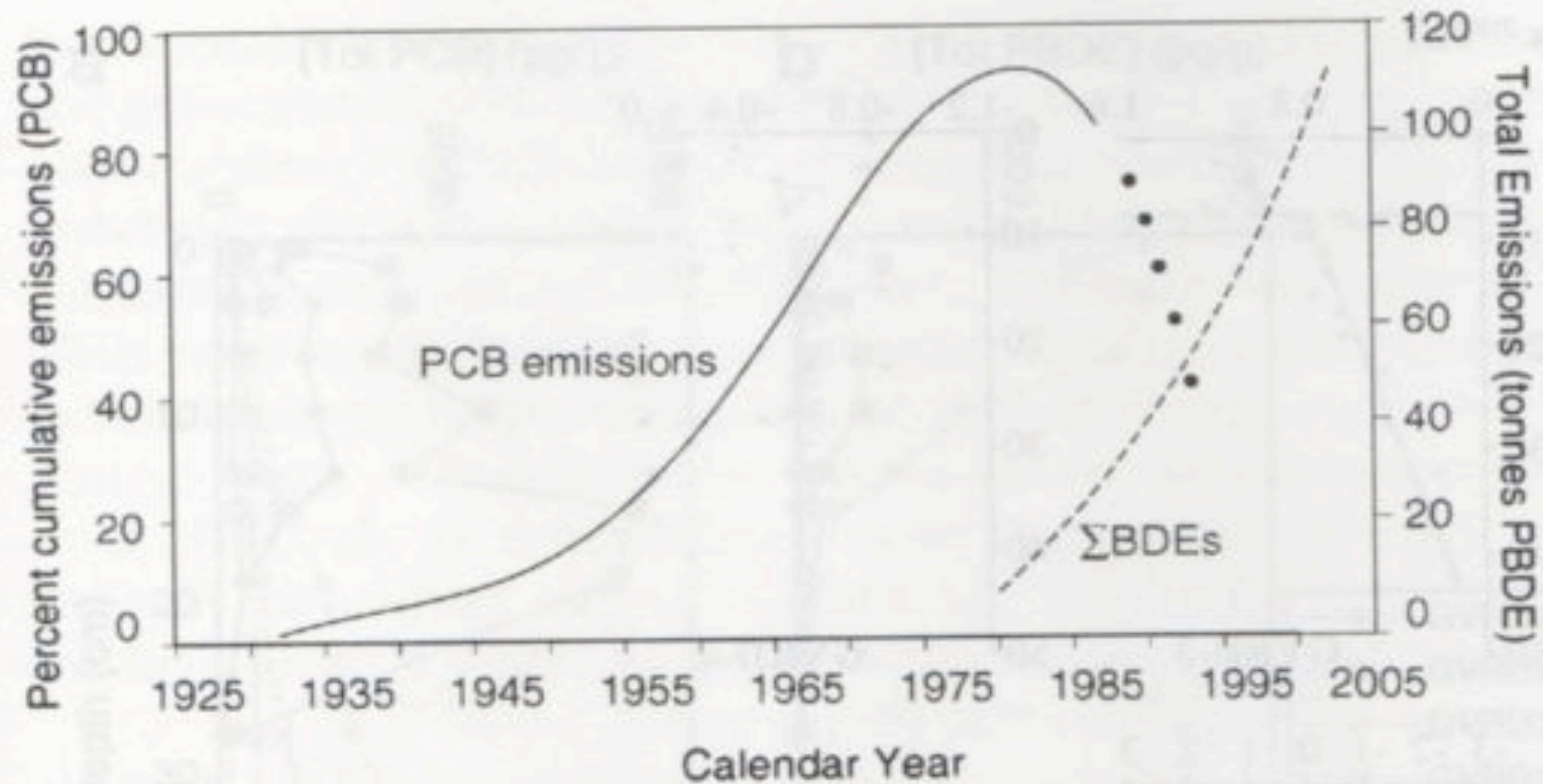


Fig. 1. Emission histories of PCBs and PBDEs, modified from Li et al. (2006) (North American PBDE emission trend) and Rapaport and Eisenreich (1988) (% of cumulative emissions of PCBs to Eastern North America). The last five years of the PCB trend (dotted) represent an extrapolation of Rapaport's polynomial fit beyond the date of its publication.

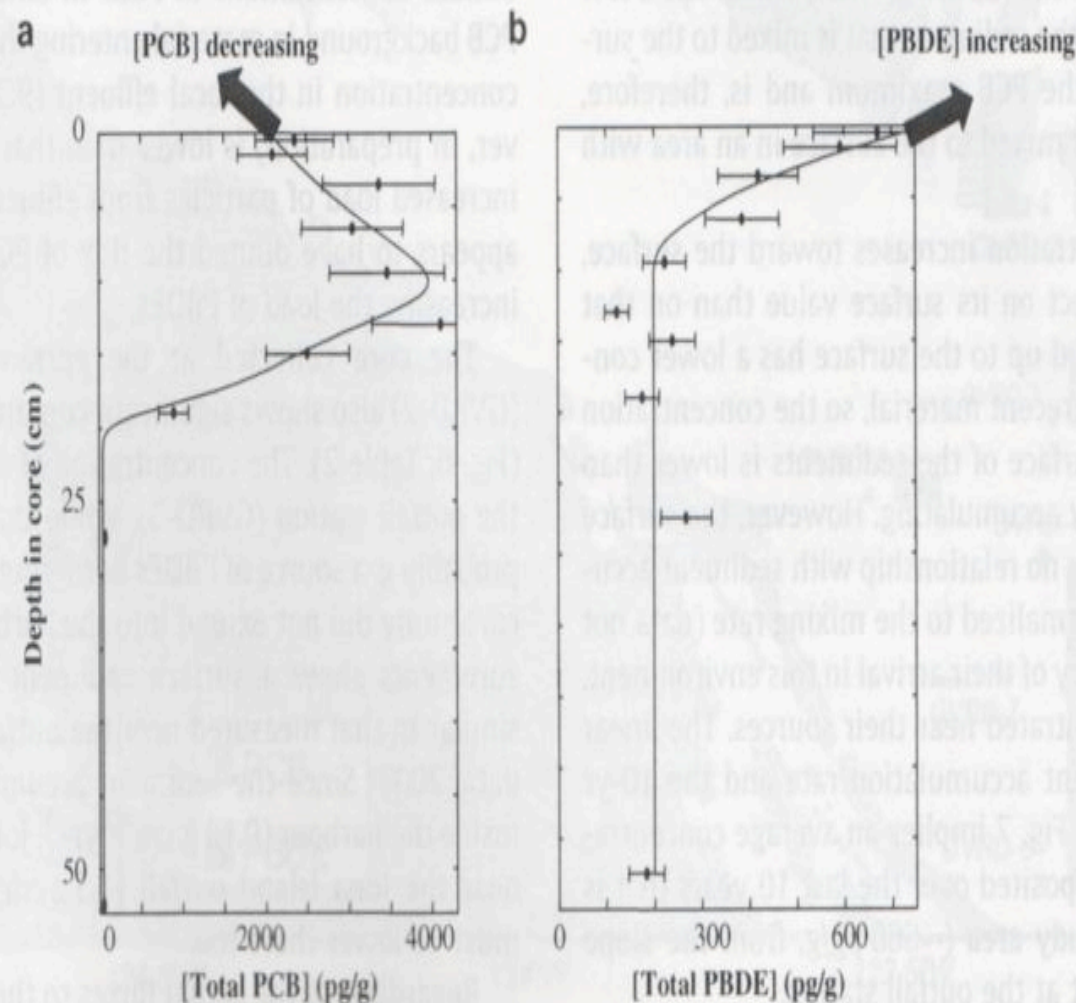


Fig. 5. Profiles of the concentration of (a) total PCB and (b) total PBDE in sediment core GVRD-1. This core was chosen, because its low sediment accumulation rate means that the entire history of PCB contamination is visible in the 50 cm core. All the cores show the same trends, although they do not all represent the same amount of time. (See Table 1 for sediment accumulation rates.) Error bars are $\pm 20\%$, the measurement uncertainty reported by the analytical laboratory.



Tuesday, May 7, 2002

By **ROBERT McCLURE**

SEATTLE POST-INTELLIGENCER REPORTER

The orca found dead on the Olympic Peninsula earlier this year carried a level of contaminants that was among the highest -- if not *the* highest -- ever measured in killer whales, laboratory tests show.

The 22-foot-long female orca was so full of polychlorinated biphenyls that when scientists first attempted to test her fat, the result was too high for the machines to read it.

Outfalls in SoG

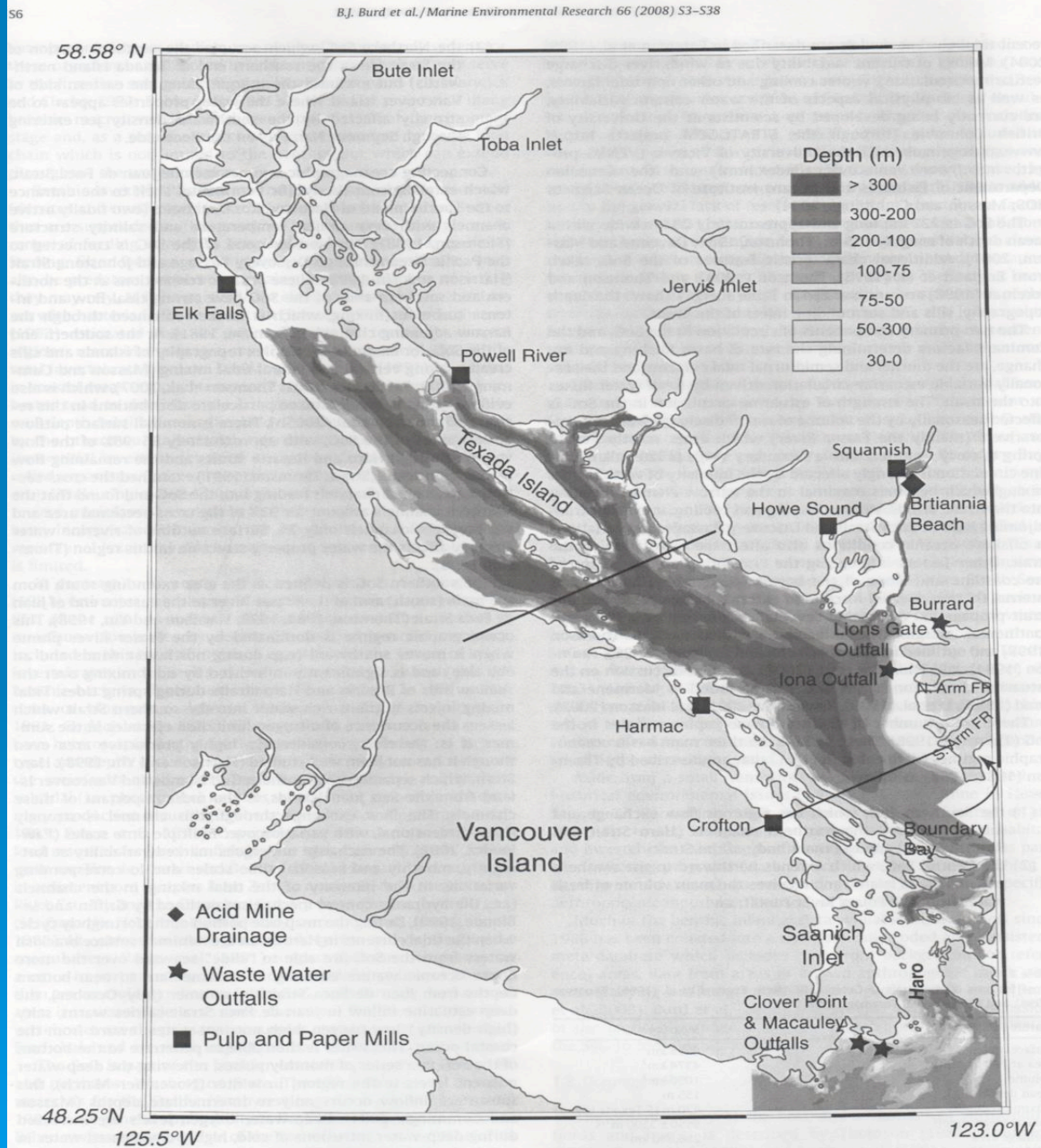


Fig. 1. The Strait of Georgia, including depth contours from multibeam imagery (see also Fig. 3), locations of important geographic units and discharge sources described herein, and theoretical boundaries of north, middle and southern oceanographic regimes within the main basin.

Environmental Protection Division

Ministry of Environment

The Annacis STP discharges about 200,000 m³/d of primary-treated sewage to a portion of the Main Arm of the Fraser River where tidal influences exist. The tidal effects, in combination with projected effluent loadings, could result in impacts on river quality in the future at extremely low river flows. These impacts could be caused by copper, lead, zinc and un-ionized ammonia. Fecal coliform values are presently high outside the initial dilution zone. High metal and ammonia levels potentially could stress aquatic life, while high fecal coliforms could impair the use of the water for irrigation or recreation.

The Annacis Island Wastewater Treatment Plant (WWTP) is the largest plant and provides secondary treatment to wastewater from approximately 1,000,000 people in parts of Burnaby, New Westminster, Port Moody, Port Coquitlam, Coquitlam, Pitt Meadows, Maple Ridge, Surrey, Delta, White Rock, City of Langley and Township of Langley.

Biosolids produced in 2006 (dry tonnes/24-34% solids concentration): 12,000

Biosolids type: Class A

Solids digestion process: Anaerobic thermophilic (55°C)



Ammonia Toxicity

pH 6 3,000:1

pH 7 300:1

pH 8 30:1

pH 9.5 1:1



3.5 Effluent Toxicity

In 1999 and 2000, comprehensive assessments of acute effluent toxicity at the Annacis Island WWTP were conducted. The findings of the assessment studies were presented at an inter-governmental agency workshop held in March 2001. The findings showed that ammonia was the primary cause of toxicity. The toxicity, however, appeared to be largely a function of the test protocol as aeration resulted in an increase in sample pH that ultimately increased the proportion un-ionized ammonia, a more toxic form of ammonia, during the test.

Environment Canada's standard test method⁴ for determining acute lethality of effluents to Rainbow trout exposes test fish to a series of effluent dilutions, and determines the fish survival rate at the end of a 96-h exposure period. The final result is reported as the 96-h LC₅₀ value, which is the % by volume (of the original sample) at which 50% of the test fish survive. A pass for all effluent samples requires that the LC₅₀ value must be *equal to or greater than* 100% (v/v sample). This means that 50% or more of the test fish must survive for 96 hours in the original undiluted sample.

In 2008, Environment Canada published an add-on test procedure⁵ for pH stabilization during the testing of acute lethality. The purpose of pH stabilization is to replace the CO₂ lost due to aeration in order to maintain the pH throughout the test at the same levels observed at the start of the test. The modified test with the add-on procedure is used whenever the standard test gives a false result due to an artifact of the test protocol.

So concurrently with the standard test, a second test is conducted using an add-on test procedure for pH stabilization during the testing of toxicity.

2008 Program

As required by the Liquid Waste Management Plan and the plant's Operational Certificate, all regular LC₅₀ results for effluent samples from GVS&DD WWTPs are followed up with work to explain the cause of results of less than 100%. Outlined below is a summary of Annacis effluent toxicity results and evaluations for 2008.

All effluent samples from the Annacis Island WWTP passed the required monthly toxicity test using Environment Canada's standard test (5 cases) and/or modified test (7 cases) with the add-on pH stabilization step.

Additionally, the pH and ammonia values in 2008 showed that the concentration of ammonia in the undiluted effluent was not acutely toxic at the measured pH value. This is demonstrated in the following chart for pH and ammonia data collected during the year. All results were below the threshold acute concentration curve for ammonia at the measured pH value of the effluent discharge.



Figure 3-1: Annacis Island WWTP - Ammonia Concentration versus pH Value

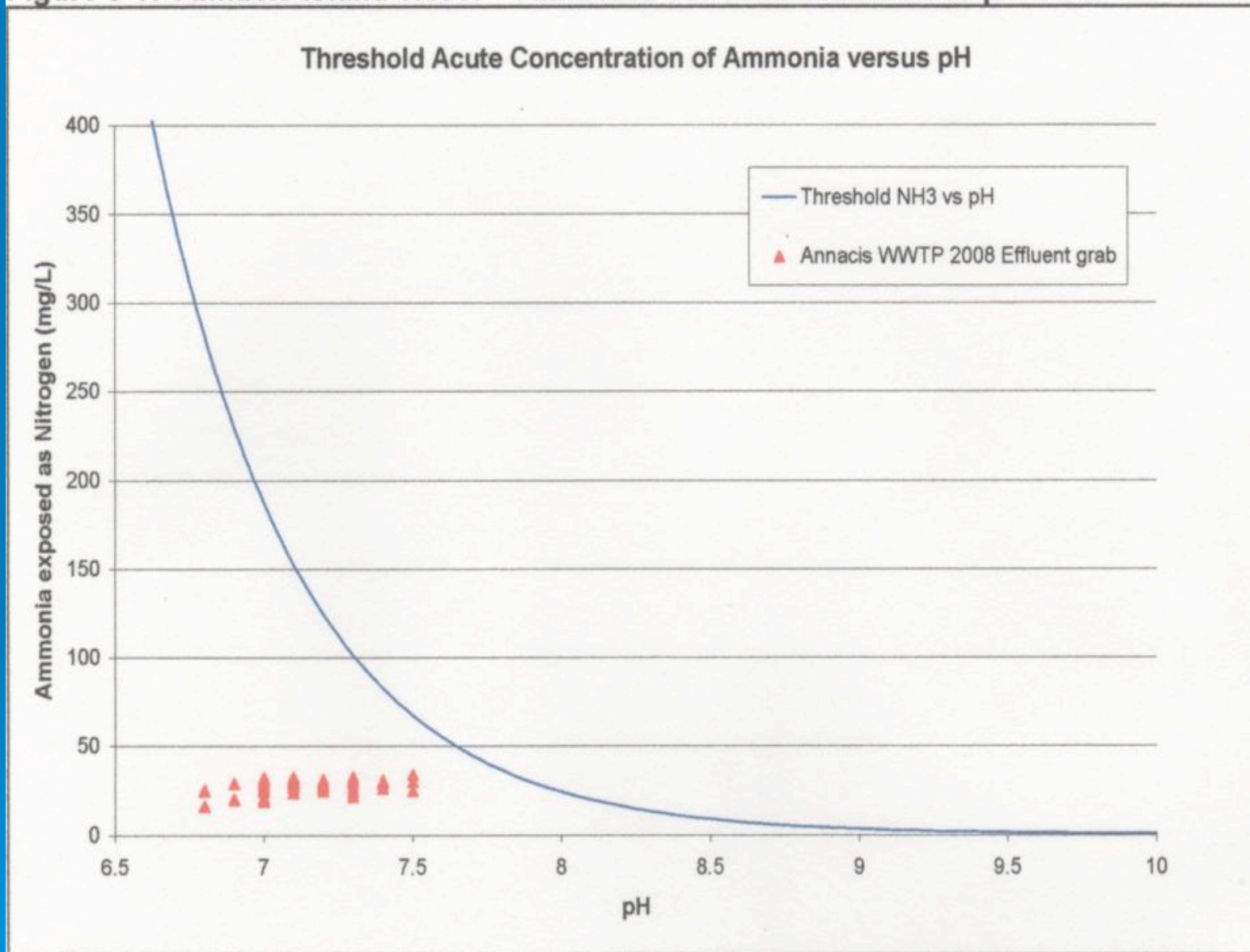


Table 3-4: Annacis Island WWTP - 2008 Routine Monitoring Results and Performance Summary

MONTH	Max. Inst. Flow Rate (m3/sec)	Total Daily Effluent Flow (MLD)			Composite pH Average		Grab pH Average	Grab NH3 Average (mg/L)	96 hr LC50* (%v/v)	
		Max.	Min.	Ave.	RAW INF	FINAL EFF	FINAL EFF	FINAL EFF	Regular	Parallel CO2
JAN	11.9	850	457	554	7.3	7.5	7.1	24.6	>100	>100
FEB	9.7	665	441	524	7.2	7.5	7.2	25.0	>100	>100
MAR	8.9	540	441	469	7.2	7.6	7.2	26.9	74	>100
APR	7.8	586	417	449	7.2	7.7	7.1	29.0	79	>100
MAY	8.5	506	414	438	7.2	7.6	7.0	30.1	86	>100
JUN	9.4	509	400	436	7.2	7.6	7.1	30.7	>100	>100
JUL	7.0	441	400	412	7.2	7.6	7.2	30.7	86	>100
AUG	8.5	544	383	437	7.3	7.6	7.2	27.3	82	>100
SEP	7.0	458	415	429	7.2	7.6	7.1	27.9	74	>100
OCT	9.2	622	412	452	7.3	7.6	7.1	27.9	98	>100
NOV	11.8	804	449	558	7.3	7.6	7.2	23.5	>100	>100
DEC	10.9	681	429	541	7.3	7.7	7.2	24.4	>100	>100

# Samples	-	-	-	366	349	358	63	55	14	14
Maximum-Yr.	11.9	850	-	-	7.5	7.9	7.5	33.9	>100	>100
Minimum-Yr.	-	-	383	-	7.0	7.2	6.8	16.1	72	>100
Average-Yr.	-	-	-	475	7.2	7.6	7.1	27.3	>90	>100

* LC50 results are reported as monthly average

MONTH	Conductivity (umhos/cm)		Ave Chloride (mg/L)	Ave Temp. (oC)	Ave. Chlorine (mg/L)	Ave. Residual Chlorine Final Effluent (mg/L)		Residual SO ₂ (mg/L)	Fec. Coliform (MPN/100mL) Final	
	RAW INF	FINAL EFF	FINAL EFF	FINAL EFF	FINAL EFF	Before SO ₂	After SO ₂	Effluent Outfall	Monthly Geomean	Max Geomean in month
JAN	507	577	66	12	-	-	-	-	-	-
FEB	490	554	48	13	-	-	-	-	-	-
MAR	505	587	50	13	-	1.07	<0.1	1.83	-	-
APR	540	636	70	15	2.9	1.02	<0.1	1.70	140	-
MAY	514	596	54	17	3.2	1.15	<0.1	1.86	54	76
JUN	497	574	54	19	3.2	1.20	<0.1	1.90	75	75
JUL	473	556	44	21	3.6	1.11	<0.1	2.66	739	2334
AUG	462	533	45	21	3.6	1.31	<0.1	2.88	1273	1114
SEP	459	532	45	20	3.7	1.35	<0.1	1.62	1171	1171
OCT	450	528	43	19	3.5	1.42	<0.1	1.78	53	2276
NOV	426	489	36	17	-	-	-	-	-	-
DEC	547	589	79	15	-	-	-	-	-	-

# Samples	349	359	54	63	218	228	228	228	62	55
Maximum-Yr.	1140	971	165	22	4.2	1.9	<0.1	6.84	35000	2334
Minimum-Yr.	338	373	28	11	1.9	<0.1	<0.1	0.23	<20	22
Average-Yr.	488	562	54	17	3.4	<1.9	<0.1	2.06	-	-
Geomean	-	-	-	-	-	-	-	-	241	586

- (1) pH, Temperature, ammonia, Residual Chlorine(taken before and after dechlorination), Residual SO₂, 96 hour LC50 and Coliform are determined on grab samples; all other parameters are determined on 24 hr. flow proportioned composite samples.
- (2) Summer = Mar. 28 - Nov 14, 2008 inclusive: Chlorinated Effluent; Winter = Jan. 1 - Mar. 27, 2008 and Nov. 15 - Dec. 31, 2008: No Chlorination

7 of 12 monthly failures of 96 hr LC₅₀ standard bioassay tests for ammonia in effluent

Ammonia concentration in the Fraser River

$$(\text{Flow 1} * \text{Conc. 1}) + (\text{Flow 2} * \text{Conc. 2}) / \text{Flow 1} + \text{Flow 2}$$

For Fraser River in March, assume 1,500 m³/s, and 0.01 mg/L NH₃

For Annacis WWTP discharge in March = 469,000,000 L/d = 5.428 m³/s,
and 26.9 mg/L NH₃

$$(1,500,000 * 0.01) + (5,428 * 26.9) / (1,500,000 + 5,428) = 0.11 \text{ mg/L at pH 7.1}$$

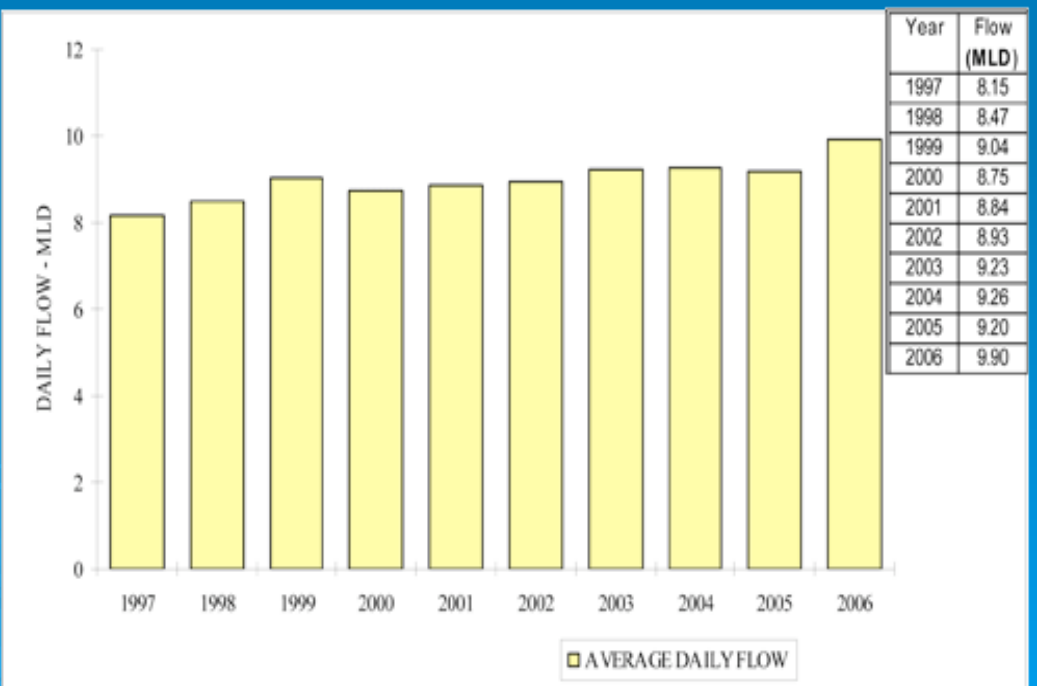
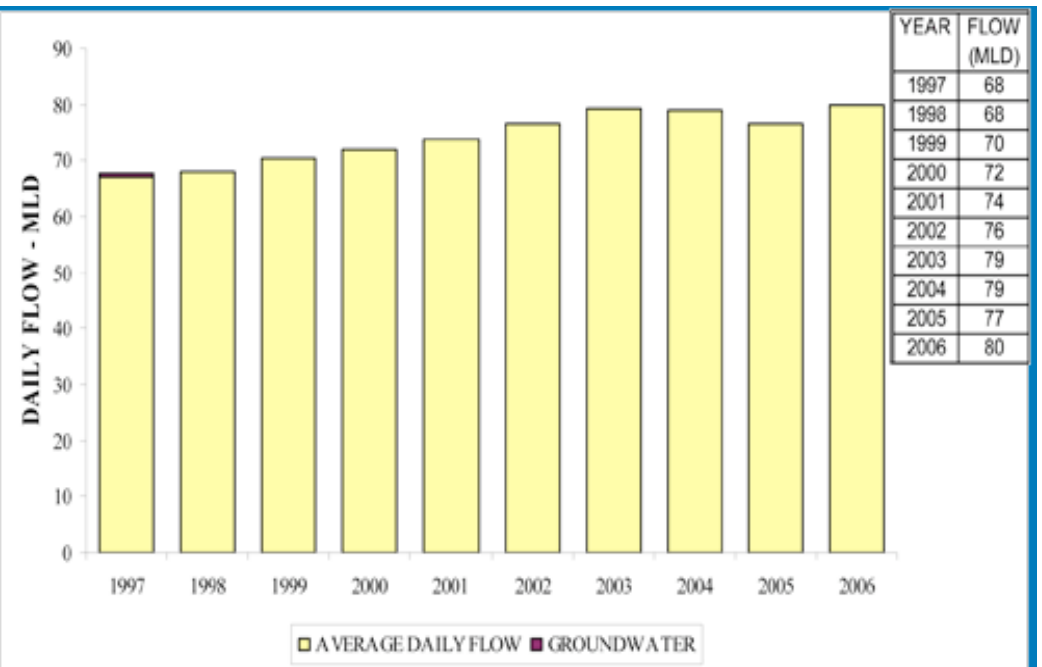
At 1,000 m³/s = 0.16 mg/L NH₃

At 2,000 m³/s = 0.08 mg/L NH₃

Table 4. Average 30-Day Concentration of Total Ammonia Nitrogen for Protection of Aquatic Life (mg/L of Nitrogen)

Temperature (T) in degrees Celcius

pH	T = 7.0	T = 8.0	T = 9.0	T = 10.0	T = 11.0	T = 12.0	T = 13.0
6.5	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.6	1.90	1.88	1.86	1.84	1.82	1.81	1.80
6.7	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.8	1.90	1.88	1.86	1.84	1.83	1.81	1.80
6.9	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.0	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.1	1.90	1.88	1.86	1.84	1.83	1.81	1.80
7.2	1.90	1.88	1.86	1.85	1.83	1.81	1.80
7.3	1.90	1.88	1.86	1.85	1.83	1.82	1.80
7.4	1.90	1.88	1.87	1.85	1.83	1.82	1.80
7.5	1.91	1.88	1.87	1.85	1.83	1.82	1.81
7.6	1.91	1.89	1.87	1.85	1.84	1.82	1.81



3.0 ANNACIS ISLAND WWTP 2008 ANNUAL SUMMARY

3.1 Effluent Quality

The quality of effluent from the Annacis Island WWTP in 2008 is summarized in the following table, along with compliance with parameters listed in the Operational Certificates.

Table 3-1: Annacis Island WWTP – 2008 Compliance Summary

Operational Certificate Requirement - ME00387, April 23, 2004.

Compliance Parameters	Frequency	OC Limits	Max. Value for the Year	No. of times Criteria Exceeded												Yr to Date
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Total Flow (MLD)	Daily	1050	850	0	0	0	0	0	0	0	0	0	0	0	0	0
cBOD (mg/L)*	3/week	45.0	17	0	0	0	0	0	0	0	0	0	0	0	0	0
Suspended Solids (mg/L)	5/week	45.0	64	2	0	0	0	0	0	0	0	0	0	0	0	2 of 360
cBOD (Tonnes/Day)*	3/week	17.0	21.7**	1	0	0	0	0	0	0	0	0	0	0	0	1 of 105
Susp. Solids (tonnes/Day)	5/week	20.0	53.4	3	0	0	0	0	0	0	0	0	0	0	0	3 of 360
Chlorine Residual (mg/L)	Daily	<0.1	<0.1	0	0	0	0	0	0	0	0	0	0	0	0	0

* cBOD reported 1/week when COD are reported 5/week

**cBOD loading for secondary effluent was reported for Jan 14, 2008 during bypass

Monitoring Parameters	OC Frequency	Sample Type	Year 2008		
			Maximum	Minimum	Average
pH***	1/month	Grab	7.5	6.8	7.1
Toxicity, 96-hour LC ₅₀ (% V/V)	1/month	Grab	>100	72	>90
Ammonia (mg/L)***	1/week	Grab	33.9	16.1	26.8
Hardness (mg/L CaCO ₃)	1/month	Comp	54.9	33.5	43.7
COD (mg/L)*	5/week	Comp	89	39	81
Conductivity (µmhos/cm)	-	Grab	971	373	562
Temperature °C	1/month	Grab	22	11	17
Fecal Coliform MPN	1/Week	Grab	35,000	<20	1000****
Residual Chlorine (mg/L)	Daily	Grab	<0.1	<0.1	<0.1
Oil and Grease (mg/L)	-	Grab	<7	<5	<7
Phenol (mg/L)	1/month	Grab	<0.01	<0.01	<0.01
Aluminum, Total (mg/L)	1/month	Comp	0.20	0.08	0.12
Arsenic, Total (mg/L)	1/month	Comp	<0.001	<0.001	<0.001
Barium, Total (mg/L)	1/month	Comp	0.011	0.004	0.007
Boron, Total (mg/L)	1/month	Comp	0.20	0.13	0.18
Cadmium, Total (mg/L)	1/month	Comp	16.7	9.6	12.9
Chromium, Total (mg/L)	-	Comp	0.004	<0.001	<0.002
Cobalt, Total (mg/L)	1/month	Comp	0.001	<0.001	<0.001
Copper, Total (mg/L)	1/month	Comp	0.072	0.028	0.056
Iron, Total (mg/L)	1/month	Comp	0.90	0.48	0.70
Lead, Total (mg/L)	1/month	Comp	0.001	<0.001	<0.001
Manganese, Total (mg/L)	1/month	Comp	3.23	2.14	2.79
Mercury, Total (mg/L)	1/month	Comp	<0.00005	<0.00005	<0.00005
Molybdenum, Total (mg/L)	1/month	Comp	0.005	<0.002	<0.003
Nickel, Total (mg/L)	1/month	Comp	0.004	0.002	0.003
Selenium, Total (mg/L)	1/month	Comp	0.01	<0.01	<0.01
Silver, Total (mg/L)	1/month	Comp	<0.001	<0.001	<0.001
Zinc, Total (mg/L)	1/month	Comp	0.040	0.029	0.036

*** Minimum, Maximum and average values are calculated from all available weekly grab data.

**** Fecal Coliform results are monthly geometric values and are only done during the disinfection period under the new Operational Certificate.

Note 1: Toxicity requirements, April 23, 2004 Operational Certificate: If a fish bioassay toxicity test fails to meet or exceed a LC₅₀ value of 100%, the permittee is required to conduct a Toxicity Identification Evaluation (TIE) study for the purpose of determining the probable cause of the failure.

Note 2: In calculating average results, all < or > signs are removed and the numbers are used in the calculations. The sign is added back to the calculated average value.