Water Pollution from Urban Stormwater Runoff in the Brunette River Watershed, B.C.

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DISCLAIMER

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Abstract

The water quality of the tributary streams and street runoff were investigated over the period of a year in the Brunette River watershed located in the Lower Fraser Valley of British Columbia. Dry weather base flow monitoring detected fecal coliforms, far in excess of water quality criteria for any recreational use, which were attributable to illegal connections of sanitary sewers to the storm drainage system. Oxygen concentrations during the summer were below levels critical to fish survival in the lower reaches of Still Creek and upper reaches of the Brunette River.

Stormwater runoff to the tributary streams demonstrated that trace metals (Cu, Mn, Pb, and Zn), and hydrocarbons were mainly associated with the suspended solids. Contaminant concentrations were usually higher during summer storms when there were longer dry periods for contaminants to build up in the streets. Concentrations of copper and zinc often exceeded water quality criteria for the protection of aquatic life and microtox bioassays demonstrated that the suspended solids were toxic.

The loading of contaminants in street runoff and the different reaches of the streams was directly related to traffic density and land cover permeability of the drainage areas. Geographic Information Systems (GIS) have been useful in relating the land use and quality conditions in these urban streams. Control of these non-point pollutants will require a management program that will integrate source control, regulations, and best management practices if society wants to enjoy the benefits of these streams and lakes in this urban setting.

Résumé

On a étudié la qualité de l’eau des tributaires et la qualité des eaux du ruissellement urbain sur une période d’un an dans le bassin de la Brunette, situé dans la vallée du bas Fraser, en Colombie-Britannique. La surveillance du débit d’étiage de base a permis de mettre en évidence la présence de concentrations de coliformes fécaux bien supérieures aux concentrations permettant un usage récréatif des eaux; cette situation était attribuable aux raccordements illégaux des égouts sanitaires au réseau de collecte des eaux pluviales. Les concentrations d’oxygène durant l’été étaient inférieures aux concentrations critiques pour la survie des poissons dans les tronçons inférieurs du ruisseau Still et dans les tronçons supérieurs de la Brunette. Les eaux pluviales de ruissellement qui se jettent dans les tributaires ont révélé que les métaux traces (Cu, Mn, Pb et Zn) et les hydrocarbures étaient principalement associés aux solides en suspension. Les concentrations de contaminants étaient habituellement plus élevées durant les orages estivaux quand de longues périodes sèches permettaient une accumulation de contaminants dans les rues.Les concentrations de cuivre et de zinc excédaient souvent les normes de qualité de l’eau pour la protection de la vie aquatique, et des bio-essais microtox ont montré que les solides en suspension étaient toxiques.

La charge de contaminants dans les eaux de ruissellement des rues et dans les différents tronçons des cours d’eau était directement liée à la densité du trafic et à la perméabilité du terrain dans la zone de drainage. Les systèmes d’information géographique (SIG) ont été utiles pour relier l’utilisation des terres à la qualité de l’eau dans ces cours d’eau urbains. Pour contrôler ces polluants issus de sources non ponctuelles, on devra mettre en oeuvre un programme de gestion qui comportera un contrôle des sources, une réglementation et un code de bonnes pratiques; c’est là une condition pour que la société puisse profiter des cours d’eau et des lacs dans un contexte urbain.

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Methods

A comprehensive monitoring program was organized to measure the water quality during dry weather conditions (baseflow), and during storm events. The baseflow water quality conditions were monitored at 13 sampling stations distributed throughout the watershed (Figure 1) on 10 occasions during 1994-1995. Field measurements were made of dissolved oxygen, temperature, conductivity, and pH and grab samples were collected and analyzed for general water chemistry, nutrients, and trace metals. Three of these stations, selected to represent different land use (impervious surface areas) and traffic density, were monitored during 12 rainfall periods in 1994-1995 (Table 1). During eight of these rainfall periods, samples of street runoff were also collected from four sites that represent different patterns of traffic use. Flow measurements were made so that contaminant loadings could be calculated. Selected samples were evaluated for toxicity by measuring photoluminescence inhibition of marine bacteria (Microtox bioassay). The complete data set is reported in Hall and Macdonald (1996).

Results and Discussion

Baseflow Quality: Baseflow monitoring indicated high fecal coliform levels in the Still Creek sub-basin, levels often exceeded criteria for safe primary contact recreation (200 MPN/100 mL) by two orders of magnitude. High ammonia levels indicate that this contamination is most likely attributable to domestic wastewaters. Fecal streptococci levels are relatively low although in some areas there is concern about fecal contamination from large numbers of geese (City of Burnaby, unpublished data). Burnaby, Vancouver and the GVRD have been conducting more detailed monitoring to isolate the sources of fecal contamination and eliminate them.

Dissolved oxygen in the lower reaches of Still Creek and in the upper reaches of the Brunette River threaten the safe passage of fish during the summer. The levels of oxygen in the surface waters of lower Still Creek drop to <5 mg/L (50% saturation) while bottom waters are often depleted. Fish kills have been observed in this reach of the river. Warm summer temperatures, stagnant flows, and decomposition of sediment contaminants combine to create these unfavorable conditions. The low summer dissolved oxygen (2.6 mg/L, 30% saturation) in the Brunette River is attributable to the highly colored water (av. 70 mg/L Pt) in Burnaby Lake which prevents light penetration into the water column and limits photosynthesis. Turbulence and mixing in the Brunette River restores the oxygen to >75% saturation a kilometre below the lake. The dissolved oxygen in the mountain tributaries is always well saturated. During the winter months, the colder water temperatures and frequent flushing by storm events provide healthy oxygen conditions throughout the watershed.

Stormwater Quality: The trace metals (Cu, Pb, Zn and Mn) have been selected to illustrate the difference between baseflow and storm event water quality conditions (Figure 2). All three stations exceed the copper water quality criterion of 2 μg/L for the protection of aquatic life during both dry and wet weather conditions. However, the average concentrations of copper in Still Creek (Renfrew and Gilmore stations) exceeds 50 μg/L during storm periods. Even though lead additives have been removed from gasoline, Still Creek still exceeds the 4 μg/L criterion for the protection of freshwater life during rainfall events. This is attributable to the natural levels of lead in gasoline and to the increase in the vehicular traffic density by over 40% in the watershed in the last 20 years (McCallum 1995). Total zinc exceeds the safe criterion (30 μg/L) in both Still and Eagle Creeks during storm runoff periods. It is obvious that there is considerable variation in trace metal concentrations during storm events when the flow is highly variable. Since a large proportion of the contaminants such as hydrocarbons (Figure 3) and trace metals (Figure 4) are associated with suspended solids, it is the variable transport of these solids that causes the transport of contaminants to vary over a storm event.

More detailed monitoring of hydrocarbons in stormwater, street surface dirt, and stream sediments has demonstrated that the hydrocarbon slick that is flushed from the roadways during a rainfall event adsorbs to the suspended sediment in the stream (Larkin and Hall, in press).

Seasonal Effects: Seasonal variability was analyzed to determine how the rainfall and runoff characteristics affect the quality of stormwater runoff. The dry days preceding a storm and the rainfall intensity did not correlate well with the stormwater quality at the three monitoring stations. However, when the summer storms (July and August) are compared to the winter storms (November to February) there is an obvious pattern. Generally, the summer storms have higher concentrations of contaminants than the winter storms. The summer rainfall events tend to be more infrequent and on average are more intense than the winter rainfall events. Thus contaminants have a longer time to build up on impervious surfaces and there is a greater potential to flush these materials from the streets when it rains harder.

Toxicity of Urban Stormwater: Initial toxicity tests using the Microtox bioassay following the standard protocol, where samples are filtered, demonstrated that the soluble components of the stormwater were non-toxic to the bioassay bacteria. Subsequent bioassays on the suspended solids demonstrated that the contaminants associated with these particulates are inhibitory to bacteria (Figure 5). The suspended solids at the Gilmore stream station had an EC_{50} of 1-2% which is characterized as a slightly toxic response while the suspended solids collected in runoff from a highly travelled roadway (Willingdon Ave.) were considered moderately toxic (EC_{50} 0.1-0.9%). The chemistry of the stormwater as illustrated by the hydrocarbons and trace metals (Cu and Zn) confirms that higher levels of contaminants are flushed with the solids from the streets. The concentration of the suspended solids flushed from the streets was approximately twice the level measured in the nearby creek (Gilmore Station) during the storm event, so the toxicity per unit of street runoff is four times that of the creek.

Stormwater Loadings: Flow measurement along with the quality monitoring allowed the loading of contaminants in stormwater to be calculated. Since discrete grab samples were collected over the rainfall event, the sampled mean concentration method was used to calculate the instantaneous loading rate over the storm event (Bellevue 1995). These loading rates are integrated over the 12 storms that were monitored and along with the rainfall record for the monitoring period this allows a calculation to be made of the annual export coefficients for contaminants. Examples of these calculations for the trace metals (Cu, Pb, Zn, and Mn) are presented in Figure 6. The export of the toxic metals (Cu, Pb, and Zn) from the Still Creek sub-basin with a high impervious area and high traffic density were 2-3 times higher than the values calculated for the Eagle Creek sub-basin which collects runoff from Burnaby Mountain. The high manganese loading in the Eagle Creek drainage is most likely attributable to the erosion of soil from the green space areas and its transport down the steep gradient of the mountain.

A comparison can be made between the export coefficients determined by Stanley et al (1992) who used a very limited stormwater quality data base to calculate stormwater loading for the Fraser Basin. For the trace metals Cu, Pb, and Zn the previous export coefficients for the Brunette watershed were 0.27, 1.15, and 1.2 kg/ha/y respectively (Macdonald et al 1996). The previous copper loading rate falls within the present range calculated for Still and Eagle Creeks. The previous zinc export coefficient is slightly higher than we determined for the more contaminated stations on Still Creek. The previous lead export coefficient was 10 times the present values. This difference in lead reflects the much lower concentrations in stormwater today and the importance of source control in regulating pollutants in stormwater runoff.

References

Bellevue Utilities.1995. Characterization and source control of urban stormwater quality: Volume 1-Technical Report. City of Bellevue Utilities Department, Washington State.

Hall, K.J. and H. Schreier. 1996. Urbanization and agricultural intensification in the Lower Fraser River Valley: Impacts on water use and quality. GeoJournal (in press).

Hall, K.J. and R.H. Macdonald. 1996. Water quality and stormwater in the Brunette River watershed: Water sampling program 1994/1995-Data report and appendices. Westwater Research Unit, Institute of Resources and Environment, The University of British Columbia, Vancouver, B.C.

Macdonald, R.H., K.J.Hall, and H. Schreier.1996. Water quality and stormwater in the Brunette River Watershed 1994/95. Westwater Research Unit, Institute of Resources and Environment, The University of British Columbia, Vancouver, B.C.

McCallum, D.W. 1995. An examination of trace metal contamination and land use in an urban watershed. MSc Thesis, Dept. of Civil Engr. The University of British Columbia, Vancouver, B.C.

Larkin, G.A. and K.J. Hall. Hydrocarbon pollution from runoff in the Brunette River basin. (Submitted to Environmental Technology , Feb. 1996)

Stanley Associates Engineering Ltd. 1992. Urban runoff quantification and contaminants loading in the Fraser Basin and Burrard Inlet. DOE FRAP 1993-19. Environment Canada, North Vancouver, B.C.

Tables

Table 1. Traffic Density and Land Cover Permeability in Sub-Basins Used for Stormwater Monitoring.

Station[1]	Renfrew	Gilmore	Eagle
Sub-Basin Size (ha)	757	1050	634
Traffic Density[2] (vehicle km/day)	670	978	177
Impermeable Area (% of total)	54	55.4	24.6

(1) Renfrew and Gilmore Stations on Still Creek and Eagle Station on Lower Eagle Creek.

(2) 1992 data from Greater Vancouver Regional District's EMME/2 transportation model.

Figures

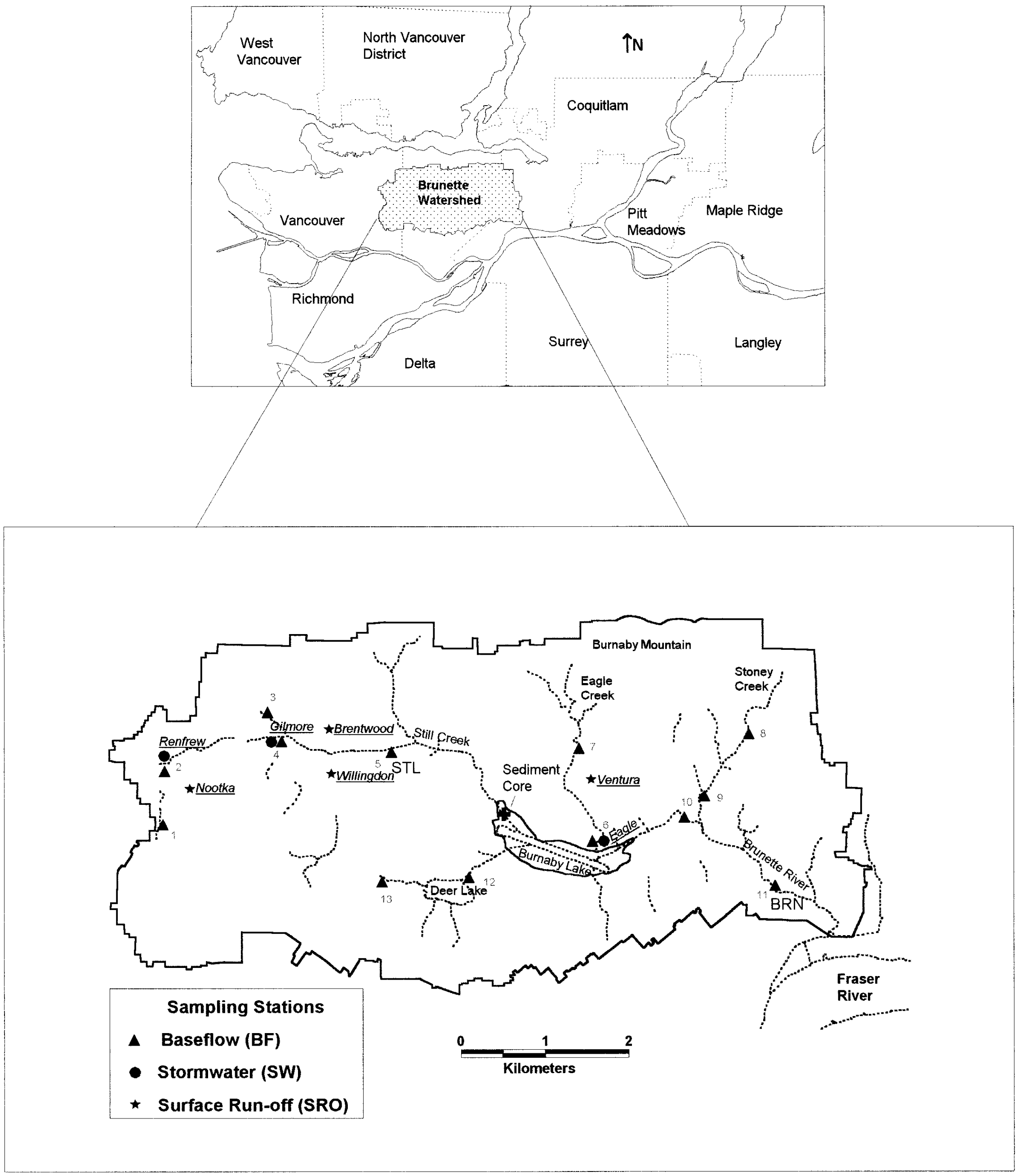


Figure 1. Location of Brunette River watershed in the Lower Fraser Valley and water quality sampling stations.

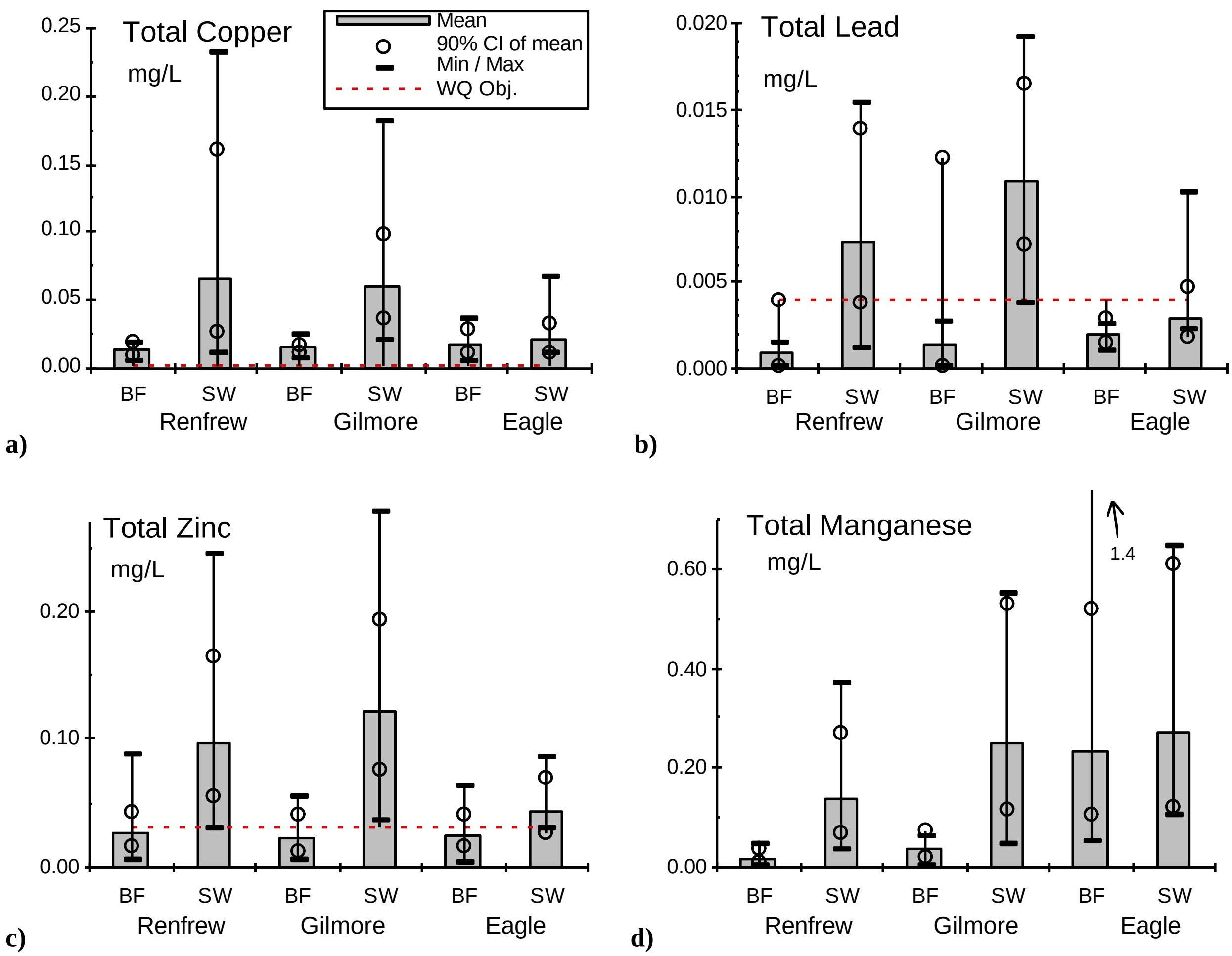


Figure 2. Comparison of mean baseflow and stormwater trace metals data at three stations in the Brunette system.

(a) Total Copper, (b) Total Lead, (c) Total Zinc, and (d) Total Manganese.
The bar represents the mean concentration, and the open circles show the 90% confidence interval of the mean. The far points are the minimum and maximum values observed. Values determined from the collected grab samples for the BF data, and from the storm averaged (SMC) values for the SW data. The dashed line indicates the WQ objective for that parameter . The WQ objectives, in mg/L are: Copper - 0.002; Lead - 0.004; - Zinc 0.030; and Manganese - no objective set.

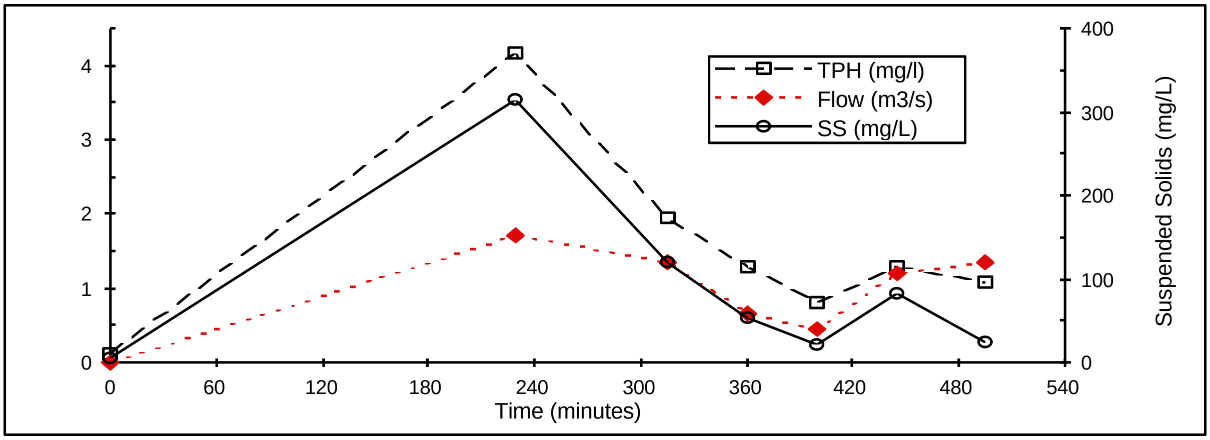
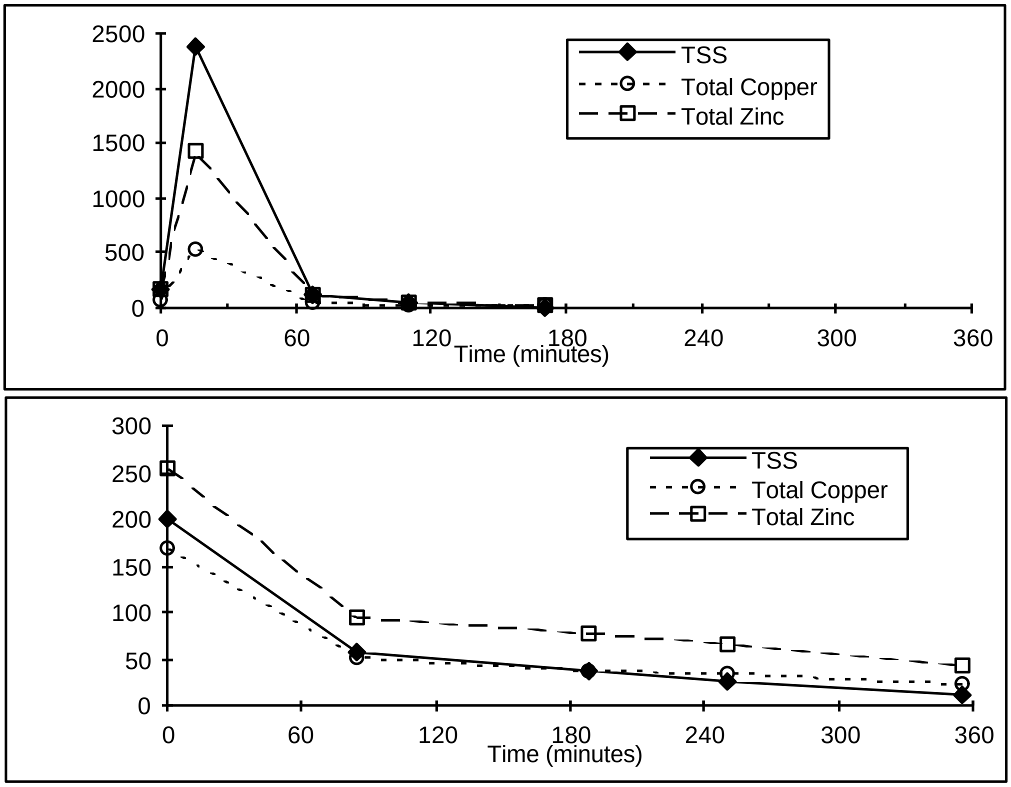


Figure 3. **Suspended solid and hydrocarbon profiles over a storm event (Renfrew station Oct. 13,1994).**



(a)

(b)

Figure 4. Trace metal and suspended solids profiles during a storm event.

Renfrew Station (a) Aug 7, 1994, and (b) May 2, 1995

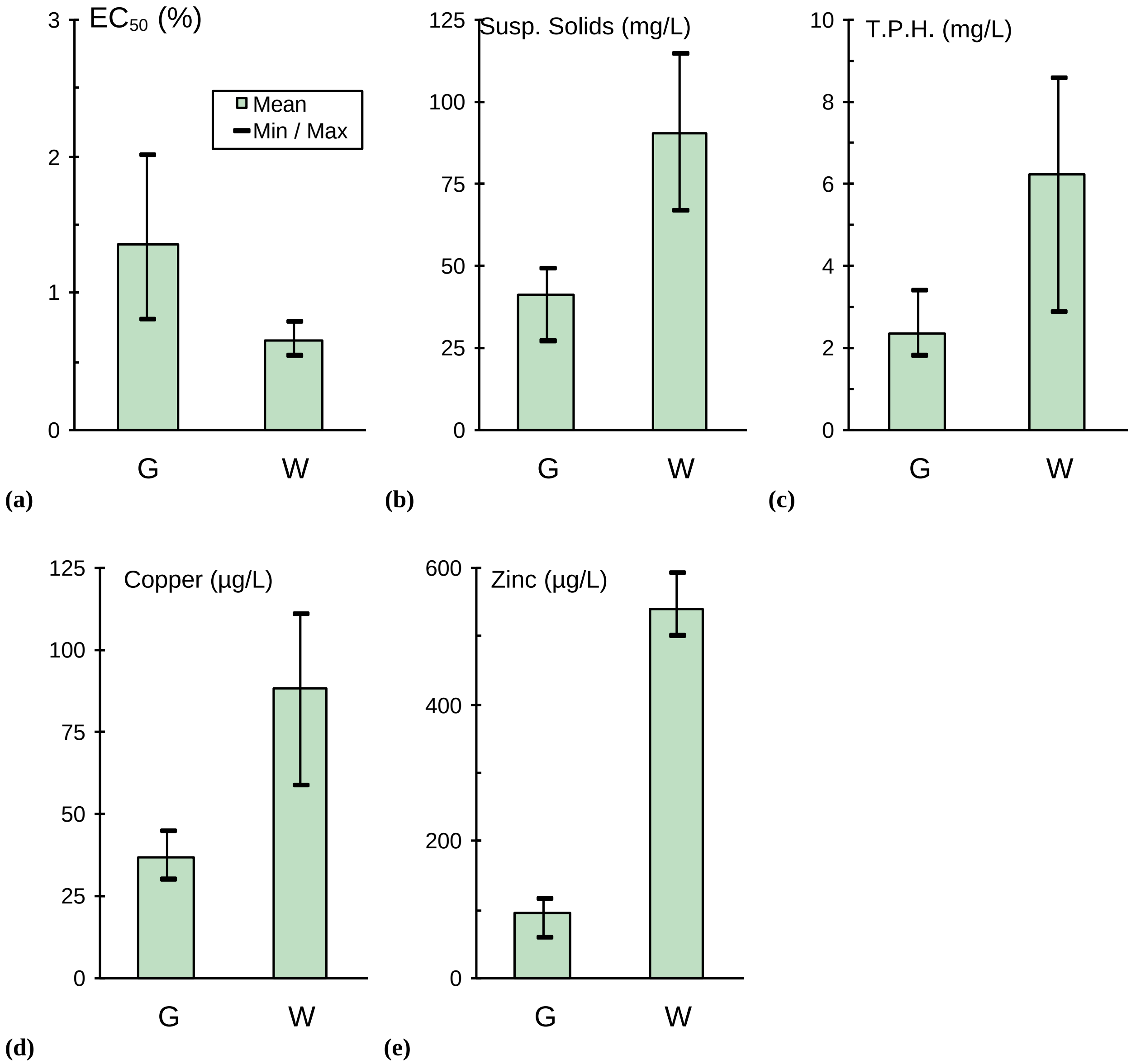


Figure 5. Toxicity of suspended sediments and stormwater chemistry.

(a) Microtox ® EC50 (%), (b) Suspended Solids (mg/L), (c) Total Petroleum Hydrocarbon (mg/L), (d) Total Copper (µg/L), and (e) Total Zinc (µg/L).
The Station G is the Gilmore Station on Still Creek draining approximately 1000 ha of mixed land use.
The Station W is a paved highway section at Willingdon Ave. a main artery in Burnaby.

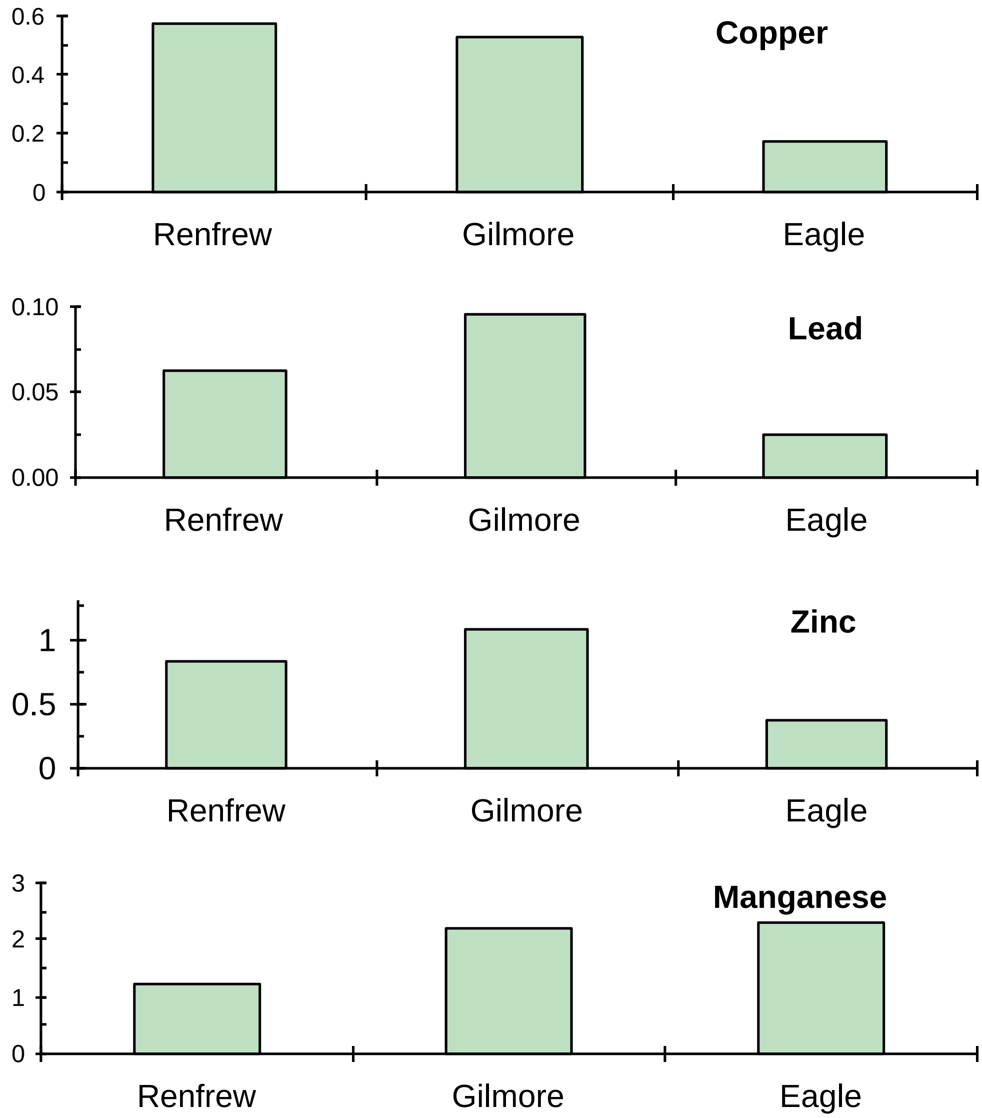


Figure 6. **Export coefficients from different sub-basins (**kg/ha/yr**).**

(a) Copper, (b) Lead, (c) Zinc, and (d) Manganese