

Fertilization in Forested Watersheds

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In British Columbia, approximately 80% of municipal water supplies are derived from surface water sources. In these watersheds, it is not surprising that activities such as forest fertilization can raise public concerns and create perceptions of impaired water quality and aquatic ecosystem function. Between 10 and 30 years ago, several British Columbia watersheds were studied and monitored to address these concerns and quantify the effects of fertilization on water quality. While results have been widely available, they are mainly in the technical literature that is not commonly accessible to the public. Hence, many of the concerns raised in past decades about changes in water quality from forest and instream fertilization still remain today in many BC communities.

In this article, we revisit case studies of forest fertilization and provide a brief synthesis on the subject. The article focuses on forest fertilization and does not describe the effects of timber harvesting or application of herbicides, pesticides, or fire retardants on stream, lake, or soil water quality.

How Does Water Quality Vary Between Lakes and Rivers?

The natural or “background” quality of water is important to consider when predicting the potential effects of fertilization. Across British Columbia, water is generally of high quality, yet varies naturally in chemical composition. Water quality varies in time and space, and is a function of differences in bedrock geology, overlying vegetation, natural

disturbances, internal cycling processes, hydrology, and human disturbances.

Aquatic primary productivity in BC rivers and lakes is mainly limited by phosphorus (P), nitrogen (N), or the combination of both N and P. Across geographic zones, lakes and rivers are variable in nutrient content and are usually classified as eutrophic (nutrient rich), mesotrophic (moderate nutrient concentrations), or oligotrophic (nutrient limited). Seasonally, some rivers and lakes may experience natural spikes in nutrient load due to decomposing salmon carcasses, internal nutrient cycling (e.g., return of P from lake sediments to the overlying water), nitrogen-fixing species, and (or) seasonal flushing of accumulated nutrients from soils. In

most water bodies not affected by pollution, the main sources of N are from forest soils and the atmosphere, while P is mainly derived from mineral sources. In many regions, human activities appear to have dramatically added to these natural sources (Table 1). In Canada, household sewage is generally the largest point source of N and P discharge to the environment while agriculture is the largest non-point source of nutrient enrichment (Chambers et al. 2001).

Why Are Forests Fertilized?

Forest stands are most commonly fertilized to increase harvest volume and reduce rotation length. Fertilizers can also be applied to individual seedlings at the time of planting to minimize the time required to achieve “green-up” or “free-to-grow” or to release newly planted seedlings from competition for resources with other plants. In British Columbia, fertilization has been used in N-limited coastal Douglas-fir forests to increase productivity. It has also contributed to the renewal of cedar-hemlock and Sitka spruce growth that is in check (i.e., N and P limited). In the BC Interior, extensive

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Table 1. Comparison of P and N loading to Canadian surface and ground waters from various sources, 1996

Nutrient source	Nitrogen (10 ³ t/yr)	Phosphorus (10 ³ t/yr)
Municipality		
- waste water treatment plants	80.3	5.6
- sewers	11.8	2.3
Septic systems	15.4	1.9
Industry ¹	11.8	2.0
Agriculture ² (residual in the field after crop harvest)	293	55
Aquaculture	2.3	0.5
Atmospheric deposition to water	182 (NO ₃ ⁻ and NH ₄ ⁺ only)	n/a

Source: Chambers et al. (2001).

¹ Industry N loads are based on NO₃ + NH₃ and are thus DIN [dissolved inorganic nitrogen] not TN [total nitrogen that also includes organic forms of N]; industrial loads do not include New Brunswick, Prince Edward Island, and Nova Scotia. Quebec data are only for industries discharging to the St. Lawrence River.

² Agricultural residual is the difference between the amount of N or P available to the growing crop and the amount removed in the harvested crop; data are not available for the portion of this residual that moves to surface or ground waters.

research has found some soils to be sulphur (S) and N deficient (see Brockley 2000, 2004). For this reason, the majority of fertilizer used in this region includes a mixture of N and S to improve growth of lodgepole pine, spruce, and Douglas-fir.

From an economic perspective, fertilization of older immature stands is often a desirable investment, since treatment costs are compounded for only a few years before harvest. Fertilizers, however, are also applied to younger stands to ameliorate serious nutrient limitations and sometimes to accelerate stand development to mitigate expected mid-term timber supply shortfalls (R. Brockley, Research Silviculturist, Forest Productivity, BC Ministry of Forests, pers. comm., 2004). Data from the BC Ministry of Forests show that most operational forest fertilization on BC Crown land occurs in the Coast Region (Vancouver Forest Region) (Table 2).

Application of Forest Fertilizers

Fertilizer is most commonly applied at the stand level using a helicopter equipped with a centrifugal-deploying bucket and computer-assisted navigation. The effective swath of application is generally 60 m (30 m each side). Buffers (fertilizer-free zones) on streams are established to avoid deliberate deposition and (or) subsequent discharge of fertilizer into stream networks. While buffers are usually 10 m wide, a 40-m offset from the edge of the water body is usually necessary to attain the 10-m fertilizer-free zone and avoid the accidental deposition of fertilizer into streams (Perrin 1994).

In the past, fertilization has occurred in both the spring and in the fall, with spring often viewed as the optimal time. The nutrient demand of growing trees, combined with low average storm intensity and ideal temperature conditions for chemical

¹ 0-0-0 = N-P-K = N = nitrogen, P = phosphorus, and K = potassium or potash expressed in percentages. For example, 25-4-11 = 25% N, 4% P, and 11% K.

Table 2. Amount of fertilization¹ (ha) funded by all sources on BC Crown land, 1993–2003

Year	Area of Crown forest land fertilized (ha)						Total
	Cariboo	Kamloops	Nelson	Prince George	Prince Rupert	Vancouver	
1993/94	-	1,327	81	4	10	3,758	5,180
1994/95	11	493	966	528	138	4,732	6,868
1995/96	274	155	72	621	248	5,178	6,548
1996/97	922	189	2,520	824	1,302	14,263	20,020
1997/98	659	714	-	483	157	4,152	6,165
1998/99	1,671	187	21	468	93	11,669	14,109
1999/00	1	279	532	305	226	8,551	9,894
2000/01	898	139	54	237	47	11,960	13,335
2001/02	443	326	905	1,057	90	11,965	14,786
2002/03	44	263	19	219	10	3,924	4,479
TOTAL	4,923	4,072	5,170	4,746	2,321	80,152	101,384

Source: BC Ministry of Forests annual reports 1993–2003.

¹ Includes fertilization at time of planting but not fertilizer operations on private forestland.

conversions, makes spring a time when losses of fertilizer can be minimized from soils to surface drainages. However, volatilization (release of ammonia to the atmosphere) loss can be high at this time in some areas, making fall the preferred time in many areas.

Nitrogen is usually applied as prill urea (46-0-0¹) at rates of approximately 200 kg N/ha. Phosphorus is usually applied as mono- or di-ammonium phosphate (12-51-0) at a rate of 75–100 kg P/ha. Urea is generally used for Douglas-fir stands whereas urea with P is used in cedar–hemlock stands on northern Vancouver Island (G. Weetman, Professor Emeritus, UBC Faculty of Forestry, pers. comm., 2004). In the BC Interior, a blend of urea (46-0-0) and ammonium sulphate (21-0-0-24S) is used at application rates of about 200 kg N/ha + 50 kg S/ha. Further information on fertilization guidelines can be found in the *Forest Fertilization Handbook* (BC

Ministry of Forests and BC Ministry of Environment and Parks 1995)

<http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/fert/ferttoc.htm>.

Why Are Rivers and Lakes Fertilized?

Parallel to forest management, some lakes, reservoirs, and streams in British Columbia are fertilized to increase primary productivity and subsequently the size and growth rates of fish. The added nutrients increase growth rates of algae, increasing the availability of food for zooplankton (in lakes) or benthic invertebrates (in streams and lakes). This, in turn, increases food availability for fish, yielding greater growth rates or survival. Fertilization of lakes with N and P has been used in the recovery of kokanee populations (Ashley and Slaney 1997; Ashley et al. 1999), following earlier successes from treatment of numerous sockeye nursery lakes in British Columbia and elsewhere (Hyatt et al. 2004).

Nutrient addition can also improve growth of trout in lakes (Johnston et al. 1999). Based on initial work by



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as salmon carcasses, carcass analogue, solid fertilizer in prill form, solid briquettes, or using struvite

(magnesium-ammonium phosphate). Lake applications can involve aircraft although less expensive options such as using boats or barges are often preferred. See Ashley and Stockner (2003) for a complete review of aquatic fertilization protocols.

Perrin et al. (1987) and Johnston et al. (1990), stream fertilization is now a viable technique used in the recovery of coho and steelhead populations (Slaney and Ashley 1999). This strategy can kick-start the replenishment of nutrients to streams through the return of nutrients from salmon carcasses after spawning (Johnston et al. 2004). Wildlife, such as bears feeding on salmon carcasses, can also replenish nutrients in forests near salmon streams (Gende et al. 2002).

Aquatic Fertilizer Application

In freshwater ecosystems, P usually limits primary production, although “co-limitation” with N can occur when both are present in extremely low concentrations. Aquatic fertilizers can include 10-34-0 (ammonium polyphosphate) and, where applicable, 28-0-0 (urea – ammonium nitrate). Application rates vary with stream discharge/lake volume and background levels of N and P. For example, Big Silver Creek (Harrison Hot Springs) was fertilized in 1995 with 9.5 tonnes of ammonium polyphosphate, whereas application rates for the same year in the smaller Adam River on Vancouver Island were 2.3 tonnes (Slaney and Ashley 1999). Similarly, the application rate for lakes depends strongly on lake volume and management goal. Nutrients can be added to streams in liquid fertilizers,



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What Are the Concerns with Forest Fertilization?

Numerous reviews have described potential effects of forest fertilization on water quality and biological production in aquatic ecosystems (e.g., Fredriksen et al. 1975; Moore 1975; Bisson et al. 1992; Binkley and Brown 1993; Perrin 1994; Binkley et al. 1999a, 1999b; Anderson 2001). These concerns are mostly related to unintentional increases in concentration of urea, nitrate, ammonia, ammonium, phosphorus, sulphur, and heavy metals in water bodies.

It is important to note that the term “ammonia” is often used interchangeably with the term “ammonium.” In this article, “ammonia” refers to the un-ionized and potentially toxic form of inorganic N (NH_3), while “ammonium” refers to the ionized form (NH_4) that is non-toxic in aquatic systems (Canadian Council of Ministers of the Environment [CCME] 2004). The term “total ammonia” refers to the combination of NH_3 and NH_4 . Both NH_3 and NH_4 can exist in water but NH_3 is only stable at pH greater than 9. Concentration of NH_3 decreases tenfold with each decrease in pH unit. Thus, for forest soils of 4–6.5 pH, only trace amounts of toxic ammonia are typically present (Binkley et al. 1999a). Differences in concentrations between the two forms are related to variations in pH and water temperature. The remainder of this article discusses, through case studies, observed increases in fertilizer-derived nutrients and compares these findings to current drinking water guidelines and criteria for aquatic life.

Nitrate and Total Ammonia

Increasing nitrate and total ammonia concentrations in water bodies are frequently one of the greatest public concerns in using fertilizers and are often perceived to cause increased primary productivity and (or) drinking water problems. After application, urea fertilizer in the presence of soil moisture is hydrolyzed to yield ammonia and then ammonium, which is effectively retained at cation exchange sites in the soil. That ammonium can be actively taken up and used as an N source by trees (Perrin 1994). The ammonium can then be nitrified in the presence of autotrophic bacteria common in BC soils to form nitrate (NO_3^-). This nitrate can also be taken up and used as an N source by trees, but it is relatively mobile in forest soils and can be lost to streams more so than ammonium. Soil temperature largely determines the rate of these

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transformations from urea to ammonium and nitrate (Perrin 1994).

Nitrate can be a concern where concentrations greater than 10 g/L as nitrate-N² adversely affect human health and can cause methemoglobinemia or “blue baby” syndrome in babies (Binkley et al. 1999a). In North America, background concentrations of nitrate-N in streams are low and average 0.31 mg/L with a median value of 0.15 mg/L (Binkley 2001). Concentrations are typically lower than this in coastal streams of British Columbia, sometimes reaching as low as 0.010 mg/L (Perrin et al. 1987). Nitrite (NO₂⁻) is a form of nitrogen that tends to be oxidized rapidly to nitrate in the environment, and thus thresholds of approximately 1 mg/L as nitrite-N in water bodies may never be reached (Binkley et al. 1999a). The guideline concentration for nitrate listed in the Canadian Environmental Quality Guidelines (CCME 2004) for community water supplies is 45 mg NO₃/L. The guideline concentration for protection of freshwater aquatic life is 13 mg NO₃/L for nitrate and 0.06 mg NO₂/L for nitrite.

NH₃ (ammonia) concentrations as low as 0.03 mg N/L can be potentially toxic to aquatic organisms in the short term and concentrations greater than 0.002 mg N/L (as ammonia) may be toxic over the long term (Binkley et al. 1999a, 1999b). While the CCME guideline for total ammonia varies with temperature and pH, the listed guideline for un-ionized ammonia is 19 g/L. Refer to the CCME guidelines (CCME 2004) for further details.

In the case studies reviewed, most fertilizer applications resulted in short-term increases in N (NO₃-N and total ammonia) concentrations to streams. When leave strips or buffers were applied to water bodies, relatively low peak concentrations of nitrate-N and ammonium-N were

found. Concentrations of total ammonia-N generally remained above background concentrations for several weeks to months after treatment whereas nitrate-N concentrations remained above background for several months to a year after treatment (Perrin 1994). Relatively high nitrate-N concentrations have been observed when fertilizer was directly applied to streams, under repeated fertilization, when using ammonium nitrate versus urea-based fertilizers and when fertilizing N-saturated hardwood forests (Binkley et al. 1999b). Overall, N concentrations following fertilization generally remained below the CCME guidelines (Table 3).

One case study in Table 3 is a notable exception. In the application of 224 kg N/ha of urea fertilizer to 80% of the Lens Creek watershed with no attempt to prevent direct deposition to water bodies or streams, Hetherington (1985) reported peak nitrate-N concentrations that approached the drinking water guideline. Hetherington (1985) reported increased concentrations of urea-N and ammonia-N that persisted for 7–13 days after fertilization, while nitrate-N levels remained above background for the duration of the 14-month study. High nitrate levels were explained as a result of nitrification during the dry 7-week post-application period, presence of red alder (from which nitrogen fixation can occur), steep slopes, and above-average precipitation (Hetherington 1985).

Three of the studies reported peak total ammonia-N levels beyond 1.98 mg/L possibly approaching toxic thresholds for aquatic life (although data for pH and temperature were unavailable to assess). Consistent among these studies was a lack of buffers around waterways. Although fish mortality was not specifically quantified as part of these studies,

none of them reported fish mortalities. Results of these case studies strongly suggest that avoiding direct deposition of fertilizer into water bodies is an important management practice to reduce the peak total ammonia concentrations in stream water. Indeed in British Columbia, the use of 10-m leave strips is a standard practice in all fertilization treatments to avoid aquatic toxicity (BC Ministry of Forests and BC Ministry of Environment and Parks 1995).

Urea

Excess urea reaching water bodies is less of a concern than transport of total ammonia. Urea is highly mobile in forest soils. Excessive leaching of urea can occur during heavy rainfall if it is not broken down into chemical forms that can be used by vegetation (Perrin 1994). There is no published toxicity guideline for urea-N. However, concentrations of several thousand milligrams per litre are required for any toxic effects, which would be much higher than what might reasonably occur in any stream environment (Binkley et al. 1999a). Surveying the literature, peak urea-N concentrations generally range from 0.1 to 50 mg/L within the first week after fertilization (Perrin 1994). Peak concentrations from various studies shown in Table 4 fall within this range. Case studies of treatments without buffers resulted in the highest peak concentrations, again showing the importance of avoiding direct deposition of fertilizer into water.

Phosphorus

Although the addition of phosphorus to lakes and streams is an effective fish management technique (described above), it is typically done with very tight control of the specific phosphorus load. Because P is often the nutrient that primarily limits biological production, overloading a system can lead to excess production

²Concentrations of nitrate and nitrite in water are often expressed in units of nitrate-nitrogen and nitrite-nitrogen, where 1 mg nitrate-nitrogen/L = 4.43 mg nitrate/L, and 1 mg nitrite-nitrogen/L = 3.29 mg nitrite/L.



Table 3. Peak nitrate-N and total ammonia-N concentration from BC case studies

Location	Treatment level (urea)	Buffer width (fertilizer-free zone)	Nitrate-N control ³ (mg/L)	Peak nitrate-N concentration (mg/L)	Duration ⁴ of elevated nitrate-N levels (days)	Total ammonia-N (NH ₄ ⁺ + NH ₃ -N) control ³ (mg/L)	Peak total ammonia-N (NH ₄ ⁺ + NH ₃ -N) (mg/L)	Duration ⁴ of elevated ammonia levels (days)	References
Sayward Forest ¹	200 kg N/ha	None	0.001	0.34	111	<0.004	3.36	111	Perrin et al. 1984
Sayward Forest ²	200 kg N/ha	50 m	0.001	0.19	100	<0.004	0.243	142	Perrin et al. 1984
Lens Creek	224 kg N/ha	None	0.028–0.151	9.3	435	0.08	1.9	13	Hetherington 1985
Gold Creek	176 kg N/ha with 52 kg S/ha	20 m	-	0.04	-	0.005–0.010	0.013	-	MacDonald 1987
Keogh River Tributary	200 kg N/ha	None	0.01–0.08	0.120	14	0.01–0.015	4.6	113	Perrin 1987a
Gold River	200 kg N/ha	30 m	0.02–0.07	0.28	73	0.011–0.017	0.03	3	Perrin 1987b
Slesse Creek	200 kg N/ha	10 m	0.21–0.33	0.21–0.33	n/a	0.020	0.024	2	Perrin and Bernard 1988
Glerup Creek	200 kg N/ha	10 m	<0.01	0.047	>39	<0.01	0.57	31	Perrin 1989
Glerup Creek	200 kg N/ha	None	<0.01	0.301	96	<0.01	3.69	31	Perrin 1989
Qualicum River	200 kg N/ha	30 m	0.035	0.088	136	<0.005	<0.005	n/a	Perrin 1990a
Rosewall Creek	200 kg N/ha	30 m	0.005–0.035	0.057	136	<0.005	<0.005	n/a	Perrin 1990a
Mashiter Creek	200 kg N/ha	50 m	0.005–0.01	0.037	47	<0.005	<0.005	n/a	Perrin 1990b
Tarundl Creek	200 kg N/ha	30 m	0.03–0.130	0.03–0.130	n/a	<0.005	0.160	29	Perrin 1991
Honna River	200 kg N/ha	30 m	0.022–0.097	0.022–0.097	n/a	0.01–0.02	0.042	9	Perrin 1991
Honna River Trib.	200 kg N/ha	None	<0.005	0.130	>97	<0.005	0.471	61	Perrin 1991
Nusatsum River	200 kg N/ha	None	0.005–0.035	0.088	>108	<0.005	<0.005	n/a	Perrin 1992
Sallompt River	200 kg N/ha	30 m	0.12–0.17	0.21	>141	<0.005	<0.005	n/a	Perrin 1992

Source: Perrin (1994).

¹ Data are the maximum concentration from 6 replicate streams, none affected by fertilizer spill.

² Data are the maximum concentrations from 4 replicate streams.

³ Data from sample sites not affected by fertilization and indicate concentrations at the time that peak concentrations were measured at the treatment site.

⁴ Number of days from time of fertilization to return to control values.

Table 4. Peak urea–N concentration from BC case studies

Location	Treatment level (Urea)	Buffer width (fertilizer-free zone)	Urea–N control ³ (mg/L)	Peak urea–N concentration (mg/L)	Duration ⁴ of elevated urea levels (days)	References
Sayward Forest ¹	200 kg N/ha	None	<0.005	49.3	141	Perrin et al. 1984
Sayward Forest ²	200 kg N/ha	50 m	<0.005	0.658	136	Perrin et al. 1984
Lens Creek	224 kg N/ha	None	0.03	14.0	7	Hetherington 1985
Nusatsum River	200 kg N/ha	None	0.005–0.018	0.005–0.018	n/a	Perrin 1992
Sallompt River	200 kg N/ha	30 m	0.005–0.018	0.005–0.018	n/a	Perrin 1992
Tarundl Creek	200 kg N/ha	30 m	<0.01	0.614	66	Perrin 1991
Honna River	200 kg N/ha	30 m	0.005–0.020	0.296	10	Perrin 1991
Honna River Trib	200 kg N/ha	none	0.005–0.055	2.43	91	Perrin 1991

¹ Data are the maximum concentration from 6 replicate streams, none affected by fertilizer spill.

² Data are the maximum concentrations from 4 replicate streams.

³ Data from sample sites not affected by fertilization and indicate concentrations at the time that peak concentrations were measured at the treatment site

⁴ Number of days from time of fertilization to return to control values.

Table 5. Peak soluble reactive P concentrations from BC case studies (data from Perrin 1994)

Location	Treatment level	Buffer width (fertilizer-free zone)	Soluble reactive phosphorus (SRP) control ¹ (mg/L)	Peak soluble reactive phosphorus (SRP) concentration (mg/L)	Duration ² of elevated SRP (days)	Reference
Keogh River Trib (no buffer)	100 kg P/ha	None	<0.001	10.6	120	Perrin 1997
Glerup Creek (no buffer)	100 kg P/ha	None	<0.001	1.92	73	Perrin 1989
Glerup Creek	100 kg P/ha	10 m	<0.001	0.560	73	Perrin 1989

¹ Data from sample sites not affected by fertilization and indicate concentrations at the time that peak concentrations were measured at the treatment site.

² Number of days from time of fertilization to return to control values.

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of unwanted algae and other water quality problems including reduced oxygen content, which kills fish, and may lead to drinking water impairment (taste/odor/treatment difficulties) (Wetzel 2001). The magnitude of the effect, however, depends on the characteristics of the receiving water body (e.g., discharge, background P concentration, water residence time).

Phosphorus itself is not toxic in drinking water and is not included in the CCME guidelines (2004) for community water supplies. Only a few case studies describe the extent of P loading caused by forest fertilization, mainly because most case studies have been conducted in association

with urea applications. Of the case studies available, peak soluble reactive phosphorus (SRP) concentrations range from 0.5 to 10 mg/L (Table 5), which is considered very high in aquatic ecosystems and well within the range that can increase growth of algae. These high concentrations, however, were not sustained and typically dropped close to, but still above background, within a few days after treatment thus limiting any time course change in biological production. Perrin (1994) found that low-level P concentrations dropped to background within 120 days, which means that some increased productivity may occur in streams receiving the P load over about four months. This low-level enrichment

may actually be a benefit for production of fish food in streams, particularly when conducted in the spring when water temperatures are rising and feeding by fish is active (Perrin 1994).

Sulphur

In areas where a blend of urea and ammonium sulphate fertilizers are used, concerns over increased S concentration in water may be raised. There is no maximum acceptable concentration for sulphate, but the CCME (2004) lists aesthetic objectives for drinking water of 500 mg/L and 1000 mg/L for livestock. The CCME guidelines also note the possibility of a laxative effect when sulphate concentrations exceed 500 mg/L. A

guideline of 500 mg/kg of S (elemental) is listed for the protection of soil under agricultural land uses. In preparation of this article, no case studies were located that studied post-fertilization increases in S levels resulting from forest fertilization.

Heavy Metal Concentrations

Because fertilizers can contain metals, the addition of fertilizers to water has been raised as a water quality concern. Urea fertilizers typically contain very low levels of heavy metal contaminants, whereas fertilizers containing P can have variable metal content (R. Brockley, pers. comm., 2004), largely related to the source that is mined to produce the fertilizer. The use of fertilizer databases (see text box) and chemical assays are two prudent ways to address concerns over potential heavy metal additions to the environment before application. Chemical assays can also verify that storage and distribution of fertilizer have not affected heavy metal concentrations post-production. In preparation of this article, no case studies were located that studied post-fertilization increases in heavy metal concentrations resulting from fertilization.

A useful source of information on fertilizer contaminants is available from the Washington State Department of Agriculture (WSDA) (<http://agr.wa.gov/PestFert/Fertilizers/ProductDatabase.htm>). This Web site provides information on concentrations of nine heavy metals (i.e., arsenic, cadmium, cobalt, mercury, molybdenum, lead, nickel, selenium, and zinc) in fertilizer. The Web site allows users to search by product name.

Is Fertilization in Forested Watersheds a Cause for Concern?

After a forest has been treated with fertilizer, changes in concentration of fertilizer elements can be expected in surface drainage. Case studies that form a technical basis for the present *Forest Fertilization Guidelines in British Columbia*, and that have been cited previously, suggest that unintentional nutrient transport to water bodies following forest fertilization is generally not enough to impair aquatic ecosystem health or affect the

Case studies suggest that unintentional nutrient transport to water bodies following forest fertilization is generally not enough to impair aquatic ecosystem health or affect the quality of drinking water.

quality of drinking water. Most of these studies reported increased post-fertilization levels of ammonia-N, urea-N, and nitrate-N for several days to months, but that these increases generally remained well below water quality guidelines.

Across the studies, the biggest increases were at sites where fertilizer-free zones were not used. These application issues have been addressed in recent years through mandatory buffers and restrictions on the percentage of a watershed that can be fertilized. Results of the case studies noted above strongly support the continuation of these key management practices.

Acknowledgements

The authors thank Rob Brockley, Ian Redden, Kevin Brown, Ken Ashley, and four anonymous reviewers who provided many useful suggestions and comments on this manuscript. Any errors in this manuscript remain solely those of the authors. ~

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