

Whatcom Creek Stream Remediation Following a Gasoline Spill

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ABSTRACT

The gasoline release, explosion and fire that resulted from the Olympic Pipe Line rupture on 10 June, 1999, in Bellingham, Washington, affected approximately 5 km of the Whatcom Creek system. One component of the response program involved remediation of the affected stream bed sections. An initial interagency streambed survey provided information that was used to develop the remediation strategy. The project was carried out between July 6 and August 16, 1999, using a combination of mechanical, manual, and hydraulic *in-situ* treatment techniques to remove product from the stream bed and stream banks, as well as a series of controlled, hydraulic flushes that were effected by opening the sluice or control gates at the head of Whatcom Creek each night. Additional larger flushes were implemented prior to, and upon completion of, the treatment operations. The field operations were supported throughout by a water and sediment sampling program. The results of analyses performed on these samples provided data on the initial stream water and stream sediment conditions and on the effects of the various remediation activities in different sections of the stream system.

INTRODUCTION

On 10 June, 1999, up to 1 million liters (277,000 gallons) of gasoline leaked from a sudden rupture in an Olympic Pipe Line Company (OPL) 16-inch pipeline that runs adjacent to the Whatcom Creek Water Treatment Facility in Bellingham, Washington (Figure 1). At about 5:00 p.m. the gasoline ignited and fire travelled through 2.5 km of the Hanna and Whatcom Creek system. The fire stopped 250 m east of the Interstate 5 highway bridges.

The response activities following the incident involved a number of concurrent components in the source area and in downstream locations. The following discussion summarizes the operations associated with the Streambed Remediation Project conducted as part of the emergency-phase of operations to minimize the impacts of the incident. This remediation project was designed, in part, in the context of a longer-term Stream Restoration Project for Whatcom Creek.

Whatcom Creek drains from Lake Whatcom, a controlled water body, through the city of Bellingham into the ocean over a distance of approximately 6.5 km (Figure 1). Hanna Creek is a

small tributary of Whatcom Creek that is fed by springs and storm drain water from adjacent residential areas. In general terms, the valleys of Hanna Creek and the upper sections of Whatcom Creek have steep-sided, high banks and a canyon-like configuration (Figure 2). The stream character in this upper section of Whatcom Creek ranges between wide shallow glides, deep pools, steep cascading sections, and water falls. Sediments in this section range in size from coarse sands to boulders several meters in diameter and bedrock outcrops. Below the Woburn Street bridge, the channel of Whatcom Creek changes to a low gradient stream of alternating glides (Figure 3) and pool-riffle complexes with low banks for a distance of 1350 m. West of the Interstate-5 bridges, the channel has been considerably man-modified and constricted so that the low-gradient stream is deeper and has steep, often man-made, vertical banks (Figure 4). Whatcom Creek enters Puget Sound through Whatcom Waterway into Bellingham Bay.

The objectives of the project were to (1) remediate the streambed affected by the spilled gasoline and to accelerate its recovery to a healthy biological system, (2) effect this remediation in a safe and efficient manner, and (3) carry out the remediation without causing secondary effects to stream banks or to downstream environments.

On 13 June, 1999, a site survey of selected locations was carried out to establish activities that might be appropriate to support future remedial operations. Two initial actions were recommended: (i) subdivide the stream into reaches for planning and operations activities, based on the physical character of the stream; and (ii) establish surveyed distance marker stakes along Whatcom Creek and Hanna Creek to provide reference points to locate sampling sites and operational sections.

OPERATIONAL DIVISIONS AND INITIAL STREAM SURVEY

Operational Divisions were set up with Division "A" beginning in Whatcom Creek at the confluence with Hanna Creek, and progressing downstream through Division "E", which ended at the Roeder Street Bridge (Figure 5). Hanna Creek was identified as Division "F".

The survey and placement of distance stakes was carried out between 15 and 20 June, 1999. Distances were marked on painted stakes or painted directly on rock surfaces where stakes could not be placed. The stakes were subsequently located by a Global Positional System (GPS) to provide latitude and longitude coordinates and elevation data. Subsequently, on 30 June, 1999, the upper section of Whatcom Creek above the confluence with Hanna Creek was surveyed and assigned the designation Division "G". This latter area was identified for operational strategic and tactical planning because of a gasoline seep into Whatcom Creek and is located in a steep canyon section below and to the north of the water treatment plant.

THE JOINT RESTORATION COMMITTEE (JRC) SURVEYS

The assessment of the nature and extent of contamination resulting from the fire and

explosion began almost immediately following the incident. By 22 June, 1999, a draft Emergency Restoration Plan had been developed that included a protocol for a joint in-stream survey to be conducted with representatives from OPL and natural resource trustees (i.e., the JRC). This inter-agency Committee was established to provide guidance and recommendations for the various restoration, sampling, and monitoring activities. Participants in the field surveys included contractors for the responsible party, the City of Bellingham, the Washington State Department of Ecology, the Washington State Department of Fish and Wildlife, the US EPA, and the Lummi Nation. The Committee met on a weekly schedule to discuss, review and approve the activities and plans of the restoration program.

Initial Stream Survey

JRC representatives conducted field inspections to document the physical character of the affected streambed sections, to develop a consensus for remedial treatment recommendations, and to agree when appropriate and sufficient remediation had been completed.

The first inspection was a survey on 23-24 June of all affected streambed sections. The key observations of this survey were:

- product was present in the streambed sediments in Whatcom Creek at a number of locations as far downstream as the York Street bridge (the end of Division D),
- in many sections, product was released by physical agitation from streambed sediments,
- the observed amounts of product that were released by agitation decreased noticeably below the York Street Bridge, and
- no visible gasoline residues were found in the stream bed in divisions E and G.

The stream bed survey did not identify any major concentrations of product and the great majority of the gasoline that was observed was characterized as a rainbow sheen that:

- was liberated from the streambed sediments by stirring, agitation, or by the movement of boulders,
- spread on the surface rapidly (in seconds) to create a silver sheen that was only a few molecules thick, and that
- generally disappeared within a meter or two downstream.

The liberation of the gasoline from the streambed sediments in all observed cases resulted in very rapid evaporation (into the air). The fact that streambed agitation would release residual gasoline that would dissipate very rapidly (*a few seconds*) and over very short distances (*a meter or two*) was substantiated by chemical analysis of downstream water-column samples. The agitation and washing techniques that were recommended in the Streambed Remediation Plan, prepared following this survey, as well as the proposed pre- and post-flushes, were designed to achieve the required results without removal of material from the affected stream beds. The rapid breakdown of the gasoline meant that there would be no recoverable product, so that downstream

containment and recovery actions would not be required.

Inspection Surveys

Following the reported completion of the operations activities in the various reaches by the site supervisors, the JRC carried out a series of field inspections to approve the demobilization of crews or to recommend any additional work that might be appropriate.

STREAM REMEDIATION AND SAMPLING PLAN

Streambed Remediation Plan

Based on the observations and results from the 23-24 June JRC interagency streambed survey summarized above, a plan was prepared and was approved on 30 June, 1999. The proposed actions and recommendations described in the Remediation Plan were based on the expected behavior of the released hydrocarbons.

The proposed end point for the remediation operations would be a situation in which no rainbow sheen would be released by agitation of the streambed materials. The JRC also proposed this end point be evaluated by chemical analyses against literature-based toxicity values that protect sensitive life stages of salmonids and other aquatic organisms.

The recommended remediation strategy described in the Plan is summarized as follows:

- physical agitation (mechanical, manual, and hydraulic) would be the primary and preferred remediation technique,
- there would be an initial flush with ponded water from Whatcom Lake after slash removal and prior to remediation, followed by a daily lower-level flush during the remediation activities,
- the remediation effort would focus on the streambed rather than the stream banks to avoid intrusion and possible destabilization or erosion of the banks,
- no removal of sediment was planned,
- remediation would be concurrent in different sections of the stream, and
- field supervisors could adapt and modify the remediation techniques on-site, as necessary and within reason.

The approved Streambed Remediation Plan authorized the following remediation techniques:

<i>manual agitation</i>	
	agitate the streambed using rakes, shovels, and pry-bars
<i>manual low-pressure (< 50 psi, fine spray) wash</i>	
	use portable pumps to take water from the stream to spray the banks from slightly above the water line to the streambed (Figure 6)

<i>mechanical agitation</i>	
	mechanically agitate the streambed sediments to depths of 30 to 50 cm using tracked excavators (Figure 7) and a walking excavator-tractor (or “Spyder”) (Figure 8)
<i>hydraulic agitation and flush</i>	
	increase stream discharge to predetermined volumes and over specific time periods, using the upstream water-control structure to agitate, re-sort, and re-configure streambed and river bank sediments (Figure 9)

Based on these remediation objectives, strategies, and techniques, a series of specific operational activities were defined:

- agitate and release the residual gasoline that exists as a residue on/in streambed sediments, sediment pore water, and on/in the sediments at the water line of the stream banks to acceptable levels,
- implement mechanical agitation wherever possible to expedite remediation,
- integrate remediation activities and restoration efforts, such as stream-bank stabilization and streambed contouring, where such stabilization and contouring was necessary to maintain habitat integrity,
- identify completion criteria before remediation begins so the Operations team has clearly defined end-points, and
- complete the remediation by mid-August to maximize salmonid habitat available for anticipated spawning in late summer and early fall.

Prior to beginning agitation work, charcoal, slash, and organic debris were to be manually removed from the stream and lower streambanks, and logs or tree limbs that posed an access problem or safety hazard were to be removed from the stream.

Following these initial actions, a controlled single-event flush was recommended to increase the stream level to a point whereby the stream of charcoal, ash and fine sediments in the stream would be washed to the extent possible before beginning agitation. Flushing was carried out through the water-control structure at the head of Whatcom Creek at Lake Whatcom. This initial hydraulic flush involved incremental raises of the control gate to a height of 30 cm (12 inches) (each 15 cm increment is equal to a discharge of approximately 115 cubic meters/second (4,000 cubic feet per second)). The initial 30 cm flush involved the release of approximately 110 million litres (30 million gallons) over a 24-hour period. The effect of a 30-cm flush was observed to raise the water level by exactly 30 cm between Woburn and Valencia Streets, in Division B, 53 minutes after the gate was raised (see Figure 9).

Subsequent daily water releases were scheduled during the remediation activities to flush Whatcom Creek on a regular basis. These daily flushes involved raising the sluice gate (a smaller

control structure) 15 cm each evening and closing it each morning.

The purpose of the flushes was to wash the riverbanks and to stir or agitate some shallow sections of gravel stream bed. Based upon water column chemical analyses, it was considered unlikely that this action would result in any secondary downstream effects in the stream or to Bellingham Bay associated with the liberation of gasoline. However, installation of two silt curtain systems was required to contain sediments in the event that the flushing actions would result in the generation of high turbidity. Sorbent booms also were to be deployed in conjunction with the silt curtain systems in the event that any persistent sheen were generated. These two systems remained deployed throughout the remediation project. In addition, water samples for chemical analytical analysis were collected downstream every four hours during flushing activities to verify the unlikelihood of downstream effects.

Sampling Plan

Water sampling was conducted throughout the response at eight sites in the creek and twelve sites in Bellingham Bay to document the decline in contamination. Sampling was also conducted near the mouth of Whatcom Creek every four hours during active remediation or flushing to ensure liberated product did not reach the bay. Interstitial water was sampled at three locations prior to remediation and twelve locations following remediation to evaluate the end point of pore-water toxicity to juvenile salmonids. Three randomly placed quadrats with eight random pipette samples each (four at 5 cm, four at 10 cm depth into the sediments) were collected at each location. Water column grab-samples and interstitial pore-water samples were analysed for BTEX (benzene, ethyl benzene, toluene, and xylenes), gasoline range hydrocarbons, and polycyclic aromatic hydrocarbons (selected samples).

PROJECT ORGANIZATION AND MANAGEMENT

The Operations Plan

The Operations Manager was assisted by one of the Environmental Group science advisors, a project Safety Officer, and a Field Superintendent. An Operations Plan was submitted to OPL that defined the required resources and logistics support as well as access, disposal and health and safety issues. A set of Remedial Action Plans ("RAP"s) were prepared for each phase of work and, for the most part, were prepared by geographical division. The intent of the RAP's was to provide the Operations teams with specific objectives and guidance for the remediation activities and to describe any constraints or safety considerations that may affect the field activities. A new RAP was prepared for each division whenever a new technique or phase of work was approved for that division.

Safety Issues

Considering the difficult work environment, safety was paramount during the project. Not only was access difficult, but also the field crews performed the work standing in water over 1-

meter deep, and adjacent to much deeper pools. In the canyon sections, workers had to climb over very large boulders to move from cascade to cascade. The streambed was slippery and, as work proceeded, became even more so because moss that had been destroyed during the fire began to grow back.

The explosion and fire generated such high temperatures that the outer parts of bedrock and of boulders shattered, making them very dangerous to walk on. The mechanical agitation methods also moved boulders and cobbles out of their original positions, which often made them much more unstable. Since tree limbs and wood debris in the forest were burned, they were more pointed than normal and hazardous to workers. The vertical cliffs and steep hillsides were difficult to navigate, which was exacerbated by the loss of vegetation from the fire. Access for emergency medical providers also was difficult.

Workers wore chest waders most of the time. Temperatures reached into the mid-20's (70's F) most work days. Even though the water provided some cooling effect, chest waders caused most people to perspire heavily and dehydration and heat exhaustion were concerns. Since completion of the work was mandated by environmental concerns involving the return of the salmon to the stream, meeting the work schedule required 10-12 hour work days. Therefore, fatigue was also a concern.

The vapor problems encountered in the cleanup were much greater than expected during planning. Although the gasoline had been in the environment for over three weeks when cleanup started, spikes of over 300 parts per million were not uncommon when some bank or bottom sediment materials were disturbed. The amount of gasoline vapor encountered during the work in Division F was much higher than expected and required additional air monitoring capability. A respirator-qualified crew was brought in to work in Division F. It was eventually determined that the bank and streambed sediments of Hanna Creek were so saturated that a more aggressive solution would have to be developed for that division. An amendment was made to the Site Safety Plan to accommodate the Level C personnel protection equipment.

The requirement for the workers to wear body protection such as "Tyvek" clothing or rain gear was considered, but there was little that could be done to keep water out of the suits. Since water dissipated the product very rapidly, it was determined that it was better for the workers to have no skin protection and to let volumes of very slightly contaminated water constantly bathe their skin, rather than to have contaminated water trapped inside personal protective equipment (PPE). Decontamination and wash stations established at work locations and staging areas provided a means to reduce dermal exposure. Visual observations of work crews, combined with additional air monitoring, were carried out under the direction of the OPL Project Safety Officer.

REMEDATION TECHNIQUES

Manual Agitation

Crews began manual agitation work during the week of 6 July, 1999, along with the slash removal activity. Approximately 70 workers walked through the creek moving slash and stirring up a large amount of sheen. Manual agitation remained a viable operation throughout the cleanup, especially in areas where mechanical agitation was not possible. The methodology was simple and included rolling rocks and using pry bars, shovels and rakes to move pebbles, cobbles, and boulders. In Division A, large rocks and waterfalls limited the access of excavators and the “Spyder” to pre-identified sections. In Divisions C and D, manual agitation was required because water depths and access precluded excavators from working.

Low-Pressure Water Wash

The Streambed Remediation Plan called for low-pressure washing using 50 psi and for the wash to be with a wide spray. These pressure parameters were identified in order to minimize potential damage to the stream banks. Fire hoses and nozzles were used to transfer water from floating pumps to the washing location on the bank or in mid-stream rocks (Figure 6). The fire nozzles could be adjusted to a wide angle to keep pressure down or hoses were used without a nozzle to provide a very low-pressure flush.

Although the floating pumps were efficient and durable they produced three safety problems. First, the exhaust muffler on the top of the device became very hot during extended use and was a “bump and burn” hazard to workers wading in the water next to the pump. A field modification was made to the pumps by fabricating a wire mesh screen around the exhaust to keep people from accidentally bumping the muffler. The second problem was that the exhaust system gave off relatively high levels of benzene. Carbon monoxide readings were 1-2 ppm, and the benzene readings were as high as 30 ppm. Workers were directed to stay upwind from the pumps at all times, and to stay as far from the units as they possibly could and still control the device. The third safety issue was noise. The decibel reading near the pump when operating was about 100 dbL. This level required double hearing protection to control the noise. Workers using the pumps wore both ear plugs and ear protectors.

On 16 July, 1999, a JRC inspection in Divisions B and C determined that the peat/silt areas around root balls of trees and banks were not being cleaned well enough by the low-pressure wash. It was the opinion of the inspection party that, not only would removal of the peat and silt remove larger volumes of gasoline residue, but also this action would make the habitat more accessible by salmon fry. Therefore, operations was instructed to use a medium- to high-pressure wash on these bank areas. The JRC team also observed gasoline residue in gravel bars and indicated that the high-pressure wash could be used in those areas as well. New RAP forms were produced and the medium/high-pressure wash was started as part of the treatment for all divisions on 17 July. The higher-pressure wash was very effective, although it did create more silt in the stream.

In the lower part of Division C and in Division D, the water depths made the use of rakes,

shovels and other manual tools ineffective. The water was also too deep for regular pressure washing. Plastic pipe “stingers” were attached to the hoses and the stingers were used to force water through the water column and into the streambed. This device was very effective for flushing gasoline from the silty sediments in these divisions. The water depths also allowed the use of a diaphragm pump in skiffs in these divisions. This type of pump worked well and was much quieter than the floating pumps, which was important when crews worked in this area as the creek banks were steep riprap or gabion-type material that contained the noise.

Mechanical Agitation

The interagency team that conducted the first (23-24 June) survey recognized that operations would have to use mechanical equipment in order to remediate the stream in an efficient, timely, and cost effective manner. Therefore, mechanical agitation was approved for treatment.

The operations team recommended an excavator (track hoe) as the best device for Divisions B, C, and the lower part of A (Figure 7). However, this equipment was not practical in the upper part of Division A where the boulders are much larger and access is limited by the steep-sided and high canyon walls. One access was down a 65- to 70-degree incline with about a 30-m drop in height. A walking tractor-excavator (“Spyder”) that is used for tree work and grass/brush cutting on steep grades was selected as the best device for the canyon area (Figure 8). Even this device was limited in parts of the canyon and was unable to operate in those areas already described above as suitable for manual agitation and pressure washing only.

The excavators agitated the bottom by picking up rocks and moving them, and by placing their bucket in a vertical position and plunging it approximately 30-50 cm into the streambed sediment. The operator would then jiggle the bucket before lifting the bucket and repeating the process from one side of the streambed to the other. The process was repeated every few feet. The operator would turn the excavator and brush the rocks back into their relative position following agitation.

The “Spyder” used the same technique with the exception that the claw could swivel 360 degrees. By turning the claw after penetrating the streambed sediment the operator could agitate a larger area without moving. Of course, this was only possible in areas of the stream where the rocks and boulders were small enough to be moved in this manner.

By 12 July, the excavator in Division A had completed three passes over the entire work area. This effort was considered satisfactory and, if further work was deemed necessary, it would have been possible to have moved the other excavator or the “Spyder” into the Division to complete the work. The second excavator worked in Divisions B and C until 19 July. During that period the machine made at least two passes over the entire zone and in some areas as many as four passes. The “Spyder” arrived on site the morning of 12 July and completed two full passes over the streambed and was demobilized at the end of the day on 16 July, 1999.

During the JRC inspection of 16 July, 1999, a few areas of Division B and C were identified as requiring more aggressive mechanical agitation because of the amount of contaminant found in the streambed. For these areas, mechanical screening was ordered. Mechanical screening involved the backhoe lifting a bucket of streambed sediment and dumping it back into the same spot. The process is very similar to tilling a garden plot.

Hydraulic Flush

The water source for Whatcom Creek is Lake Whatcom, a large natural lake located a few kilometers west of the City of Bellingham. The sluice-gate and control-gate structures would normally have been closed most of the time at this time of year. In the preparation of the Streambed Remediation Plan it was recognized that the control structures could be used to increase flow through Whatcom Creek on a planned basis to assist in hydraulically flushing the stream.

The Streambed Remediation Plan called for a single large flush of the stream to occur after slash removal and construction of the silt fences, and prior to beginning mechanical and manual agitation. The slash removal and silt fences were finished on 9 July a flush of about 30 cm (12 inches) at the control gate was carried out that evening.

The Streambed Remediation Plan also called for a nightly increase in stream flow to help flush any materials that were released during the daytime operations and beginning on the evening of 10 July, the sluice gate was opened 15 cm each evening for approximately 90 minutes.

On 22 July, permission was given to have a 30-cm flush that night prior to the scheduled inspection of Divisions A, B, and C on the 23rd. The flush was started at 5:30 p.m. and stopped at 7:30 a.m (Figure 9). However, a log jammed in the control gate and this had to be cleared before the gate could be shut, which resulted in the gate being opened to 1 metre for approximately 2 minutes and which caused a large short-term volume of water to scour the canyon.

Following the inspection of 23 July, it was agreed to begin 30-cm flushes on a nightly basis until 14 August, when a mid-day 45-cm flush was approved for Whatcom Creek. A flush of Hanna Creek, using water from “frac” tanks, was carried out on 14 August concurrent with the Whatcom Creek flush.

SIGN-OFF PROCEDURES

The Site Supervisors reported when they considered that a reach had been remediated to the point at which no rainbow sheen would be released by agitation of the streambed materials. Remediation of Divisions A, B, and C was completed on 23 July and during a JRC inspection on that day, the inspection team found only four small areas that required additional minor treatment. The identified areas were treated that same afternoon.

The maintenance of Hanna Creek was the only work site identified for streambed remediation that was not fully completed. Initially, it was thought that at least the lower part of Hanna Creek could be treated using the same methods as planned for Whatcom Creek. However,

after working the lower half of Hanna Creek for several days between 6-7 July and 13-17 July, and after receiving a briefing on the extent of plumes migrating from the source, it was decided that the best method for dealing with Hanna Creek throughout the site was excavation of the saturated soil.

After a meeting of a special sub-committee of the JRC on 12 August, 1999, it was decided that Hanna Creek would be flushed to resolve any final remedial requirements. The Streambed Remediation Project team was tasked with preparing the streambed ahead of time by trenching across the creek bed at each of the identified hot spots, and at any other locations deemed appropriate, and with setting up two “frac” tanks for a high-volume water source. Both of these tasks were completed on 13 August, 1999, and a flush of Hanna Creek was authorized for 14 August, 1999, using 75,000 litre “frac” tanks, during daylight hours. The flush appeared to have moved considerable product from the streambed. Samples were taken near the mouth of Hanna Creek prior to, during, and following the flush to determine the effect of the flush on Whatcom Creek. Relatively high levels of hydrocarbons were measured near the mouth, but levels downstream were undetectable. A 45-cm flush of Whatcom Creek occurred at the same time as the flush of Hanna Creek.

SAMPLING AND MONITORING PROGRAM RESULTS

Over 400 creek-water column samples were collected and analyzed for gasoline range hydrocarbons, benzene, ethyl benzene, toluene, and xylenes. More than 100 water samples were collected and analyzed from Bellingham Bay. Approximately 50 water sampling events at downstream locations occurred during remediation and flushing to determine potential transport to the Bay. In excess of 100 sediment and sediment pore water samples were analyzed in the Bay and Creek in June. Samples from nine sites for bulk sediment and decanted water were analyzed in July, and 12 sampling sites for sediment and decanted water were analyzed in August. There were also a total of 12 sites sampled (in some cases two or three times) for approximately 340 post-remediation (verification) samples of interstitial pore-water. Water column and sediment Polycyclic Aromatic Hydrocarbons (PAHs) were also analyzed at numerous locations. Gasoline is typically dominated by monocyclic aromatic compounds, however, the fire would have transformed much of the fuel to higher molecular weight pyrogenic PAHs common to fires. Interstitial water PAH in Whatcom Creek did not differ from control and reference locations. Hence, bioavailable PAHs in the sediment water were not a primary concern.

A substantial decay of gasoline concentrations in the water column occurred within the first two days following the incident (Figure 10). Fluctuations between detection and non-detection occurred from approximately June 18, 1999, and throughout the remediation activities as pockets of product were released. It was clear that the water column reached “below detection limit” concentrations quickly, but product could be released from the sediment to the water column by

agitation. However, evidence suggests most or all of the product volatilized prior to reaching Bellingham Bay (Figure 10). For samples collected during the same time period, reduced concentrations can be seen at each downstream location. The Whatcom Waterway samples indicate that appreciable amounts never reached the Bay. This evidence suggested that agitation would not result in a threat of downstream contamination. Nonetheless, downstream samples were collected for verification.

Downstream gasoline hydrocarbon levels at Dupont Street were at or near “non-detection” indicating that the product likely volatilized quickly after release and did not expose Bellingham Bay. The water column sampling results (Figure 10) also suggest that any levels found at Dupont Street would be substantially reduced by the time the creek entered the bay since concurrent samples at Dupont Street were higher than both Roeder Street and the Whatcom Waterway when gasoline levels were detectable. The falls below Dupont Street, as well as the many cascades and falls upstream, provided effective means of volatilization and release of product to the atmosphere via sparging. Similar results were found for BTEX compounds.

The main question was whether agitation reduced levels of gasoline hydrocarbons in the sediment and sediment water and, if so, to what degree. Interstitial toxicity in the sediment pore-water was a primary concern for invertebrate in fauna and salmonid eggs and young. Interstitial water and sediments were sampled for gasoline, BTEX, and PAHs in July, August, and September, 1999, as a final site-specific evaluation of potential chronic toxicity to sensitive aquatic life stages. Samples were collected using pipettes inserted into the gravel and allowed to equilibrate with pore-water. Criteria for chronic toxicity were developed by a Chemical Toxicity Working Group within the JRC. Literature values of toxicity of gasoline constituents to salmonid juveniles were converted to lowest effects concentrations to develop action levels. These criteria and sampling results (Figure 11) led the JRC to determine that a substantial risk of chronic toxicity did not exist in Whatcom Creek following September 1999. This is consistent with literature regarding degradation of gasoline products in the environment (Pontasch *et al.*, 1988; Schultz *et al.*, 1975; Guiney *et al.*, 1987).

CONCLUSIONS

The stream remediation project successfully removed residual gasoline from the sediments and riverbanks of Whatcom Creek over a 6-week period. This remediation was achieved by manual and mechanical agitation combined with regular hydraulic flushing using an upstream control-structure. Analyses of water column and pore-water samples were used to determine if the cleanup criteria were met and showed that no downstream movement of the released gasoline towards Bellingham Bay could be detected.

The establishment of a project team within the overall response organization provided a mechanism for the efficient and effective remediation of the stream. The project team was focussed only on this issue and so was not side-tracked by other problems or priorities. The preparation of detailed operations plans and the daily documentation of field activities that were provided to the JRC ensured that close communication was maintained throughout the project. The JRC was informed on a daily basis of the progress that was being made, as well as some of the difficulties that were encountered, and responded to this openness of information in a positive and constructive manner.

The presence of gasoline in some of the canyon sections several weeks after the accident provided a new perspective on this type of spill situation and indicates the need to be ready to have crews available and prepared to work with respirators at all stages of a gasoline spill response.

BIOGRAPHY

Dr. Ed Owens has been involved with oil spill response planning, training, and operations for more than 30 years. He has responded to inland and river spills in North America, Russia and South America, and on coastal spills worldwide. Dr. Owens has been a UN/IMO Expert Consultant and a member of the U.S. National Academy of Sciences Oil Spill Research and Development Review Committee.

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- Figure 1 General Location of Bellingham, WA
- Figure 2 Upper, Canyon Section of Division A, Whatcom Creek (28 June, 1999)
- Figure 3 Central Stream Section in Division C: Wide Stream with Low Banks (12 July, 1999)
- Figure 4 Lower Stream Section in Division E: with Deep, Narrow Channel and Man-modified Stream Banks (24 June, 1999)
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- Figure 10 Gasoline-range Hydrocarbons in Whatcom Creek through Time at Four Sample Stations approaching Bellingham Bay (James Street is the most Easterly of the Four Sample Stations and is in Division D, Figure 5)
- Figure 11 Pre- and Post-remediation Interstitial Water BTEX at Spawning Sites in Whatcom Creek (above Racine Street in Divisions A and B, Fig. 5)







