Thermo-Gel® 200L and Water Quality in British Columbia:

A Case Study of
Martin Mars Water Bomber Delivery for Aerial Fire Line Creation

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Integrated Resource Analysis Section

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On 14 June 2005 seven separate drops from Flying Tankers Inc.'s *Hawaii Mars* water bomber were delivered as part of a FERIC led study into the effectiveness and feasibility of a recent addition to the toolbox of aerial fire fighters. Thermo-Gel® 200L is a hydrophilic polymer based in mineral oil. It is packaged in a liquid concentrate form that has been successfully used in the United States and other jurisdictions mixed with water at 1-2% concentrations. This study was conducted using a concentration of 1.1% upon injection into the water tanks of the *Hawaii Mars*. TimberWest's Integrated Resource Analysis Section (IRAS) participated to assess the potential for basic water quality impacts in this initial case study in British Columbia. Forest fire protection systems have obvious benefits to the protection of all forest resources, including water quality and fish habitat. Results of using Martin Mars air tankers for a single delivery of Thermo-Gel® 200L supported existing research on the product. There was no material degradation of water quality observed.

Background

The Martin Mars Bombers are a unique water-based aerial fire fighting suppression tool because of their ability to deliver large volumes of water at a sustained rate. When appropriate source and drop configurations exist, 27000 litres of product can be delivered by each aircraft every 15 minutes. On cycle with both aircraft, delivery of this volume can occur every 7 minutes. This delivery can include straight 'unimproved' source water, water mixed with foam concentrate, and now, water mixed with gel retardant.

There are a variety of reasons to use each of the three delivery products available from the Mars. Unimproved (just water) is generally used when infrastructure or commodities under suppression could have additional damage done by the inclusion of additives to the delivery or when direct public safety concerns exist. In general, direct attack of hotspots involves the application of water mixed with foam. This combination is proven to penetrate hydrophobic surfaces better than water and cool surfaces quickly. The new combination of gel and water adds flexibility to suppression techniques by surpassing the properties of foam/water to provide enhanced fire line creation.

While foam continues to be ideal for hot spots and direct attack, gel has been shown through many tests by the United States Forest Services (USFS) to be environmentally benign while also more enduring than foam for fire lines purposes. Through the delivery process, Thermo-Gel® binds water and forms a longer lasting shield to reduce heat and oxygen on fuels. This report summarises a test of these properties upon water quality and the feasibility of Martin Mars delivery at a test site on TimberWest's managed forest near Gooseneck Lake, west of Campbell River, British Columbia.

This report is intended to complement the main research into the thermal and hang time properties of Thermo-Gel® conducted by FERIC and BC Ministry of Forests and Range Fire Protection Branch during the day of testing on 14 June 2005. The reader is directed to that report for detailed findings of their study parameters. The supplementary parameter results reported here by TimberWest's Integrated Resource Analysis Section from this trial are focused on the effects to water quality that Thermo-Gel® could be expected to produce under normal operating conditions when building a fire line.

Methods and Results

Using standard sampling techniques, nine (9) different watercourse sites around the planned test drop sites were sampled between 1-4 hours prior to the relevant drop by the Mars to get an ambient or baseline value. Figure 1 is the location map of the study site, while Figure 2 shows the general area of drop zones as well as the water sample sites. Of these nine initial sample sites, six were never directly impacted by drops and/or were not sampled in a controlled manner. As such, only the two sites at the swamp (surface and subsurface) along with the stream location at "210-mid" form the basis of the three scenarios explicitly monitored.

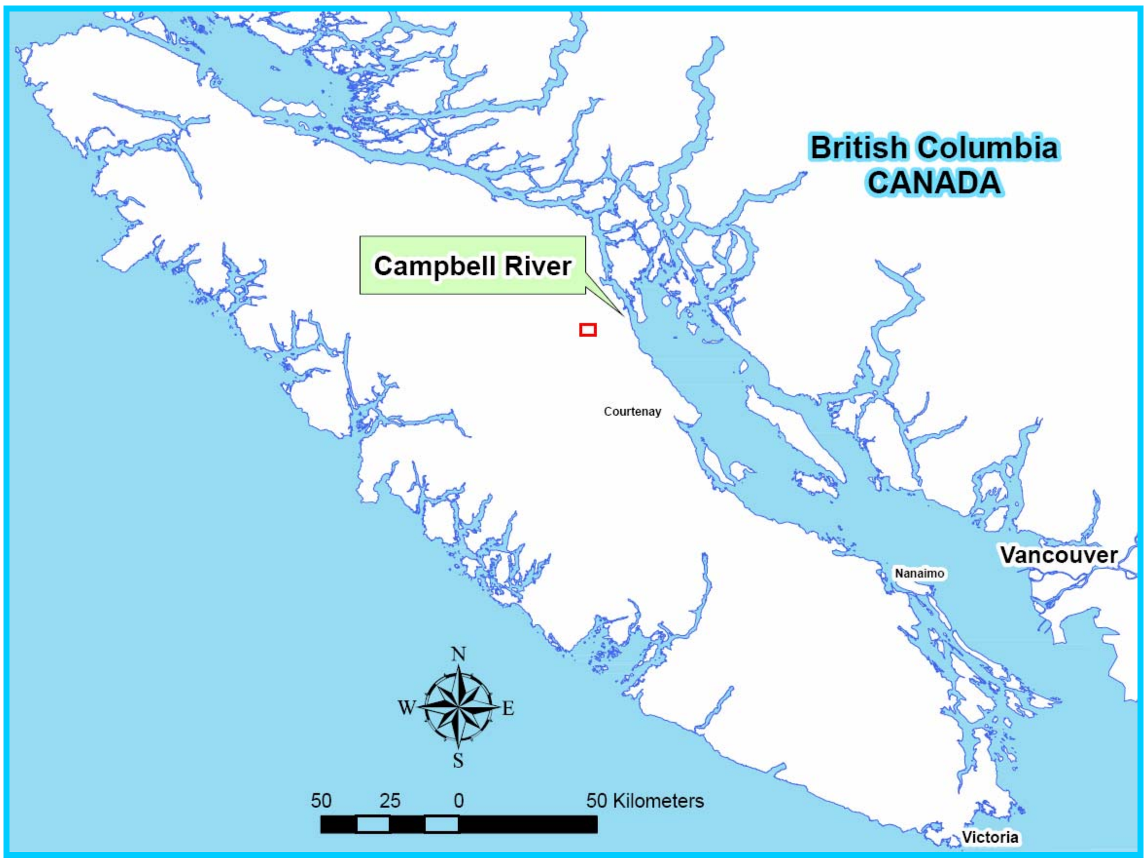

Figure 1. Overview location map of Gooseneck Lake area, Vancouver Island, BC.

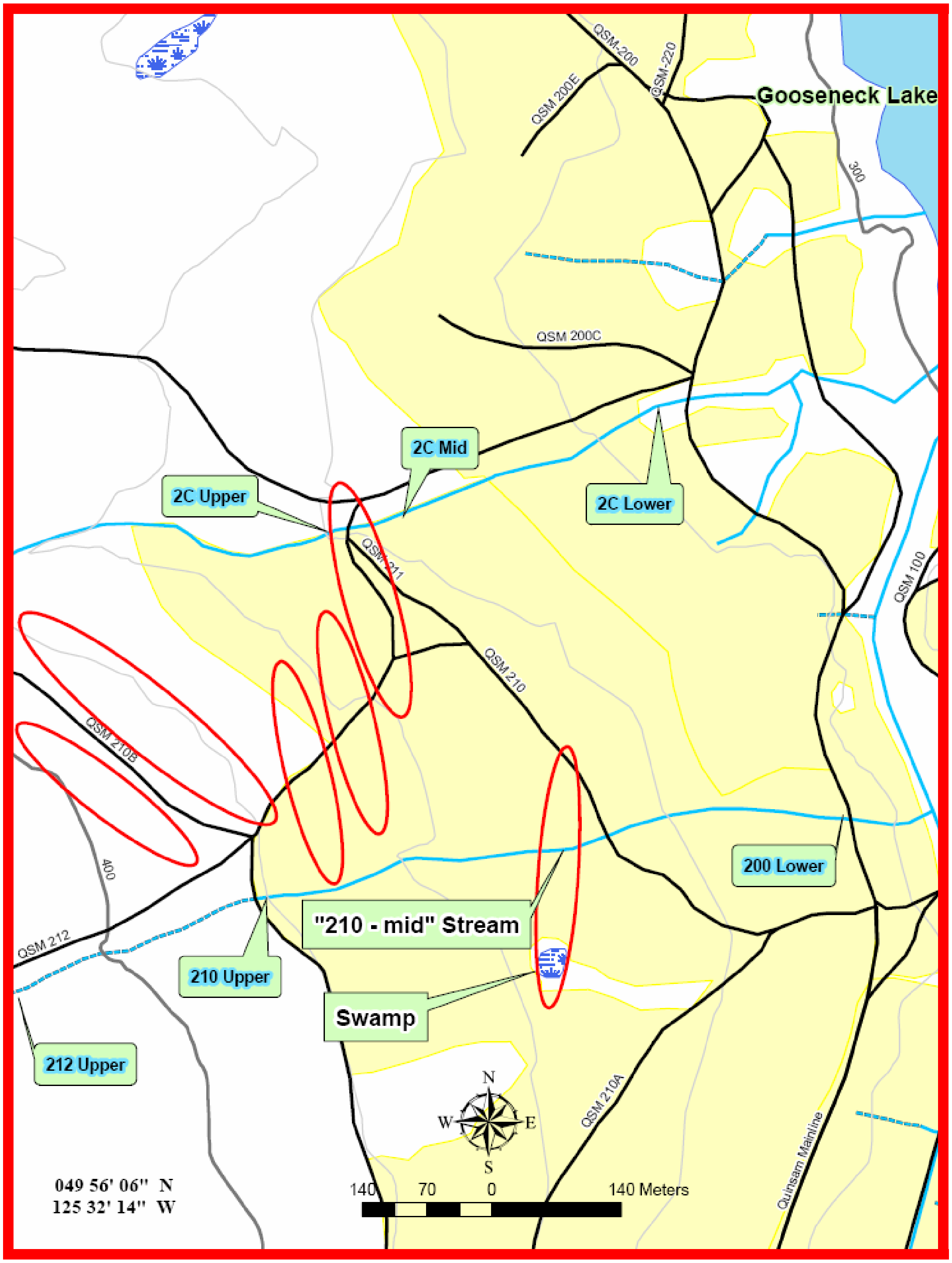

Figure 2. View of drop areas and sample sites.

Samples at "**210-mid**" were taken within five minutes of the drop. Figure 3 shows the coverage along the flight path 5m away from the stream channel. Figure 4 shows the dissipation of Thermo-Gel® that has occurred 5 minutes since the drop. This stream was flowing approximately 25L/min at the time of delivery.

Figure 3. Typical coverage of Thermo-Gel in opening.

Figure 4. Dissipated Thermo-Gel residue 5 minutes after delivery at 210-mid.

Samples at the **swamp** were taken 1 hour after the initial drop. Figure 5 shows the *Hawaii Mars* as it began its drop on the swamp and creek.

Figure 5. *Hawaii Mars* begins drop on sample sites.

Figures 5 and 6 show the red food colouring dye of Thermo-Gel® visible on the swamp surface.

Figure 6. Wide view of colouring on swamp.

Figure 7. Close up view of colouring on swamp surface.

Figure 8 visibly contrasts the effects of Thermo-Gel® on the surface on the right (more colour) with the subsurface samples on the left one hour after delivery. The water surface area of the swamp was about $200m^2$ and there was no surface runoff in or out of the swamp during the trial. The swamp was 1-3m deep.

Figure 8. Contrast of subsurface and surface colouring.

North Island Laboratories in Courtenay was retained to analyse nine parameters that are commonly associated with water quality. Seven of these parameters were tested at all three sites, while two hydrocarbon tests (light and heavy chain) were only tested at the swamp. Tables 1 through 3 show the water sample results and their relative changes soon after the delivery (as detailed above) and upon follow up samples one week later.

Table 1. Hydrocarbon sample results from swamp.

	EPH (C10-C19) ug/L			EPH (C19-C32) ug/L		
	Ambient	After	Week After	Ambient	After	Week After
Swamp Surface	100	13600	200	100	400	100
Change from Ambient	-	*136 X*	*2 X*	-	*4 X*	*N / C*
Swamp Subsurface	100	2400	200	100	100	100
Change from Ambient	-	*24 X*	*2 X*	-	*N / C*	*N / C*

Table 2. Cation and hardness sample results from swamp and stream.

	d-Calcium mg/L			d-Magnesium mg/L			d-Sodium mg/L			Hardness (CaCO3) mg/L		
	Ambient	After	Week After	Ambient	After	Week After	Ambient	After	Week After	Ambient	After	Week After
Swamp Surface	3.8	1.0	3.7	0.87	0.30	0.80	1.8	9.6	2.0	13.0	0.1	13.0
Change from Ambient	-	*-74%*	*-3%*	-	*-66%*	*-8%*	-	*433%*	*11%*	-	*-99%*	*N / C*
Swamp Subsurface	3.8	3.5	3.6	0.88	0.78	0.78	1.9	2.7	2.0	13.0	12.0	12.0
Change from Ambient	-	*-8%*	*-5%*	-	*-11%*	*-11%*	-	*42%*	*5%*	-	*-8%*	*-8%*
"210 - mid" Stream	4.9	4.6	4.8	0.82	0.77	0.84	1.6	2.0	1.6	16.0	15.0	15.0
Change from Ambient	-	*-6%*	*-2%*	-	*-6%*	*2%*	-	*25%*	*N / C*	-	*-6%*	*-6%*

Table 3. Dissolved Organic Carbon (DOC), pH, and ammonia sample results from swamp and stream.

	DOC - Dissolved Organic C mg/L			pH pH units			ammonia (N) mg/L		
	Ambient	After	Week After	Ambient	After	Week After	Ambient	After	Week After
Swamp Surface	2.1	6.9	4.8	6.3	6.7	6.2	0.02	0.02	-
Change from Ambient	-	*229%*	*129%*	-	*6%*	*-2%*	-	*N / C*	-
Swamp Subsurface	2.3	2.8	3.0	6.2	6.3	6.3	0.02	0.02	-
Change from Ambient	-	*22%*	*30%*	-	*2%*	*2%*	-	*N / C*	-
"210 - mid" Stream	1.3	1.6	1.6	6.9	6.7	6.5	0.02	0.02	-
Change from Ambient	-	*23%*	*23%*	-	*-3%*	*-6%*	-	*N / C*	-

Background on relevant previous testing by others:

Thermo-Gel® 200L has been previously tested and approved in accordance with the Environmental Protection Agency (EPA) and the United States Forest Service (USFS). Two tests relevant to TimberWest's contribution to water quality impact assessment are fish toxicity and biodegradability.

According to information provided to Mr. Jeff Barry of the BC Forest Service on 09 May 2005 by Trinity Turnbow, Project Engineer for Thermo Technologies:

> **Fish Toxicity Tests:**
> The fish toxicity of the concentrate to rainbow trout (*Oncorhynchus mykiss*) was determined in accordance with EPA OPPTS 850.1075, Ecological Effects Test Guidelines, Fish Acute Toxicity Test, Freshwater and Marine. Static test conditions in ASTM soft water at 12 ±1˚C was maintained throughout the 96-hour test period. All fish were 60 ± 15 days post hatch.
>
> The requirement was that LC_{50} must be ≥ 10 mg/L. The actual performance of Thermo-Gel® 200L concentrate resulted in an LC_{50} = 28 mg/L.*
>
> **Biodegradability Tests:**
> The biodegradability tests were performed in accordance with EPA OPPTS 835-3110, Section O, Ready Biodegradability. The tests were conducted for performance information only. A product is considered to by readily biodegradable if it has at least 60% biodegradation within 28 days and biodegradable if it has at least 60% biodegradation within 42 days. Thermo-Gel® 200L was 45% percent biodegraded at 42 days.**

* In this standard fish toxicity test, concentrations of a liquid below 10mg/L that result in the mortality of 50% (LC_{50}) of individuals means that a substance would be considered toxic. Thermo-Gel® 200L concentrate was not found to produce LC_{50} mortality levels until 28mg/L. This is about three times less than what would be considered toxic. Therefore, Thermo-Gel® 200L is not toxic.

** In this standard biodegradability test, Thermo-Gel® 200L concentrate was not found to meet formal biodegradable status. In standard test conditions, the concentrate biodegraded 45% in 42 days. Thermo-Gel® 200L concentrate was shown to biodegrade; however, it did not meet the test definition of biodegradable. While it does biodegrade, the most useful property of Thermo-Gel is the durability it provides for building fireguards for the purpose of limiting the spread of fire.

It is important to note that <u>these two tests were conducted on the concentrate</u>. Most applications of Thermo-Gel® 200L occur under 5% concentration. It is reasonable to infer here that using a 1.5% or less solution in the Mars flying tankers will produce less toxic results and greater biodegradability rates than the concentrate.

Discussion

As a supplement to the larger FERIC study on the effectiveness of Thermo-Gel® 200L as a fire suppressant, this report shows possible impacts to water quality that may occur during operations. It must be stated that foam and gel are not dropped from Mars bombers onto watercourses unless there are no other practicable options for attacking a fire. Our samples before, after, and one week after on the small swamp and small creek were intended to display a worst case scenario where no choice would have existed other than to include watercourses in the drop zone of a fire line. However, despite the attempts to avoid dropping on watercourses in operational events, the results of this report show that given similar ambient conditions, most of the impact of introduced Thermo-Gel® 200L is dissipated after one week.

Table 1 shows the relatively high volatility of Thermo-Gel® 200L in the significantly higher sample results for the lighter EPH carbon chain (C10-C19) in the swamp. The mineral oil base that dominates the formulation is relatively light, a characteristic of degradable compounds. This relatively light molecular weight is also displayed in the nearly 5 times higher concentration of hydrocarbons on the swamp surface as compared to subsurface. After one week, both hydrocarbon groups on and below the surface were shown to have returned almost completely to ambient levels.

Although some irritation could be experienced by aquatic life, the short duration of the spike in petroleum hydrocarbons is not expected to have adverse impacts. Aquatic larvae of amphibians were observed before and after the drops. These forms of amphibian are completely aquatic and were expected to have remained in the swamp for the entire week prior to follow up sampling. At that time one week later, similar levels of these larvae (tadpoles) were again observed with no mortality evident. No other readily observable changes were noted in the ecological characteristics of the swamp, which is part of a timbered riparian reserve included amidst recent harvesting (Fig. 2).

Table 2 shows the changes to cation and hardness values resulting from the application of the Thermo-Gel® 200L at 1.1% solution from the Mars. One of the impacts of Thermo-Gel is cation (positively charged ions such as calcium, magnesium, and sodium) exchange. This means that the sodium portion of Thermo-gel (i.e. the sodium part of the sodium polyacrylate in mineral oil) exchanges with the calcium and magnesium that are naturally occurring in the environment. This explains the increase in sodium and decrease in calcium/magnesium immediately after the drop.

The exchange of cations, in turn, affects the measure of hardness (Table 2). The ambient conditions measured are considered soft at 13mg/L. The Canadian Drinking Water Guidelines suggest values begin to be unacceptable to humans around 100mg/L (hard). In the case of this study and the relatively low ambient hardness values, the short term drop to these values is expected to have negligible impact to aquatic life. In cases where ambient hardness levels are higher and Thermo-gel application drops hardness to near nil, short term sensitivity to certain metals in the water may occur with some species. What is important to note is that similar trends to quick recovery of ambient hardness can be expected when Thermo-gel is applied at similar concentrations as in this trial.

Table 3 shows that the magnitude of change in Dissolved Organic Carbon (DOC), pH, and ammonia, was respectively less significant. As Thermo-Gel is an organic polymer, an increase in organic carbon levels in the watercourses was expected as the gel diffused. In the less dynamic environment of the swamp, an order of magnitude higher result was observed immediately after as compared to the stream, which was measured only 5 minutes after delivery. Of all the parameters tested, DOC showed the slowest trend to ambient levels. The swamp was observed to still remain at more than double the pre-delivery level one week later, while the stream results remain unchanged after one week. While this difference cannot be readily explained, increases to absolute magnitudes in this case of DOC by 5mg/L are not considered distressing to species expected to frequent such habitat. The trend for full recovery still remains quick as one week later (Table 3), DOC levels were nearly half of the post-delivery levels.

Also shown in Table 3 is that pH is changed by a negligible amount immediately after delivery of Thermo-Gel to both the swamp and the stream. Similarly negligible changes were noted one week later. Many amphibians and fish species are sensitive to changes to pH. Ammonia (Table 3) was shown to have no detectable changes immediately after the drop, and as such was not tested one week later.

Summary

This case study of water quality impacts from aerial delivery of Thermo-Gel® 200L has reasonably shown that while immediate impacts may cause sensitivity to a limited number of species guilds, the ambient conditions can be expected to return after roughly seven days in standing water. Running water was observed to return to baseline values even sooner.

The complete FERIC report will address more properties of Thermo-Gel® 200L as an operational tool. Again, the reader is directed to that report (unpublished as of September 2005) for such details. Included in FERIC's review will be results of other aerial delivery methods, such as helicopter and smaller air tankers. One aspect of the feasibility of aerial delivery that will evolve with further studies and experience is that of ambient water hardness and appropriate gel concentrations to achieve desired viscosity of delivered product. During these initial tests with the Martin Mars in the Gooseneck Lake Area, typical conditions of very soft water were encountered.

These soft water conditions are typical of Vancouver Island wherein the geologic origin is volcanic. Concentrations of 1.3% were found to result in product viscosities too high for effective coverage or ejection. However, it is anticipated that in areas with normal hardness levels (e.g. 80mg/L) such a concentration would be appropriate. It is also reasonable to expect similarly benign impacts to water quality whenever operational constraints require delivery to watercourses. In all cases, aerial delivery has been shown to use very low concentrations of Thermo-Gel® 200L.

Combining the results observed in this study, along with the EPA and USFS results included above, suggest that the use of Thermo-Gel® 200L in applications that may require delivery over water bodies or watercourses as operating conditions dictate should not unduly harm or degrade water quality in the larger context of minimising the extent of a wildfire. Thermo-Gel® 200L was shown to be an environmentally friendly new option to use in the management and suppression of wildfires.

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