

**Justice Institute Of B.C.
Maple Ridge Fire and Safety Training Centre
Intermediate Treatment of Oily Wastewater from Fire Fighter Training Exercises**

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ABSTRACT

The Justice Institute of British Columbia (JIBC) operates a Fire and Safety Training Centre located in Maple Ridge, British Columbia. The training centre utilizes two water treatment systems designated as "Class A" and "Class B". The "Class A" system treats wastewater generated from training exercises involving wood burning fires and appears to be performing adequately. The "Class B" system treats wastewater associated with training exercises involving fuel related fires. Waste streams in the Class B system typically include the carryover of AFFF (aqueous film-forming foams), Purple K Dry Chemical Powder, Soot, and Aviation Grade Fire Training Fuel. Wastewater from both systems is reclaimed and reused in training exercises.

The JIBC has now completed the intermediate upgrade of the Class B wastewater treatment system. The objectives of the upgrade were to improve the quality of the reclaimed water and eliminate any potential health concerns associated with exposure of the students and staff during its use in training exercises.

Dayton & Knight Ltd. was retained by the J.I.B.C. to study options for improving the treatment of the oily wastewater including bench scale testing and provide design of new facilities. The completed design included the enlargement of existing influent tanks to increase hydraulic retention time, installation of a coalescing plate pack oily water separator provided by Mohr Separations Research, Inc. to improve separation of hydrocarbons, addition of a ferric chloride flocculation system, and retrofitting of settling tanks with baffles for improved floc settling.

Supporting works include a 14,000 L vertical storage tank complete with a floating suction to provide enhanced separation of the reclaimed hydrocarbons and a waste solids storage tank.

The presentation will provide a review of the program objectives, discuss the approaches used in the selection of treatment solutions, and provide a general overview of the current project status and future additions. Site and equipment drawings and photo images will be used as a reference for the discussion.

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SUMMARY

The Justice Institute of British Columbia (JIBC) operates a Fire and Safety Training Centre located in Maple Ridge, B.C. The training centre utilizes two water treatment systems designated as Class A and Class B. The Class A system treats wastewater generated from training exercises involving wood burning fires and appears to be performing adequately. The Class B system treats wastewater associated with training exercises involving fuel related fires. The treated effluent from this system was not acceptable for re-use in training exercises due to the occurrence of objectionable odours and skin irritations.

The JIBC decided to install treatment upgrades to produce Class B treated effluent that is suitable for re-use in training exercises.

This paper describes the conceptual process and design options for the intermediate treatment of Class B wastewater.

1.0 Introduction

The Class B system was originally constructed in 1983 with a subsequent upgrade in 2001. The wastewater collected in the Class B system consists of either City or Class B recycled water along with varying quantities of unburned aviation fuel, synthetic firefighting foam, fire fighting powder and soot.

Figure 1 illustrates the layout of the site for the current construction.

The commercial names of the fuel and fire fighting products are as follows:

1. Fuel – E III Aviation Grade Fire Training Fluid
2. Foam – Chemguard Simufoam
3. Powder – Purple K Dry Chemical

The previous treatment system included gravity separation and mechanical removal of unburned hydrocarbon fuel, settling, and filtration with granular activated carbon (GAC) filters to remove suspended solids. The majority of the unburned fuel was removed and was processed until it reached a purity whereby it can be re-used in training exercises.

Even following the 2001 improvements, the existing system did not remove all of the contaminants from the water satisfactorily. Some contaminants were not being completely removed by the oily water treatment system and were being carried over into the recycled water that is used in the training exercises. Students have complained of

skin irritations and odours associated with use of the recycled water and these are believed to be linked to the carryover and presence of the wastewater constituents listed above. Other fire fighting training facilities with similar treatment works have indicated similar issues arising from the use of recycled wastewater.

In addition to the cited personal health issues, the carryover of residual fuel that is not separated out by the process appears to be resulting in blinding of the GAC filters requiring an accelerated change out of the media every two years

This Class B system has been the subject of several different studies to assess the effectiveness of the wastewater treatment system as well as optimize its capacity and treatment quality.

A review of current technologies used to treat wastewater generated from similar training facilities is included in this design brief for reference. Previous investigations undertaken by others have determined that AFFF foam causes an emulsification of fuel within the wastewater making separation of the fuel from the wastewater considerably more difficult (a standard oil/water separator is typically not effective for separating emulsifications without considerable detention time). The Maple Ridge training facility recently switched from the use of AFFF foam to Simufoam. Although Simufoam does not exhibit the same film forming properties as AFFF its potential for causing emulsification of fuel is unknown.

Dayton & Knight Ltd. identified flocculation as a potential method for removal of suspended solids such as the Simufoam, powder, and soot from the Class B wastewater. In-house flocculation tests were performed with a number of different flocculating agents on Class B wastewater samples collected from the JIBC. Ferric chloride was identified as being the most effective agent for flocculating the suspended solids contained in the Class B water samples.

2.0 SIMILAR TRAINING FACILITIES AND TREATMENT APPROACHES

Dayton & Knight Ltd. investigated other firefighting training facilities to identify the different approaches currently being used for treating associated wastewater. These facilities included airports, military installations, and college training centres. Although select unit processes have been installed in Canada, the majority are located in the United States where more stringent water management policies are in effect.

2.1 Airport Facilities

Wastewater collected from airport firefighting training exercises typically contains E III Aviation Grade fuel, firefighting foam, and glycol (de-icing fluid) with glycol being the major component. The firefighting foam that is used at these facilities is predominantly AFFF.

The approach that has been successfully proven at airport training facilities is the use of a seeded activated carbon system, generally referred to in the industry as an Anaerobic Fluidized Bed Reactor (AFBR). This type of system was originally pioneered by EFX Systems Inc. in the U.S. Several of these systems have been installed at different airport facilities on the eastern seaboard of the United States (e.g. Albany, NY) and have proven successful in the removal of contaminants from firefighting wastewater (Gibson, 2002). The mechanism credited with the success of these systems is the uptake of glycol as a food source for the biomass which in turn removes particulates. Attempts have been made to implement this technology in firefighting wastewater containing no glycol with limited success (Gibson, 2002).

2.2 Military Installation

Wastewater originating from facilities on military installations tends to contain little or no glycol. The contaminants are limited to firefighting foam and carried over fuel. Several studies have revealed that the presence of AFFF foam may result in approximately 10 to 15% of fuel being emulsified. Once in an emulsified state, fuel cannot be effectively separated using traditional oil/water separators.

A unit process known as an Air Sparged Hydrocyclone (ASH) system was developed to specifically treat wastewater containing emulsified fuels and is comprised of three stages: flocculation; air injection; and centrifuging.

In the first stage, a flocculating agent, generally ferrous chloride, is injected into the stream resulting in the formation of floc. The flow is then directed into a hydrocyclone where compressed air is passed through the water while it is being centrifuged. This results in the floc being effectively scrubbed out of solution. The final effluent quality is generally between 2-5 ppm oil and grease (Naval Facilities Engineering Service Center, 2000).

This system tends to be quite cost prohibitive having a starting price of approximately \$200,000 USD for the base model (Pers. Comm., John O'Hehir, Sales, Kemco Systems, 2005) with incremental pricing for larger flow rates.

2.3 Firefighting Training Institutes

In 1999, the University of Nevada, Reno (UNR) opened a Fire Science Academy (FSA) in Carlin, NV; one of the largest of its type in the United States. The treatment facilities for UNR FSA incorporated two American Petroleum Institute (API) oil/water separators for treating wastewater produced by the training exercises. These training exercises originally involved the use of AFFF foam and fuel. During the first year of operation, the effluent from the separators was found to be out of compliance with government discharge limits for oil and grease and the facility was subsequently closed in 2000.

To achieve compliance and reopen the treatment facility, The UNR FSA switched from the use of AFFF type foam to a product called Microblaze™, which does not result in emulsification of fuels. In addition, a dissolved air floatation (DAF) unit was installed downstream from the separator and incorporated the removal of skimmings through decanting. The Academy has indicated that since the implementation of these upgrades, effluent quality is now compliant.

3.0 SAMPLING AND FLOCCULATION TESTING

Figures 2 and 3 illustrate the ROO1 and 2007 plan layouts of the Class B1 water treatment. The four cell API separator is shown as Tanks A, B, C and D. The 2007 plan has Tanks A and B combined.

3.1 Sampling

A series of wastewater grab samples were collected on-site on April 22, 2005. The samples were taken from the various treatment tanks of the “Class B” system during firefighting exercises in an effort to capture both raw influent and subsequent effluent from the sequential treatment tanks. All of the training exercises occurring at the time of sampling involved the use of fire fighting foam.

During the flow of influent wastewater from the training exercises, only a minor amount of surface foam was observed in Tanks A and B but a significant amount was present in Tank D downstream. Based on these observations, it would appear that wastewater had been short-circuiting through Tanks A and B into Tank D. Short-circuiting decreases the treatment effectiveness as it reduces the detention time in the tanks and the corresponding time for oil/water separation.

3.2 Flocculation Testing

All samples collected were transferred to the testing facilities at Dayton & Knight Ltd. to undergo flocculation tests. A total of three different flocculating agents were tested and include:

- ClearPAC,
- SternPAC,
- Ferric Chloride.

Of the three chemicals tested, ferric chloride was found to generate the largest and most stable floc and required the least amount of settling time after the cessation of agitation. Optimal dosages for the three flocculating agents are indicated below:

- ClearPAC – 40 mg/L
- SternPAC – 80 mg/L
- Ferric Chloride – 30 mg/L

Ferric chloride appears to have the lowest required dosage at 30 mg/L. The approximate cost associated with each chemical is listed below.

- ClearPAC – \$1.17/kg
- SternPAC – \$1.32/kg
- Ferric Chloride – \$0.82/kg

Overall, ferric chloride appears to be the best flocculating agent for use in the Class B treatment system. This product is locally available, used in many municipal wastewater applications, and has the lowest cost.

3.3 Aeration Testing

Tests were also performed to determine the effectiveness of implementing dissolved air flotation after flocculation. This is in accordance with the approach currently being undertaken by the UNR FSA.

It was found that the introduction of aeration after flocculation and settling resulted in the immediate break up of the formed flocs, causing the water to become cloudy. Once the aeration in the tanks was discontinued, flocs were found to eventually reform but at a much smaller than original size.

An aeration test was also conducted on a raw sample without the addition of flocculating agents to determine whether any separation of suspended particles could be achieved solely through dissolved air flotation. The aeration was observed to have no visible affect on separation and the oil and foam particles remained in suspension. Overall, there appears to be no merit in using aeration as part of the upstream treatment process.

4.0 PROCESS AND DESIGN RECOMMENDATIONS

4.1 Process

In the investigative phase of the work, Dayton & Knight Ltd. provided the following recommendations:

- The current use of the Chemguard Simufoam should be switched to a non-emulsifying; self-degrading product such as MicroBlaze-Out™. This should be conducted on a pilot scale basis to determine whether any improvement in treatment can be obtained through the use of this alternate foam.
- An increase in the influent tank size to lengthen the initial detention time for separation of the oil was proposed.
- A special coalescing plate module system as provided by Mohr Separations Research, Inc. of Oklahoma was recommended to be installed to enhance separation. This portion of the design also included merging Tanks A and B

- to provide a larger tank for settling solids particles and provide a sump for solids accumulation.
- A flocculation and settling system was recommended for removing suspended solids downstream from the oil separation tank.
 - The GAC backwash should be returned to Tank A instead of Tank C in order to optimize the overall treatment of the wastewater.

4.2 Design

Dayton & Knight Ltd developed the following design for implementing the design recommendations. The previous 2001 construction and system as modified are shown in Figures 2 and 3 respectively. Figure 4 illustrates a sectional view of Tanks A and B showing the 2001 oil stripper and 2007 Coalescing system.

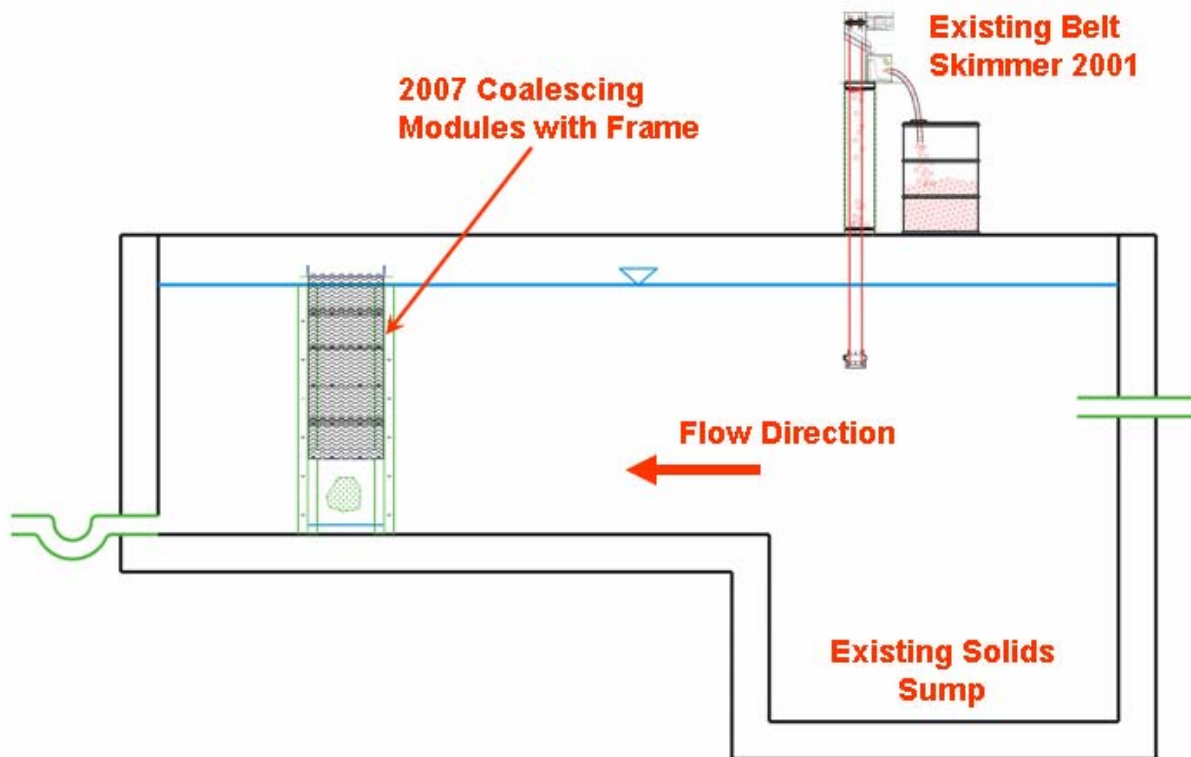
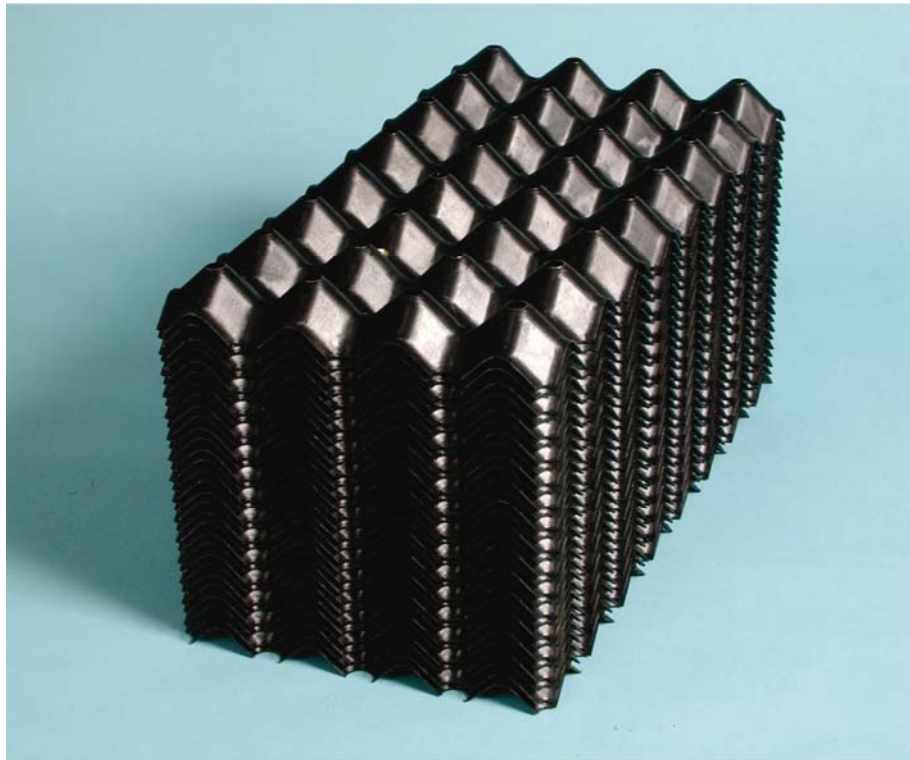


Figure 4 – Belt Skimmer and Coalescing Plate Oil Capture

4.2.1 Design of the Coalescing System

A system utilizing coalescing plate separator modules from Mohr Separations Research, Inc. was chosen for the project. These modules use oleophilic

polypropylene plates stacked one on top of another in large modules. The photo below shows a typical module.



Black Plate Module

The system uses a combination of laminar flow coalescence and oleophilic attraction. Slowing the flow of water to low velocities where laminar flow regimes exist minimizes turbulence. Turbulence causes mixing of the oil and water and reduces oil droplet sizes. Stokes's law states that larger droplets will rise faster and thus separate better. The oleophilic nature of the plates allows the oil droplets to attach and encourages them to coalesce into larger ones which will rise faster.

These modules provide better separation than could be arrived at without plates. The rise rate of a droplet (or the fall rate of a solid particle) is defined by Stokes's Law and is independent on the size of the system. For this reason, small droplets are more easily separated since they have only to rise a few mm before they are captured instead of the entire distance to the water surface. Corrugated plates in this type system are spaced a nominal 8 mm apart. Because the plates are corrugated, rise distances of droplets in the vertical direction are greater than the perpendicular distance between plates. The oil droplets must rise approximately 8mm for the narrow spacing which was chosen for this application. Because the vertical rise distance to be covered is less than for the droplets rising the entire vertical depth of the vault, the same size particle is separated in less time. Conversely, the same amount of space time provided within the plate area causes effective separation of smaller size particles.

The coalescing modules are mounted in an aluminum frame with a built-in solids trough. Because it was expected that the modules would collect some solids, the trough is designed with doors openable from the surface so that the solids may be flushed out without the operator entering the tank (the liquid level will need to be lowered and the solids accumulation in the modules as well as in the front of the tank are removed by vacuum truck, or other means.

The photos below show the modules as mounted in the frame and a detail of the opening door arrangement.



Plate Module Frame (inlet end)



Plate Module Frame (door open)

4.2.2 Modification of Existing Tanks A and B

Oil separation and removal was previously achieved in Tank A using gravity separation and a belt skimmer. Due to the relatively small volume of Tank A, a majority of the influent flow entering Tank A from the training exercises short circuited into Tank No. B before fuel could be properly separated and removed. It was recommended to combine Tanks A and B by removing the existing wall and syphon arrangement. This achieves a larger detention time for oil/water separation.

Table 1 below indicates both detention times based on the current and revised configurations of the two tanks respectively. Although the average daily flow to the separator is $0.05 \text{ m}^3/\text{min}$ ($71.4 \text{ m}^3/\text{d}$), the peak instantaneous flow rate during training exercises may reach $2.0 \text{ m}^3/\text{min}$ ($2721.6 \text{ m}^3/\text{d}$), or approximately 40 times higher, during wet weather flow.

TABLE 1: ESTIMATED DETENTION TIMES AT MAXIMUM FLOW

Configuration	Approximate Effective Tank Volume^a (m³)	Flow (m³/min)	Detention Time (min)
Tank A	20	2.0	10
Combined Tank A-B	38	2.0	19

notes: ^a Effective tank volume is defined as the depth of the tank minus the freeboard (200 mm) and the operating depth (500 mm).

The increased detention time of 19 min. for the combination of Tanks A and B is consistent with current design recommendations for oil/water separators.

Coalescing plate packs were recommended in Tank B in order to enhance oil/water separation. Coalescing plate packs are used extensively in precast oil water separators in oil refineries, chemical plants, stormwater processing and other applications where oil removal is required. Because these pieces of equipment have no moving parts, they require minimal maintenance and are very cost effective in providing added separation.

In addition to combining Tanks A and B, the siphon arrangement currently used for transferring flows from Tank B to D was removed. Instead, a trapped bottom outlet was used between the new combined Tank A-B and Tank C (this revised outlet system is shown schematically in Figure 2 above). Having an outlet at the bottom of the tank will prevent the top oil layer from being carried over into the subsequent tanks. A flocculating agent injection system was implemented on this outlet piping, as discussed in detail in subsequent sections.

The existing air header system which blows air across the surface of the tank to move the oil on the surface, currently in use in Tank A, is planned to be extended to encompass combined Tanks A-B. This system is used to direct the top oil layer back towards the existing oil skimming equipment located in Tank A.

Solids Removal in the Coalescing Plate Packs

To estimate the rate of retention of solid particles in the coalescing plate packs, it is necessary to determine the rate of sedimentation of the particles. This sedimentation must happen according to Stokes's law, and the data required for the Stokes's Law calculations for the solid particles are the same as for the oil droplets:

The particle size varies with the compound, but can be expected to be very small. The density also varies with the compound. Two kinds of particles can be expected:

- Soot particles
- "Purple K particles"

Soot Particles

Experience with soot particles (from petroleum coke particles encountered in an Ontario oil refinery) indicates that they are much smaller than the average particle for road dust (55 microns) and are very close in specific gravity to water. A study done in an Ontario refinery study showed particles of about 18 micron average size. This correlated well with testing in the refinery with a small coalescing plate separator. The particles were captured in the coalescing plate separator in very small quantities – perhaps less than 10% of the particles were captured even at very low specific flow rates. It is likely that this is because not only are the particles small, but also irregular in shape and have a tendency to be porous, contain unburned hydrocarbons, and be oil coated.

Pure carbon has a specific gravity of 2.15, but coke particles do not act according to Stokes's Law for particles of that high specific gravity. They act much more like particles of approximately 1 specific gravity. The irregular shape causes more hydraulic drag on a given particle than would be expected on a spherical particle, so the sedimentation rate of these particles is much less than it would be for a spherical particle. (Stokes's Law calculations assume spherical particles).

The combination of porosity and unburned hydrocarbon content probably explains the low specific gravity. Assuming an 18 micron particle with a 10% coating of the hydrocarbon – meaning an average composite size of 22 microns (2 microns on each side of the original 18 micron particle), the net particle specific gravity would be 1.16 (assuming a composite *solid* specific gravity of 1.5). Using these data, the removal of such particles would be about 19% at the design flow, and somewhat better at lower flow rates.

A solids removal calculation was done using the specific gravity estimated above – 1.16 and a particle size of 24 microns. This calculation indicates that the plate packs should capture 20-25% of the particles (at the design water flow rate) which is substantially more (and hence more conservative) than the refinery results. It is likely that most of the soot particles will become oil coated and rise up with the oil being removed as part of the oil phase.

Of course, there will also be a substantial number of the soot particles that will be significantly larger than the 24 microns. Many if not most of these will settle in the front of the separator.

“Purple K”

The manufacturer's MSDS available on the web (Kidde Fire Fighting) indicates a specific gravity of 1. Purple K is a very, very fine powder and floats on water because its properties include a combination of being the same specific gravity as the water and not wetting with water. A different manufacturer's MSDS (Ansul) lists the particle size as 20 microns. Even if the particle size were not small, the Purple K would still float on the surface tension of the water. The combination of these properties would lead to an

expectation that, if there is any significant amount of hydrocarbons present, the Purple K would migrate into the hydrocarbon phase more or less immediately.

Assuming a 20 micron particle with a 10% coating of the hydrocarbon – meaning an average composite size of 24 microns (2 microns on each side of the original 20 micron particle), the net particle specific gravity would be 0.89. Using these data for the Stokes's Law calculations, the removal of such particles would be about 19% at the design flow, and somewhat better at lower flow rates.

This estimate indicates that 81% of the Purple K particles will continue on through the plate pack to the flocculation chamber downstream. Concerning the 19% captured, because these are very small particles and oil coated, it is very likely that most of them will remain with the free flowing oil phase instead of within the plate pack.

Solids Removal Calculations:

The capture of solid particles of soot / fuel could be about 20-25%, but so many assumptions have to be made in the calculations that all that we may be sure of saying is that there will be some capture of these particles in the plate packs and most will continue downstream to the flocculation chamber. The really large particles may settle in the front of the chamber.

Both types of particles will probably go preferentially with the hydrocarbon phase, both within the pack and prior to it. It is possible; of course, that they may tend to agglomerate and form larger particles that may act differently, but if that happens it is still likely they will rise to the top of the water with the oil.

Based on these assumptions and calculations, a coalescing plate system was recommended, but installed in a removable cage and provided with an integral solids trough. Because it may be necessary to periodically flush the plates using the cleaning wand provided with the plate packs, the trough should be provided with doors that may be opened to allow the solids flushed out of the solids to go back into the main pit where they may conveniently be removed with a vacuum truck or pump.

A photo is provided below showing the installation of the plate module frame within the tank.



Installed Plate Pack Module Down Stream View

4.2.3 Flocculation Agent Injection System

Operation of Tank A-B was modified to incorporate the injection of a flocculating agent at the outlet of the tank while still retaining the current flow-through operation. A minimum level of 700 mm is recommended to ensure that the water level is never drawn lower than the tank outlet and thereby prevent the oil skimmings layer from being carried over to the next tank.

The outlet consists of three components; a low pressure differential check valve, a flocculating agent injection point, and a angle propeller mixer. The check valve prevents reverse flow to Tank A-B from Tank C during periods of low flow. A flocculating agent is injected into the wastewater flow exiting from Tank A-B into Tank C during evolution events. The propeller mixer would provide rapid mixing normally required for efficient flocculation.

4.2.4 Modification of Existing Tank C

It is proposed to subdivide the total length of Tank C (6.0 m) into two sections by means of a baffle wall, as shown in Figure 4, with resulting lengths of 2.6 and 3.4 m for Tank C-1 and C-2 respectively. Tank C-1 would be used as a slow mix phase for flocculation. A mechanical mixer would be required in this section in order to achieve maximum flocculation. The mixed solution would then overflow into Tank C-2 where primary settling would occur. Baffles would also be installed on the overflow of Tank C-2 to disperse hydraulic energy and promote settling of solids in Tank D.

Tanks C-1 and C-2 would operate at the same level as Tank AB. Based on flocculation testing conducted by Dayton & Knight Ltd. with ferric chloride, it was discovered that the minimum time required for adequate flocculation and settling was approximately 1 minute and 3 minutes respectively. The estimated minimum detention times with the proposed revisions, are indicated below in Table 2 and are considered to be adequate for the two processes.

TABLE 2
ESTIMATED DETENTION TIMES IN TANKS C-1/C-2 AT MAXIMUM
WASTEWATER FLOW

Configuration	Approximate Effective Tank Volume ^a (m ³)	Flow (m ³ /min)	Detention Time (min)
Tank C-1 (Flocculation)	12	2.0	6
Tank C-2 (Settling)	16	2.0	8

notes: 1. Effective tank volume is calculated using 1.7 m as a value for the HL(depth of tank (2.4 m) minus the freeboard (200 mm) minus the minimum operating depth (500 mm)).

There are two options for processing generated solids. In either case, Tank C-2 will need to be modified to collect settled material at the outlet end. Modifications would include implementing a sloped bottom in Tank C-2 using a grout build-up on other suitable means.

In the simplest scenario this material would be removed periodically and disposed at a licensed disposal facility. The material collected is removed intermittently using a submersible pump and a hand held wand vacuum hose.

At the average daily flow rate of 0.05 m³/min (71.4 m³/d), the system is expected to produce between 0.11-0.22 m³/d of sludge. This assumes a solids concentration in the sludge blanket of 1-2%.

The collected solids are pumped to a 6800 L (1800 USG) storage tank. This allows for approximately 2-3 months of storage. Tank contents are removed using a vacuum truck and disposed of at a licensed disposal facility.

An overflow is installed at the end of Tank C-2 to evenly collect the effluent of Tank C-2 and transfer it to Tank D where it undergoes final polishing.

4.2.5 Modification of Existing Tank D

Minimal changes were required for Tank D. To prevent settled floc from being pumped out of Tank D by the existing GAC pumps, a small, removable baffle wall

would be constructed just upstream from the GAC pump intake. This traps, and accumulate, any settled floc and material that may be carried over from Tank C. The settled material is periodically removed using a vacuum truck, or other suitable method, as determined by the Operations staff.

5.0 OPERATIONAL CONSTRAINTS UNDER PROPOSED CHANGES

Three aspects of system operation were examined:

1. Exercise Duration – The maximum allowable exercise duration for a given flow rate assuming that the tanks are originally empty.
2. Recovery Time – The required amount of time in order to conduct a new evolution once the overflow condition has been reached.
3. Backwash Requirements – Constraints with regards to when the backwash is conducted.

The tables provided below were created to summarize these constraints and provide overall operational guidelines. During routine evolutions, the wastewater flows are not anticipated to exceed the capacity of the proposed treatment system and consultation with the tables is not normally be required. However, during times of atypical evolutions, in either volume or duration, these tables may be used as a reference for evolution planning.

5.1 Evolution Duration

Table 3 indicates the maximum allowable evolution duration based on the flow rate for a given number of hoses in use. The flow rate through one nominal hose has been estimated at 100 GPM. The flow rate through the monitor is considered to match the maximum capacity of the fire water pump, or, 500 GPM. Table 4 indicates the approximate water usage for each of the evolution periods listed in Table 3. The values provided in Tables 3 and 4 assume that the Class B treatment tanks are starting at the low water level at the beginning of the evolution.

TABLE 3
MAXIMUM DURATION OF EVOLUTION

No. of Hoses in Use ^a	Maximum Duration (1-Pump ^b) (min)		Maximum Duration (2-Pumps ^b) (min)	
	During Rain ^c	Without Rain	During Rain ^c	Without Rain
1	290	370	510	790
2	130	145	165	185
3	85	90	98	104
4	62	66	70	74
5	50	52	55	56

Notes:

- a. The flow rate from any given hose is approximated as 100 GPM. This represents the median of the range of 50 to 150 GPM. This large range represents the variation due to hose size, nozzle type and pressures from the hydrant. 5 hoses in use approximate the flow for when the monitor is in use. The flow rate of 500 GPM represents the maximum capacity of the system pump. This is generally only reached when the monitors are being run during the exercises.
- b. '1-Pump' indicates the use of a single granular activated carbon filter (GAC) pump in operation (approx. 35 GPM) and '2-Pumps' indicates the use of both GAC pumps are in operation (approx. 70 GPM).
- c. Wet conditions, as defined in the D&K report 'Study to Upgrade the Class B Water Treatment System' (March 2000), include an additional rainfall volume of 90 m³/d for the 1 in 2 year daily storm event.

TABLE 4
ALLOWABLE WATER USAGE

No. of Hoses in Use ^a	Water Allowance (1-Pump ^b) (m ³)		Water Allowance (2-Pumps ^b) (m ³)	
	During Rain ^c	Without Rain	During Rain ^c	Without Rain
1	110	140	193	299
2	98	110	125	140
3	97	102	111	118
4	95	100	106	112
5	94	98	104	106

- Notes:
- a. See Note a, Table 3.
 - b. See Note b, Table 3.
 - c. See Note c, Table 3.

During the summer of 2007 monitoring period, a flowmeter will be considered to show accumulated volume used for each evolution. This could be reset on the onset of a new evolution to give the user direction for estimating allowable operations.

5.2 Recovery Time

When the high water level has been reached in the Class B treatment tanks, Tables 5, 6, 7 and 8 indicate the required waiting or recovery time before the next evolution can be conducted for a variety of different conditions. The recovery time takes into account the time required to sufficiently draw down the contents of the Class B treatment tanks to accommodate the next evolution inflow of a given duration.

For example, an extended evolution is conducted in the morning and results in the treatment system reaching maximum capacity. A class intends to conduct a subsequent evolution which will involve 2 hoses and is anticipated to last 15 minutes. Only one GAC pump is in operation and heavy rain is occurring throughout the day. Referring to Table 5, for an evolution duration of 15 minutes two hoses in use, one GAC pump in operation, and wet conditions, the class must wait 170 minimum (approximately 3 hours) before they can commence. By comparison, referring to Table 6 and assuming dry conditions, the wait time is reduced to 55 minutes using 2 GAC pumps.

TABLE 5
RECOVERY TIME UNDER WET^a CONDITIONS (1-PUMP^b)

No. of Hoses to be Used ^c	Required Exercise Length (Minutes)			
	15 Minutes	20 Minutes	25 Minutes	30 Minutes
1	90	120	150	180
2	170	>3 hrs ^d	>3 hrs	>3 hrs
3	>3 hrs	>3 hrs	>3 hrs	>3 hrs
4	>3 hrs	>3 hrs	>3 hrs	>3 hrs
5	>3 hrs	>3 hrs	>3 hrs	>3 hrs

- notes: a. See Note c, Table 3.
b. See Note b, Table 3.
c. See Note a, Table 3.
d. Recovery times in excess of 3 hours are not specifically provided.

TABLE 6
RECOVERY TIME UNDER WET^a CONDITIONS (2-PUMPS^b)

No. of Hoses to be Used ^c	Required Exercise Length (Minutes)			
	15 Minutes	20 Minutes	25 Minutes	30 Minutes
1	40	50	60	70
2	70	90	110	130
3	100	130	160	> 3 hrs
4	130	170	> 3 hrs	> 3 hrs
5	160	> 3 hrs	> 3 hrs	> 3 hrs

- notes: a. See Note c, Table 3.
b. See Note b, Table 3.
c. See Note a, Table 3.
d. See Note d, Table 5.

**TABLE 7
RECOVERY TIME UNDER DRY CONDITIONS (1-PUMP^a)**

No. of Hoses in Use ^b	Required Exercise Length (Minutes)			
	15 Minutes	20 Minutes	25 Minutes	30 Minutes
1	55	70	85	100
2	100	130	160	>3 hrs
3	145	>3 hrs	>3 hrs	>3 hrs
4	>3 hrs	>3 hrs	>3 hrs	>3 hrs
5	>3 hrs	>3 hrs	>3 hrs	>3 hrs

Notes: a. See Note b, Table 3.
b. See Note a, Table 3.
c. See Note d, Table 5.

**TABLE 8
RECOVERY TIME UNDER DRY CONDITIONS (2-PUMPS^a)**

No. of Hoses in Use ^b	Required Exercise Length (Minutes)			
	15 Minutes	20 Minutes	25 Minutes	30 Minutes
1	30	40	50	60
2	55	70	85	100
3	80	100	120	140
4	105	130	155	180
5	130	160	>3 hrs	>3 hrs

notes: a. See Note b, Table 3.
b. See Note a, Table 3.
c. See Note d, Table 5.

5.3 Backwash Requirements

Backwashing of the granular activated carbon (GAC) filters is arranged to occur after completion of the daily training exercises. The level in the Class B treatment tanks must be drawn down at least 0.5 m below the high liquid level prior to commencement of the backwash cycle. A backwash flow rate and duration of 200 GPM and 60 minutes respectively was assumed using City water.

6.0 CONCLUSIONS

The following are the process and design conclusions:

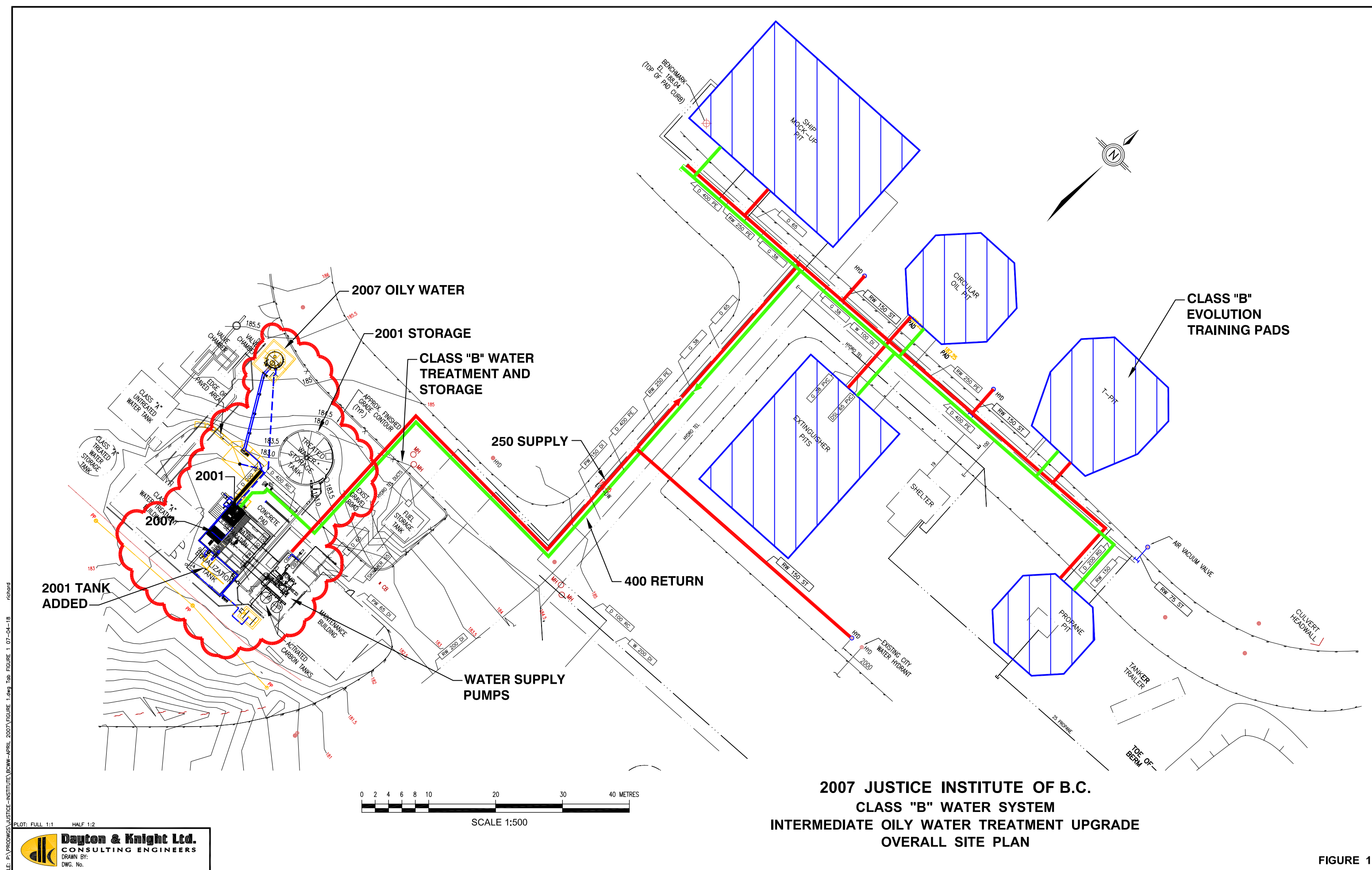
- The wastewater collected by the Class B system contains varying quantities of carried over aviation fuel, firefighting foam, firefighting powder, and soot. The use of AFFF fire fighting foam is considered to be responsible for emulsification of the aviation fuel in the wastewater stream.
- Experiences of similar training facilities have shown that emulsified fuel cannot be effectively separated using traditional oil/water separators.

- MicroBlaze-Out™ fire fighting foam is reported to not result in emulsification of fuels and should be tested, on a trial basis, at the JIBC Maple Ridge Facility.
- Flocculation testing indicated that ferric chloride is the most effective flocculating agent for the Class B wastewater with the lowest associated dosage, and cost of all agents tested. Ferrous chloride is a potential substitute that is lower in cost. It is recommended to conduct further testing before final design.
- Aeration testing proved not effective with the floc formed using ferric chloride. There seems to be no merit in further consideration.
- Tanks A and B were combined to increase the initial detention and coalescing plate packs added to enhance oil/water separation. Recent observations suggest that a second set of packs may be warranted; however, further testing is needed.
- The air system should be extended in order to aid in collection of the surface skimmings.
- The existing syphon arrangement should be removed on Tanks A-B and replaced with a bottom outlet to Tank C. This would incorporate a flocculating agent injecting point and a static inline mixer to achieve maximum flocculation.
- It is proposed to subdivide Tank C to create a flocculation and settling system to remove the suspended solids downstream of the oil/water separation tank.
- Tank D should be modified to prevent solids from being carried over to the GAC systems.
- The allowable operating time and cumulative volume for a training evolution(s) is dependent on the number of hoses, and the corresponding flow rates, used during the evolution(s) and the amount of rainfall occurring during the exercise.
- Backwashing of filters should not occur until the end of the training day. The treatment tanks should have a minimum 0.5 m freeboard below the high water level before backwashing can begin to provide for adequate storage of the backwash water.

7.0 REFERENCES

Gibson, T. (2002). *Let the Bugs do the Work*. Progressive Engineer. September, 2002.

Naval Facilities Engineering Service Center. (2002). *Test and Evaluation of Pilot-Scale Air-Sparged Hydrocyclone Technology to Remove Aqueous Film Forming Foam from Wastewater*. Technical Report TR-2116-EVN. April, 2000.



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FIGURE 1



