FIRE TRAINING UNIT DIESEL RECOVERY PLANT – RECYCLING AND REDUCING DISCHARGE

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ABSTRACT

New Zealand Defence Force (NZDF) operates a Fire Training Unit at the Sea Safety Training Squadron at the Devonport Naval Base, Ngataringa Bay, Devonport. The school utilises a fire simulation building in which trainees are required to enter and extinguish fires. To establish the fires, diesel is used as a fire propellant to ignite piles of wood and simulate a smoky fire in an enclosed structure.

While a portion of the diesel is ignited, most of the diesel is washed away with the firefighting water and foam before it can be burned. All fire fighting water is treated on site and recycled for reuse. As part of the water treatment system, the unburned diesel is separated out as an emulsified scum layer along with AFFF foam, water and ash. This scum layer was historically extracted and trucked away for further treatment as a special waste at significant cost to the NZDF. The accumulation of the scum layer in the water treatment plant, between extraction events, was causing contamination issues with the recycled water, limiting the ability to discharge to the sanitary sewer as a trade waste.

The initial project Brief was to improve the quality of the trade waste discharge from the training school, but once engaged by NZDF the effects of the diesel on the trade waste quality and resultant loss of a potential resource was identified and the Brief was changed to designing an improved system to remove and treat the emulsified scum layer and recover diesel for reuse in the fire training unit.

A pilot trial was conducted, using 1000 litre tanks, to establish the efficiency of gravity separation of the scum layer. On the basis of the pilot trial a three vessel fractionating plant was designed.

Tank 1 provides for two phase separation of free water from the scum layer. With a longer hydraulic residency time, Tank 2 allows for three phase separation of water, diesel and impurities (AFFF foam and ash). Tank 3 allows for further diesel purification with further water and scum separation. The refined diesel is then available for reuse. All separated water is returned for reuse and the collected impurities are stored for periodic disposal.

During the design phase, special consideration had to be given to the hazardous nature of the diesel and the hazard management requirements of the Environmental and Risk Management Authority (ERMA) and the internal requirements of the NZDF.

The full scale treatment system was installed and commission in February 2011 and has been providing a high recovery rate of good quality diesel, suitable for reuse in the fire training unit. While it is anticipated that new diesel will occasionally be required, in the six month period following commissioning, no new diesel was necessary for the fire training unit, over a period that would have previously required 10,000L of new diesel.

Overall the project has resulted in a net environmental benefit and has exceeded the initial project objectives in that it is now providing a complying trade waste discharge, while also reducing diesel usage and volumes disposed to special waste.

KEYWORDS

Fire training wastewater, Diesel phase separation and Recycled diesel.

1 INTRODUCTION

The New Zealand Defence Force operates a Sea Safety Training Squadron (SSTS) at the Devonport Naval base, located at Ngataringa Bay, Devonport. In addition to other training programs, the SSTS provides fire training to NZDF personnel, particularly based on managing fires in a ship based environment. The training unit also trains a large number of fire service staff.

Part of the fire training programme involves extinguishing fires in a number of environments that may be encountered on a naval ship. To establish fires for training purposes, fires are ignited utilising piles of wood, doused in diesel. Trainees then extinguish the fires utilising a combination of water and AFFF (aqueous film forming foams). As a result of the fires being extinguished a large volume of wastewater is generated consisting of AFFF, diesel, ash and water.

To minimise the volumes of fresh water utilised by the SSTS, wastewater from the fire training unit and other training programmes is treated on site and recycled for reuse in the training school. The water treatment system is based on phase separation and filtration systems, with large volumes of floatable scum being formed as a by product of the treatment system. With no method of managing the scum on site, it was allowed to accumulate in the primary separation tank until sufficient volume accumulated for tankering off site as a special waste at significant cost to NZDF.

As a result of the scum being allowed to accumulate in the water treatment facility, contaminants in the scum (particularly diesel) were being progressively emulsified in the water, impacting on the quality of the recycled water that is discharged to trade waste.

With the implementation of tighter trade waste consent limits, NZDF sought independent advice in order to improve the trade waste quality, however, it was soon evident that the key to improving the quality of the trade waste was to implement improved management facilities for the scum layer that was being generated. It was identified early on that within the scum layer there was a large portion of unburned diesel that was a potential resource, but was essentially being lost.

2 THE WATER TREATMENT PLANT

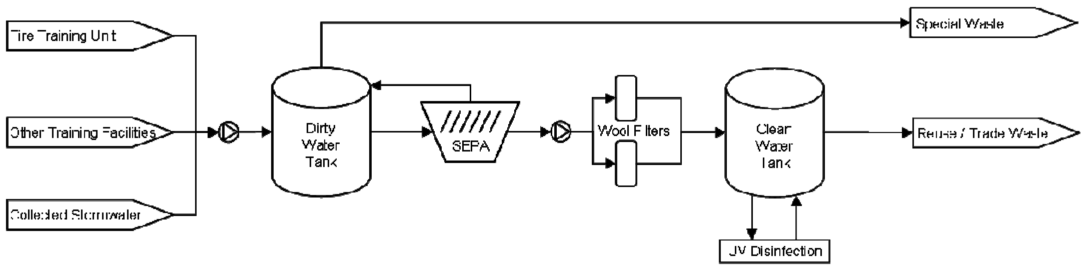
The SSTS water treatment plant treats all collected wastewater from the fire training unit, other training facilities and site stormwater for the purpose of treatment and reuse. The water treatment process is summarised as follows and illustrated in Figure 1.

The water treatment process consists of primary phase separation within a large storage tank (Dirty Water Tank) where floatable contaminants are allowed to separate out in a scum layer on the water surface. A small portion of solids also settles out in the base of this tank. The separated water phase is then passed through a lamella plate clarifier (SEPA Unit) to provide additional phase separation prior to passing through wool filters. The treated water is then stored in a larger storage tank where it is progressively UV disinfected to minimise bacterial growth. The treated water is then reused in the training facilities at the SSTS, including the Fire Training Unit.

All collected floatable scum layers from the Dirty Water Tank and the SEPA unit are accumulated in the Dirty Water Tank prior to regular disposal to special waste. Settled solids in the base of the Dirty Water Tank are removed approximately every 4 months during training shut down periods.

Because the training unit is within a single contained footprint, all collected stormwater is combined into the water treatment system resulting in a net increase in water volume with minimal need for additional water from reticulation. As a result of the addition of stormwater, a portion of the treated water must be regularly disposed of to the sanitary sewer as a trade waste, particularly prior to and after storm events.

Figure 1: SSTS Water Treatment System prior to Upgrade



When the scum layer requires removal, the operator utilises a pipe weir decanter within the Dirty Water Tank, which is lowered or raised to skim the scum layer off the water surface. In order to mobilise the scum layer, a portion of water is also removed.

3 TREATMENT PILOT TRIAL

The floatable scum layer that is collected in the Dirty Water Tank consists of an emulsification of AFFF, diesel, wood ash, water and other impurities. When the emulsification is allowed to stand for several days, three phase separation occurs with a water phase at the base, an intermediate diesel phase and a layer of concentrated impurities on top. Because water is also collected with the scum layer when it is skimmed from the Dirty Water Tank, the water phase makes up approximately 85% of the total solution with diesel and impurities making up the remaining 15%.

On the basis of three phase separation, a pilot trial was set up to remove the scum layer from the Dirty Water Tank and store the collected emulsification in a series of 1,000 L intermediate bulk containers (IBC). The aim of the pilot trial was to operate the phase separation on a large scale so that the recovered diesel could be trialled in the fire training unit.

The IBC's were modified into rudimentary fractionating columns with graduated collection taps installed up the side of each container. With 12 IBC's in operation, the operator was able to skim the surface layer from the Dirty Water Tank on a daily basis, filling several IBC's at a time. The separated water layer could then be returned to the system, the diesel layer collected separately and the impurities layer concentrated for disposal as a smaller volume to special waste.

The findings of the pilot trial were that the water layer was the quickest to separate, with the bulk of the water separating out after a day. Because water makes up the bulk of the collected emulsification, the volume of material collected could be rapidly reduced by removing the water layer first. With longer standing times, phase separation of the diesel layer and additional water from the emulsification layer was then possible with the layers being more refined the longer the solution was left to stand.

Due to the large volumes associated with the pilot trial vessels, the SSTS were able to operate the plant on a temporary nature but as a full scale system. The water treatment plant operators were able to implement daily removal of the Dirty Water Tank scum layer and process it through the fractionating system. Following the implementation of the temporary treatment system, the trade waste concentrations were improved, diesel was able to be recycled and the volumes being disposed of to special waste were reduced. Initial trials were implemented for burning of the recycled diesel and while the recycled diesel was more difficult to ignite than fresh diesel, it burned with a blacker smoke which some considered to be better from a training perspective for fire simulation.

4 FULL SCALE SYSTEM DESIGN

With the pilot trial identifying the benefits of refining the collected scum layer, the NZDF commissioned the design of a full scale system. The scope of the design was to install a tank fractionating system that would be housed adjacent to the water treatment system and recycle refined diesel back into fresh diesel system for reuse and separated water was to be either reincorporated to the treatment plant or disposed of to trade waste.

Due to manual based operation of the existing water treatment system and the intended daily batch wasting of the scum layer, the full scale system was to be based around manual operation of a batch based fractionating system.

4.1 INITIAL DESIGN INVESTIGATIONS

Prior to the commencement of process and civil design, consideration had to be given to the operational properties of the diesel including:

- The effects of utilising the diesel on the air emissions from the training school;
- The requirements of the Hazardous Substance and New Organisms (HSNO) Act 1996; and
- Any additional diesel treatment requirements to facilitate the reuse in the existing diesel pumps.

4.1.1 AIR EMISSION CONSIDERATIONS

The reuse of diesel as a combustion product has the potential to result in air emissions that are uncharacteristic of burning virgin diesel due to contamination from other products such as AFFF utilised to extinguish the fires. AFFF contains a number of chemicals including glycol ethers, hydrocarbon surfactants, magnesium sulphate and fluoro-surfactants (Brady 2007).

All air emissions from the fire training unit are collected and passed through a gas fired burner to reduce visible air emissions and provide complete combustion of partially combusted gases and particulates. Because the burner operates at a very high temperature (850°C to 1,000°C), consideration had to be given to any combustion by-products that may result from the use of the recycled diesel in the fire training unit.

Glycol ethers and hydrocarbon surfactants which may enter the diesel from the AFFF will result in the same combustion products as the fuels themselves and the magnesium sulphate will remain inert. The fluoro surfactants contain hydrogen fluorine which has the potential to form acidic hydrogen fluoride when burned as well as fluoro-substituted dioxins. Due to the high incinerator temperature, in the presence of excess oxygen, dioxin discharge will be minimal and no worse than the combustion of virgin diesel (Brady 2007).

The recycled diesel was analysed for fluorine content to establish the likely hydrogen fluoride content in combustion gases, and was found to be very low at 3 mg/l. At these levels the fluorine content is similar to heavy fuel oil. Even with continued recycling of the diesel, the fluorine content would only be expected to reach levels of 9 mg/L, resulting in very low emissions of hydrogen fluoride in the discharge (Bradey 2007).

Anticipated air emissions from the use of recycled diesel in the fire training unit were not considered to be significantly different from the use of virgin diesel.

4.1.2 HAZARDOUS PROPERTIES INVESTIGATIONS

While the main accelerant utilised in the fire training unit is diesel, small amounts of petrol are utilised, requiring the hazardous classification of the recycle diesel to be reassessed. HSNO flammable liquid classification numbers are based on the temperature at which spontaneous combustion occurs, indicating whether a hazardous atmosphere would likely occur. The recycle diesel was tested for spontaneous combustibility, with combustion occurring at 94°C (Brockett 2007), well above the HSNO lower flash point of 60°C for diesel classification. This indicated that the recycled diesel could continue to be classified as a 3.1D hazardous liquid and that hazardous atmosphere consideration was not necessary for the treatment facility.

Due to the similarities of the recovered diesel to virgin diesel, all other HSNO classification numbers were based on virgin diesel including 3.1D, 6.1E, 6.3, B 6.7B and 9.7B (ERMA 2004). The difficulty with the design going forward was determining at what stage in the process the product contained hazardous status applicable to each classification number. In consultation with the NZDF it was determined that the design would incorporate facilities necessary to meet HSNO and NZDF protection requirements, as a diesel product, from the point of scum collection through until final product utilisation or disposal.

Specific protection facilities to be installed with the system included secondary containment of all tanks (to 110% capacity of the largest tank), secondary containment of all underground pipes conveying diesel or scum and HSNO approved signage. Due to diesel not forming an explosive atmospheric zone, explosion proof motors and electrics were not required. Special consideration had to also be given to the close proximity of a public space and protection from fireworks and cigarette butts.

4.1.3 FURTHER DIESEL TREATMENT REQUIREMENTS

The intention of the system was to pump all recycled diesel though to a diesel storage facility adjacent to the existing virgin diesel tank. The fire training unit would then utilise the recycled diesel via the existing diesel dispenser. To avoid damage to the existing dispenser system, the recovered diesel from the pilot trial was assessed for solids and water content.

Assessment of the recycled diesel water content and entrained solids content identified that the only additional treatment that was required for the storage and reuse was filtration, with the water content and solids content being assessed at 0.15% and 0.002% respectively (Brockett 2007).

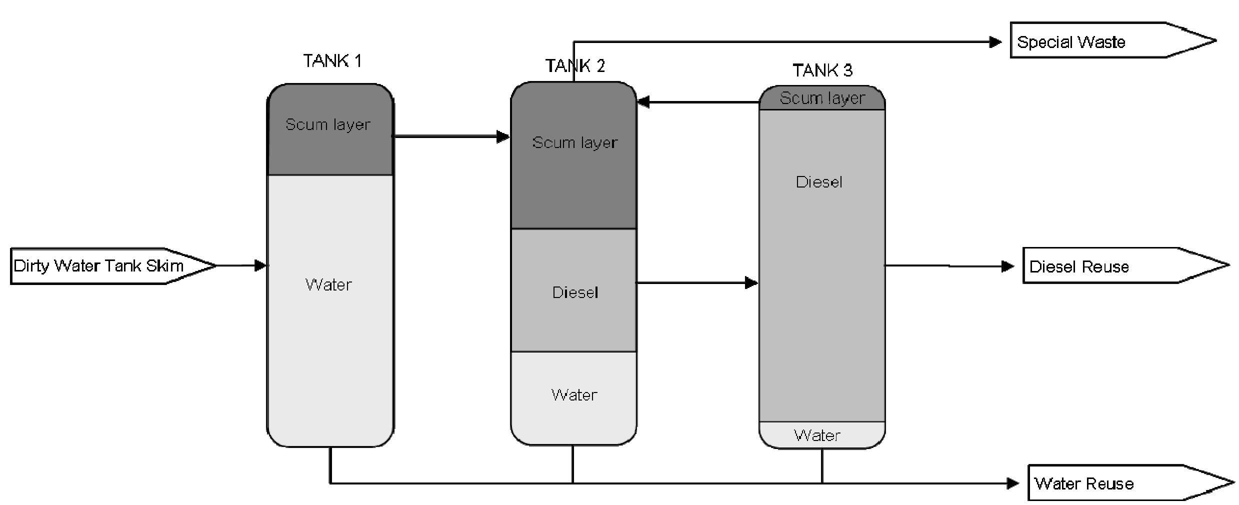
4.2 PROCESS DESIGN

The system design was based around a three tank system, as detailed in Figure 2. Tank 1 receives the raw skim from the dirty water tank on a daily basis, providing the initial bulk separation of water phase for return to the system following 24 hours of settling. The remaining emulsified layer could then be transferred onto the second tank for further separation.

With a reduced liquid volume and a longer hydraulic residence time in the second tank, three phase separation is achieved. In the second tank residual water continues to be emitted from solution, with an intermediate diesel phase separating with time and emulsified impurities forming at the top of the tank. The water layer can progressively be removed on a daily basis and the diesel transferred to the third tank.

The third tank provides for polishing of the separated diesel, allowing for extended periods of storage, separating out any remaining water or impurities. While the third tank allows for collection of diesel, most of the scum layer is allowed to accumulate in the second tank until it requires disposal to special waste.

Figure 2: Scum Layer Fractionation Process



Tank 1 was sized at 6,000 L to provide more than sufficient capacity for a single batch skim from the Dirty Water Tank. Tanks 2 and 3 were also sized at 6,000 L to provide extended hydraulic residence time for the scum and diesel layers to promote maximum phased separation. In order to promote efficient separation, and reduce system footprint, tank sizing was based around a small diameter, tall tank system.

Figure 3 details the process flow diagram for the final system design. Batch processing within the system is based around the use of a single diaphragm pump for multi purpose operation. Inlet and outlet manifolds enable the single pump to perform the following functions:

1. Transfer of the separated water phase from Tanks 1, 2 or 3 back to the Dirty Water Tank;

2. Transfer of the diesel phase from Tank 2 to Tank 3;

3. Transfer of the scum layer from Tank 1 and 3 to Tank 2;

4. Transfer of the skim layer from the Dirty Water Tank to Tank 1.

A second gear pump was also provided, solely for the purpose of transferring the separated diesel from Tank 3 to the recovered diesel storage tank.

To enable the separate phases to be extracted from Tanks 2 and 3, a series of fractionating pipes were provided up the side of each tank. This was not necessary for Tank 1 as only two phase separation occurs in this tank, with both phases being removed on a daily basis. Open containers (tundishes) at the base of each extraction pipe were included to enable the extracted liquid to be visually assessed prior to pumping. As a phase change is identified the operator can then stop the flow from that tank.

Based on the daily batch extraction from the Dirty Water Tank, the system was designed around the following daily operation:

Step 1: Transfer water phase from Tank 1 to Dirty Water Tank;

Step 2: Transfer diesel from Tank 3 to the Recovered Diesel Storage Tank

Step 3: Transfer the diesel phase from Tank 2 to Tank 3;

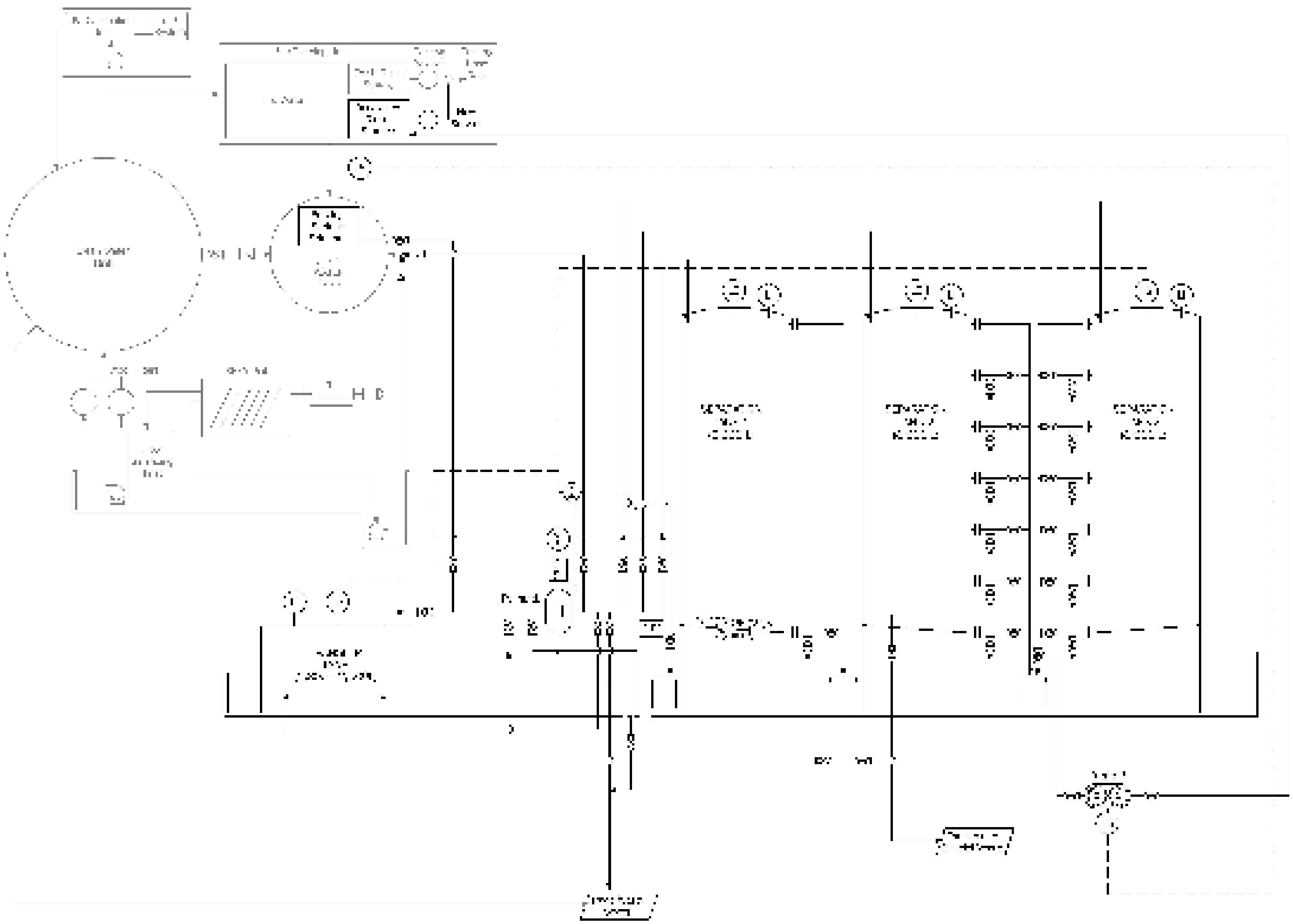
Step 4: Transfer the water phase from Tank 2 to the Dirty Water Tank

Step 5: Transfer the Scum layer from Tank 1 to Tank 2; and

Step 6: Skim the scum layer from the Dirty Water Tank to the now empty Tank 1.

While the above operation was developed to minimise disturbance of separated phases in each tank prior to removal, an intermediate storage tank was provided within the system to enable a phase to be extracted and stored if necessary. This can also provide for additional storage of the concentrated scum layer prior to disposal, if necessary.

Figure 3: Diesel Recovery Plant Process Flow Diagram



4.3 CIVIL AND STRUCTURAL DESIGN

Due to the proposed location of the plant being situated on reclaimed land, over estuarine mud, a reinforced concrete raft was required as a single foundation slab for all three process tanks and the intermediate storage tank. Given that the tanks required secondary containment, bund walls were included on the concrete raft to provide in excess of 6,600 L of available storage.

Because the recovered diesel storage tank was to be situated on the opposite side of the training facility, an existing storage facility bund had to be expanded and a pipeline installed to transfer the diesel to this location, approximately 70m from the treatment facility. Much of the pipe line was able to be installed within an existing service pit, running the length of the site. Due to the service pit containing natural gas pipe lines at certain locations the diesel pipe line required encasing with fire resistant lagging at these locations to meet HSNO requirements. All pipe work was manufactured from welded galvanised pipe.

Because the tanks were to hold a hazardous substance much of the structural design of the tanks and base foundation was included in the construction contract, with the intention that the contractor would utilise the expertise of an experienced contractor in the field of petroleum tank construction to ensure that the tank materials and structure would meet the relevant HSNO, national and international standards for bulk containment of diesel. All tanks were constructed from epoxy coated, 6mm plate steel as single skin tanks. With the exception of the recovered diesel tank, all tanks were specifically designed and manufactured for the job.

5 SYSTEM COMMISSIONING AND PERFORMANCE

The diesel recovery plant was commissioned in early 2011, and has been operational since. With the key objective of the system being to improve trade waste contaminants to meet trade waste limits, discharges from the water system have maintained compliance with the trade waste limits since the diesel recovery plant was commissioned.

Previous to the system being installed the SSTS utilised approximately 5,000 L of virgin diesel in a three month period. During the pilot trials it was estimated that three quarters of this diesel remained unburned before being extinguished and incorporated into the water system. In the six months following the installation of the diesel recovery plant, no additional diesel had needed to be purchased for the site, for a period that would have previously required 10,000 L of virgin diesel. While the site will have to eventually purchase more diesel, it is estimated that diesel consumption will have more that quartered as a result of the facility. In addition, the quality of the diesel is better than that obtained during the pilot trial (based on visual observations), with the longer residence in Tank 3 providing for better phase separation.

With the removal of water and diesel from the collected scum layer, the volume of material being disposed of to special waste has reduced significantly to approximately 60% of its previous volume.

Overall the project has achieved more than the original objective of improving the trade waste quality to meet discharge limits. The project has resulted in a net environmental benefit with savings on diesel of about 15,000 L/yr and a reduction in the volume of material going to special waste with an estimated reduction of 18,000 L per year.

ACKNOWLEDGEMENTS

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