CENTRE OF DOCUMENTATION, RESEARCH AND EXPERIMENTATION ON ACCIDENTAL WATER POLLUTION

715, Rue Alain Colas, CS 41836 - 29218 BREST CEDEX 2, FRANCE
Tel: +33 (0)2 98 33 10 10 - Fax: (33) 02 98 44 91 38
Email: contact@cedre.fr Web: www.cedre.fr

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Response to a spill in a frozen river: the Poplar Pipeline incident (Montana, US)

On the morning of 17th January 2015, the operator Bridger Pipeline LLC noticed a drop in pressure in its underground Poplar Pipeline. Two block valves, around 2,000 metres apart, were rapidly shut to isolate the damaged section, which ran under the bed of the Yellowstone River around 10 km upstream of Glendive (Montana, US).

The damaged section, 30 cm in diameter, was carrying over 140 m^3 of light crude oil (Bakken crude), which was immediately suspected to have leaked into the frozen river.

Close-up of the breach in the Poplar Pipeline, after the section had been excavated in April 2015 (source: Bridger Pipeline LLC)

The spill was confirmed a little later that day, when sheen was observed at the water surface, around 1 to 30 km downstream, during an overflight organised by the operator.

The US Environmental Protection Agency (EPA) was notified of the incident the same day, and of the pollution of the river the following day, via the National Response Center (NRC). The US EPA was took charge of coordination the response through a Unified Command comprising representatives[1] of the relevant administrations and the pipeline operator. The quantity spilt was initially estimated at between 50 and 200 m^3, and was ultimately confirmed to be closer to the high end of this bracket.

Risks were immediately anticipated for the sensitive facilities located downstream of the spill, including a power station and, more importantly, water treatment plants between Glendive and North Dakota. This led to the water quality being monitored at the water intakes and distribution networks. As the crude released was a light oil, air quality monitoring was also carried out, while the residents of Glendive were advised preventively against consuming tap water, following the temporary detection of volatile organic compounds near the water intake at the local water treatment facility (pending the purge of the treatment and distribution network).

***Left**: Manual collection of crude oil surfacing through cracks in the ice (Source: MT-DEQ); **Right**: Surveys, by cutting holes in the ice (note the use of safety harnesses by responders) (Source: US EPA)*

In addition to the efforts made by the operator to identify the location of the breach and to purge the line, initial spill response operations consisted primarily in assessing the spread of the spill and containing and recovering as much oil as possible.

These operations were however greatly hindered by the ice.

The ice, which varied in thickness (reaching up to 1 m in places), restricted access and called for (i) the mobilisation of specialised equipment, in particular airboats, and (ii) the prior identification of areas for the deployment of personnel and equipment.

From the first day, booms (it was not specified whether these were containment or sorbent booms) were deployed at the surface where the water was free-flowing, some 30 km downstream, where sheen had been seen on the Yellowstone River.

1 In particular, Bridger Pipeline LLC (and their contractors), local authorities (Dawson County), and the relevant government bodies for the state of Montana (Disaster and Emergency Services –MT DES, Department of Environmental Quality –MT DEQ) and the federal government (US Department of Transportation Pipeline and Hazardous Materials –DOT PHMSA, US Fish and Wildlife Service –USFWS, and US Coast Guard Pacific Strike Team).

Then, immediately upstream of sensitive facilities, as well as at a few points downstream of the spill (from 5 km to approximately 50 km), the responders attempted to contain the oil, sometimes drifting below the ice, by cutting slots – where the oil was thick enough to operate safely – designed to channel the floating oil, somewhat like deflection booms, towards a calm area where it could be recovered by pumping or with sorbents.



Containment and recovery on the frozen river: cutting slots in the ice to deflect the oil
(Source: US EPA)

Sorbents were used briefly to recover sheen, observed at the surface of free-flowing water, but this strategy was abandoned after a few days due to a lack of efficiency.



Visible presence of oil: hole drilled in the ice (left); oil surfacing through cracks in the ice (5 km downstream of the slots) (right) (source: US EPA)

In addition, holes were made to attempt to locate any pockets of oil trapped under the ice. In addition to direct observations, aerial surveys were carried out throughout the response.

From the last week in January, a mild spell complicated the response further by weakening the ice.

As the ice began to thaw, operations on the water became hazardous and were therefore suspended. When the ice completely melted in mid-March, no more recoverable accumulations were observed during surveys of the river.

In total, although the response operations were greatly hindered, 80 m^3 of crude oil had been directly recovered from the damaged section of pipeline by the end of January, and 10 m^3 from the river (leaving an estimated 110 m^3 in the environment).

Two days after the incident, the US Fish and Wildlife Service initiated environmental impact surveys in the waters and on the banks of the Yellowstone River, with a particular focus on the threatened species in the affected area. No visible effects were identified in the final report published on 24th March by the US EPA.

For further information:
http://poplarresponse.com/
http://deq.mt.gov/DEQAdmin/dir/postresponse/yellowstonespill2015

A series of spills due to pipeline sabotage attacks (Ecopetrol Transandino Pipeline, Colombia)

On two occasions in June 2015, sabotage attacks on the Transandino pipeline, operated by the Colombian state-run company Ecopetrol, caused major spills of crude oil into various watercourses in the Department of Nariño (Colombia), on the Pacific side of the Andes, including the rivers Rosario and Mira.

The first incident occurred on 8th June, when a bomb exploded, opening up a breach in the pipeline which, although it was not in service, released a few hundred cubic metres of crude oil – almost 650 m^3 (4,000 barrels) according to Ecopetrol – into sensitive watercourses, used for fishing and drinking water. Despite attempts to contain the slicks, by deploying over 2,000 m of containment booms across 8 sites, the oil reached the River Rosario and, stretching across 20 km, travelled down the river, which flows into the Pacific Ocean (our sources of information do not specify whether or not the coastline was ultimately affected). The main impacts mentioned related to drinking water production, with local residents being provided with a temporary water supply (bottles, tanker trucks, etc.) by the authorities.

On 22nd June, another bomb went off, this time causing the release of around 1,600 m^3 of crude oil into the River Mira, near the shores of the Pacific Ocean, into which it feeds. Once again, despite the deployment, announced by Ecopetrol, of booms to contain the oil and protect sensitive sites (intakes at a water treatment facility), the spill is believed to have spread as far as the Pacific coast and to have left around 160,000 residents of Tumaco without drinking water.

Containment area for the floating crude oil set up using containment booms on the River Mira (Source: Gobernador de Nariño / Ecopetrol)

Little information is available in our information sources on the environmental impacts of these repeated terrorist attacks on the Colombian petrochemical infrastructures, as well as on the response techniques implemented and the results obtained.

Their share in the total quantity of pollutants spilt in inland waters in the North-West of South America is however probably relatively high, especially as this category includes the spills resulting from attacks on on-land transport vehicles, such as the release of 500 to 750 m^3 of crude oil following an attack, on 8th June 2015[2], on a convoy of 19 tanker trucks in the Department of Putumayo (polluting the ground and watercourses of the Amazon Basin, near to the border with Ecuador).

Crude oil spill on floodplains (RN-Yuganskneftegaz pipeline, Siberia)

On 23rd June 2015, near the village of Singapay on the outskirts of Nefteyugansk city (Khanty-Mansi Autonomous Okrug, Siberia), a leak of crude oil (from the Ust-Balykskiy oil field) occurred from a pipeline operated by the company RN-Yuganskneftegaz (a subsidiary of the Russian state-owned company Rosneft) into a system of watercourses which feed into the Ob River.

The oil spread out to form slicks at the surface of the floodwater from the Ob River, which had burst its banks following heavy rainfall. The pollution extended from the spill point across over 10 hectares, according to various press sources, in just a few days.

The operator stated that the leaking section of the line had been immediately isolated, containment equipment (booms) had been mobilised, and the pollution of the main river had been prevented. The details of response operations are not provided, but Rosneft indicated that 60 responders had been involved, 1,100 metres of containment boom deployed and boats and specialised equipment mobilised[3].

To the best of our knowledge, no official estimation of the quantity spilt has been given. Several sources reported a 1 mm thick film of oil over a 4-hectare area (around 30th June), although it is difficult to determine how reliable this information may be.

The possible environmental and health impacts are not specified either, although various photos suggest that homes in rural areas were affected.

RN-Yuganskneftegaz was charged with an administrative violation of water protection regulations.

[2] Repeating the scenario of the attack carried out in July 2014 (see LTEI n° 23), in the same area, in the same manner and, in all likelihood, for the same reasons.

[3] According to a press release: "six boats and five sets of oil gathering equipment"

Spills from wells

Spill in a river from dilapidated components at a well (Seibou 2 Wellhead, Nigeria)
On 23rd January 2015, the rupture of a corroded 6-inch (15 cm) pipe at Seibou 2 Wellhead operated by Shell Petroleum Development Company (SPDC) in the Nigerian state of Bayelsa led to a crude oil spill, estimated at just under 90 m^3, into Ogboinbiri River. In total, 30 hectares of water was contaminated according to SPDC. The spill also affected several local communities near to the spill point. Little information is available on this spill and the response implemented (which is said to have involved boom deployment by the operator). This incident is believed to have generated controversy over the notification of the incident by the operators and of the extent of the spills caused by the dilapidated facilities (unlike the spills caused by sabotage, which are also frequent but for which Nigerian regulations do not inflict any compensatory measures).

Minor spill from a faulty pipe: well operated by Mississippi Resources Limited (Mississippi, US)
On 16th April 2015, the rupture of an internal line connected to a wellhead operated by Mississippi Resources Limited led to the release of around 16 m^3 of light crude oil into Oakey Woods Creek (Covington County, Mississippi, US). By the time booms were laid, the spill had already spread over 3 km downstream of the spill point. These difficulties do not appear to have greatly penalised the efficiency of the operations carried out by the emergency services, which claimed to have recovered 8 to 10 m^3 of oil in a few days – a good performance, given that this was a light oil with a high evaporation rate (which often also means rapid spreading). According to the emergency services, the rain contributed to the success of operations, by naturally rinsing the oil trapped in log jams, which could then be collected in containment areas.

Road and rail transport spills

Fire and pollution due to a light crude oil spill (CSX rail convoy, US)
On 16th February, near Charleston in West Virginia (US), a CSX rail convoy, composed of over 100 tank cars carrying Bakken light crude oil (produced in North Dakota), derailed for an unspecified reason. Twenty-seven tanks overturned, 15 of which went on fire, leading to a series of explosions. The fire spread to the cargo which was flowing out of the damaged tanks. An unspecified quantity of oil flowed into watercourses which feed into the Kanawha River. The initial priority in terms of emergency response was to control the fire and ensure that local residents were safe, involving the temporary evacuation of a number of inhabitants due to the risks (health, black-out, etc.) generated by the disaster. A state of emergency was declared in 2 counties (Kanawha and Fayette). A Joint Information Center (JIC) was set up, gathering the bodies involved in incident management (within a Unified Command), from both the public sector (federal agencies – US EPA, USCG, US Department of Transportation, the state of West Virginia -Environmental Protection, Military Affairs, Public Safety, etc.) and the private sector (CSX and their contractors). Once the fire had been extinguished, spill response operations aimed to recover the crude oil by pumping following its containment (i) within the drainage trenches dug in the banks (in particular at the confluence between the Kanawah and one of its tributaries, Armstrong Creek), (ii) by booms deployed on the water and (iii) in natural depressions at the surface of the ice which partially covered the watercourse. Sheets of metal were inserted into the ice to prevent blocks of ice potentially comprising trapped oil from drifting due to the rise in temperature. One week after the accident, the JIC announced that around 140 m^3 of a water/oil mixture had been recovered from the drainage channels at the confluence between Armstrong Creek and the Kanawha River, and indicated a 'minimal' (but unspecified) spill into the watercourses. Over and above the temporary evacuation of local residents, the main impact reported was the water intakes at two water treatment plants (Montgomery and Cedar Grove) on the Kanawha River being closed. This rail accident, involving a spill of light Bakken oil and a fire, was one of a series of events regularly reported in North America over the past years (see for instance LTEI n°21 and 22). We remind

readers that a revision process is currently being implemented by the US Department of Transport (US-DoT and its agencies FRA and PHMSA[4]) relating to rail transportation of hazardous substances, with a specific focus on unconventional oils from the Bakken field (subject to specific inspections launched in 2013 nicknamed Bakken Blitz). However CSX indicated that the tanks involved in February's accident were in compliance with the new standards relating to the transport of large quantities of flammable liquids, which in turn raised doubts over the effectiveness of amending this regulation in reducing the occurrence of such incidents. The volume of Bakken crude produced in the US and Canada has considerably increased during the 2010s, leading in some regions (in this case in North Dakota) to a significant rise in the quantity of oil transported by rail to refineries (according to the Association of American Railroads, this quantity doubled between 2012 and 2013... and increased 40-fold between 2008 and 2012).

Spills from various facilities

Diesel spill from a refinery (Phillips 66/Cenovus Energy, US)

On 15th April 2015 in Illinois (US), a leak occurred, for an unspecified reason, from a pipe running from the Wood River Refinery (Phillips 66/Cenovus Energy) to a barge loading dock on Cahokia Canal, which drains into the Mississippi. After shutting off the leaking section, which is reported to have released just under 100 m^3 (25,000 gallons) of diesel according to the operator, spill response operations were implemented under the supervision of the US EPA and the US Coast Guard, consisting in particular in containment measures to prevent the spill from spreading to the neighbouring state of Missouri. The operations required 56 km of watercourse to be closed off.

• Main spills of other substances worldwide

Spill of denatured ethanol into a river (Canadian Pacific rail convoy, Balltown, US)

On 4th February, in Balltown (near Dubuque, Iowa), a rail convoy comprising 14 railcars carrying ethanol derailed while travelling on a section of railway bordering the Mississippi.

Eight of these overturned railcars may have leaked and 3 ignited. An estimated 210 m^3 of denatured ethanol (3-5% petrol/gasoline) was released into the Mississippi or burned (an undetermined share).

To respond to this emergency, the operator Canadian Pacific Railway contracted specialised companies to: (i) transfer the cargo still contained in the damaged tanks – prior to removal of the railcars, and (ii) implement a 2-week water quality monitoring programme (concentrations of ethanol, dissolved oxygen and organic compounds present in the petrol/gasoline fraction[5]), coordinated by the Iowa Department of Natural Resources (IDNR).

05/2/2015: railcars partially submerged in the Mississippi (Source: US EPA)

The spill response was coordinated by the US EPA (in collaboration with the US Coast Guard, IDNR and the local fire departments) and included a preliminary investigation into the damages to flora and fauna by the US Fish and Wildlife Service, in particular in the Upper Mississippi River National Wildlife and Fish Refuge, as well as into the threatened species of freshwater bivalves (*Lampsilis higginsii* and *Plethobasus cyphyus*[6]).

The National Oceanic and Atmospheric Administration (NOAA) was called upon to model the fate of the ethanol in the environment and to provide its insight into the resulting environmental risks. Based on the estimation made by the authorities of the quantity spilt (50,000 gallons, i.e. approximately 200 m^3), then on worst case scenarios, forecasts showed maximum concentrations in the water of 100 ppm and, in all cases, concentrations which remained below the toxic effect threshold for aquatic organisms (levels referenced in the NOAA Chemical Aquatic Fate and Effects Database). This was also the case for benzene (organic compound contained in the petrol/gasoline fraction), which raised greater concern but whose concentrations did not exceed 5 ppb. These predictions were confirmed with the initial water analysis results (normal dissolved oxygen levels, ethanol concentrations below

[4] Respectively Federal Railroad Administration and Pipeline and Hazardous Materials Safety Administration

[5] Gasoline range organics (GROs)

[6] Respectively "endangered" and "vulnerable" according to the IUCN (International Union for Conservation of Nature) Red List classification.

toxicity limits, etc.).

In terms of spill response, access to the site was problematic, as the site was both very steep and remote. An additional difficulty lay in the fact that part of the cargo spilt had frozen on the surface of the icy river (where it covered a total area of around 4000 m^2) and in depressions in the land (estimated surface area of around 2000 m^2). In these depressions, heating tests using steam sprayers were carried out from the day after the accident, to determine whether the chemical could then be pumped off. However, on the ice, this technique quickly proved to be difficult to implement as the melting point of ethanol, which is lower than that of water, meant that the chemical was liable to evaporate/disappear before the ice melted (and before the mixture could be pumped). Vacuum pumping operations were carried out for about a week to recover slush consisting in a mixture of water and denatured ethanol.

As for the ethanol which leaked under the ice, no recovery (or location and tracking) operations were possible.

Upon completion, the recovery efforts resulted, according to US EPA, in a total of 633 tonnes of contaminated solids (including soil, gravel, sleepers, etc.) and around 40 m^3 of ethanol-contaminated water.

***Left**: 07/2/2015, IDNR teams supervising semi-solid ethanol pumping operations at the surface of the ice (Source: US EPA); **Right**: 06/2/2015, sampling from an airboat (Source: US EPA)*

Based on the monitoring of local bivalve populations (see above), the final report published in June 2015 (4 months post-spill) concluded that no adverse effects had been caused by the spill.

For further information:
https://www.epaosc.org/site/site_profile.aspx?site_id=9738

• Statistics

Spills from pipelines in Europe: statistical analysis over 43 years (1971-2013)

The association CONCAWE (a joint European oil industry initiative established to carry out research on environmental issues relevant to the oil industry)[7] published a statistical overview, entitled Report on the Performance of European Cross-Country Pipelines, in 2015 based on the data collected relating to spills between 1971 and 2013 from cross-country oil pipelines in Europe.

These 43 years of data provide historical insight into the performances of the majority of pipelines, which transported some 680 million m^3 of oil products across Europe in 2013.

This review considers the quantities involved in spills as well as their causes, divided into 5 categories (mechanical, operational, corrosion, natural events and third party interference).

One of the most striking results of 2013 is the very significant increase in spills due to fuel theft attempts (petrol, diesel, kerosene, etc.), with 18 such events in 2013 alone, compared to 25 for the period 1971-2010 and 23 for the period 2011-2013.

These theft attempts aside, 8 spills were reported in 2013:

- In relation to the length of pipelines covered (0.23 per 1000 km), this number of events is slightly higher than the average expressed for the past 5 years analysed (0.18 per 1000 km) but remains below the values for the 1970s (1.2 per 1000 km) and therefore confirms the gradual downward trend observed in the long term.
- Three of these spills were due to mechanical failure, 1 to operational errors, 1 to corrosion and the 3 others to third party interference. This latter category remains the main cause identified for spills in the long term, followed by mechanical failures.

Again excluding theft attempts, 2013 saw the spillage of the equivalent of 4 m^3 of oil per 1000 km (i.e. an annual total of 130 m^3, of which 45% was recovered), a significant drop from the long term mean volume of 71 m^3 per 1000 km. No surface water pollution was reported following the 2013 spills (compared to 5 cases of pollution following the 55 incidents during the period 2009-2015).

[7] and a division of the European Petroleum Refiners Association

Another trend observed: while, in the past, pipelines carrying heated products (heavy refined/intermediate products) were a regular source of spillages due to corrosion – related to their design and construction – these pipelines have since been decommissioned or converted to transport unheated products (e.g. crude oil). No incidents from pipelines transporting heated products (45 km still in service to date according to CONCAWE) have been reported since 2002.

For further information:
https://www.concawe.eu/publications

• Recovery

Small spills of light products and vessels of opportunity: detachable SeaHow systems

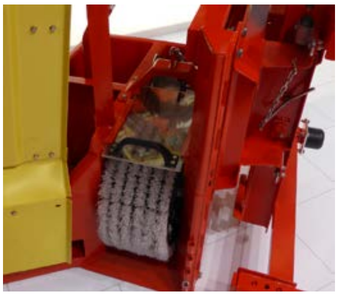
In 2015, the Finnish firm SeaHow, specialised in surveillance and maintenance services (including spill response) for inland, port and inshore waters, launched its own range of oil recovery arms for use on water. This range comprises models of suitable dimensions for use with various vessels: from systems integrated within the structure of specialised response vessels to light-weight, detachable devices, designed for small vessels of opportunity (use in ports, inland waters, estuaries, etc.).

Within this range is the MiniBagger aluminium sweeping arm which offers a sweeping width of 2.5 metres and is fitted with a polyethylene rotating brush skimmer.

This comparatively light device (weighing 106 kg in total) can be mounted on the side of a workboat (minimum of about 5 metres long) without requiring lifting equipment or specialised tools, for use in ports, watercourses, etc.

The MiniBagger sweeping arm (Source: SeaHow)

The skimmer's power unit is positioned on the deck of the workboat, as is the so-called SmartSacker sacking system, for storing the recovered oil in sacks, with a capacity of around 1 m^3, placed in an aluminium frame connected to the discharge hose.



The rotating oleophilic brush skimmer at the base of the sweeping arm (Source: Cedre)

The nameplate capacity specified by the manufacturer is 10 m^3/hour on heavy oil, on which brush skimmers are generally efficient, and 6 to 8 m^3/hour on light oil, with up to 90% oil in the recovered mixture. According to SeaHow, the system's efficiency with light oil results from its patented brush-comb design.

The MaxiBagger model is based on the same concept but in larger dimensions and is designed to be mounted on vessels over 9 m long. It has a sweeping width of 3 m and is claimed to offer recovery rates of 15 to 40 m^3/hour on light and heavy oil respectively.

According to SeaHow, its modular systems meet an emerging need for equipment capable of recovering light products, in particular with the entry into force in Northern Europe of the Sulphur Directive, which is liable to greatly increase the use of low sulphur content fuel (including marine diesel for instance).

In late 2015, the German Central Command for Maritime Emergencies (Havariekommando) announced that it had acquired several MiniBaggers to equip up to 6 aluminium workboats (7.5 m-long Faster 650 CATs manufactured by Nordland-Hansa), in order to fill the gaps in terms of spill response equipment for use in shallow waters, either inshore or in ports/estuaries which cannot be accessed by specialised vessels.

For further information:
http://www.seahow.fi/media/liitetiedostot/seahow/minibagger_eng_19.4.2016_low.pdf
http://www.seahow.fi/media/liitetiedostot/seahow/maxibagger_eng_19.4.2016_low.pdf

Koseq equipment for vessels of opportunity: Compact 502 and Victory Oil Sweeper

The Dutch firm Koseq offers a compact, containerised version of its sweeping arms: Koseq Compact 502.

Unlike previous models, intended to be mounted on spill response vessels, this system is designed for small non-specialised boats, commonly referred to as vessels of opportunity (VOOs), which can be deployed in relatively sheltered waters, coastal waters, estuaries, rivers, etc.

It is based on the same sweeping arm principle but in smaller dimensions with a 5 m-long arm, with a weir skimmer at the base, coupled with a submersible pump (Marflex MSP 100) with a nameplate capacity of 150 m^3/hour. The skimmer can be an oleophilic brush (like the larger models), disc or drum skimmer.

Deploying the Koseq Compact 502 (Source: Koseq)

With its auxiliary equipment, including an independent hydraulic power pack (driven by a diesel engine), a lifting device (telescopic crane) and the control box, the whole system (weighing around 10 tonnes) is stored in a standard 20-foot container which can be easily transported by road, rail, etc.

The firm also sells another model of recovery arm, the Victory Oil Sweeper, developed specifically for vessels of opportunity which do not have enough deck space to store equipment.

The Victory Oil Sweeper operated by a push-tug (Source: Koseq)

This system is composed of 2 sweeping arms positioned in a V shape designed to be pushed by (or attached alongside) a workboat. By adjusting the angle between these arms, the sweeping width can be adapted according to the speed of travel.

At the apex of the system, the collection chamber is equipped with 2 Marflex MSP 150 pumps (with a nameplate capacity of 2x360 m^3/hour), bearing in mind that the weir can be replaced by oleophilic modules (belt or brushes), or even a conveyor belt for collecting floating debris.

For further information:
http://www.koseq.com/
http://www.vidicon.info/projecten/koseq.com//site/media/Brochure%20Compact%20502.pdf
http://www.vidicon.info/projecten/koseq.com//site/media/Brochure%20VOS.pdf

Small skimmer heads for small spills

Small skimmer heads are simple to deploy and more elaborate than simple suction heads (e.g. floating flat head) in that a floating weir improves their selectivity. They are compact, light and suitable for use in relatively calm, shallow waters. They only require a limited number of operators (generally 2 people) and prove useful for recovering small spills in relatively sheltered areas: harbours, small watercourses, lakes, etc.

As for all mechanical weir skimmers, the device's trim is a determining factor in its selectiveness: various manufacturers therefore sell robust models fitted with lateral floats positioned in a catamaran configuration.

SKSkim

The SKSkim (manufactured by Le Floch Dépollution -LFD) comprises two lateral floats (aluminium or stainless steel) on either side of an adjustable weir. This device can operate in very shallow waters (6 to 3 cm according to the model).

The skimmer is connected via a semi-rigid suction hose to a pumping system (pump, vacuum truck, etc.) whose pump rate (25 to 90 m^3/hour according to the manufacturer) should be adapted according to the model (SKSkim40, 80 or 120: opening/sweeping width of 40, 80 or 120 cm respectively) and the operating conditions (oil thickness, quality, etc.).

SKSkim device (Source: LFD)

For further information:
http://leflochdepollution.com/

Pedco Skimmer	
The Pedco Skimmer (manufactured by Canadyne Technologies Inc.) is also fitted with 2 lateral floats made of aluminium. Connectors are positioned at the front of each float to attach 2 booms to the device in order to funnel the oil into the weir, for use in current. The device is connected to pumping equipment via one or two (Pedco 1 and Pedco 2 respectively) rigid hoses. The weir automatically adjusts to suit the pumping rate. For further information: http://www.canatec.com/products_pedcoweirskimmer.html	 *The Pedco 2 Skimmer (Source: Canadyne)*
NorVac	
Finally, the NorVac skimmer (manufactured by NorVac) is made of aluminium and also has a floating weir and lateral floats, and is designed to be connected to a vacuum system or suction pump. The semi-rigid suction hose, connected to the discharge outlet, is fitted to an aluminium pole, which can be used by the operator to handle/move the skimmer, for instance from a quay or bank, in order to position it in the areas with the thickest layers of oil. For further information: http://no.noren.no/?id=22&title=vacuum-skimmer	 *NorVac Skimmer (Source: Noren)*

• Solidifying agents

Recovering sheen: *C.I.Agent Sheen Machine*

The company C.I.Agent Solutions (US) markets a containment and recovery system designed to capture sheen by solidifying it. According to the manufacturer, it is designed to be used in difficult access areas or in marinas and harbours.

This system is composed of an aluminium collection unit (the "Sheen Machine" itself: 60 x 30 cm opening and 40 cm deep) fitted with floats and attached to 2 sections of containment boom (foam-filled) equipped with a skirt (total height of around 30 cm).

Front view of the Sheen Machine (Source: C.I.Agent Solutions)

When deploying the system (in static or dynamic mode), the sheen is concentrated and funnelled towards the collection system, which feeds into a detachable bag made of Agent Q, i.e. 2 layers of a non-woven fabric embedded with a layer of the solidifying agent manufactured by the brand. Once the bag is filled with oil, it can be replaced by another one using the plastic connectors, with no specific tools required.

The principle of this system is to develop an application using solidifying agents (which have the advantage of not releasing any oil into the water and not dripping when saturated) in order to clean up small spills or residual pollution (e.g. for final clean-up operations), in environments which are difficult to access with larger equipment (the Sheen Machine weighs around 15 kg, and the bag around 10 kg, making the whole system, in principle, relatively easy to carry by 1 or 2 people).

For further information:
http://www.ciagent.com/ciagent/application_sheets/SheenMachine_hi-res.pdf

• Response at difficult access sites

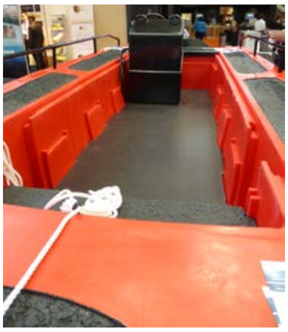
Lamor Seahunter workboat

The Finnish firm Lamor is now marketing a workboat dubbed the Seahunter, designed (originally by the Norwegian firm Bodo Industri) for conducting response on difficult access sites, in shallow waters, near to banks (rivers, lakes, marshes, estuaries, etc.) or seashores, in particular to deploy the personnel and equipment (pumps, primary storage capacities, etc.) required to carry out various response operations: containment, skimming/recovery on the water, clean-up, etc.

This is a modular system, with quick locking pins to connect additional hulls at the front of the main engine-driven platform, which in this case acts as a push boat, or alongside it, to provide a work platform with increased deck space during operations.

The main unit is 5.6 m long and 2.4 m wide, and is equipped with a 9.9-hp outboard engine (or 25 to 30-hp with a steering console). The connectible modules have the same dimensions and can be transported on a road trailer. According to the specifications, each module has a carrying capacity of 1.5 tonnes.

Deploying booms from the double hulled Seahunter with a 25-hp engine (LSH 25 SC) (Source: Lamor)



View of the deck area (Source: Cedre)

Among the advantages of this platform, we note the hull's stability and durability. It has a catamaran-shaped design, a low draught (35 cm), and is made of rotomolded thermo plastic (polyethylene), which, with no seals or joins, improves its solidity. The Seahunter can therefore be used as a landing craft on banks and even rocky shores (its propeller is protected to prevent damage). The flooring (including top and front) is covered with an anti-skid material to reinforce operator safety when working with oil.

For further information:
http://www.lamor.com/oilspillresponse/vessels/seahunter/

Responding in remote wetlands and marshlands: the Amphibious Crawl Carrier, ACC (Elastec)

The American firm Elastec manufactures an all-terrain tracked vehicle, for areas with a low load-bearing capacity (such as wetlands, marshes, etc.), designed to transport response equipment (containment/recovery on the water, bank clean-up, etc.) and personnel to clean-up sites.

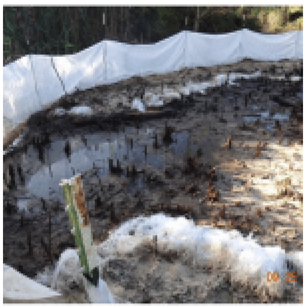
As the name suggests, unlike models already marketed by the manufacturer, the Amphibious Crawl Carrier can also operate in water. On the water, the foam-filled aluminium structure is driven by 2 hydraulically driven props, which also enable it to tow, deploy and retrieve containment booms. Its payload capacity is in excess of 1 tonne on land and is approximately 600 kg when working on water. An optional tow-behind trailer can also be attached to the vehicle. The whole system can be transported on a trailer.

For further information:
http://www.elastec.com/allterrainvehicles/acc/

• Sorbents

Filter barrier for slicks and sheen: *CEREX OilShark®*

The US firm CEREX Advanced Fabrics, Inc. has developed a fabric capable of filtering a polluted watercourse, by letting the water through while capturing the contaminant. The OilShark® Fence is a non-woven nylon spunbond fabric which, when installed vertically using stakes or stretched between two trees, is said to withstand currents, tides and high rainfall.



Various examples of configurations using the OilShark® Fence in inland waters in the US (Source: US EPA)

The OilShark® Fence has been successfully implemented during the response to recent spills in rivers in the US, for preventative containment (to reduce the spread of the spill in anticipation of violent rainstorms), as back-up in addition to conventional protection systems (containment booms and pipes), to channel the pollutant and protect banks, or to limit the spread of the spill during the rising tide in submersible marshlands.

This type of filter system really made its debut in the field of spill response at the time of the Deepwater Horizon spill (2010), during which UltraTech International offered its Ultra-X-Tex® fabric (see LTEI n°21) to protect the marshes in Louisiana.

For further information:
http://www.oilshark.com

• Oil measurements and monitoring

OSIL Micro Field Buoy

The British firm Ocean Scientific International Ltd. (OSIL) has released a new, ultra compact model of buoy, able to accommodate various sensors for taking continuous measurements in the surrounding water (fluorometer, dissolved oxygen, turbidity, etc.) and which could potentially be used for oil detection.

The Micro Field Buoy is 30 cm in diameter and weighs 15 kg (without instrumentation), and can therefore easily be handled by a single operator. It can be deployed from quays, banks, or even boats or aircraft, and is equipped with a data logging and real time transmission system (GSM/GPRS/3G technologies). According to the manufacturer, the buoy can operate unattended for one month.

This is therefore a relatively short-term measurement system, whose main advantage is that it can be rapidly deployed for emergency monitoring purposes.

For further information:
www.osil.co.uk

• Research

Subsurface oil detection: investigation by service dogs

As part of a programme run by the API (American Petroleum Institute) Joint Industry Oil Spill Preparedness and Response Task Force, several complementary studies have been carried out on subsurface oil detection and delineation techniques, in particular in shoreline sediments, but also on the banks of watercourses, estuaries, etc.

- A review[8] has shown that current practice relies heavily on visual observations, made in excavated pits and trenches in substrates. Such investigations are time-consuming, and can generate data which is too sparse too provide an accurate survey of the buried pollution.
- A review of techniques which currently exist or are under development in this field has been carried out and recommendations made, including the potential use of service dogs (olfactory sensitivity), in light of the work conducted by SINTEF in 2008 in Svalbard[9] (as part of the Oil in Ice JIP[10]).

In this context, field investigations into the feasibility of and possible improvements to this technique were implemented in 2015, and were outlined on a poster presented at Clean Pacific 2015 (Vancouver). Based on 2 groups of dogs trained by a dog training school, 2 types of tests were carried out, involving the detection of (i) a single point source of buried oil within an area of around 0.5 hectares (5,000 m^2) and (ii) 50 samples placed in plastic tubes and positioned in various configurations[11], simulating discontinuous pollution scenarios, within areas of 1,250 m^2.

For each of the 7 point source tests, it took the dogs an average of 3 minutes to detect the samples,

[8] http://www.oilspillprevention.org/~/media/oil-spill-prevention/spillprevention/r-and-d/shoreline-protection/1149-1-subsurface-oil-detection-report.pdf
[9] Brandvik, P.J. & T. Buvik, 2009. Using Dogs to Detect Oil Hidden in Snow and Ice – Results from Field Training on Svalbard April 2008, *SINTEF Oil-in-Ice final report No. 14*, Trondheim.
[10] Joint Industry Program on oil spill contingency for Arctic and ice-covered waters, between the oil and gas industry and several research organisations, coordinated by SINTEF and aimed at assessing the contributions of various technical solutions for oil spill response in the Arctic environment.
[11] 50 tubes buried at depths of up to 90 cm, containing alternately small quantities of contaminated sediment, clean sediment or no sediment.

with no false positives. By the end of the 14 scattered sample tests, 20 errors (undetected samples or false positives) had been recorded, 19 of which were attributed to the experimentation procedure by the study's authors (Owens Coastal Consultants). According to the authors, the average investigation time with this technique (11 minutes for 1,250 m^2) in experimental conditions is equivalent to the time required to investigate 1 or 2 points by a conventional SCAT team[12].

For further information:

Owens, E.H., Dubach, H.C., Castle, R.W., Bunker, P., 2015. *Field trials to locate and delineate subsurface oil on land and shorelines using detection dogs*. Proceedings Clean Pacific 2015 (poster)

• Response preparedness

Review of the behaviour and impacts of crude oil in the aquatic environment

In late 2015, the Royal Society of Canada published a report on The Behaviour and Environmental Impacts of Crude Oil Released into Aqueous Environments, produced by an expert panel. This review aims to meet the needs and answer the questions posed by the Canadian Energy Pipeline Association (CEPA) and the Canadian Association of Petroleum Producers (ACPP), which addressed the following issues:

- Expected behaviour of a crude oil spill, according to the type of oil, the environment (fresh, brackish or seawater) and according to environmental variables.
- Compared chemical composition and potential environmental toxicity of transported crude oils.
- Influence of microbial degradation on the physical and chemical properties, and toxicity, of crude oils spilt in the aqueous environment.
- Current reliability of prediction methods (scientific knowledge, tools, etc.) of the behaviour and fate (toxicity, degradation) of crude oils according to their physical, chemical and toxicological characteristics.
- Based on the previous points:
    - identification of gaps and priority research areas.
    - contribution to the definition of optimal response strategies (preparation, response, restoration) in the event of a spill in fresh or sea water.

The global need for better comprehension of the chemistry, properties and potential behaviour of unconventional crudes – bitumens, diluted bitumens, etc. – was highlighted by the expert panel.

In terms of the fate of oil spilt in identified high risk areas – including inland waters and wetlands – the need for greater knowledge was identified in the following areas:

- assessment of the risk of pipeline leaks
- interaction of contaminants with solids (sediment, fines, plant debris, litter, ice, etc.).

In terms of the environmental impacts of spills of various crude oils in inland waters, we note the following research recommendations:

- the effects of the structure of biological communities and the effects induced on the functioning of the ecosystem (i.e. at the various trophic levels)
- their interactions – and potentially their combined effect – with anthropic pressures (chronic pollution, eutrophication, etc.) or natural variables (adsorption of matter in suspension, seasonal oxygen depletion, etc.) in freshwater environments
- the implementation of a review, through a specialised national research programme, and the development of a better understanding (characterisation of natural fluctuations, parameters structuring communities, etc.) of the most at-risk ecosystems, especially where few studies have been conducted, in order to provide up-to-date sensitivity atlases, including in areas for which there is currently little coverage (in particular in inland waters in Canada)
- the establishment of a programme of in situ experiments in order to obtain data with sufficient statistical power to distinguish the effects induced by a given crude, according to its behaviour. The federal government was implicitly called upon in this respect for the authorisation of experimental releases into the natural environment.

[12] Shoreline Cleanup Assessment Team

- the use of cases of real spills, both past and future, as opportunities for research and in situ studies, is also recommended in order to assess (i) the long term effects and (ii) the benefits of various response options (including the question of "How clean is clean?" relating to clean-up endpoints) and restoration methods.

Finally, various improvement opportunities for current models are recommended (biodegradation and influence of physical and chemical properties on crude oils, aggregate formation – in particular for heavy products – whose fate is closely dependent on matter in suspension and organic materials, often present in high concentrations in inland waters, etc.).

This nearly 500-page report is a useful basis for the development, by the oil industry and/or the relevant public agencies, of optimised response strategies for spills potentially involving products for which gaps in knowledge remain, notably unconventional crudes.

For further information:
https://www.rsc-src.ca/sites/default/files/pdf/RSC%20Oil%20in%20Water%20Presentation_1.pdf
https://rsc-src.ca/sites/default/files/pdf/OIW%20Report_1.pdf

Specificities of oil spills in inland waters: NOAA's perspective

The National Oceanic and Atmospheric Administration (NOAA) recently published on its institutional website a review of the specificities of oil spills in rivers and estuaries, compared with spills in marine or shoreline environments, supported by examples of real spills.

Despite the fact that each spill is unique due to its specific circumstances (product, environmental context, etc.), a number of common observations and trends relating to oil spills in rivers are outlined by NOAA, in particular:

- the frequent immersion of oil slicks in freshwater (with the exception of very light oils), whose density is lower than that of seawater. One of the most emblematic recent cases of such a situation is that of the pollution of the Kalamazoo River in 2010, whereby the rapid evaporation of the light fractions of the dilbit spilt (diluted bitumen from oil sands) led to the immersion and settling of the oil on the riverbed, causing complications for response operations (see LTEI n°15, 19 and 21)[13].
- in estuaries, the spread of floating slicks is largely controlled by the flood tide. In comparison to an open environment (especially the ocean), the wind has a far lower influence on where the oil will come ashore (other than on the bank the most likely to be affected).
- in addition to riverbanks naturally restricting the lateral spread of floating slicks, according to NOAA the presence of infrastructures (dams, locks, etc.) on major watercourses improves the efficiency of recovery operations on the water (skimming, vacuum pumping, etc.) by concentrating and thickening the slicks, compared to open environments where the oil is more likely to spread. There is however an exception to this rule: man-made weirs, which let floating slicks flow over the top of the weirs, which vary in height and the degree of turbulence, possibly leading to mechanical dispersion of the pollutant (due to mixing of the oil with the water), to a varying extent and which may or may not be long-lasting (possible coalescence in calm areas downstream).
- as a general rule, riverbank vegetation generates the issue, characteristic of inland waters, of how to clean oiled vegetation. A range of techniques, some more aggressive than others, can be implemented: low pressure flushing, cutting, burning (in the US), possibly treatment with chemicals... Again, the recent case of the Kalamazoo River spill (see above) is emblematic, exacerbated by the fact that the incident during flooding when the river had burst its banks, leaving a large surface area of oiled vegetation.
- the sediment carried by the water flow, in comparatively high levels in rivers in relation to the marine environment, which leads to the adsorption of oil droplets and settling of the oil-sediment combination, also generates specific constraints in terms of the transfer of the pollutant to the riverbed, in areas at varying distances from the spill location. In this respect, NOAA makes reference to the spill following the collision of the chemical tanker *Tintomara* and the barge *DM932* (see LTEI n°11) on the Mississippi (sometimes nicknamed The Big Muddy) at New Orleans, following which sheen appeared in the dredged mud, at a site at the river mouth.

For further information:
http://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/resources/oil-spills-rivers.html

[13] We also note the inclusion of this specific topic (behaviour and fate of dilbit spills) in the document Spills of Diluted Bitumen from Pipelines: A Comparative Study of Environmental Fate, Effects, and Response, published in 2016 by the US National Academies of Sciences, Engineering and Medicine.

Automated emergency containment system for use in industrial port areas

The Swedish port of Gothenburg, one of the most active ports on the Scandinavian peninsula, is the home of significant oil activity (refining) and therefore is at risk of oil spills occurring.

In order to improve its spill response preparedness, the structure responsible for the Energy Port decided to equip the port with an automated containment boom deployment system. The boom is towed by a robot, developed by the Swedish firm SP Marine Technologies, in order to reduce response times and to improve safety (no operators or boats required on the water near the pollutant during the emergency response phase).

Trials involving the SP Marine Technologies system (Source: Port of Gothenburg)

A catamaran-shaped Autonomous Tug Vessel (equipped with a GPS positioning system), secured to a frame and driven by a turbine, tows a 400 m section of lightweight containment boom (50 cm draught and 20 cm freeboard, on a pre-positioned reel) between two wharfs, in just 10 minutes. Tests carried out in 2015 highlighted the system's efficiency, in terms of deployment time. It took 5 years to adapt the system to the conditions in the estuary of the Göta älv river (where the Port of Gothenburg is located).

For further information:
http://www.spmarine.se/

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