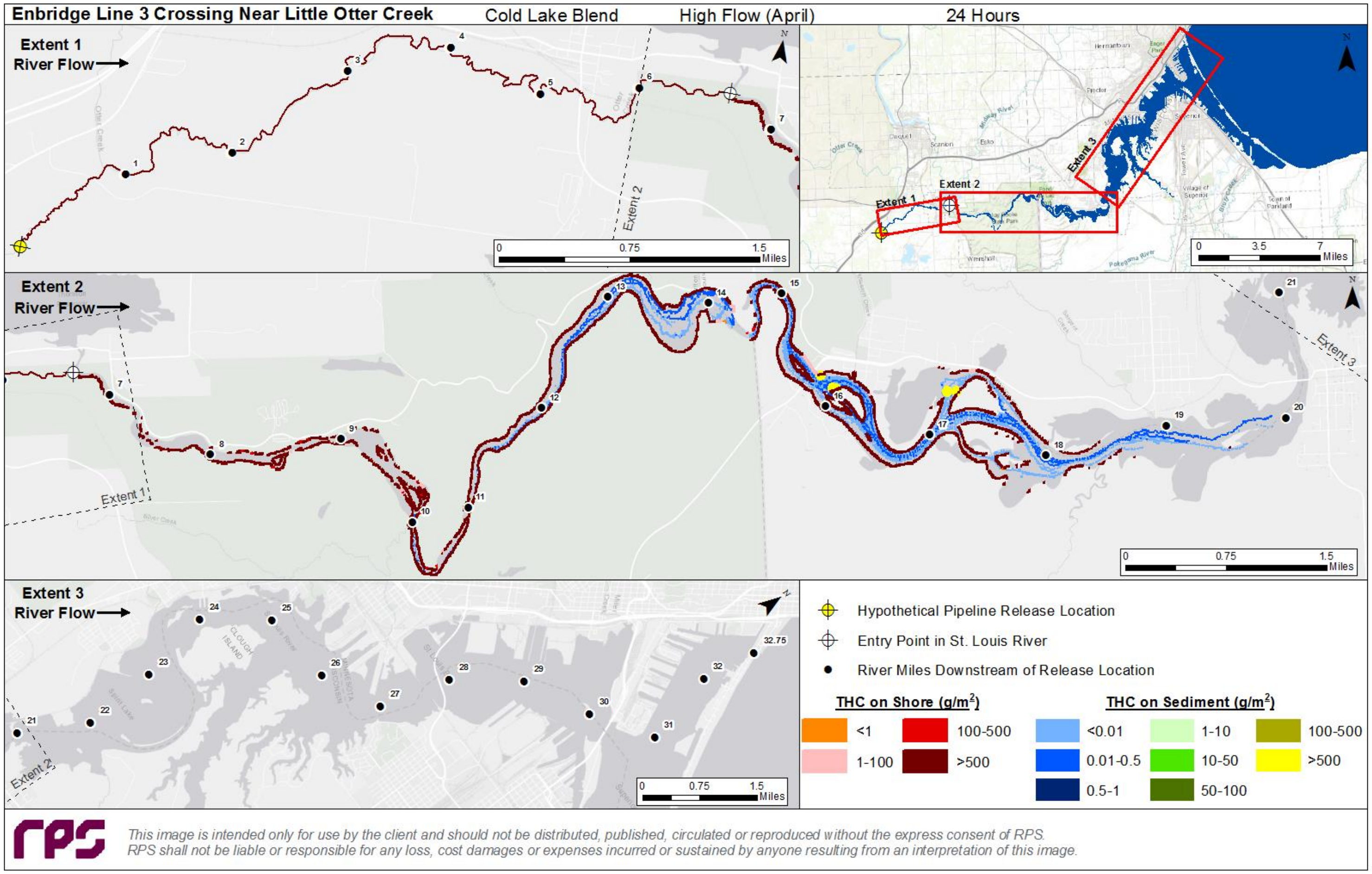

Figure 4-8 High River Flow (Spring) Season - Maximum Total Hydrocarbon Mass on the Shore and on Sediments at 24 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

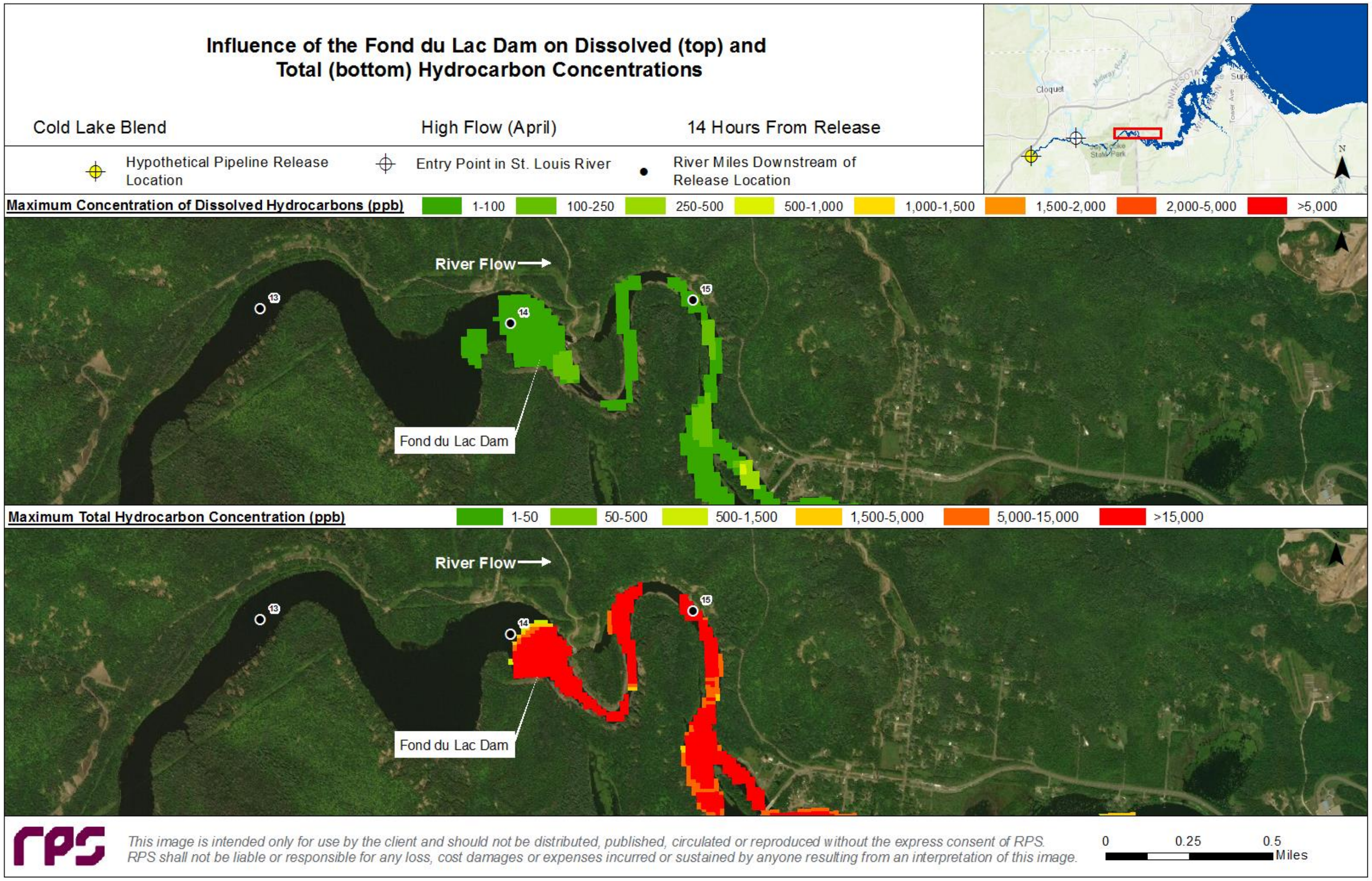

Figure 4-9 High River Flow (Spring) Season - Maximum Total Dissolved Hydrocarbon Concentration (top) and Maximum Total Hydrocarbon Concentration in the Water Column (bottom) at Fond Du Lac Dam. Results are Provided from SIMAP Approximately 14 Hours After the Release of CLB at the Little Otter Creek Release Site. Points indicate downstream distance (miles) from hypothetical release site.

4.2.1.2 Trajectory and Fate Results for Average Flow (Summer-Fall)

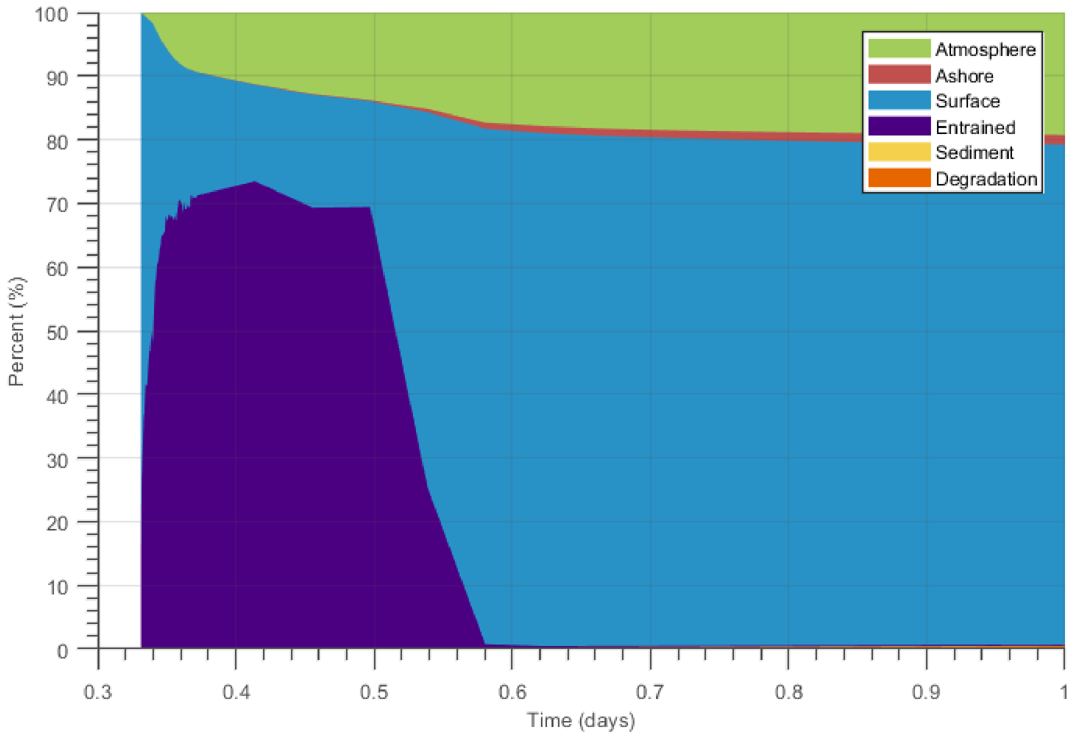

Figure 4-10 Average River Flow (Summer-Fall) Season - Oil Mass Balance Graph from SIMAP for Release of CLB at the Little Otter Creek Release Site. Note that the SIMAP simulation begins after the initial release (time zero) as the downstream transport of oil was first modeled within Little Otter Creek and Otter Creek using OILMAPLand. Please refer to Table 4-1 for OILMAPLand mass balance information.

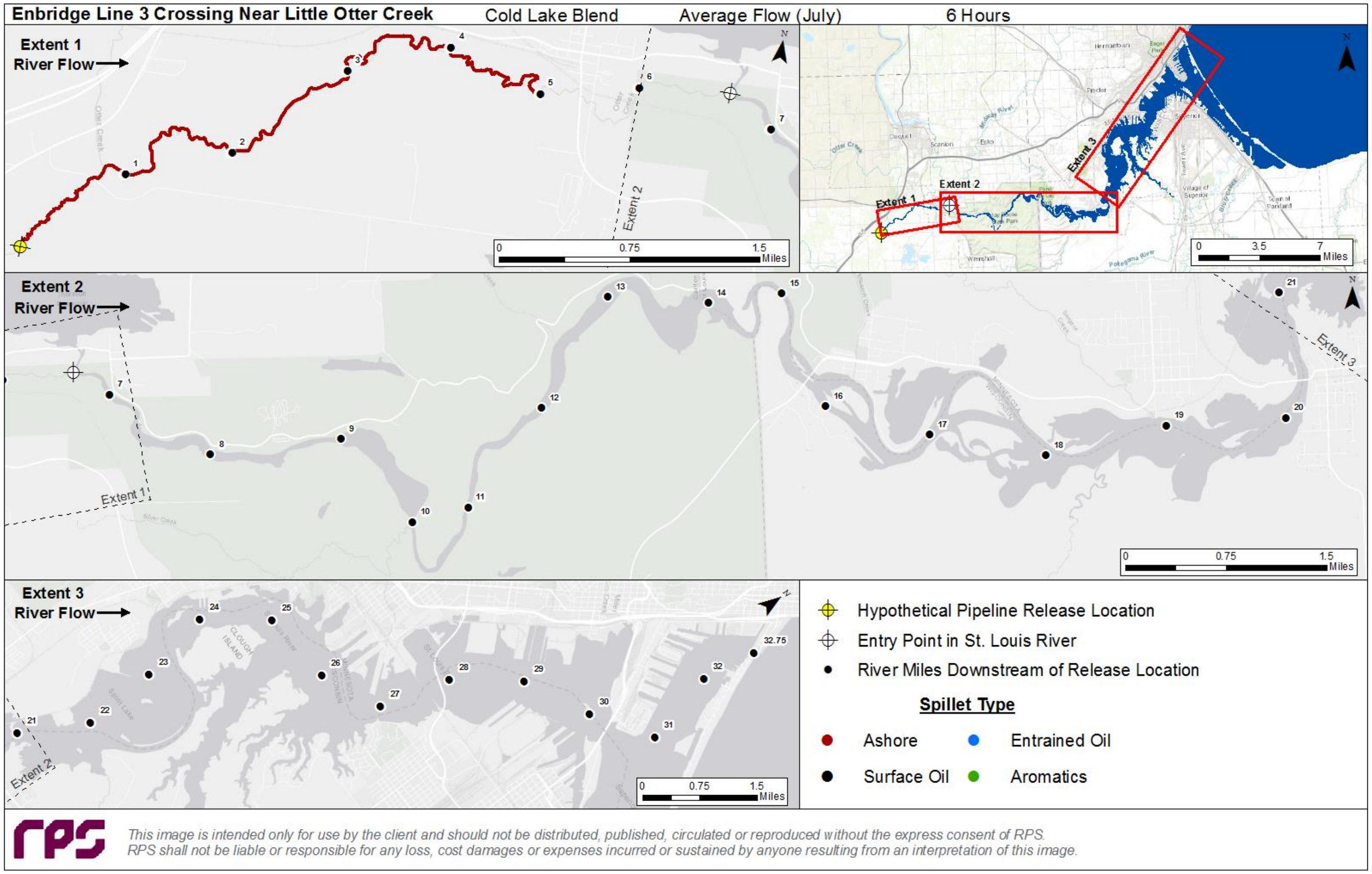

Figure 4-11 Average River Flow (Summer-Fall) Season - Oil Trajectory at 6 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. Note that all of the oil is still within Little Otter Creek and Otter Creek. Data provided came from OILMAPLand outputs. Points indicate downstream distance (miles) from hypothetical release site.

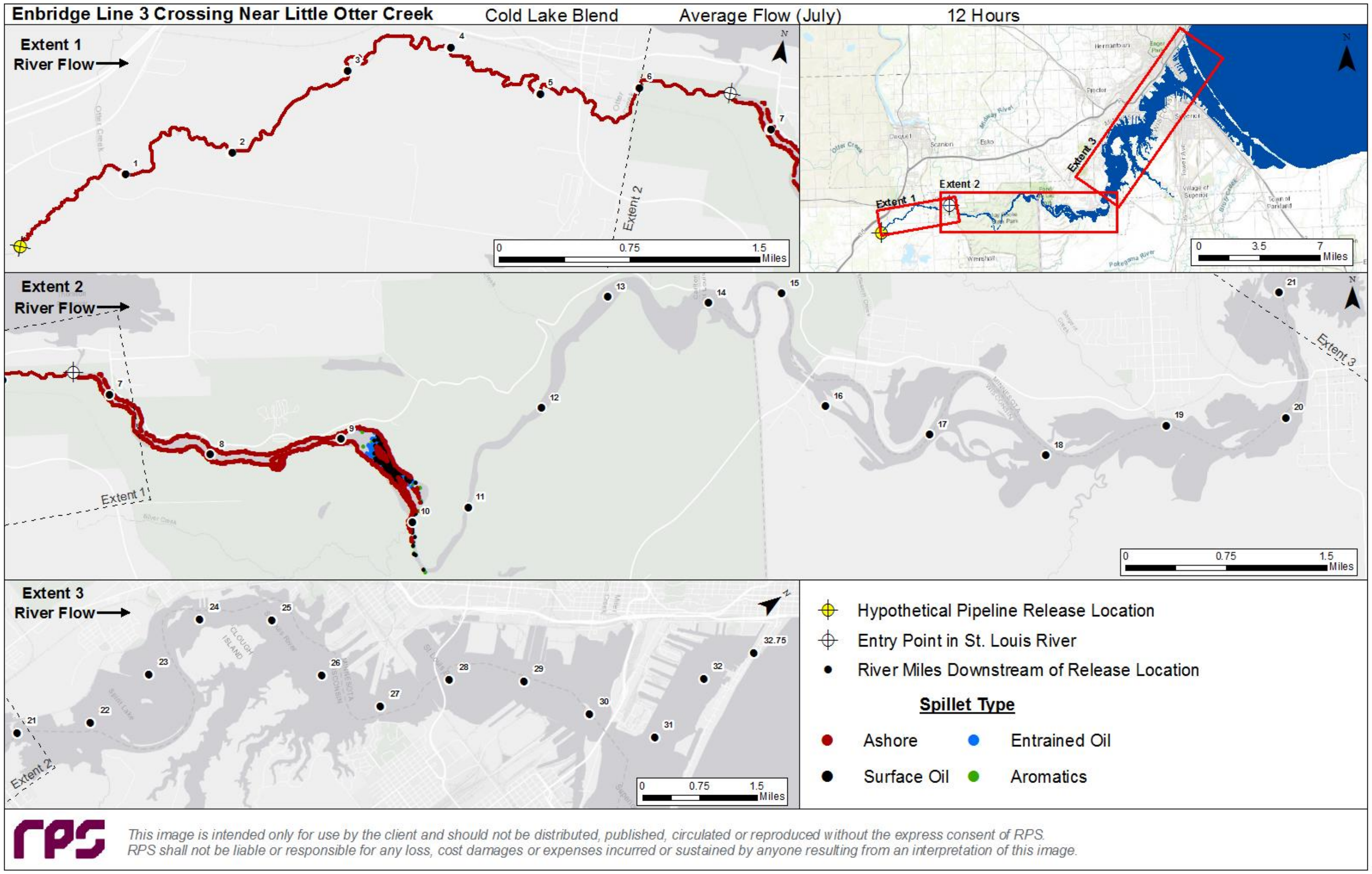

Figure 4-12 Average River Flow (Summer-Fall) Season - Oil Trajectory at 12 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

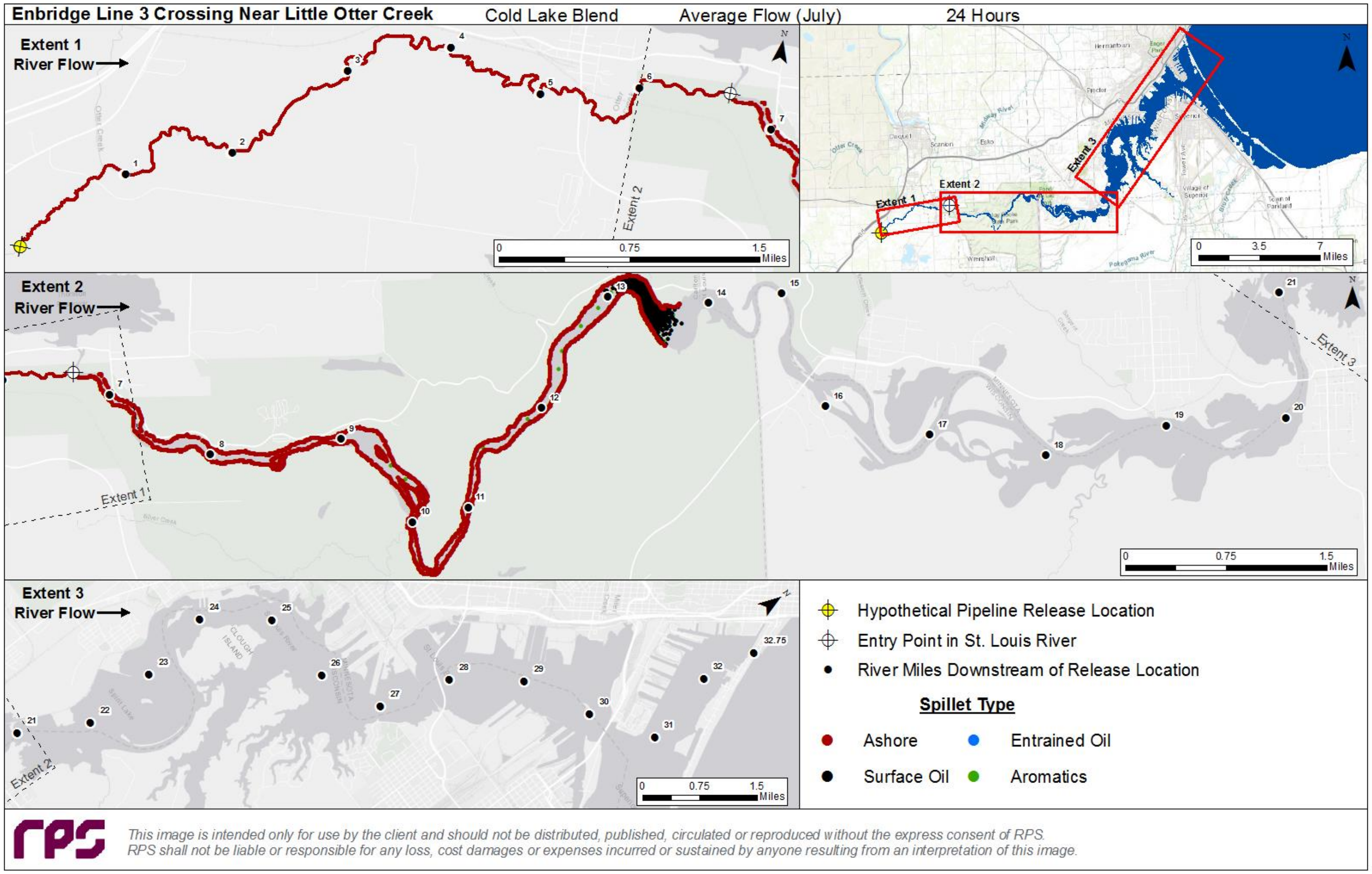

Figure 4-13 Average River Flow (Summer-Fall) Season - Oil Trajectory at 24 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

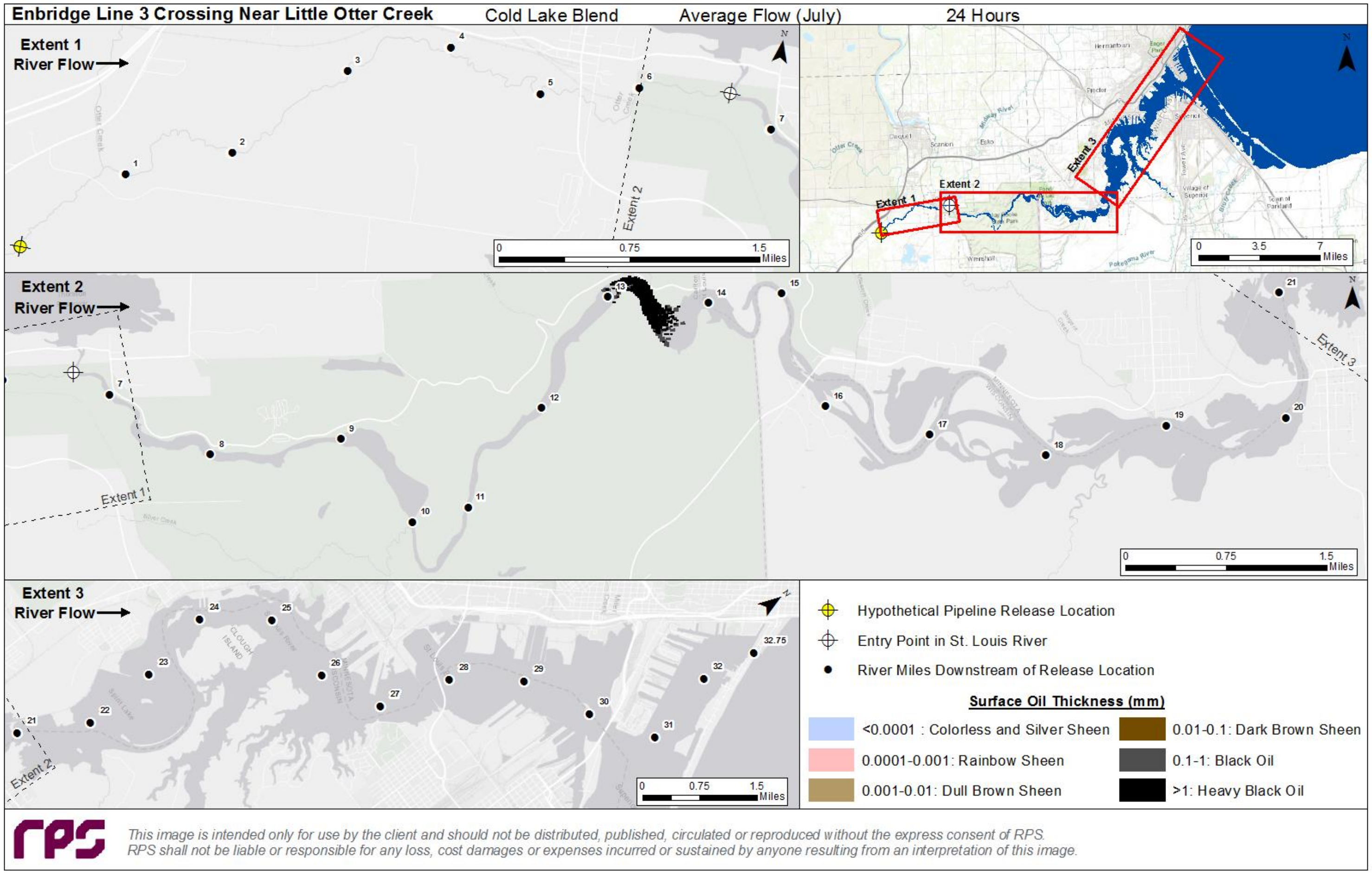

Figure 4-14 Average River Flow (Summer-Fall) Season - Maximum Floating Surface Oil at 24 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. Points indicate downstream distance (miles) from hypothetical release site.

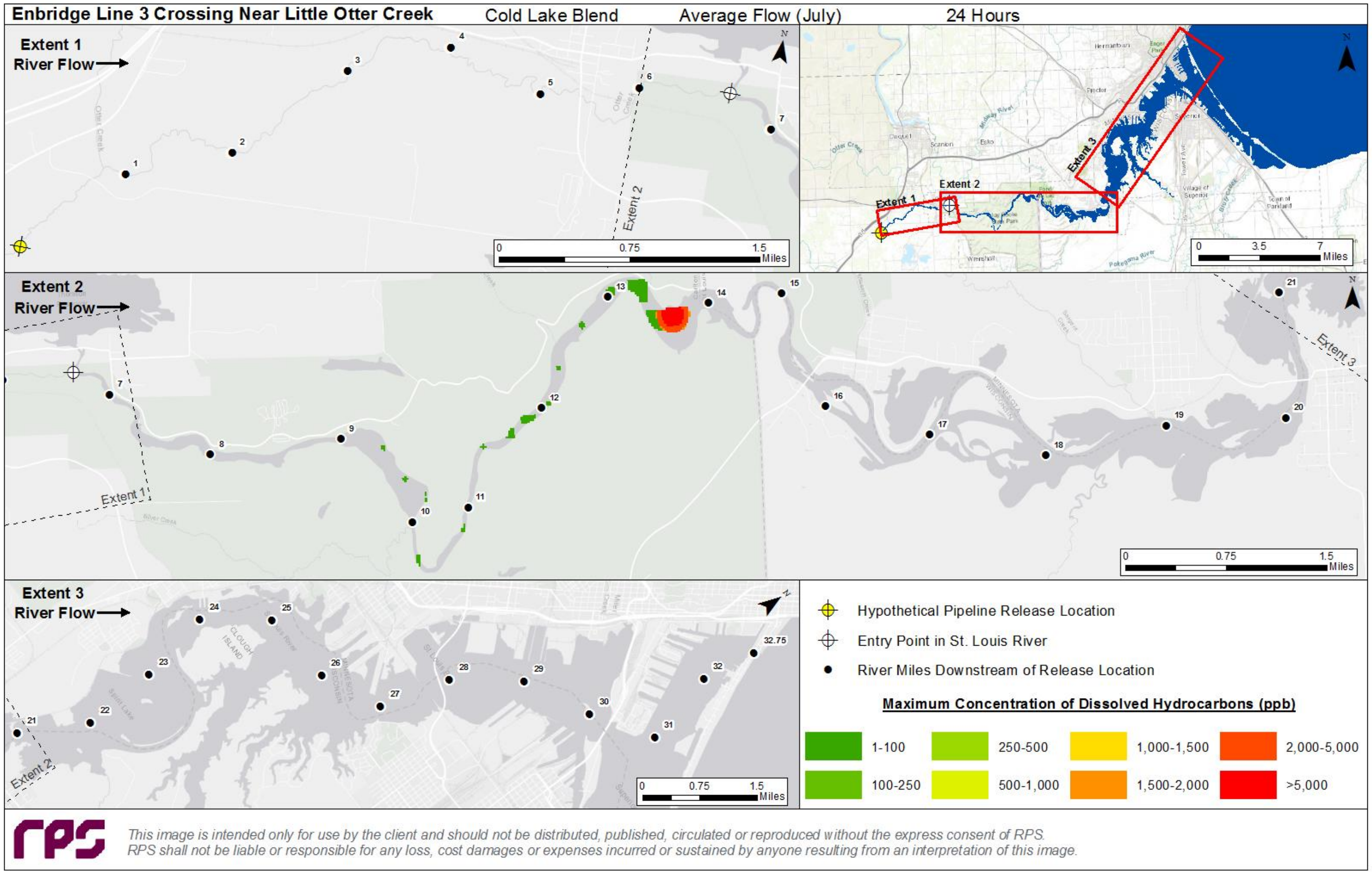

Figure 4-15 Average River Flow (Summer-Fall) Season - Maximum Total Dissolved Hydrocarbon Concentrations at 24 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. Points indicate downstream distance (miles) from hypothetical release site.

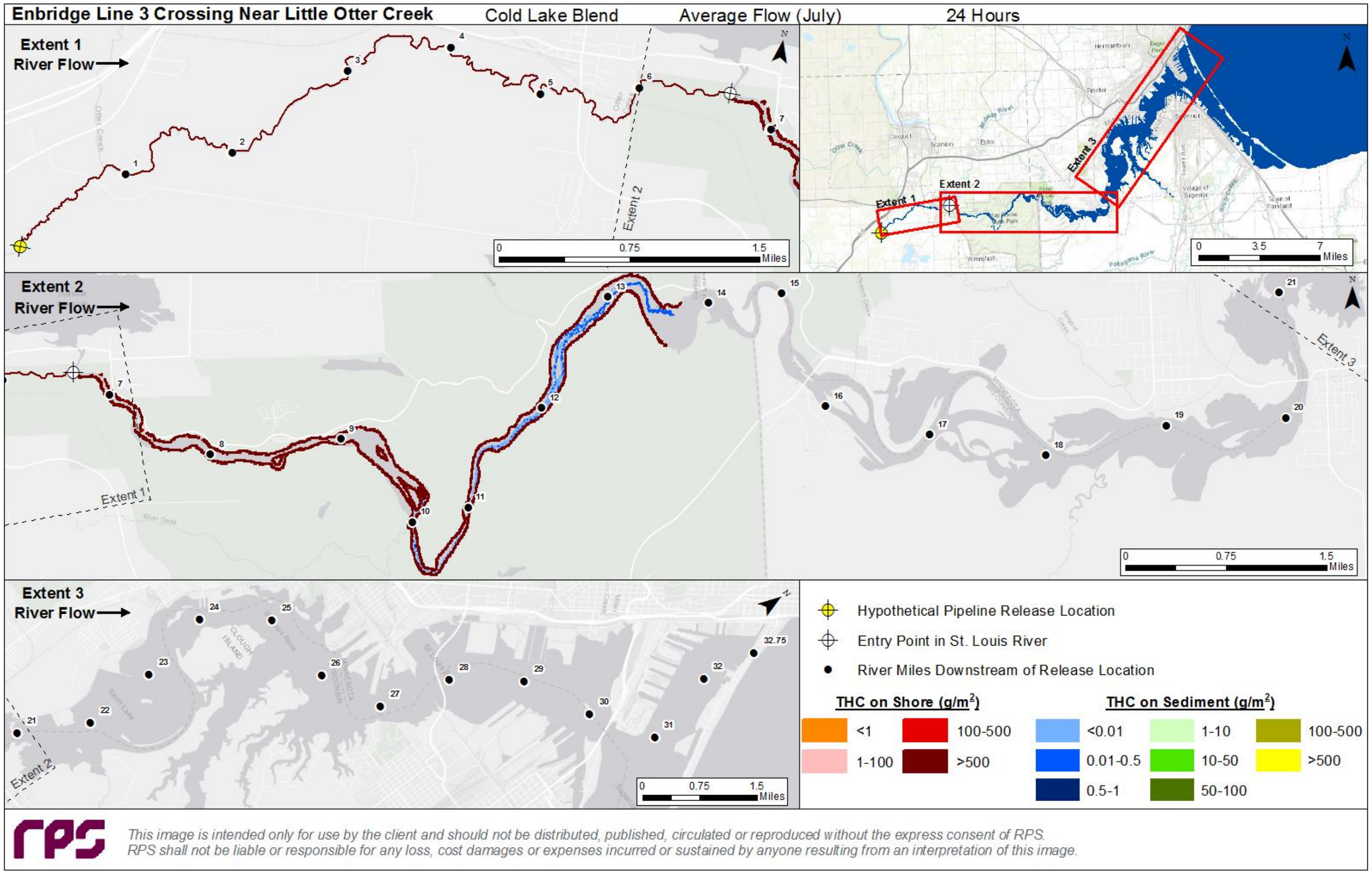

Figure 4-16 Average River Flow (Summer-Fall) Season - Maximum Total Hydrocarbon Mass on the Shore and on Sediments at 24 Hours for the Release of CLB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

4.2.1.3 Trajectory and Fate Results for Low Flow (Winter)

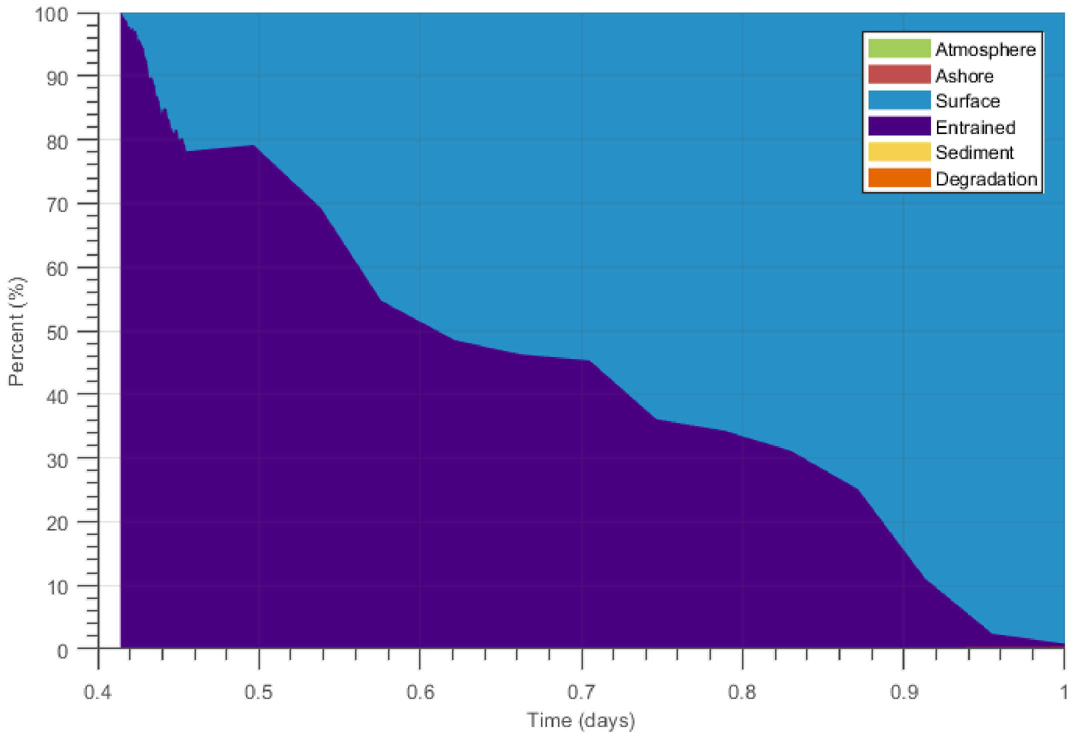

Figure 4-17 Low River Flow (Winter) Season - Oil Mass Balance Graph from SIMAP for Release of CLWB at the Little Otter Creek Release Site. Note that the SIMAP simulation begins after the initial release (time zero) as the downstream transport of oil was first modeled within Little Otter Creek and Otter Creek using OILMAPLand. Please refer to Table 4-1 for OILMAPLand mass balance information.

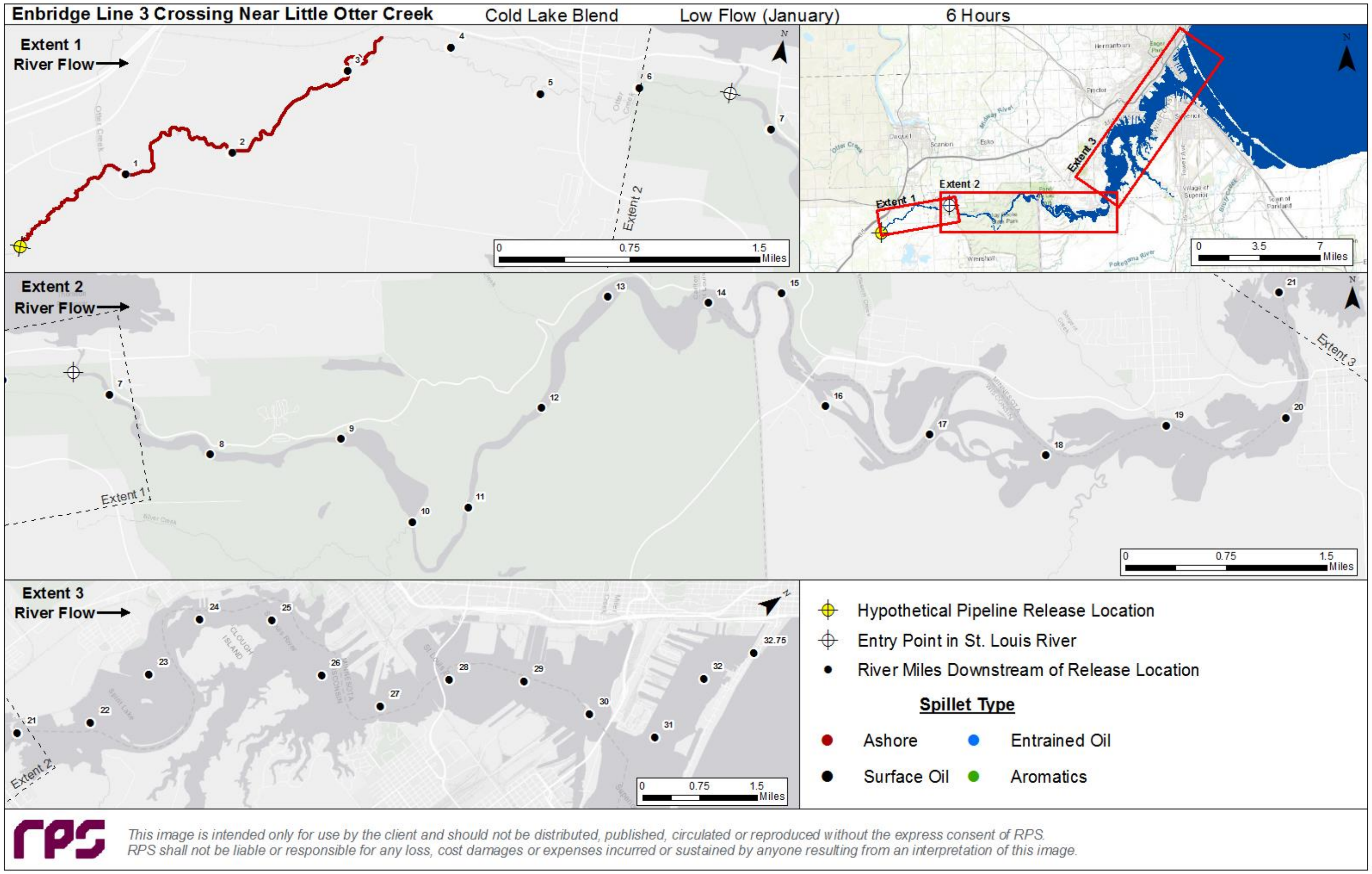

Figure 4-18 Low River Flow (Winter) Season - Oil Trajectory at 6 Hours for the Release of CLWB at the Little Otter Creek Release Site from SIMAP. Note that all of the oil is still within Little Otter Creek and Otter Creek. Data provided came from OILMAPLand outputs. Points indicate downstream distance (miles) from hypothetical release site.

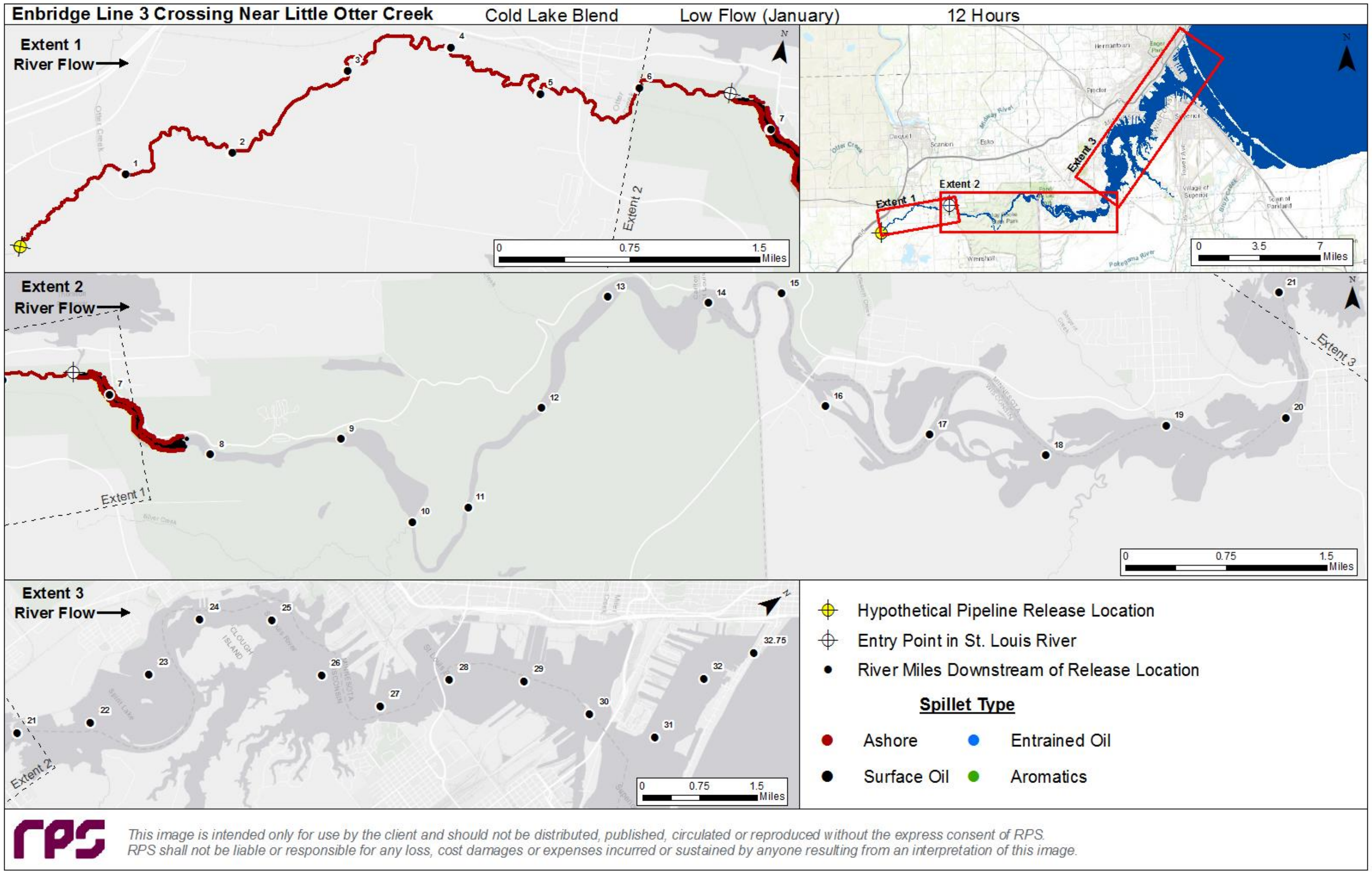

Figure 4-19 Low River Flow (Winter) Season - Oil Trajectory at 12 Hours for the Release of CLWB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

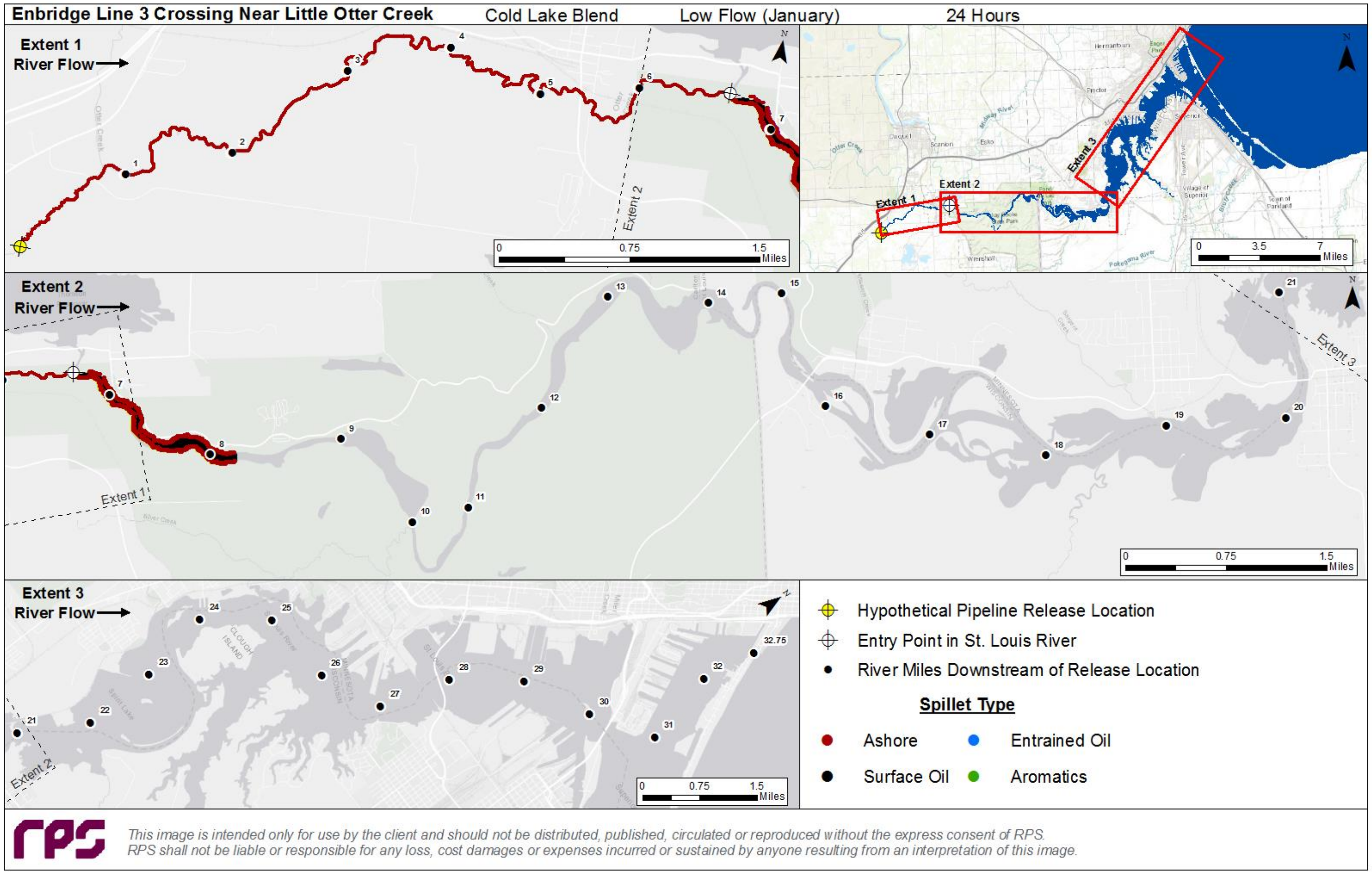

Figure 4-20 Low River Flow (Winter) Season - Oil Trajectory at 24 Hours for the Release of CLWB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

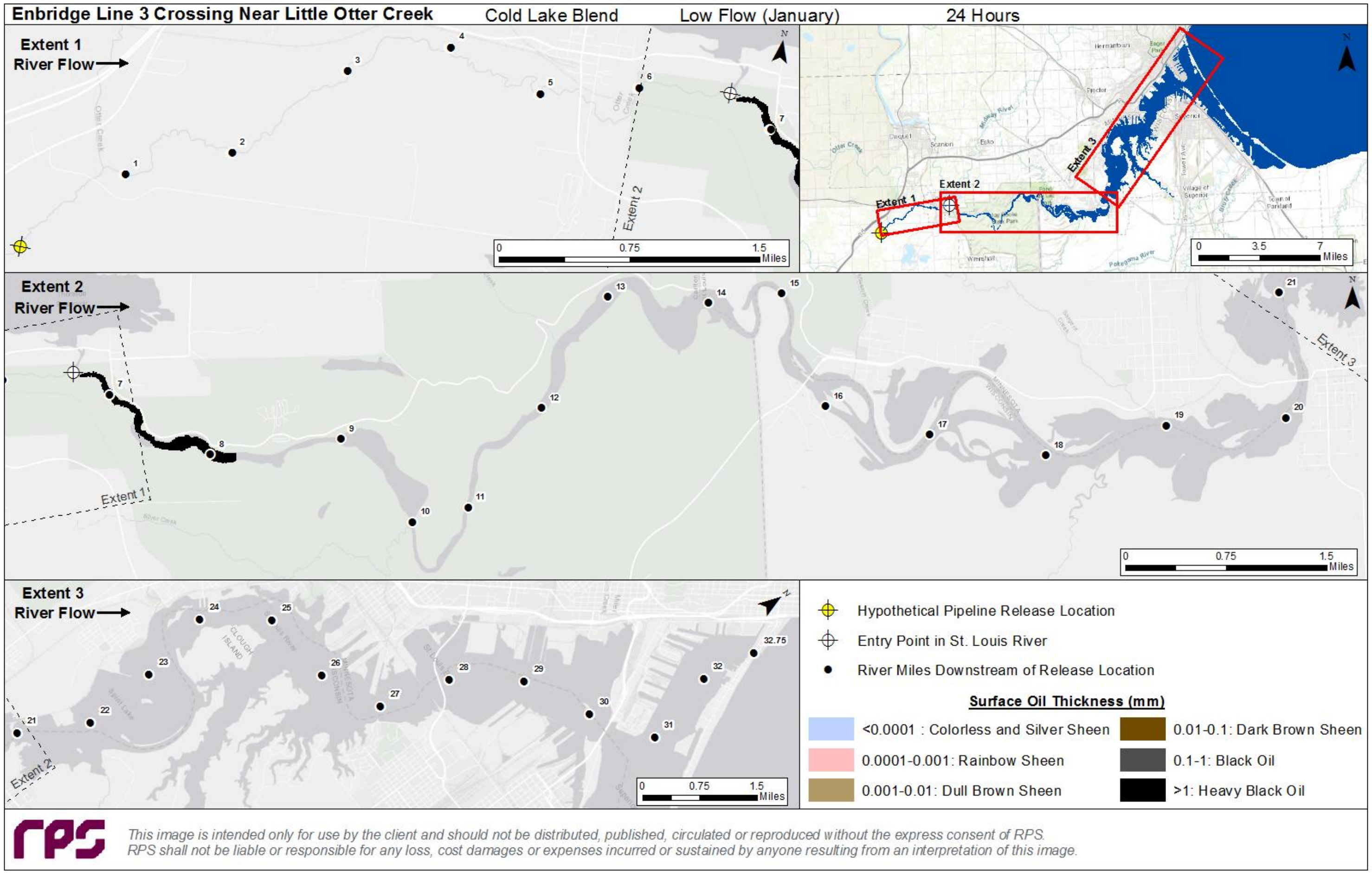

Figure 4-21 Low River Flow (Winter) Season - Maximum Floating Surface Oil at 24 Hours for the Release of CLWB at the Little Otter Creek Release Site from SIMAP. Points indicate downstream distance (miles) from hypothetical release site.

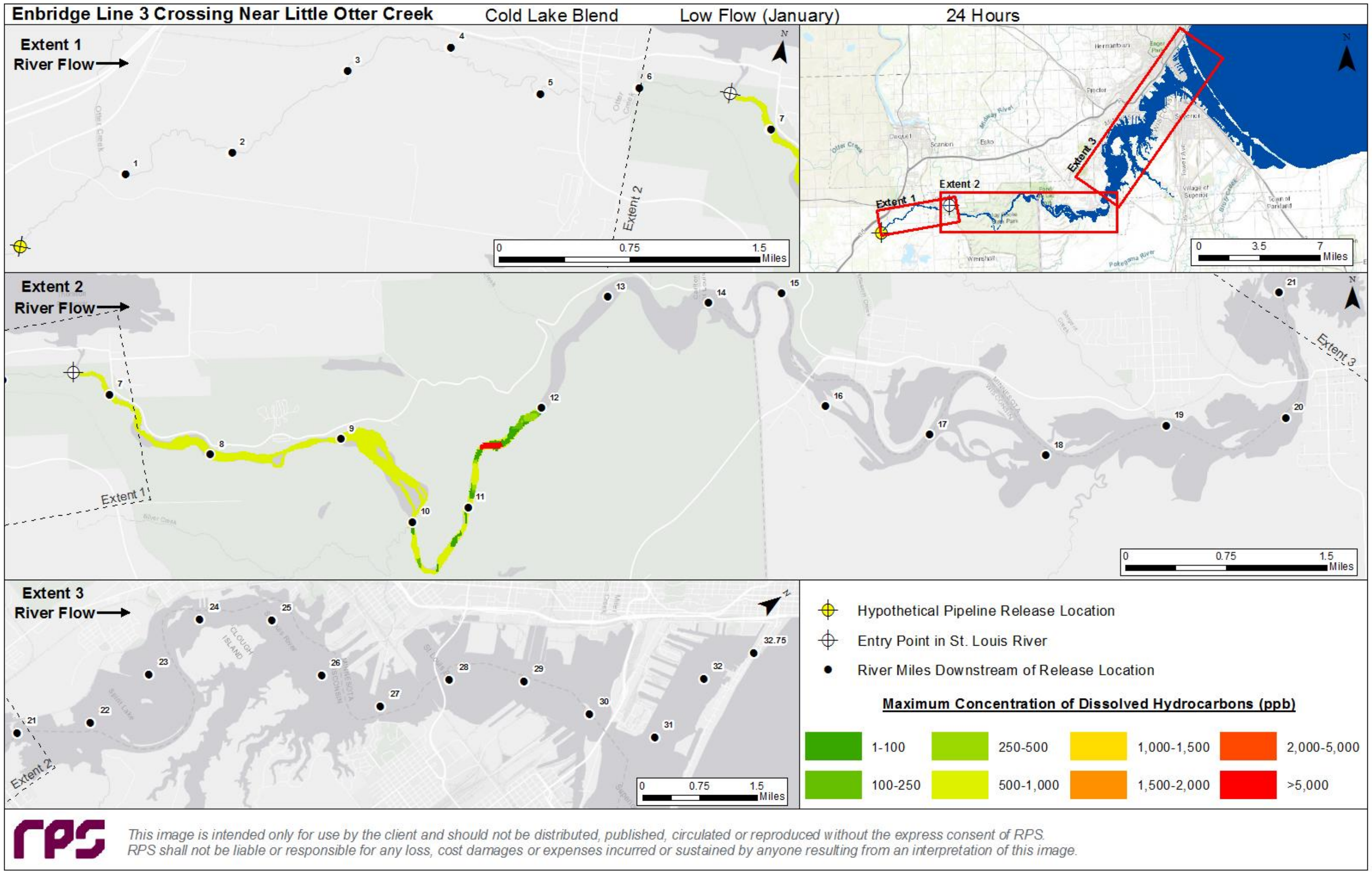

Figure 4-22 Low River Flow (Winter) Season - Maximum Total Dissolved Hydrocarbon Concentration at 24 Hours for the Release of CLWB at the Little Otter Creek Release Site from SIMAP. Points indicate downstream distance (miles) from hypothetical release site.

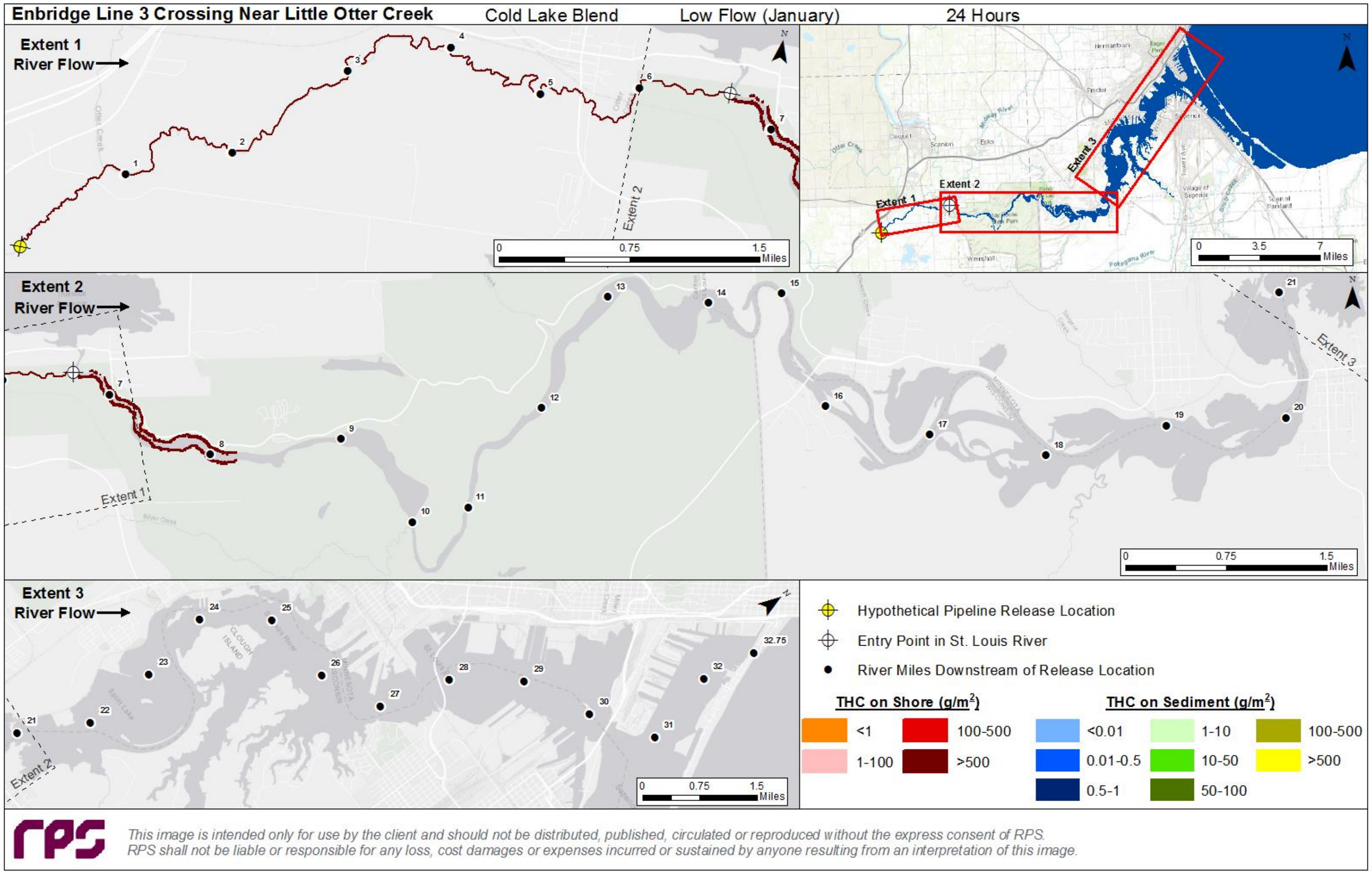

Figure 4-23 Low River Flow (Winter) Season - Maximum Total Hydrocarbon Mass on the Shore and on Sediments at 24 Hours for the Release of CLWB at the Little Otter Creek Release Site from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release site.

4.2.2 Bakken Crude Scenarios

A full bore rupture of 13,007 bbl (2,068 m^3) of Bakken Crude oil was simulated into Little Otter Creek using OILMAPLand. Table 4-4 provides a summary of the mass balance predictions from OILMAPLand at the point where oil would enter the St. Louis River. Table 4-5 provides the predicted volume and associated timing of this entry. The fate of oil that was predicted to enter the St. Louis River was modeled using SIMAP. Table 4-6 provides mass balance information at the end of the 24-hour simulation for the portion modeled within SIMAP. It is important to note that the combined simulation lengths for OILMAPLand and SIMAP totalled 24-hours.

Figure 4-24 provides the furthest predicted downstream extent of crude oil. Hypothetical releases of Bakken Crude oil under high river flow conditions resulted in oil that was transported downstream 6.5, 13.6, 16.2, and 19.7 miles (10.5, 21.9, 26.1, and 31.7 km) after 6, 12, 18, and 24 hours, respectively (Figure 4-24, Figure 4-26, Figure 4-27, and Figure 4-28). Under average river flow conditions, the release had a maximum extent of approximately 13.7 miles (22.0 km) after 24 hours (Figure 4-24, Figure 4-35). During low river flow conditions, the majority of the release was predicted to be trapped at the ice-water interface within approximately 12.0 miles (19.3 km) downstream of the hypothetical release point within 24 hours. Had the simulation been allowed to continue past 24 hours, it is predicted to reach its termination point at 14.8 miles (23.8 km) based upon the calculated equilibrium thickness of Bakken crude oil under ice (Figure 4-43; Section 3.3.1.5).

Table 4-4 Mass Balance Summary of the Percent of the Total Volume of Bakken Crude Oil Simulated in OILMAPLand for the Little Otter Creek and Otter Creek Portion of the Release up to the Point Oil Was Predicted to Enter the St. Louis River.

Scenario	Evaporated (%)	River Surface (%)	River Banks (%)
Bakken—High Flow (Spring)	18.4	78.6	3.0
Bakken—Average Flow (Summer-Fall)	25.6	71.4	3.0
Bakken—Low Flow (Winter)	<0.01	>99.9*	

*Value represents percent of oil remaining under the ice.

Table 4-5 Predicted Volume and Associated Timing of Bakken Crude Oil Leaving Little Otter Creek and Entering into the St. Louis River from the OILMAPLand Simulations.

Scenario	Volume Entering the St. Louis River (m^3)	Volume Remaining in the St. Louis River (m^3)	Volume Evaporated (m^3)	Time Into Release (hr)
Bakken—High Flow (Spring)	1,624	63.5	380.5	6.12
Bakken—Average Flow (Summer-Fall)	1,476	62.6	529.4	7.93
Bakken—Low Flow (Winter)	1,844	224	0	9.92

Table 4-6 Mass Balance Summary of the Percent of the Total Volume of Bakken Crude Oil Simulated in SIMAP for the St. Louis River to Lake Superior Portion of the Release at the End of the 24-Hour Simulation.

Scenario	Surface (%)	Evaporated (%)	Water Column (%)	Sediment (%)	Ashore (%)	Decayed (%)
Bakken—High Flow (Spring)	38.3	44.1	3.8	<0.01	13.3	0.4
Bakken—Average Flow (Summer-Fall)	51.9	44.7	2.1	<0.01	0.9	0.4
Bakken—Low Flow (Winter)	99.5*	<0.01	0.3	<0.01	<0.01	0.2

*Value represents percent of oil remaining under the ice.

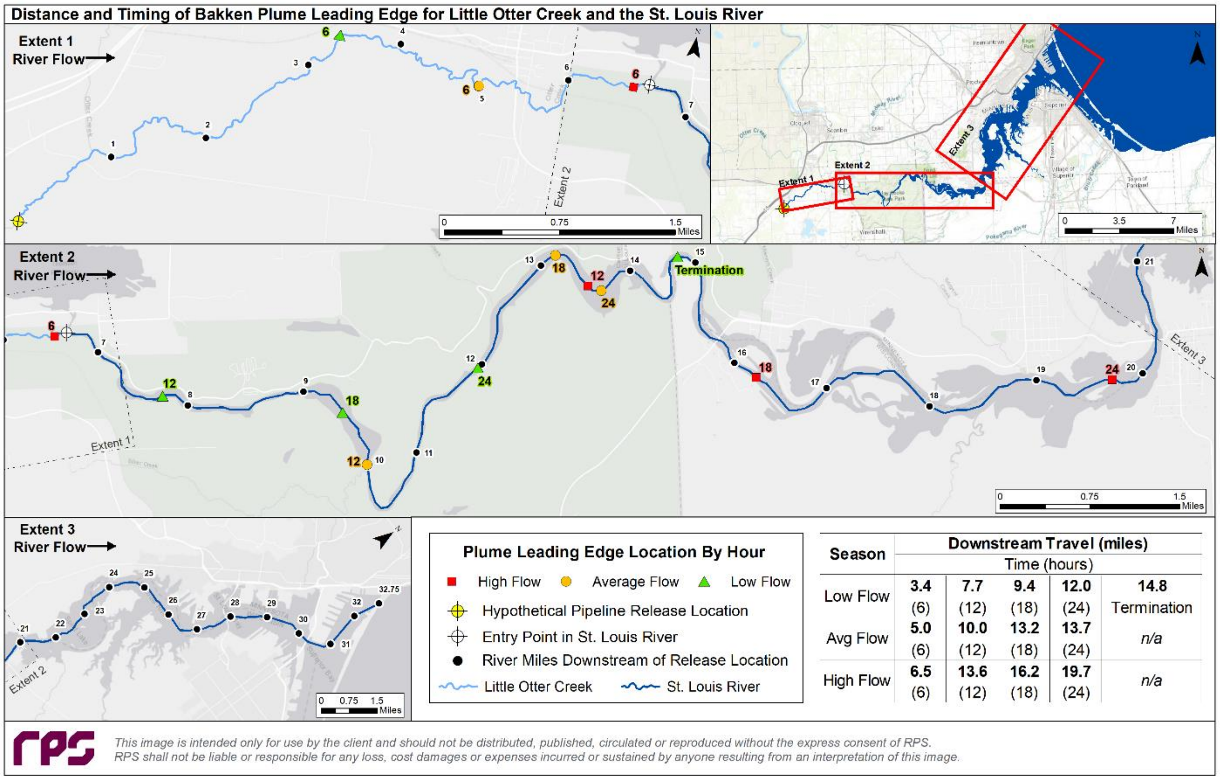

Figure 4-24 Predicted Downstream Transport of Bakken Crude Oil at the Little Otter Creek Release Location. Points indicate downstream distance (miles) from hypothetical release location.

During high and average river flow conditions, approximately 70-80% of the total release volume of Bakken Crude Oil was predicted to be transported downstream within Little Otter Creek and Otter Creek to the point where it entered the St. Louis River (Table 4-4). Under high river flow conditions, with the highest river velocities, this was predicted to take approximately 6.12 hours (Table 4-5). Under average and low river flow conditions, this predicted travel time was increased to 7.93 and 9.92 hours, respectively. These values are identical to those for the CLB simulations because the environmental conditions were identical between the two cases. Because of the high volatile content contained within the Bakken Crude Oil, 18-26% of the release was predicted to evaporate by the time the oil reached the St. Louis River, with the highest value predicted for the warmer summer conditions which enhanced evaporation rates.

At the point where Otter Creek enters the St. Louis River, approximately 3% of the release was predicted to adhere to the shorelines. This value is much smaller than the predicted amount of shoreline retention for CLB and is the result of the lower viscosity of Bakken Crude oil and the reduced thickness of oil stranding on shorelines. Under low river flow conditions, approximately 11% of the release was predicted to be trapped at the ice-water interface to a thickness of 0.07 in. (0.19 cm) (Table 4-4; Section 3.3.1.5).

At the confluence of Otter Creek with the St. Louis River, the velocity and turbulence of the water increases as a long section of rapids extends from 6.5-10.0 miles downstream of the hypothetical release site to the east through Jay Cook State Park. In this section, the majority of the Bakken was predicted to entrain within the water column, denoted by a large purple peak in the mass balance between 6-10 hours (0.25-0.4 days) into the release for high river flow (Figure 4-25) and 9-12 hours into the release for average river flow (Figure 4-32). Approximately 9-12 hours into the release for the high river flow conditions, most of the oil was predicted to be below the rapids (Figure 4-27). As the water slows and becomes more quiescent, entrained oil is predicted to resurface, spreading over the Fond du Lac Headpond, enhancing evaporation. Additionally, in these quiescent waters below regions of enhanced mixing (i.e., below rapids, waterfalls, dams), oil-particle aggregates that may form within the water column would no longer remain in suspension, and some of the oil-particle aggregates may sink to the river bed. Under average river flow conditions, the Bakken was predicted to remain above the Fond du Lac Dam after 24 hours (Figure 4-42). For the high river flow scenario, Bakken was predicted to go over the Fond du Lac Dam (0.65-1 day into the release) becoming re-entrained within the water column and transported downstream to river mile 20 after 24 hours (Figure 4-28).

Hydrocarbon contamination is predicted for downstream portions of the St. Louis River. Surface oil thickness of Bakken within the St. Louis River was predicted to be predominantly in the form of black oil (0.1-1 mm) and dark brown sheen (0.01-0.1 mm), with localized patches of heavy black oil (>1mm) within confined river channels. At hour 24 for the high river flow case, discontinuous patches of Bakken were predicted from mile 14-19 (22.5 to 30.6 km) within the St. Louis River prior to entering Spirit Lake (Figure 4-29). For the average river flow case, a relatively continuous patch of Bakken is predicted to remain above the Fond du Lac Dam as predominantly black oil (0.01-1 mm) (Figure 4-14). These predicted oil slick thicknesses are lower than predictions for CLB, as Bakken is a lighter and less viscous oil that spreads to a thinner level.

Maximum total dissolved hydrocarbon concentrations are predicted to be greatest near the leading edge of the release and in turbulent reaches, where entrained oil droplets and surface slicks have had a chance to become dissolved into the water column. Similar to CLB simulations, for each Bakken Crude oil model run, dissolved hydrocarbons are likely to exceed 5,000 ppb within much of the river, as an instantaneous maximum over 24 hours. However, peak concentrations typically pass quickly (minutes to hours) followed by larger regions of water predicted to experience dissolved hydrocarbon concentrations at lower levels, <250 ppb and typically <100 ppb. The area (and therefore duration of exposure) of high concentrations of dissolved hydrocarbons was predicted to be larger for Bakken, as the increased soluble content would result in larger regions behind the leading edge experiencing contamination at levels between 1,000-1,500 ppb (Figure 4-30). For the average river flow scenario, concentrations were predicted to be higher than the high river flow scenario above the Fond du Lac Dam, as most of the released oil entering the St. Louis River would be mixed into the water column in the extensive rapids between the Thomson Reservoir and Fond du Lac Headpond. As the entrained oil enters the more quiescent waters of the Headpond, the dissolved hydrocarbon concentrations were predicted to exceed the 5,000 ppb range for a longer period of time, when compared to CLB simulations (Figure 4-37). In water concentrations of dissolved hydrocarbons combined with the duration of exposure for Bakken Crude oil are predicted to be higher than those of CLB due to the higher soluble content of Bakken.

Relatively continuous shoreline oiling is predicted under the high and average river flow scenarios with shoreline concentrations of oil in the 100-500 g/m^2 range in upstream regions (owing to the Bakken Crude oil being less viscous than CLB) and exceeding 500 g/m^2 further downstream (owing to the weathering of the oil leading to higher viscosity as time progressed) to approximately 18.5 and 13.5 miles (29.8 and 21.7 km), respectively (Figure 4-31; Figure 4-38). Because of the strong vertical mixing within the rapids, and the lower viscosity of the Bakken, an intermediate amount of sedimented oil was predicted for the average river flow scenario between mile 12.2-13.5 (19.6 to 21.7 km) at levels predominantly 0.5-10 g/m^2. Because of the enhanced flow, mixing, and sediment load under high river flow conditions (Section 3.3.2.2.3), greater and more extensive (less patchy) oiling of sediment was predicted, with values consistently between 0.1-0.5 g/m^2 between mile 12-18 (19.3 to 29.0 km), with localized pockets between 1-50 g/m^2 in quiescent regions throughout.

For the low river flow scenario, all of the oil was predicted to remain trapped beneath the ice and was therefore either in the water column (purple) or rising to the "surface" (blue) where it would be trapped beneath the ice (Figure 4-39). The hydrocarbon trajectory at the end of the 24-hour simulation extended 12 miles (19.3 km) from the hypothetical release site (Figure 4-42) as a continuous slick of heavy black oil 0.07 in (0.19 cm) thick at the ice-water interface (Figure 4-43). Had the simulation been allowed to continue beyond 24 hours, it would be expected to reach its termination point at 14.8 miles (23.8 km) based upon the calculated equilibrium thickness of Bakken crude oil under the ice. While the whole oil fraction remained trapped under the ice, the soluble portion of hydrocarbons were free to move downstream within the water itself as a dissolved fraction (Figure 4-44). Concentrations exceeding 5,000 ppb may be possible near the leading edge of the plume, which is transported downstream approximately 11.5 miles (18.5 km) within the 24-hour model simulation. However, concentrations were predominantly 750-1,000 ppb in the waters below the trapped oil and upstream of the leading edge, as all of the soluble fraction dissolved into the water column as evaporation was capped. This higher concentration is the result of Bakken having a higher volatile content than the CLB. A small amount of patchy and discontinuous sediment oiling may be possible for the low river flow scenario at levels of approximately 0.1 g/m^2 (Figure 4-45).

There was very little decay of hydrocarbons predicted for any of the three hypothetical releases within the 24-hour timeframe modeled (Table 4-6).

4.2.2.1 Trajectory and Fate Results for High Flow (Spring)

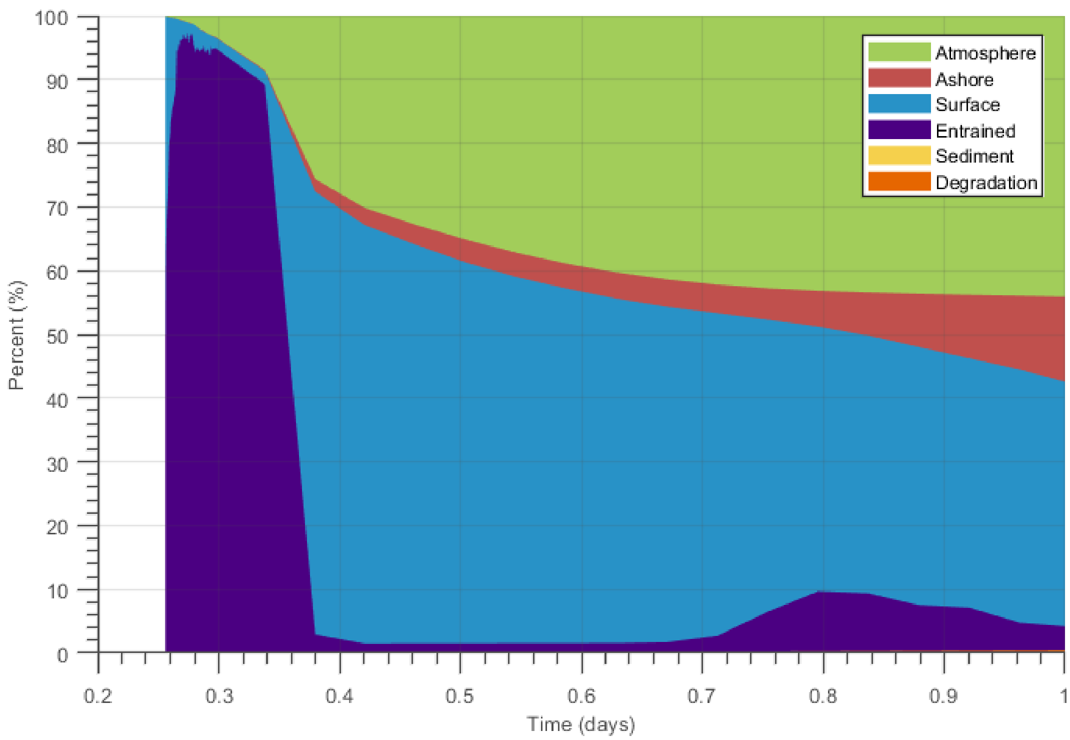

Figure 4-25 High Flow (Spring) Season - Oil Mass Balance Graph from SIMAP for the release of Bakken Crude at the Little Otter Creek Release Site. Note that the SIMAP simulation begins after the initial release (time zero) as the downstream transport of oil was first modeled within Little Otter Creek and Otter Creek using OILMAPLand. Please refer to Table 4-6 for OILMAPLand mass balance information.

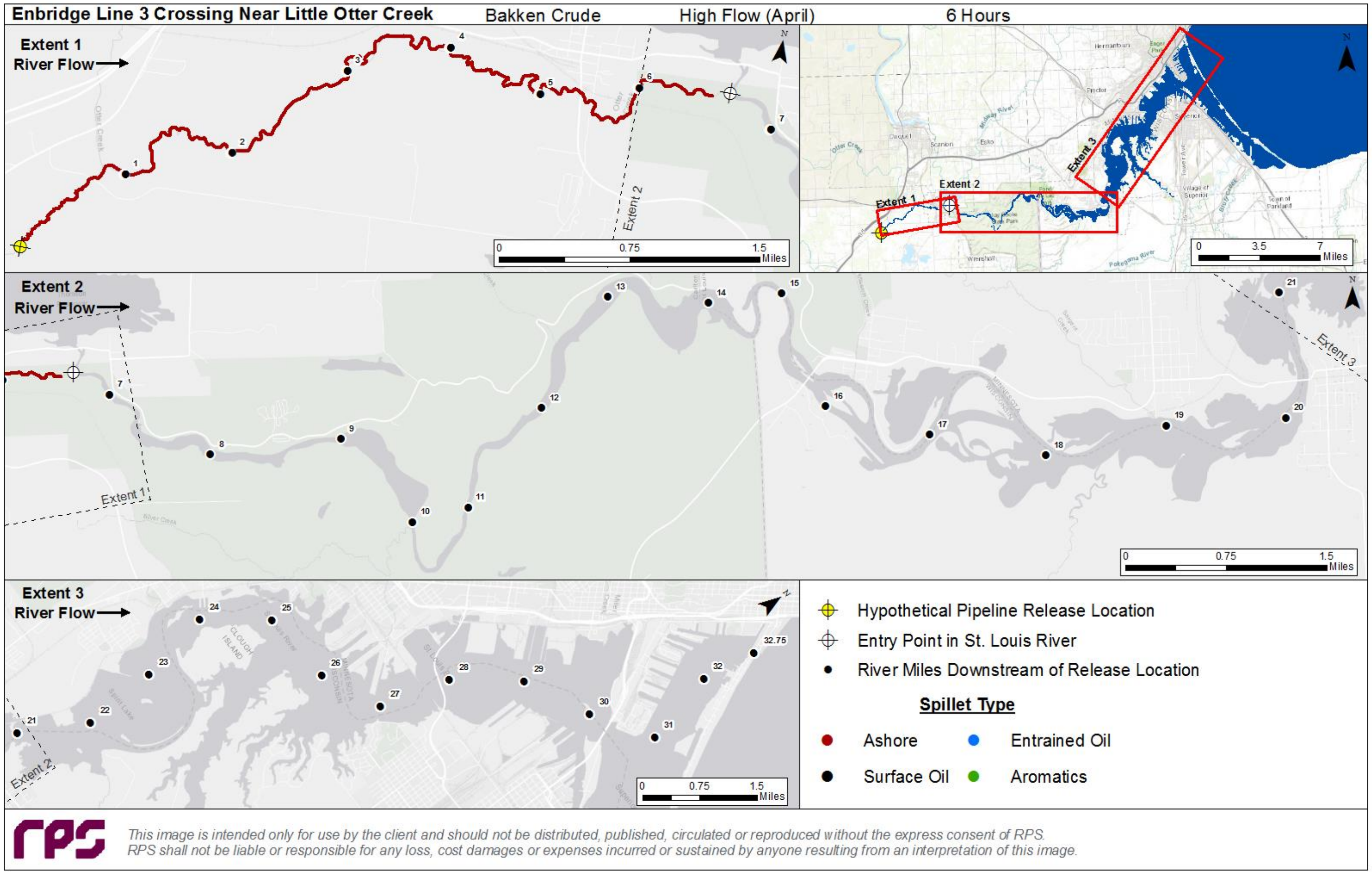

Figure 4-26 Oil Trajectory at 6 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the High Flow (Spring) Season from SIMAP. Note that all of the oil is still within Little Otter Creek and Otter Creek. Data provided came from OILMAPLand outputs. Points indicate downstream distance (miles) from hypothetical release location.

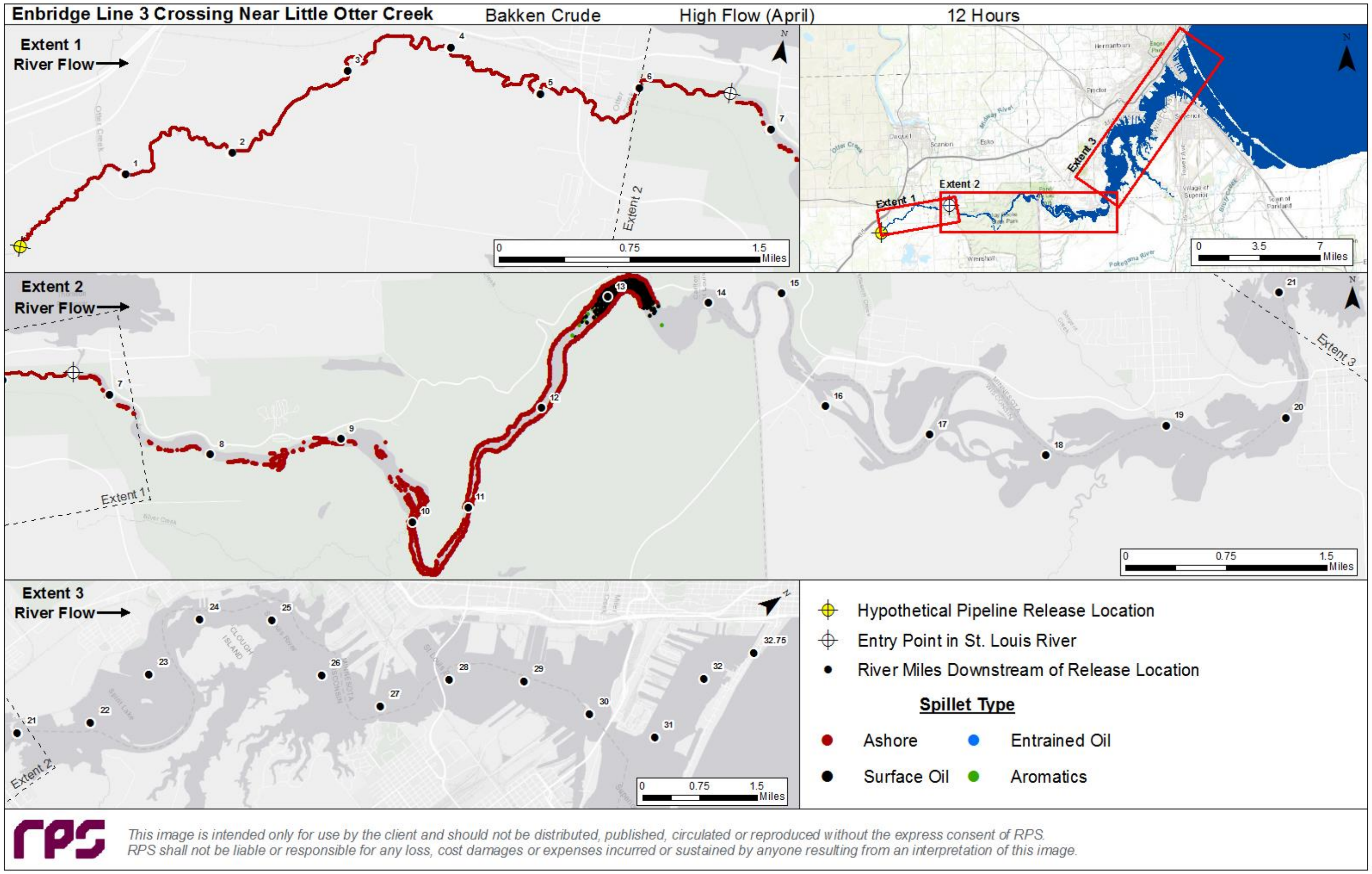

Figure 4-27 Oil Trajectory at 12 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the High Flow (Spring) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

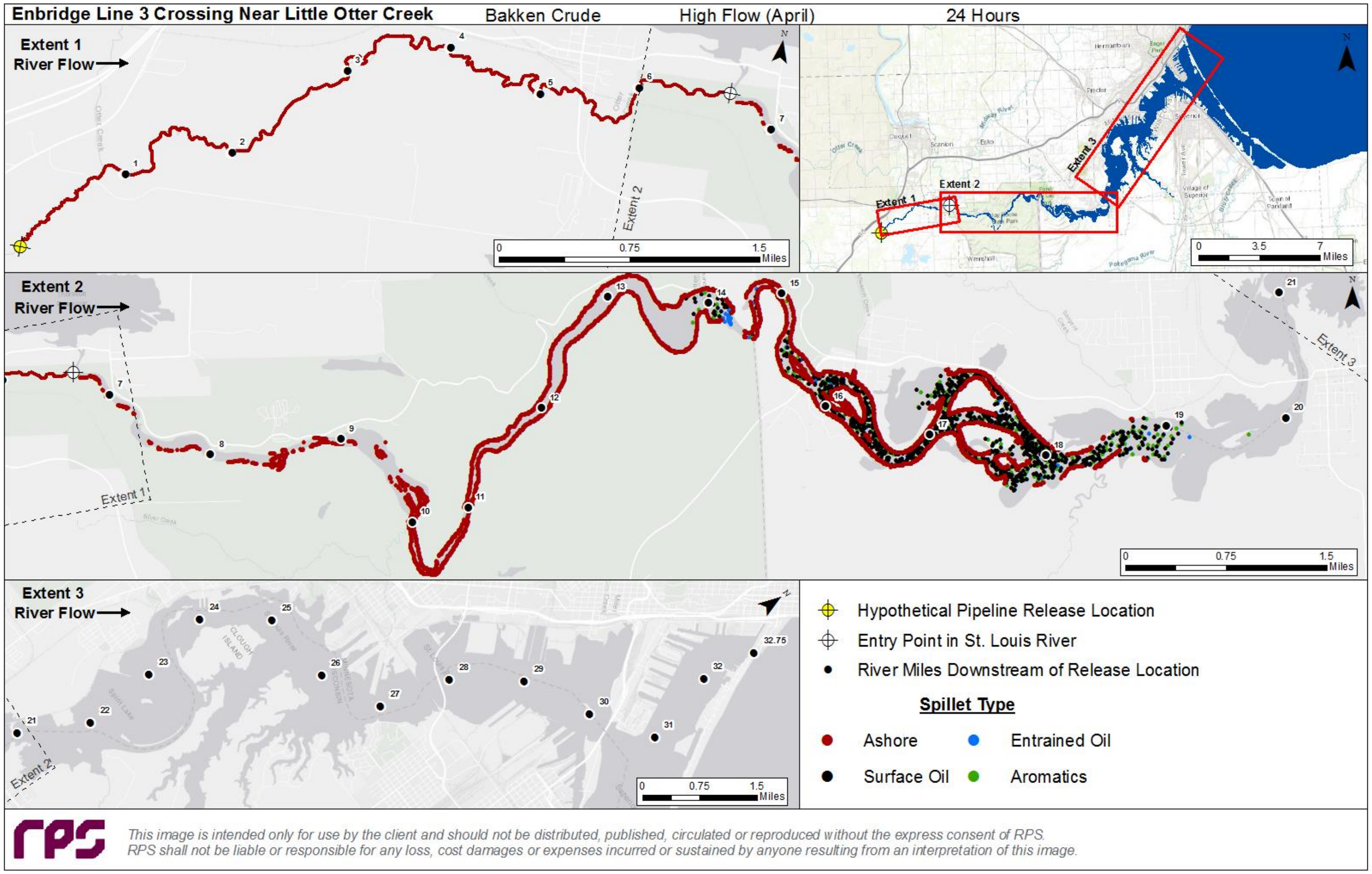

Figure 4-28 Oil Trajectory at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the High Flow (Spring) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

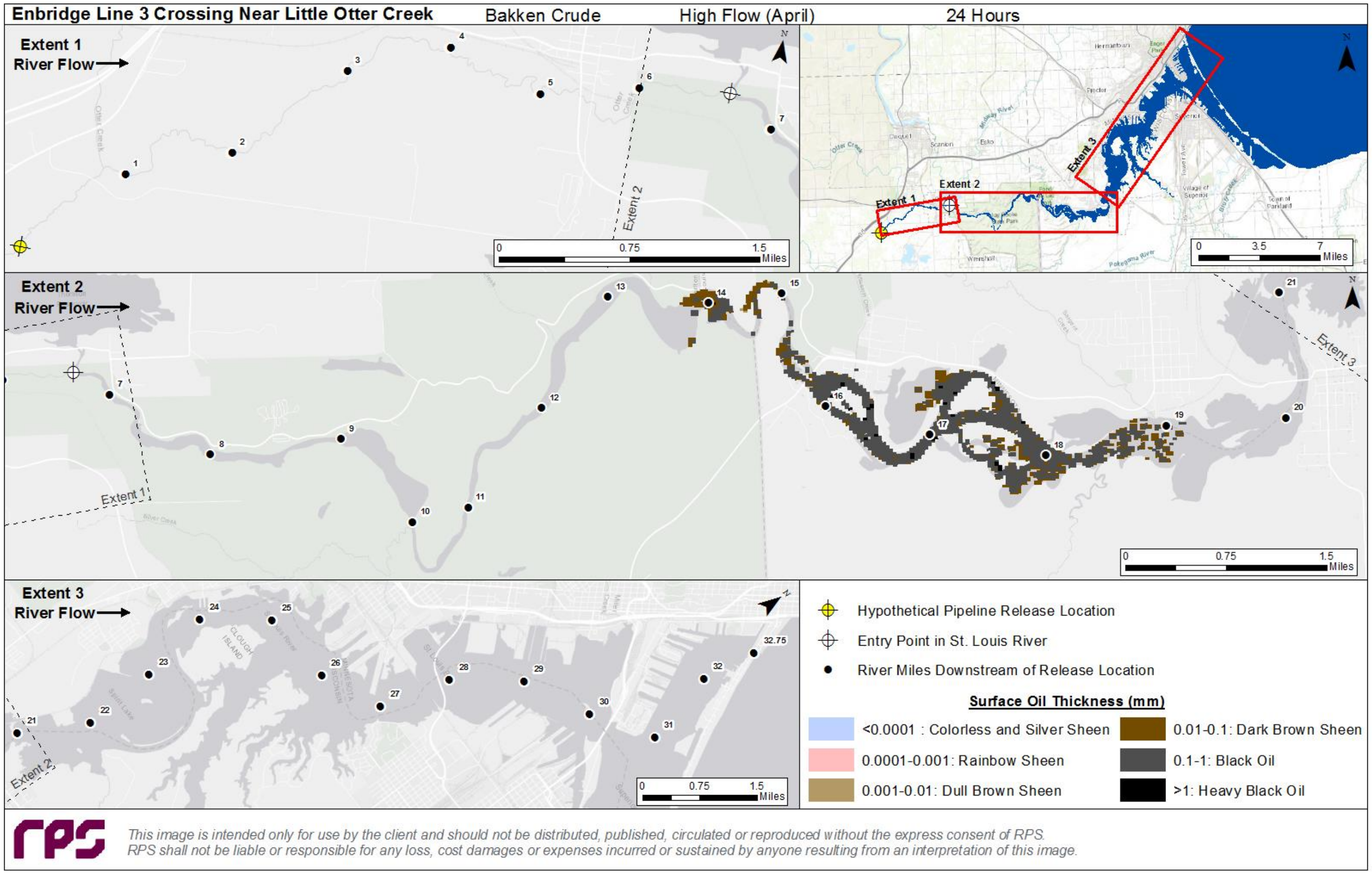

Figure 4-29 Maximum Floating Surface Oil at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location during the High Flow (Spring) Season from SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

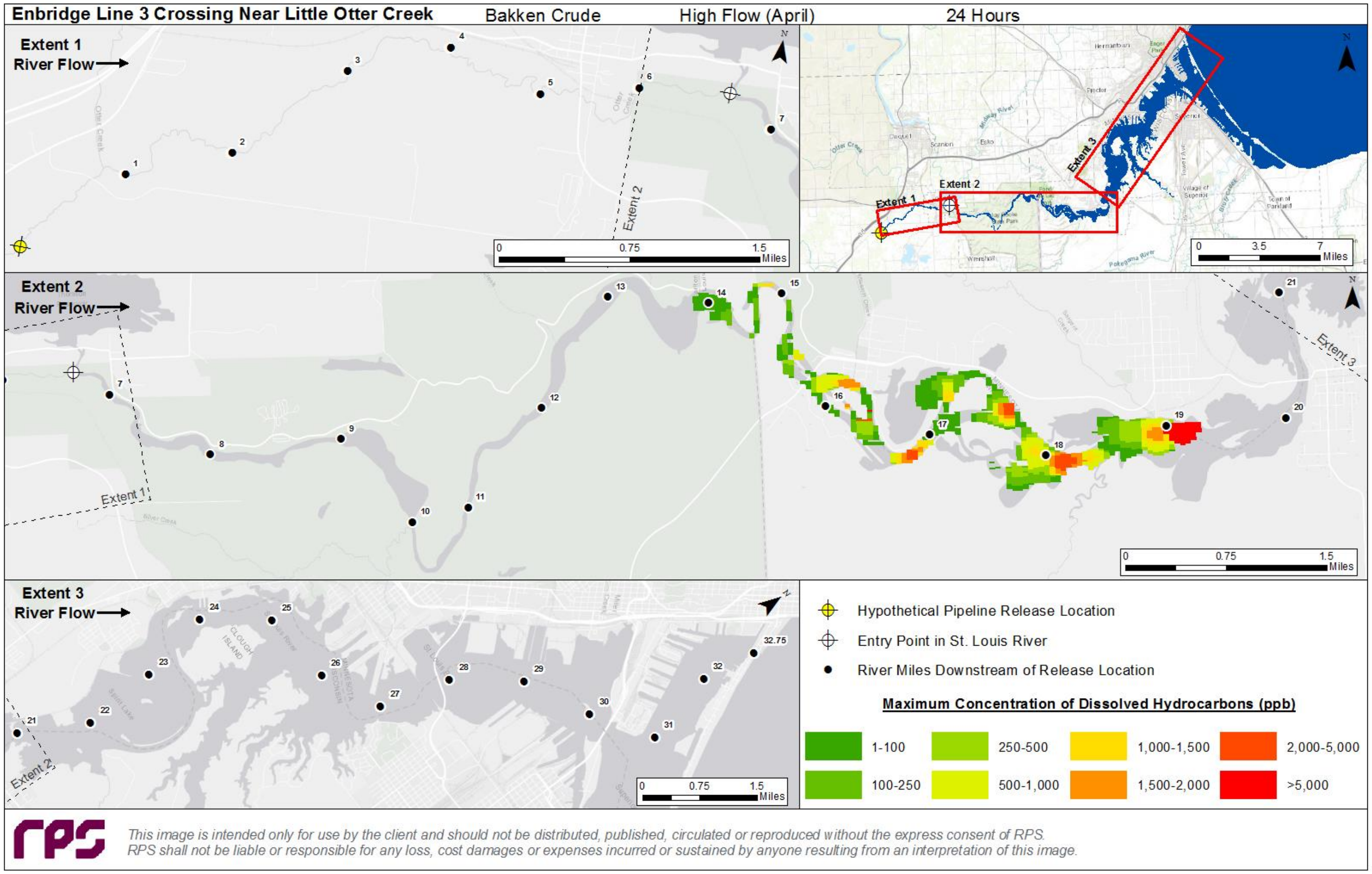

Figure 4-30 Maximum Total Dissolved Hydrocarbon Concentrations at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the High Flow (Spring) Season from SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

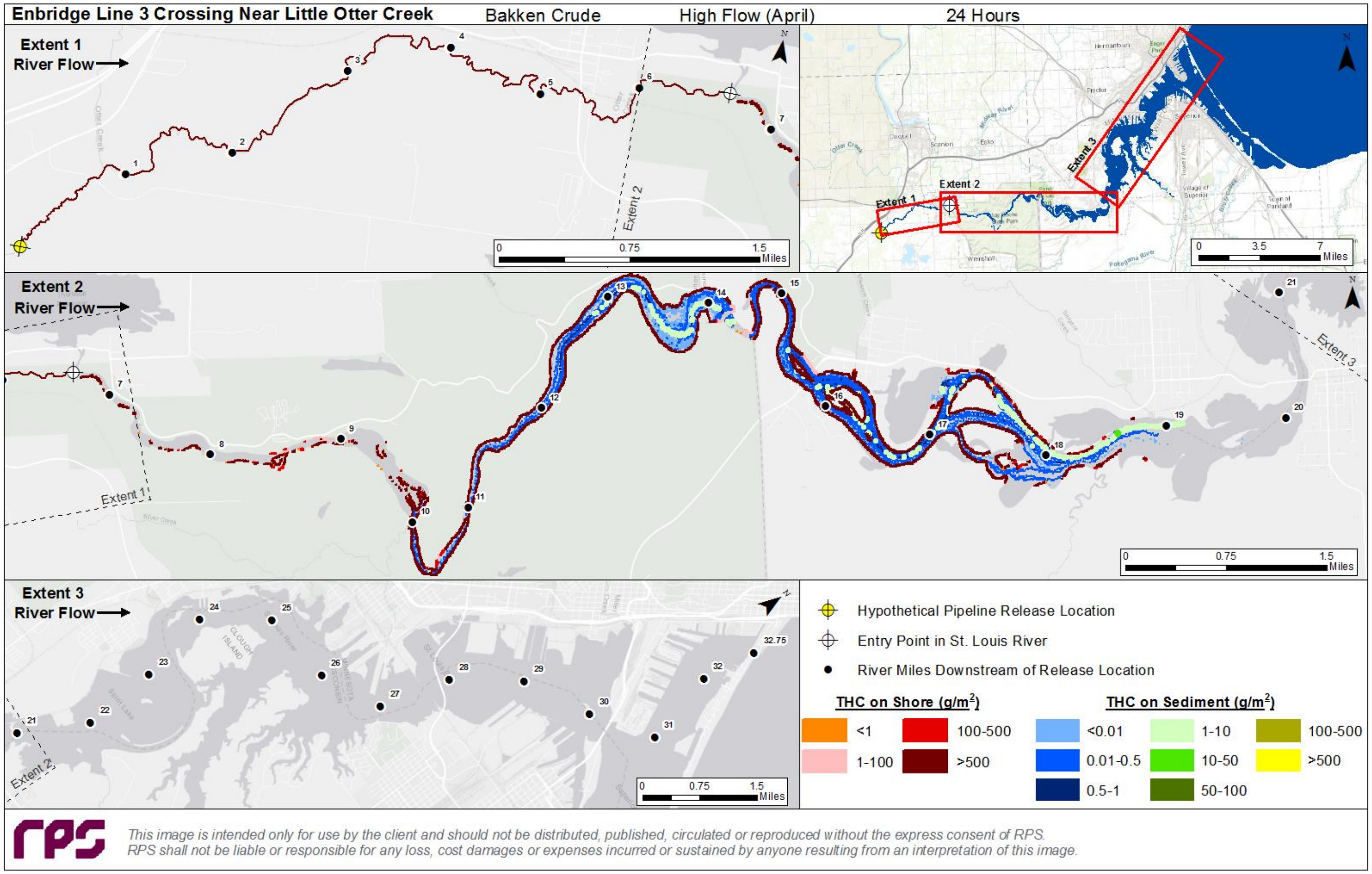

Figure 4-31 Maximum Total Hydrocarbon Mass on the Shore and on Sediments at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the High Flow (Spring) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

4.2.2.2 Trajectory and Fate Results for Average Flow (Summer-Fall)

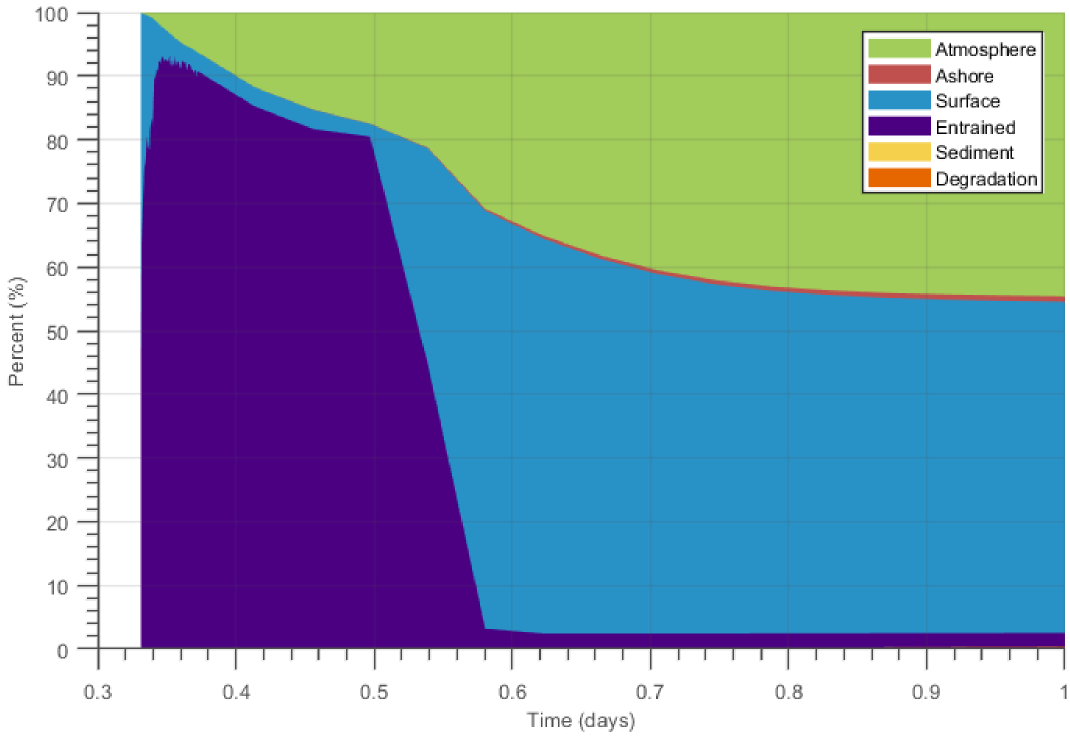

Figure 4-32 Oil Mass Balance Graph from SIMAP for the Release of Bakken Crude at the Little Otter Creek Release Site During the Average Flow (Summer-Fall) Season. Note that the SIMAP simulation begins after the initial release (time zero) as the downstream transport of oil was first modeled within Little Otter Creek and Otter Creek using OILMAPLand. Please refer to Table 4-6 for OILMAPLand mass balance information.

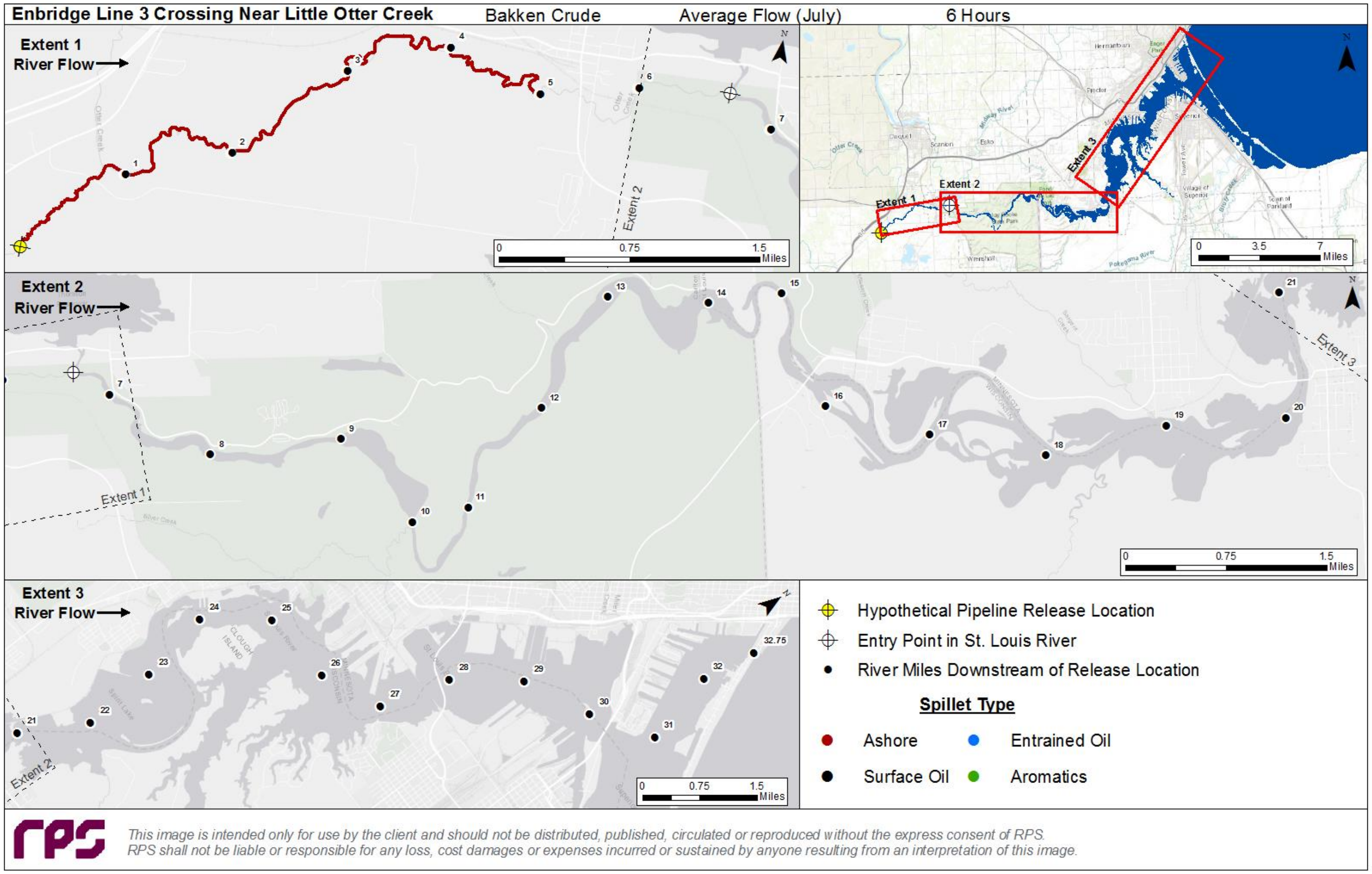

Figure 4-33 Oil Trajectory at 6 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Average Flow (Summer-Fall) Season from SIMAP. Note that all of the oil is still within Little Otter Creek and Otter Creek. Data provided came from OILMAPLand outputs. Points indicate downstream distance (miles) from hypothetical release location.

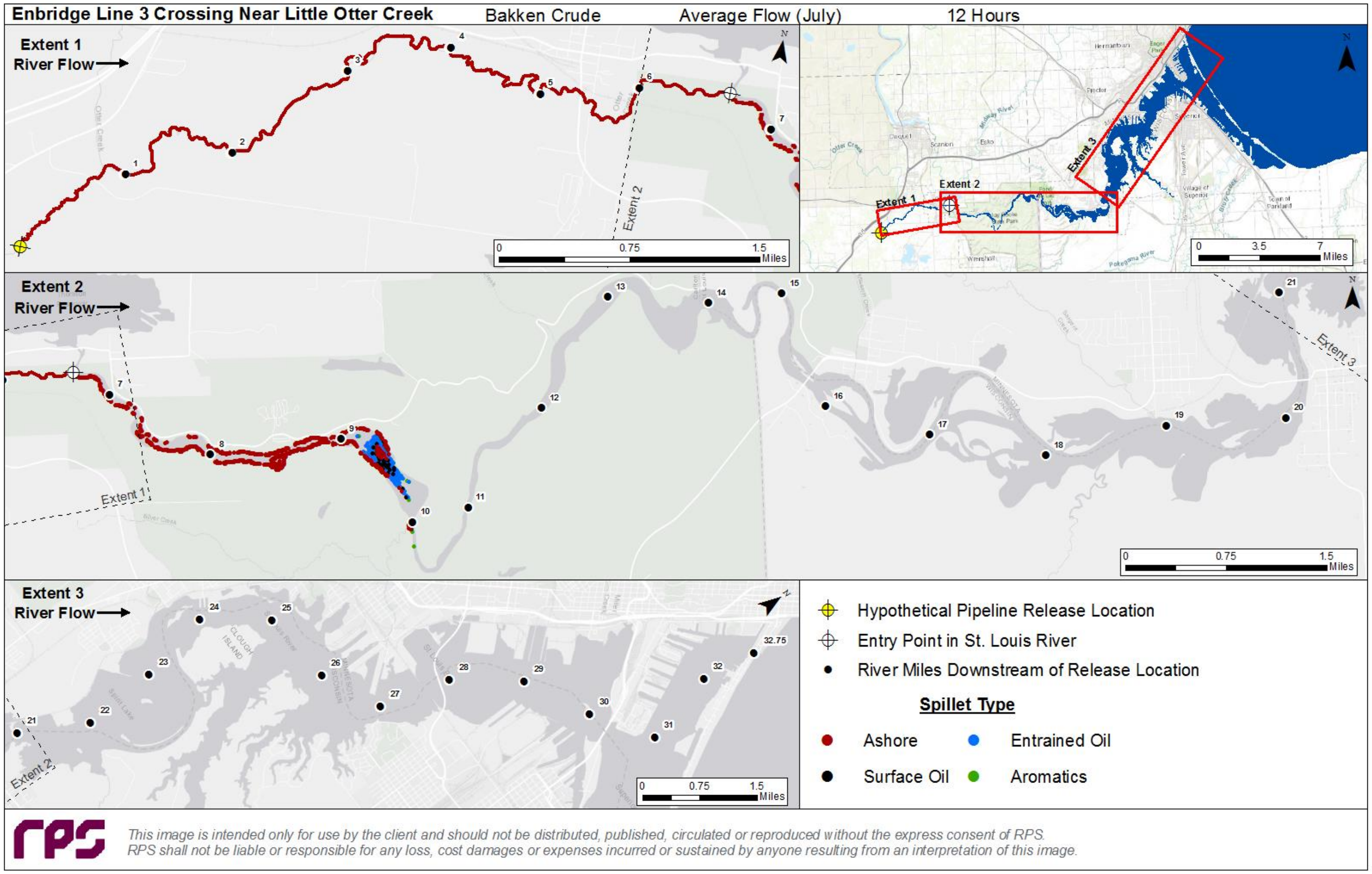

Figure 4-34 Oil Trajectory at 12 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Average Flow (Summer-Fall) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

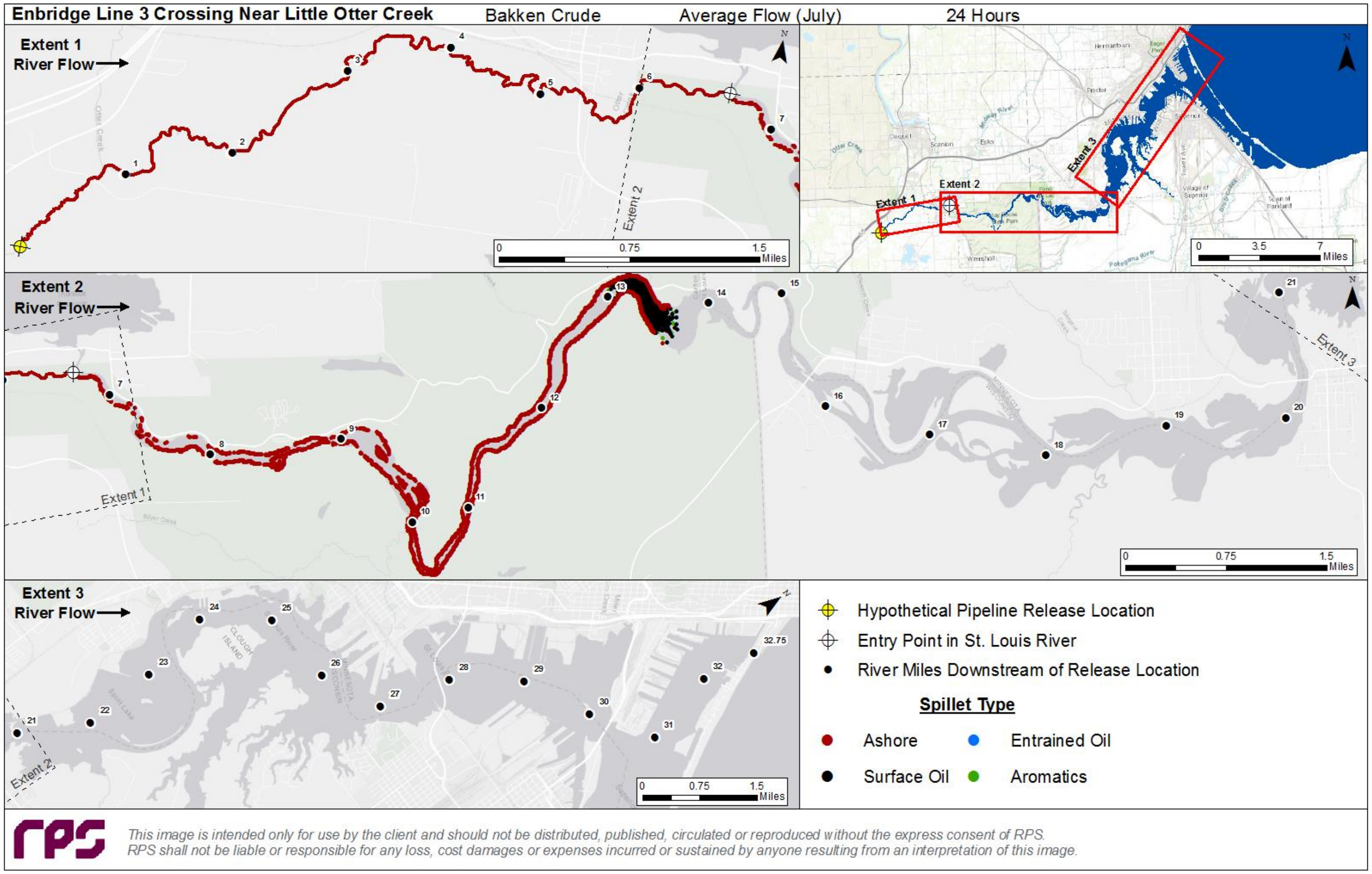

Figure 4-35 Oil trajectory at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Average Flow (Summer-Fall) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

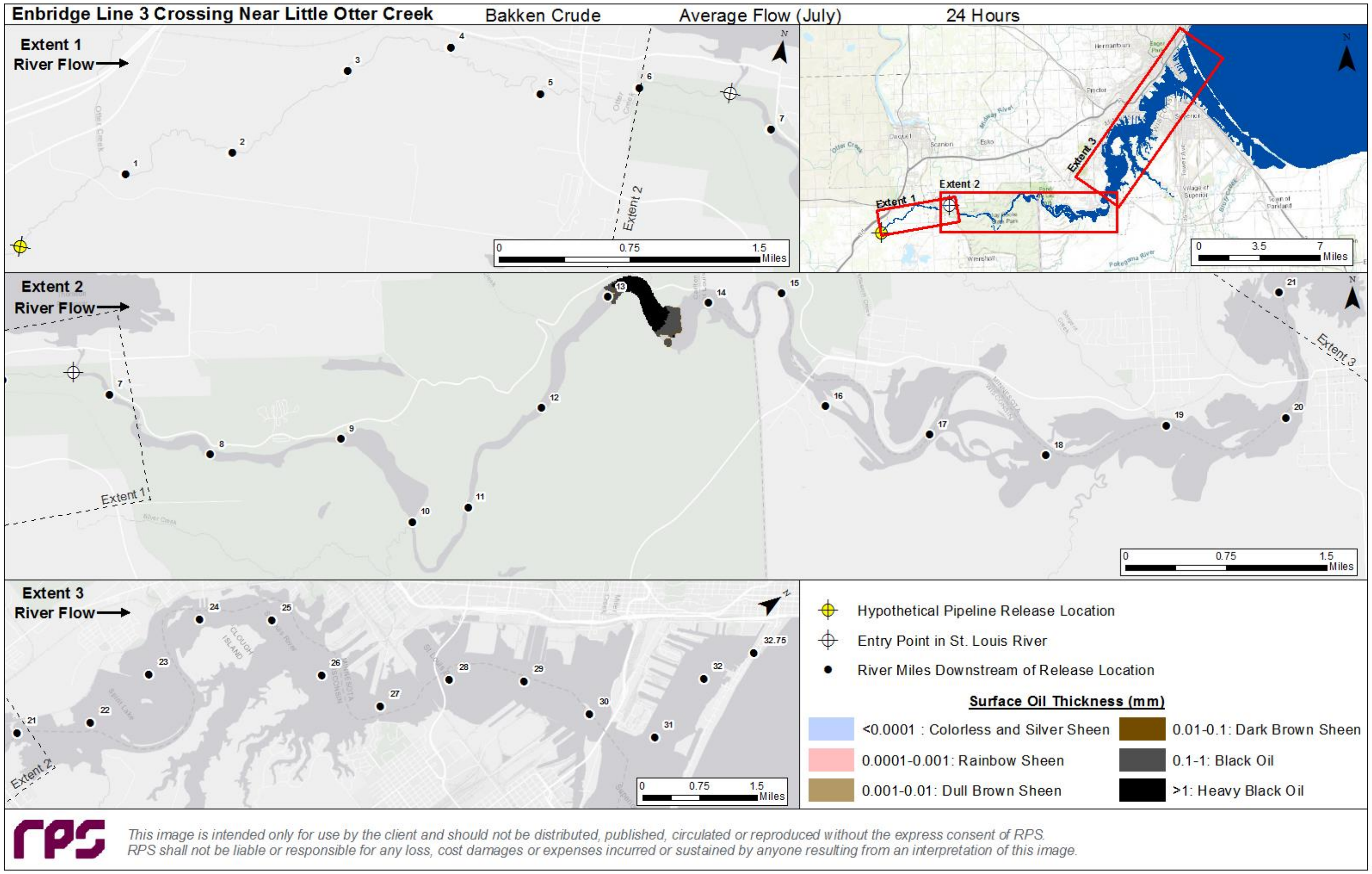

Figure 4-36 Maximum Floating Surface Oil at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Average Flow (Summer-Fall) Season from SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

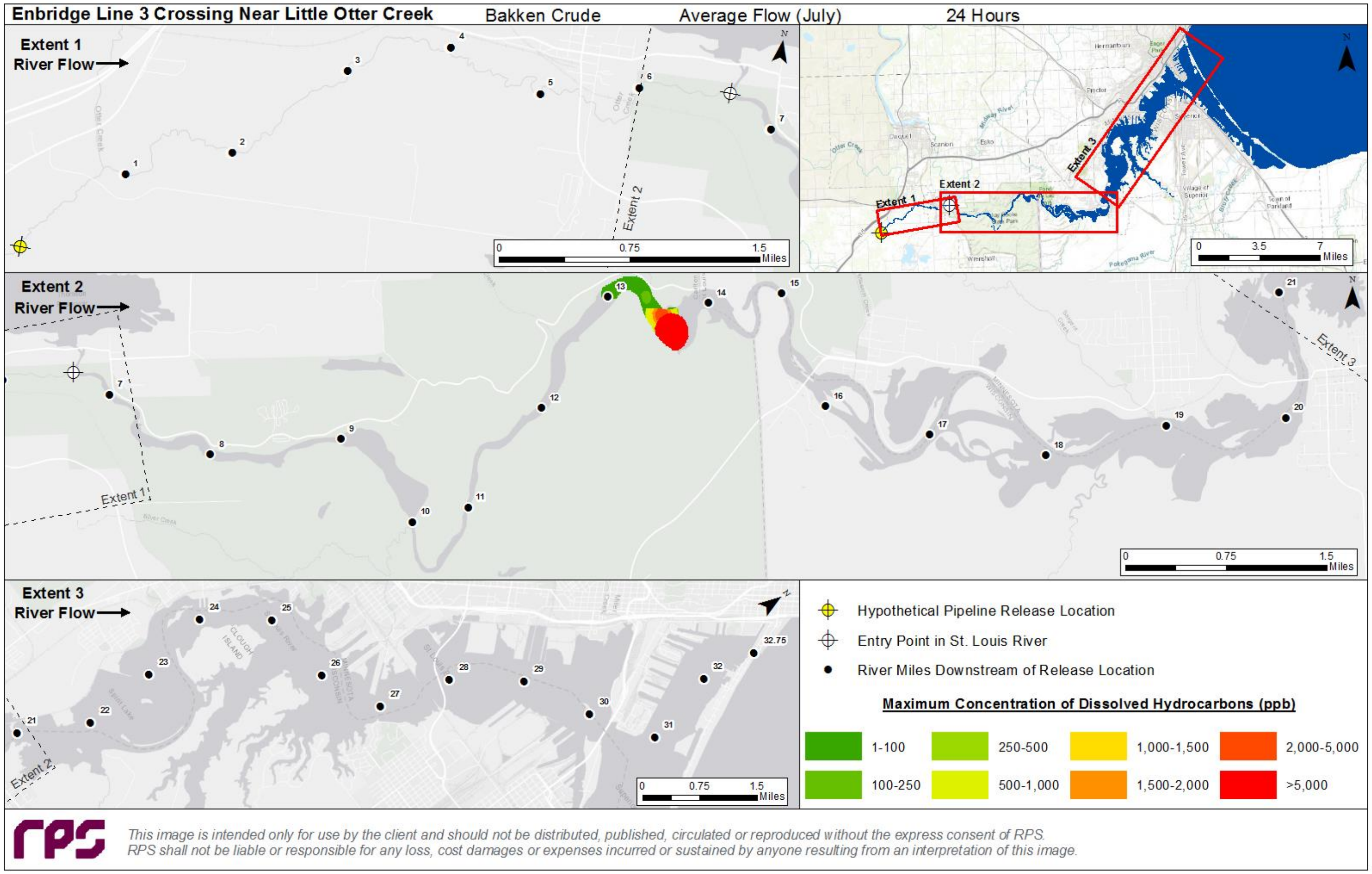

Figure 4-37 Maximum Total Dissolved Hydrocarbon Concentrations at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Average Flow (Summer-Fall) Season from SIMAP. Points indicate downstream distance (miles) from hypothetical release location. Points indicate downstream distance (miles) from hypothetical release location.

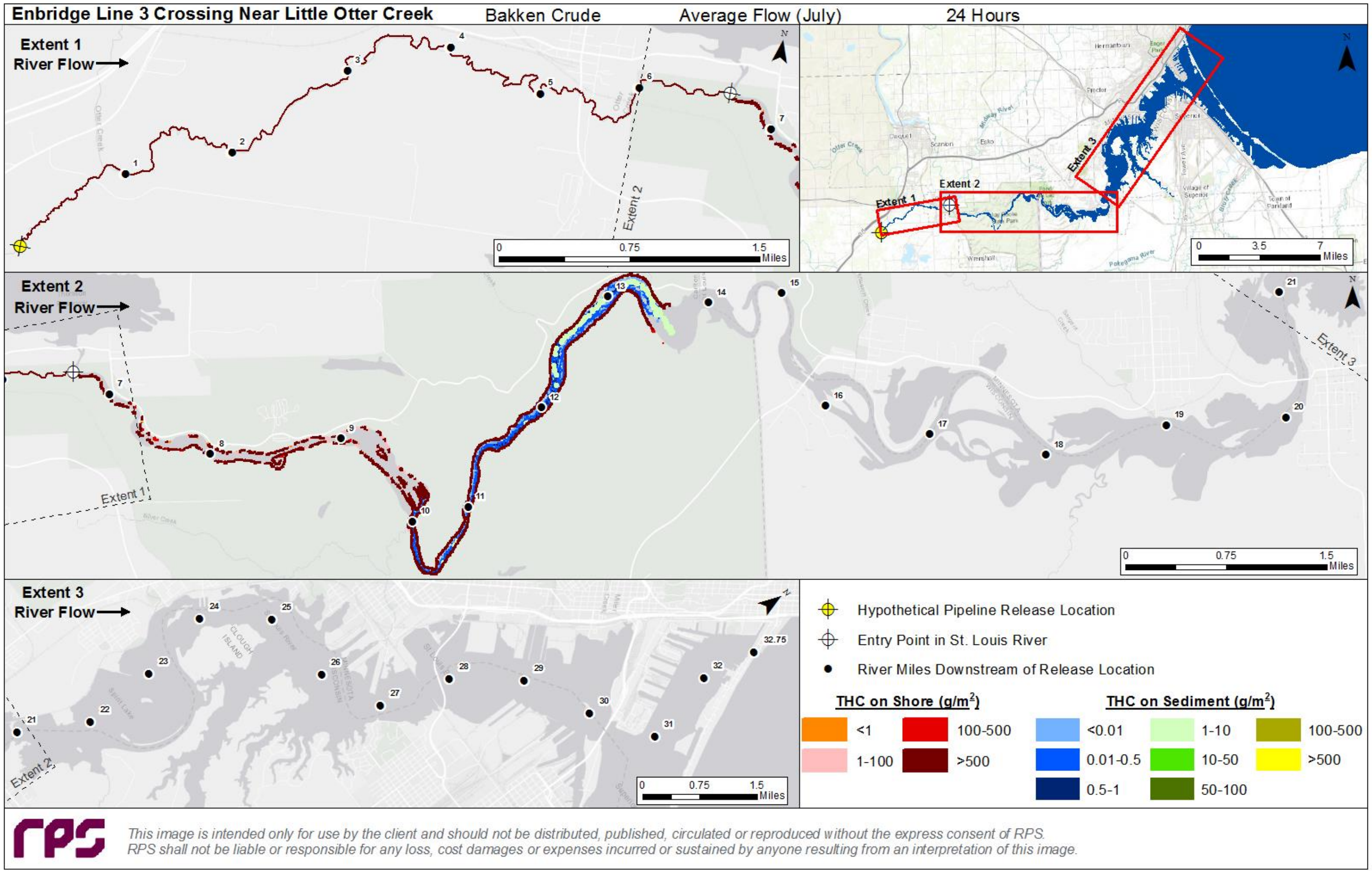

Figure 4-38 Maximum Total Hydrocarbon Mass on the Shore and on Sediments at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Average Flow (Summer-Fall) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

4.2.2.3 Trajectory and Fate Results for Low Flow (Winter)

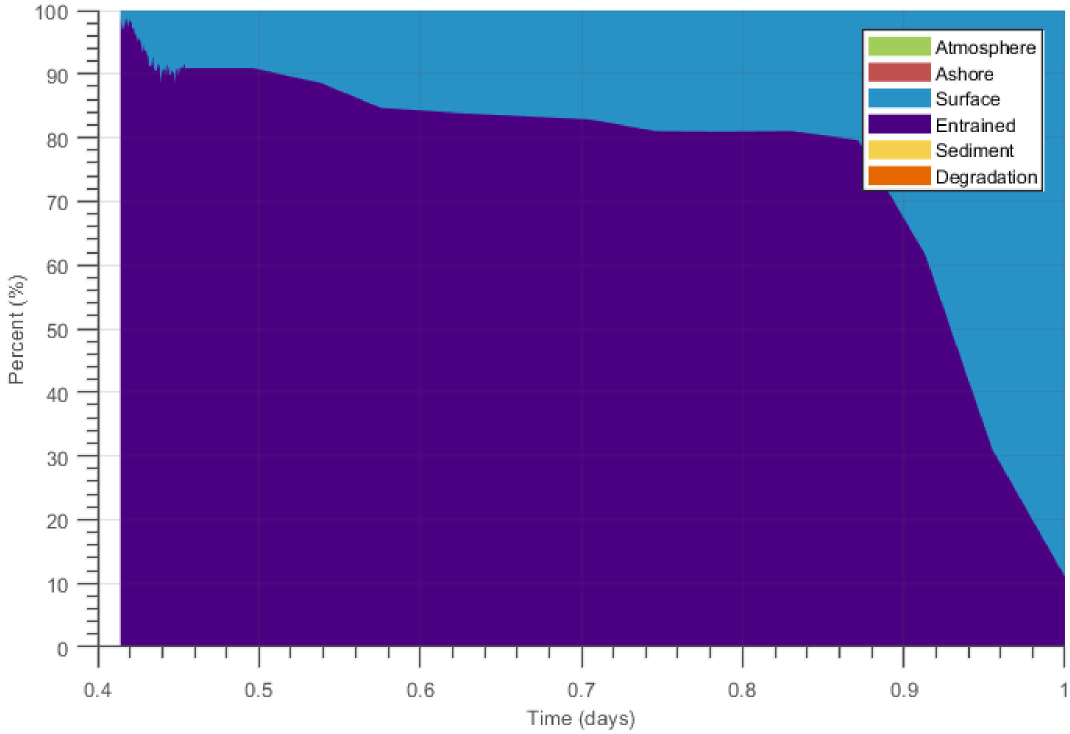

Figure 4-39 Oil Mass Balance Graph from SIMAP for the Release of Bakken Crude at the Little Otter Creek Release Site During the Low Flow (Winter) Season. Note that the SIMAP simulation begins after the initial release (time zero) as the downstream transport of oil was first modeled within Little Otter Creek and Otter Creek using OILMAPLand. Please refer to Table 4-6 for OILMAPLand mass balance information.

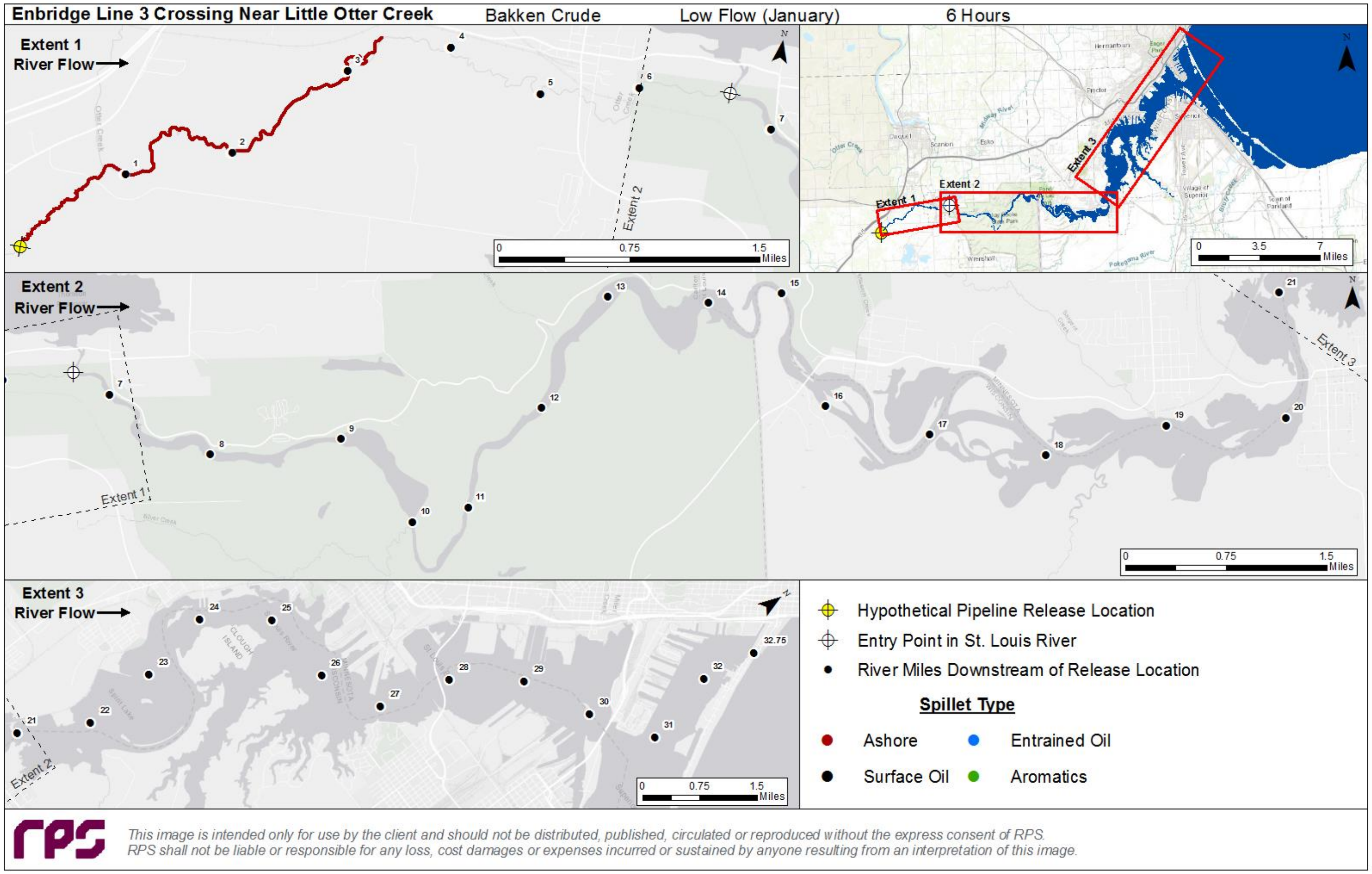

Figure 4-40 Oil Trajectory at 6 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Low Flow (Winter) Season from SIMAP. Note that all of the oil is still within Little Otter Creek and Otter Creek. Data provided came from OILMAPLand outputs. Points indicate downstream distance (miles) from hypothetical release location.

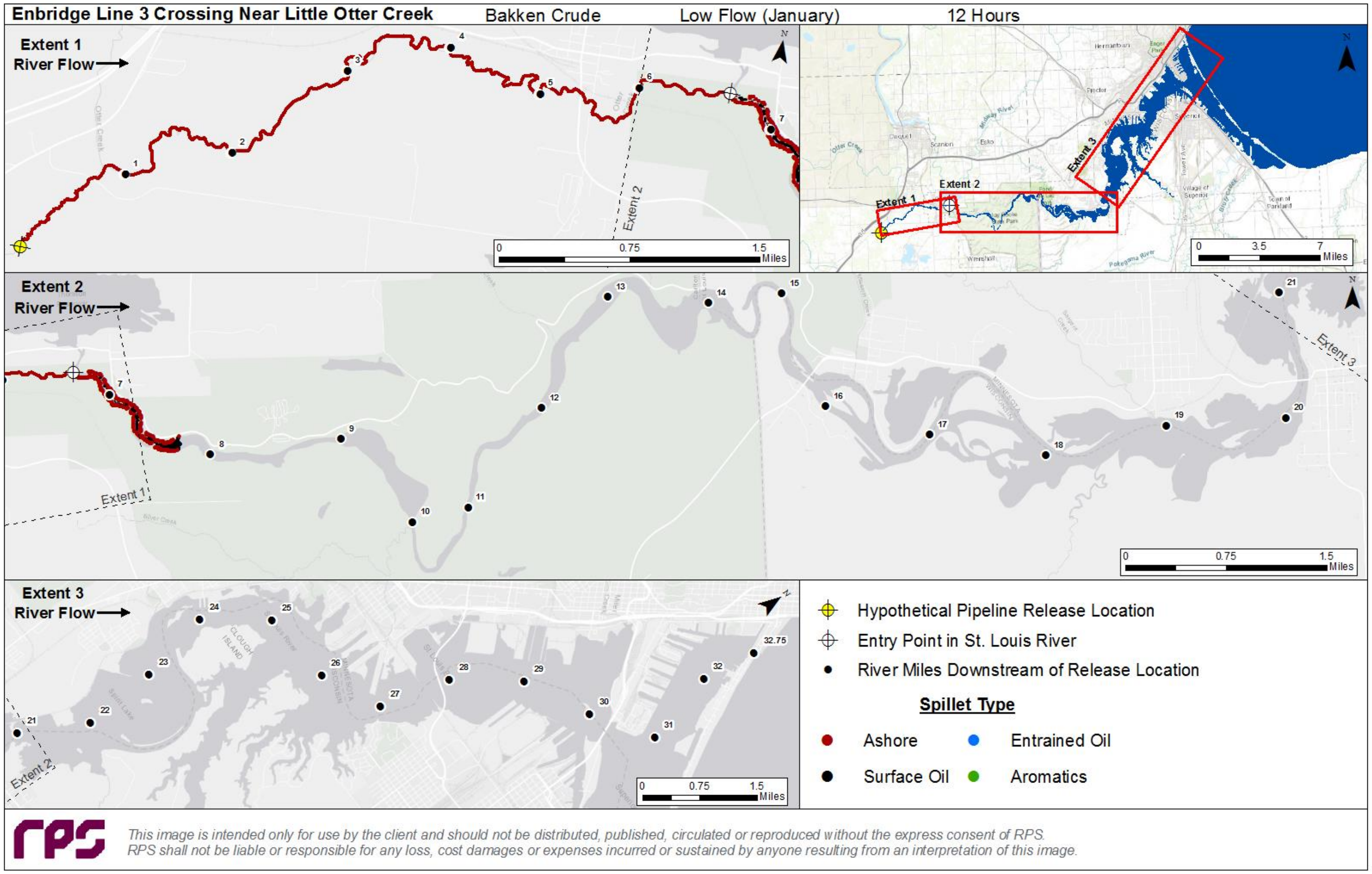

Figure 4-41 Oil Trajectory at 12 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Low Flow (Winter) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

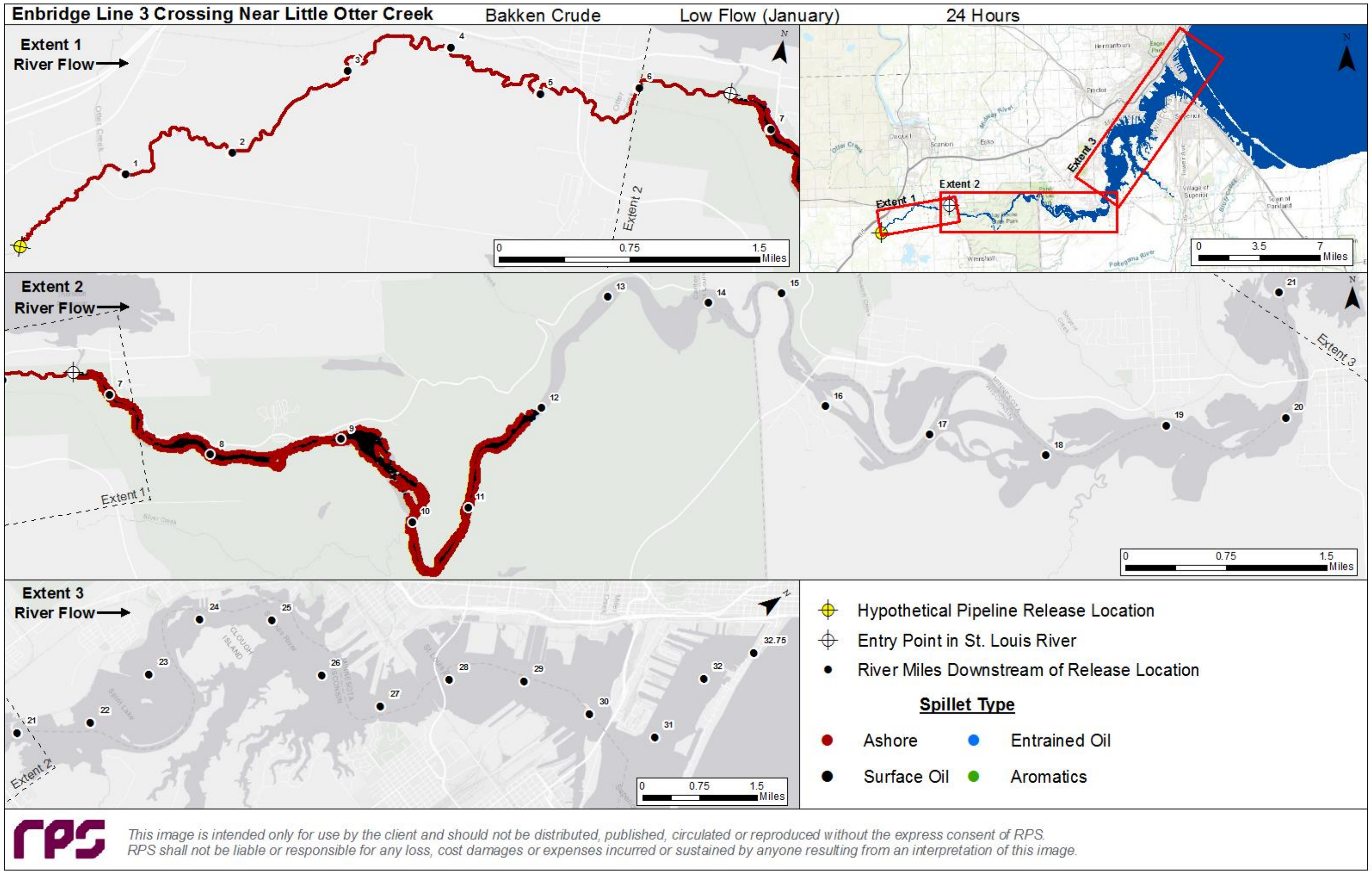

Figure 4-42 Oil Trajectory at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Low Flow (Winter) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

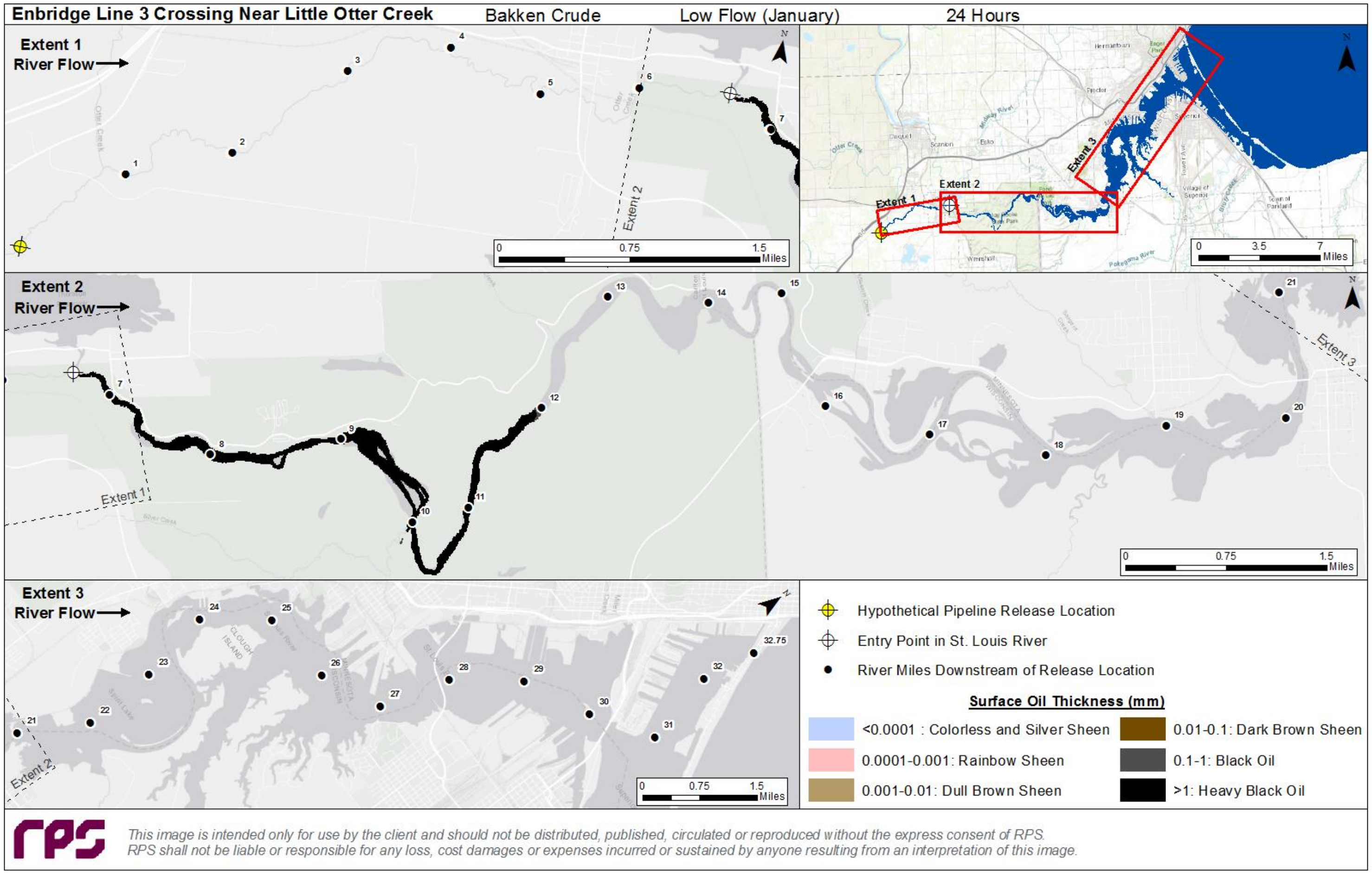

Figure 4-43 Maximum Floating Surface Oil at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Low Flow (Winter) Season from SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

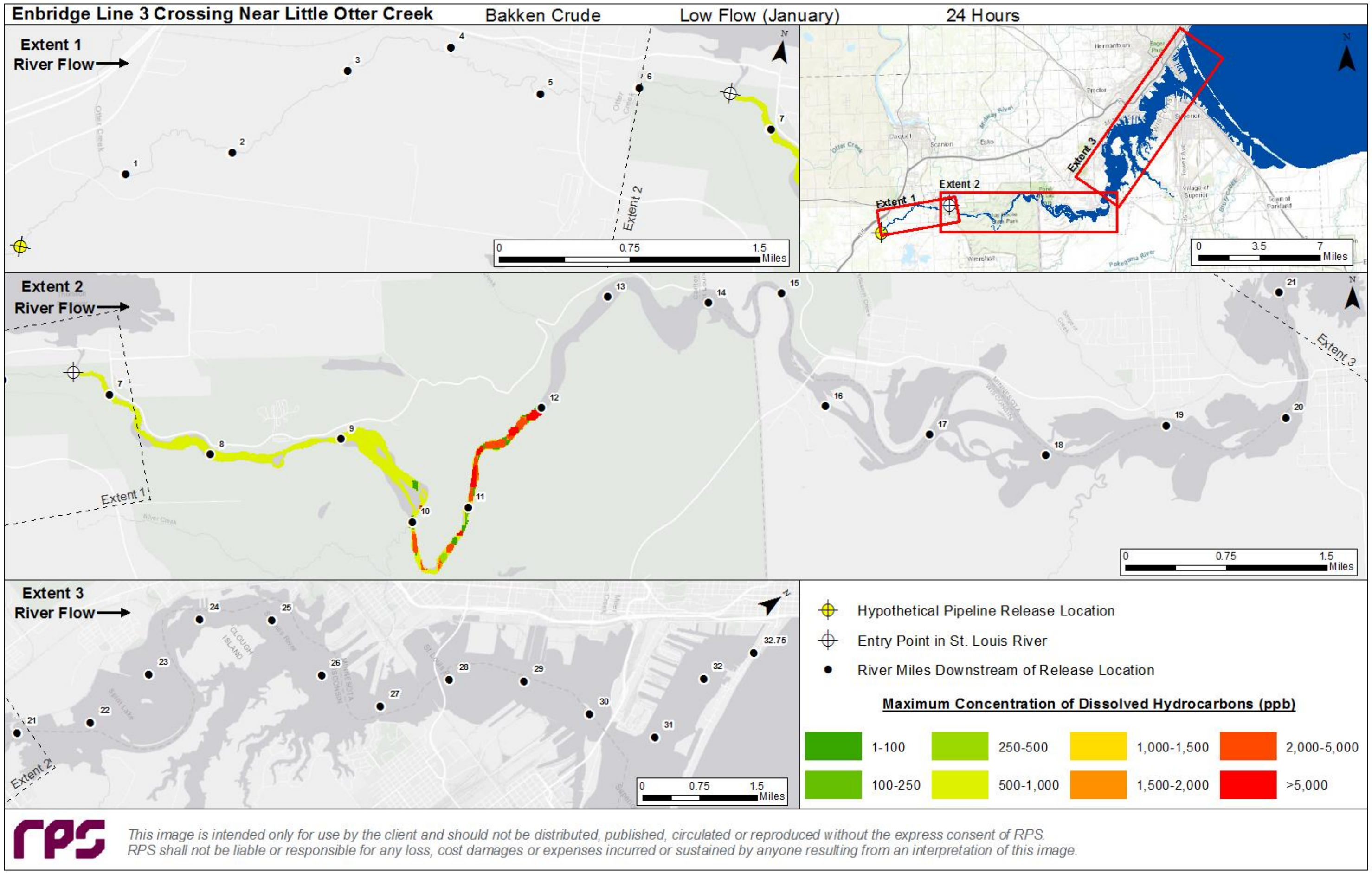

Figure 4-44 Maximum Total Dissolved Hydrocarbon Concentrations at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Low Flow (Winter) Season from SIMAP. Points indicate downstream distance (miles) from hypothetical release location.

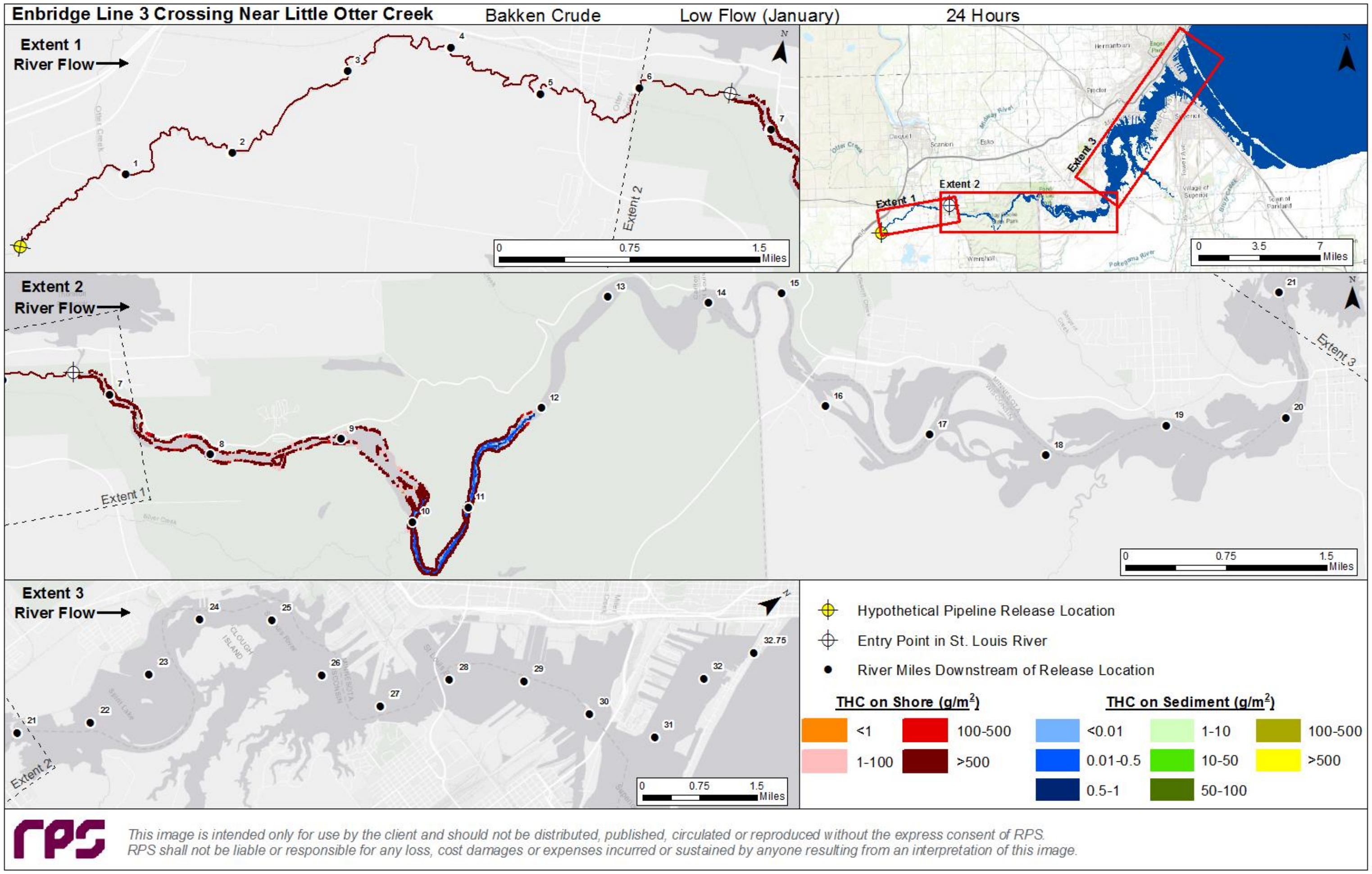

Figure 4-45 Maximum Total Hydrocarbon Mass on the Shore and on Sediments at 24 Hours for the Release of Bakken Crude at the Little Otter Creek Release Location During the Low Flow (Winter) Season from SIMAP. OILMAPLand results for Little Otter Creek and Otter Creek are also provided. Points indicate downstream distance (miles) from hypothetical release location.

4.3 Summary of Trajectory and Fate Results

The Little Otter Creek scenarios represent a small watercourse within the Lake Superior watershed that flows into a larger and more high energy environment (i.e., St. Louis River) that contains rapids, waterfalls, and dams. Ultimately, the release could enter the St. Louis River Estuary (including Spirit Lake and St. Louis and Superior bays) and potentially Lake Superior.

A full bore rupture of 13,007 bbl (2,068 m^3) of either CLB or Bakken Crude oil was simulated. Because Little Otter Creek and Otter Creek are small, low-gradient watercourses, the movement and fate of crude oil entering Little Otter Creek was simulated using the 2-D OILMAPLand model. However, once the oil reached the St. Louis River, modeling was transferred over to the 3-D SIMAP model. While site specific geographic and environmental conditions were used for the modeling, the approach and types of inputs were the same as those used for the other seven representative sites (Stantec et al. 2017).

OILMAPLand was used to simulate the trajectory and fate of oil within Little Otter Creek and Otter Creek during ice-free conditions, with approximately 80% of the CLB and 70-80% of the Bakken predicted to be transported downstream to the point where it entered the St. Louis River. The amount of Bakken predicted to reach the St. Louis River is the result of countervailing processes of enhanced evaporation and lower shoreline retention due to the higher volatility and lower viscosity, respectively, of the Bakken crude oil, compared to CLB. This was apparent with the <2% evaporation predicted for CLB versus approximately 20-25% evaporation predicted for Bakken within the OILMAPLand simulations. In contrast, approximately 20% of the CLB was predicted to be retained on shorelines within Little Otter Creek and Otter Creek, compared with 3% shoreline retention predicted for Bakken. While the rates for each fate process (i.e., evaporation and shoreline retention) were different between the oils, they countered one another and resulted in similar amounts of either oil (1,500-1,600 m^3) ultimately predicted to reach the St. Louis River, under high and average river flow conditions. Under low river flow wintertime conditions with ice cover, more Bakken was predicted to enter the St. Louis River (1,844 m^3) when compared to CLB (820 m^3) due to the thinner equilibrium thickness (and reduced retention) of Bakken under the ice. Under high, average, and low river flow conditions, both CLB and Bakken oil were predicted to reach the St. Louis River at hour 6.12, 7.93, and 9.92 following the release.

SIMAP was used to simulate the trajectory and fate of oil within the St. Louis River down to the estuary (including Spirit Lake, St. Louis and Superior bays) and ultimately Lake Superior. During ice-free conditions, approximately 60-80% of the CLB release was predicted to be on the water surface after 24 hours, versus only 40-50% of the Bakken release. This was due to the enhanced evaporation of Bakken Crude oil, compared to CLB. Under high river flow conditions, less oil was predicted to remain on the surface after 24 hours due to the larger amount of oil retained on shorelines (i.e., further downstream transport resulted in more shoreline oiling) and the larger surface area over which evaporation would occur. In general, CLB was predicted to result in larger amounts on oil retained on shorelines due to its higher viscosity when compared to Bakken. In general, increased viscosity results in thicker deposition of oil on shorelines per square meter. In addition, the lower volatile content of CLB reduces the potential evaporation when compared to the Bakken crude oil. Under average river flow conditions, shoreline retention within the St. Louis River was predicted to account for only 1% of the released Bakken and 2% for CLB after 24 hours due to the relatively narrow (10 cm) width over which oil may adhere to the shorelines. However, under high river flow conditions in the St. Louis River, a wider shore width (approximately 1 m) increased retention and resulted in approximately 13% of the released Bakken and 18% of the CLB predicted on shorelines after 24 hours.

In general, river flow conditions are the largest influence of the timing and extent of downstream transport. High river flow conditions resulted in the most rapid downstream transport and furthest potential extent for the simulated releases within the modeled 24 hour period (Table 4-7). None of the simulations for either type of oil under any of the three seasonal conditions resulted in oil reaching Spirit Lake or entering Lake Superior. Slight differences in the downstream extent between the CLB and the Bakken (Table 3-7) are likely the result of the enhanced evaporation of the Bakken crude oil, due to its increased volatility. The visual appearances of floating surface oil thicknesses within the St. Louis River were predominantly heavy black oil (>1 mm) for CLB and dark brown sheens (0.01-0.1 mm) and black oil (0.1-1 mm) for Bakken. Due to advection and dispersion within the river, surface oil was predicted to pass each region in a matter of hours and became increasingly more patchy and discontinuous with thinner oil in the upstream portions as the oil continued to move further downstream. Relatively continuous oiling of shorelines was predicted for each of the simulated releases under ice-free conditions, with concentrations exceeding 500 g/m^2 for CLB and ranging between 100-500 g/m^2 for Bakken, with localized patches above 500 g/m^2. Under high river flow conditions, shoreline oiling was predicted to extend downstream as far as 20 miles (32.2 km) within 24 hours, terminating above Spirit Lake. Under average river flow conditions, shoreline oiling was predicted to extend downstream for 13.7 miles (22.0 km), with oil terminating above the Fond du Lac Dam.

Table 4-7 Maximum Downstream Distance (miles) Oil is Predicted to be Transported at the End of the 24-hour Simulations.

Location	Oil Type	Season / River Flow		
		Low	Average	High
Little Otter Creek to St. Louis River and Estuary	Bakken Crude	12.0	13.7	19.7
	CLB	8.2	13.7	20.0

The presence of rapids, waterfalls, and dams within the St. Louis River influenced the fate of the released oil within each simulation. Enhanced turbulence and mixing within these high energy environments resulted in the entrainment of surface oil into the water column. Large amounts of oil were predicted to entrain into the water column (>80% of the simulated release) throughout the roughly 4 miles of rapids below the Thomson Dam through Jay Cooke State Park. While oil was predicted to re-surface in the quiescent waters above the Fond du Lac Dam, large amounts of oil were predicted to re-entrain into the water column as the oil and water passed over the Fond du Lac Dam, with a drop of approximately 78 feet. While oil droplets were predicted to resurface in quiescent reaches of the river below each turbulent section, soluble portions of the oil were predicted to dissolve into the water column during each entrainment event. Maximum total dissolved hydrocarbon concentrations are predicted to be greatest near the leading edge of the release, where entrained oil droplets and surface slicks have had a chance to become dissolved into the water column. For each model run, dissolved hydrocarbons are likely to exceed 5,000 ppb within much of the river, as an instantaneous maximum over 24 hours. However, peak concentrations typically pass quickly (minutes to hours) followed by larger regions of water predicted to experience dissolved hydrocarbon concentrations at lower levels. In general, dissolved hydrocarbon concentrations within the water column were predicted to be <100 ppb for CLB and <250 ppb for Bakken scenarios under average and high river flow conditions. Higher in water concentrations of dissolved hydrocarbons combined were predicted over larger areas, resulting in longer predicted durations of exposure for Bakken Crude oil due to the higher soluble content of Bakken. Highest dissolved hydrocarbons concentrations in ice free conditions were predicted in the quiescent waters immediately downstream of the rapids, behind the Fond du Lac Dam, with concentrations in the >5,000 ppb range within the surface meter or two.

Sediment oiling was predominantly predicted under high and average river flow conditions. During these conditions, suspended sediment concentrations within the water column were elevated and energy levels were sufficient to disperse oil throughout the water column, thus increasing the potential for the formation of oil particle aggregates. As energy levels within the water column decrease in quiescent waters below regions of enhanced mixing (i.e., below rapids, waterfalls, dams), the oil-particle aggregates would no longer remain in suspension, and some of the oil-particle aggregates would be expected to sink to the river bed. Under average river flow conditions, sediment oiling was predicted between mile 11.0-13.5 (17.7 to 21.7 km) for both CLB and Bakken after 24 hours. Due to the increased velocity and downstream transport under high river flow conditions, sediment oiling was predicted between mile 12-20 (19.3 to 32.2 km). In general, total hydrocarbon concentrations were <0.5 g/m^2 under average and high river flow conditions for both oils. Highest predicted concentrations of total hydrocarbons on sediments occurred below the rapids and above the Fond du Lac Dam between river mile 12-14, and again from river mile 16-19 following the additional round of mixing as the oil was transported over the Fond du Lac Dam. Localized pockets of oil on sediments were as high as 10 g/m^2 for Bakken crude oil and >500 g/m^2 for CLB. Highest sediment concentrations occurred during high river flow conditions, with higher suspended sediment, with 0.3% of the total release volume predicted on sediments for CLB and <0.01% for Bakken. In general, Bakken was predicted to result in slightly more uniform sediment oiling at lower levels due to its low viscosity and higher potential to form smaller droplets, while CLB was predicted to result in slightly more patchy sediment oil at higher levels.

For the low river flow scenarios, with an assumed 100% ice cover, all of the oil was predicted to remain trapped beneath the ice. Oil was predicted to either be in the water column or on the “surface,” where it was trapped at the water-ice interface. Evaporation was assumed to be negligible (due to ice cover), which enhanced the dissolution of a portion of the volatile fraction that was soluble and resulted in elevated concentrations of dissolved hydrocarbons within the water column. Whole oil was predicted to extend downstream to 8.2 miles (13.2 km) below the release location for CLB at a continuous thickness of 0.4 inches (1.06 cm) at the ice-water interface by the end of the 24-hour simulation. The predicted extent for Bakken was greater, due to the thinner equilibrium thickness of 0.07 inches (0.19 cm) resulting in whole oil at the ice-water interface down to 12 miles (19.3 km) from the hypothetical release location.

For low river flow scenarios, while the whole oil fraction remained trapped under the ice, the soluble portion of hydrocarbons was free to move downstream within the water as a dissolved fraction. Concentrations exceeding 5,000 ppb are likely near the leading edge of the plume, which is transported downstream approximately 11.5 miles (18.5 km) within the 24-hour model simulation. However, concentrations were predominantly 500-750 ppb for CLB and 750-1,000 ppb for Bakken in the waters below the trapped oil and upstream of the leading edge. This higher concentration for Bakken is the result of a higher fraction of soluble compounds, when compared to CLB. Very limited shoreline and sediment oiling was predicted to occur during low river flow scenarios due to the low sediment load, reduced mixing in the water column, and ice shorelines during wintertime conditions.

4.4 Estimated Likelihood of a Large Release of Crude Oil

The primary purpose of this addendum to the AAR (Stantec et al. 2017) is to provide quantitative and qualitative information regarding the risk of a crude oil release from the proposed L3RP within the Lake Superior watershed. Risk is defined most concisely as the “chance of loss”. Accordingly, in the context of the risk associated with the operation of the L3RP pipeline, the term “risk” is used as a joint expression of chance (the annual probability of incurring a full bore rupture in the L3RP pipeline), and loss (the consequences associated with such a rupture). The failure frequency analysis (Stantec et al. 2017, Chapter 4) focused on identifying potential threats for the seven representative sites along the proposed L3RP pipeline. For those threats that have the potential to contribute to the overall failure probability at each representative site, the annual probability (frequency) that a large release of crude oil will occur was assessed. In general, the probability of failure was directly related to the total length of the pipeline segment that may affect each watercourse crossing. In this addendum to the AAR, rather than carrying out the probability analysis (as was done in the AAR), the total segment length was quantified and compared to the other lengths for the previously modeled seven representative sites, without the quantitative assessment of probability.

To address the probability of a large crude oil release, quantitative estimates of total segment length that could be used to determine rupture frequency were assessed at the Little Otter Creek site. This approach is identical to that used in the previous study (Sections 4.1 and 9.1; Stantec et al. 2017). In linear infrastructure such as pipelines, the probability of failure over a given time period is proportional to segment length, with longer segments being associated with greater probabilities. Therefore, given that this representative site is associated with the crossing of a waterway, the length of the pipeline segment that was considered in this analysis was established through a high-resolution outflow and overland spill modeling assessment for the Little Otter Creek crossing. Full-bore rupture release scenarios were modeled in OILMAPLand as multiple individual releases at intervals of 32.8 ft (10 m) inland from each side of each river crossing. The OILMAPLand model characterized site-specific local topography and land cover using a release volume specific to each hypothetical failure point to determine whether released oil might reach the water body by means of overland flow. The length of pipeline defined by endpoints located inland from each riverbank, over which the oil released from a hypothetical full bore rupture could impact the water body (either directly, or by means of overland flow), was termed the “potential impact segment”. The total length of the potential impact segment is provided (Table 4-8). The segment length at Little Otter Creek is slightly longer than other sites, implying that it is likely to be a slightly more probable event but of the order of 10^{-06} per year (Stantec et al. 2017). Having established the potential impact segment at each of the eight representative sites, quantitative estimates of rupture frequency for these segments can be made, similar to those conducted in Section 4.1 of Stantec et al. 2017. However, the quantitative estimation of failure probability from segment length has not been made in this addendum. Note that the volume of oil entering Little Otter Creek modeled within this addendum would be a credible maximum, as the entire full bore rupture was assumed to enter the watercourse. Should the release occur on land, the volume entering the watercourse would be lower at increasing distance from the watercourse, due to lower drain-down volumes, retention of some of the released crude oil on the land surface, and evaporation before reaching the watercourse. Having established the potential impact segment at each of the eight representative sites, quantitative estimates of rupture frequency for these segments can be made.

Table 4-8 Total Pipeline Segment Length (ft) with Potential to Enter the Identified Watercourse Crossing.

Site	Total Pipeline Segment Length (ft)
Site 1: Mosquito Creek Crossing	1,824.83
Site 2: Mississippi River at Ball Club	207.379
Site 3: Sandy River Crossing	1,151.11
Site 4: Shell River Crossing	2,543.00
Site 5: Red River Crossing	1,587.92
Site 6: Mississippi River at Palisade	1,469.92
Site 7: Mississippi River at Little Falls	1,311.20
Site 8: Little Otter Creek to St. Louis River and Estuary	2,985.56

5 ASSESSMENT OF ENVIRONMENTAL EFFECTS OF OIL RELEASES

This Chapter describes the potential environmental effects of hypothetical crude oil releases at the proposed pipeline crossing of Little Otter Creek, in the Lake Superior watershed, near the communities of Cloquet and Carlton, Minnesota, about 21 miles (34 km) southwest of Duluth.

The information provided here is intended to supplement information and technical analysis previously provided to DOC-EERA as the AAR technical report (Stantec et al. 2017). The AAR technical report described potential consequences of hypothetical large volume crude oil spill scenarios at seven representative sites that were representative of the range of environmental conditions likely to be encountered along the preferred and alternative pipeline routes through Minnesota.

The AAR technical report (Stantec et al. 2017, Section 7.1) included a detailed review of the observed and expected effects of actual crude oil releases on key ecological and human receptor types. That review will not be repeated here but will be relied upon by reference as required. The review considered crude oil characteristics (Stantec et al. 2017; Section 7.1.1.1), with a Bakken-type crude oil being selected as representative of the light-end of the crude oil spectrum, and CLB/CLWB crude oils (depending upon the season) being selected as representative of heavier diluted bitumen types. The effects of season and physical factors (e.g., spreading, evaporation, dispersion, dissolution, sinking) on the fate of released crude oil were assessed in Sections 7.1.1.2 and 7.1.1.3.

The effects of crude oil spills on various ecological receptors were reviewed by Stantec et al. (2017) in Sections 7.1.2 and 7.1.3 of the AAR technical report. These were classified as being Land Cover Receptors (e.g., air quality, groundwater, lakes, rivers, sediments, shoreline and riparian bank habitats, wetlands, terrestrial soils) or Biological Receptors (e.g., terrestrial vegetation, benthic invertebrates, fish, aquatic plants, amphibians and reptiles, birds, and mammals). In addition, Section 7.1.4 of Stantec et al. (2017) addressed the effects of crude oil spills on Human Receptors (including human health, and land resource use, including historical or cultural sites and cultural use of resources by tribal members). For each receptor type, the available information from actual crude oil spills was integrated and synthesized to relate potential environmental effects to crude oil properties, the environmental setting, and the season when a release might occur. This information provided a template for predicting potential environmental effects of various hypothetical crude oil spill scenarios at the seven representative sites in Minnesota. The same process will be applied to the prediction of potential environmental effects of crude oil spill scenarios for the Little Otter Creek pipeline crossing site in the Lake Superior watershed.

5.1 EXPECTED ENVIRONMENTAL EFFECTS OF LARGE RELEASES OF CRUDE OIL NEAR LITTLE OTTER CREEK

The proposed pipeline is expected to cross Little Otter Creek approximately 0.8 miles southeast of Highway 35, and 0.4 miles southeast of Road 61, about midway between the communities of Otter Creek and Cloquet/Scanlon, Minnesota. This scenario captures a hypothetical release of crude oil into a watercourse that lies within the Lake Superior watershed and flows via the St. Louis River and St. Louis River Estuary into Lake Superior at Duluth, Minnesota and Superior, Wisconsin.

Several access points beginning at the proposed pipeline crossing of Little Otter Creek and working downstream were visited by a Stantec field biologist on July 19, 2019, to provide additional insight into baseline conditions for the watercourse. Photographs of representative locations along Little Otter Creek, Otter Creek and the St. Louis River are provided in Photos 5-1 through 5-8. Field observations are summarized in Table 5-1. The locations of access points are mapped in Figure 5-1.

Table 5-1. Environmental Characteristics Observed at Selected Access Points on Little Otter Creek, Otter Creek, the St. Louis River, and Estuary, Downstream of Pipeline Crossing Near Cloquet/Scanlon, MN on July 10, 2019.

Access Point	Access Point Number on Figure 5-1	Notes
Little Otter Creek at Douglas Road	1	Vegetation includes a floodplain wet meadow/shrub swamp. The ground layer is dominated by native species including water sedge, lake bank sedge, bluejoint grass, sensitive fern, fowl manna grass and dark green bulrush. Shrubs comprise approximately 80% cover and include pussy willow, speckled alder and Bebb's willow. Submergent vegetation includes several species of native pondweeds and wild celery. Overall vegetation composition/quality in this area is good. Wildlife observed include yellowthroat and several dragonfly species.
Otter Creek at Carlton, MN	2	Vegetation includes a floodplain wet meadow/shrub swamp. The ground layer includes a mix of water sedge, bluejoint grass, giant goldenrod and lesser amounts of the non-native species such as reed canary grass and common tansy. Shrubs comprise approximately 50% cover and include pussy willow, speckled alder, and Bebb's willow. Submergent vegetation includes several species of native pondweeds and wild celery. Overall vegetation composition/quality in this area is good. Wildlife observed include various dragonfly species, cat bird, yellowthroat, and European starling. Disturbances on the shoreline also indicates potential beaver and/or muskrat presence.
Otter Creek east of Carlton, MN	3	Vegetation on stream edge is 100% canopy forest cover, with green ash the dominant tree species. Shrub layer is moderate to thick and includes smooth sumac, hawthorn trees, juneberry, and others. The ground layer includes timothy grass, early goldenrod, poison ivy, yarrow, alumroot, Canada bluegrass, rusty woodsia fern, and others. Wildlife observed included American robin.
Otter Creek at Confluence with St. Louis River	4	Due to the prevalence of bedrock, lack of topsoil, and evidence of past flood events, there is very little vegetation in areas that could be inundated. Wildlife observed included monarch butterfly.
St. Louis River at Jay Cooke State Park	5, 6	Due to the prevalence of bedrock, lack of topsoil, and evidence of past flood events, there is very little vegetation in areas that could be inundated. Wildlife observed: none.

Access Point	Access Point Number on Figure 5-1	Notes
St. Louis River at Fond du Lac (Highway 23 Bridge)	7	Island includes vegetation that indicates it periodically floods but is not inundated for long periods of time. Includes approximately 75% tree canopy cover primarily of green ash. The shrub layer is moderate with dogwood, willow and alder. The ground layer includes a mix of flood tolerant and transitional plants including ostrich fern, reed canary grass, woolgrass, Canada thistle, figwort, arrowhead and others. Wildlife observed included cliff swallow.
St. Louis River Estuary at Highway 23 and 121 Ave. West	8	Narrow fringe of shoreline buffer vegetation at access point (former railway right of way) that includes scattered green ash trees with lesser amounts of balsam poplar. Common shrubs include speckled alder, and red osier dogwood. Ground layer vegetation includes a mix of native (Canada anemone, bluejoint grass) and non-native vegetation (common tansy, reed canary grass). Emergent vegetation on the estuary side of railway embankment includes a mix of common bur reed, blue flag iris, and other emergent native plants. Wildlife observed included walleye, bass species, redwing blackbird, goldfinch.
St. Louis River Estuary at Boy Scout Landing	9	Broad expanse of open water near access point. Vegetation includes emergent marsh/wet meadow fringe with hybrid cattail common, and lesser amounts of the non-native yellow flag iris near trailer park. Upland fringe away from boat landing/trailer park is 90-100% tree canopy with green ash, black ash and balsam poplar common. The shrub layer is moderate to thick with red osier dogwood and ground layer of mostly native graminoids and forbs. Wildlife observed included redwing blackbird and herring gull.
St. Louis River Estuary at Oliver, WI	10	Access point characterized by broad expanse of open water. Deep marsh areas (~3-5 ft. deep) have scattered yellow water lily. Shoreline is relatively abrupt with narrow band of shoreline vegetation that includes 90-100% tree canopy of green ash and balsam poplar. Shrub layer is moderate to dense with red osier dogwood, beaked hazel, willow, meadowsweet, and fly honeysuckle. Ground layer includes mix of water sedge, and bluejoint grass, as well as non-natives tansy and garden valerian. Fisherman reported catching channel catfish, small mouth bass, rock bass.

Figure 5-1 Locations of Field Reviewed Access Points.

5.1.1 Description of the Freshwater Environment

At the pipeline crossing site, Little Otter Creek is a small watercourse originating in wetlands to the west of Route 35. The pipeline right-of-way crosses Route 35, then Route 61, and the Willard Munger State Trail (specifically the Alex Laveau Memorial Trail segment) before entering the wetland, in a crossing of approximately 700 m. The land rises on the east side of the wetland, and it appears that small-scale aggregate extraction has occurred, or is occurring, close to the watercourse on the downstream side of the pipeline right-of-way. The watercourse is small, approximately 6 to 13 ft (2 to 4 m) wide and 1 to 3 ft deep with a substrate of silt and sand. The creek meanders throughout this wetland section. The wetland is predominantly bog or fen, with dense shrub coverage in parts, and more open areas in other parts. Vegetation includes floodplain wet meadow and shrub swamp. The ground layer is dominated by native species including sedges, bluejoint grass, sensitive fern, fowl manna grass, and dark green bulrush. Shrubs make up to 80% cover and include pussy willow, speckled alder, and Bebb's willow. Submergent vegetation includes several species of native pondweeds (*Potamogeton* spp.) and wild celery (*Vallisneria* sp.).

Photo 5-1. View of Little Otter Creek at Douglas Road Bridge, Near Carlton, MN.

The second stream segment (Otter Creek) is larger and flows generally eastward approximately 3.9 miles (6.2 km) to enter the St. Louis River as it exits from the Thomson Reservoir. Otter Creek is typically 15 to 35 feet (5 to 10 m) wide, with occasional pools and many riffles, shoals, and rock outcrops. Aquatic macrophytes such as pondweeds and *Vallisneria* sp. are frequently present. Riparian habitat is largely undisturbed and includes shrubby marsh areas rising to mixed forest.

At the crossing of Third Street/Road 1 immediately south of Carlton, Minnesota, the stream is generally greater than 3 ft (1 m) deep, with a sandy bottom. Photo 5-2 shows a view of the creek looking downstream at the bridge on Road 1 (Third Street) south of Carlton, Minnesota. Vegetation includes floodplain wet meadow and shrub swamp, with native water sedge, bluejoint grass, giant goldenrod and non-native species including reed canary grass and common tansy. Shrubs provide approximately 50% cover and include pussy willow, speckled alder and Bebb's willow. Disturbance on the shoreline suggests the activity of beaver and/or muskrat.

Over the last mile (1.6 km) of Otter Creek where it passes east of the town of Carlton, Minnesota and enters Jay Cooke State Park, the stream becomes narrower and the terrain rockier. This section of stream falls approximately 118 ft (36 m) in elevation by the time it enters the St. Louis River. Riparian vegetation transitions quickly to mixed forest. Photo 5-3 shows a view of the creek a short distance farther downstream, as the slope increases and the terrain becomes rockier.

Photo 5-2. View of Otter Creek at Carlton, MN.

Photo 5-3. View of Otter Creek east of Carlton, MN.

The St. Louis River exits the Thomson Reservoir approximately 0.3 miles (500 m) north of the confluence with Otter Creek. The river cuts across and along a series of rocky ridges and outcrops for a distance of approximately 4.7 miles (7.5 km), falling almost 325 ft (100 m) in elevation before the river enters the headpond of the Fond du Lac hydro-electric generating station at an elevation of approximately 686 ft (208 m) above mean sea level. Due to variable flows and the prevalence of bedrock (Thomson slate), there is very little vegetation (aquatic or terrestrial) in areas that could be flooded or contacted by spilled oil. Photo 5-4 shows the St. Louis River just upstream from its confluence with Otter Creek, visible in the top right portion of the image. Photo 5-5 shows a view upstream of the St. Louis River east of Thomson, MN.

Brown trout are reported to be present in the St. Louis River, along with walleye and northern pike in slower sections. Brown trout and some brook trout are reported to be present in Otter Creek. It is unlikely that Little Otter Creek would provide year-round habitat for salmonid fish due to the potential for high water temperatures during the summer, as well as a general lack of suitable spawning habitat. In addition to these sport fish, a variety of cyprinids (minnows) and other warm-water fish species are likely to be present throughout the study area.

Photo 5-4. View of St. Louis River and Confluence with Otter Creek Below the Thomson Reservoir, MN.

Photo 5-5. View Upstream of the St. Louis River East of Thomson, MN.

The Fond du Lac Headpond is approximately 2.8 miles (4.5 km) long. The tailrace of the Thomson Powerhouse, a hydro-electric generating station fed by a forebay and penstocks from the Thomson Reservoir to the northwest is located near the head of the Fond du Lac Headpond. At the Fond du Lac Dam, the river falls approximately 75 ft (23 m) in elevation. The Minnesota-Wisconsin state line is located immediately downstream from the Fond du Lac Dam, with Wisconsin forming the southern shoreline of the St. Louis River, and Minnesota forming the northern shoreline from this point eastward, to Lake Superior. Photo 5-6 shows a view of the St. Louis River downstream of the Fond du Lac Dam.

Photo 5-6. View Downstream of the St. Louis River Below the Fond du Lac Dam.

Downstream from the foot of the Fond du Lac Dam, the St. Louis River can be considered an estuary (the St. Louis River Estuary) at the head of Lake Superior. The river flow becomes braided around marshy islands within about 2 miles (3 km) below the foot of the dam. A narrow occurs at the town of Oliver, Wisconsin about 6.25 miles (10 km) below the Fond du Lac Dam. Below Oliver, the estuary widens out forming water bodies known as Mud Lake and Spirit Lake, and then entering St. Louis Bay. Mud Lake measures approximately 0.6 miles (1 km) long by 0.4 miles (0.7 km) wide, and Spirit Lake approximately 2.3 miles (3.7 km) long by 1 mile (1.6 km) wide. The downstream boundary of Spirit Lake is formed by Clough Island. Photo 5-7 shows a view of the St. Louis River Estuary near Fond du Lac, Minnesota.

Photo 5-7. View Upstream of the St. Louis River Estuary Near Fond du Lac, MN.

The shorelines of Mud Lake and Spirit Lake are largely natural, whereas St. Louis Bay becomes increasingly industrial and urban in character, with loading wharves for coal and iron ore, as well as parklands and roads in proximity to the shoreline. From Clough Island to the downstream end of St. Louis Bay is a distance of approximately 6.5 miles (10.5 km).

5.1.2 High Consequence Area Assessment for Little Otter Creek near Carlton Crossing Site

As defined in Chapter 7.0 of the AAR technical report (Stantec et al. 2017), HCAs include populated areas, drinking water source areas, ecologically sensitive areas, and commercially navigable waterways. Sensitive AOIs include Minnesota drinking water management areas, native plant communities, sensitive lake shores, recreational areas, tribal lands, and protected areas of several types (e.g., national forests, military lands, state parks). The HCAs and AOIs along Little Otter Creek, Otter Creek and the St. Louis River are shown in Figures 5-2 and 5-3, respectively, and are described in Tables 5-2 and 5-3, respectively.