APPENDIX A: Research Methods

The goal of this report is to illustrate which areas are at risk from increased tanker traffic and which destinations have received oil shipments originating from Westridge Marine Terminal (WMT). Full analysis was conducted using pandas in a jupyter notebook, available upon request.

We purchased historical Automatic Identification System (AIS) data from Marine Traffic,[i] requesting all tankers departing from an area including WMT, from January 2013 through February 2018. The conditions for this initial data request are as follows:

- TIMESTAMP between '2013-01-01 00:00' and '2018-02-28 23:59'
- LAT between 49.28539 and 49.29528 and LON between -122.9589 and -122.9431
- VESSEL_TYPE = Tanker
- For each vessel select the last record when it was moored or anchored (STATUS = 5 or 1) before it went "underway using engine" (STATUS = 0)

This request returned 231 records of (terrestrial) AIS ship positions in the Marine Traffic database. However, upon reviewing the data, it was determined the initial bounding box was too large and encompassed vessels that were stopped nearby in Burrard Inlet but that did not actually call at WMT. In particular, a number of vessels entered the initial box before or after calling at facilities located just to the west and east of WMT. There were also a number of duplicate records, where the same vessel was flagged as "departing" more than once. After reviewing vessel movement history we identified 176 records that either fell within a smaller bounding box [49.289, -122.951, 49.2925, -122.947], or were confirmed by track analysis to have visited WMT.

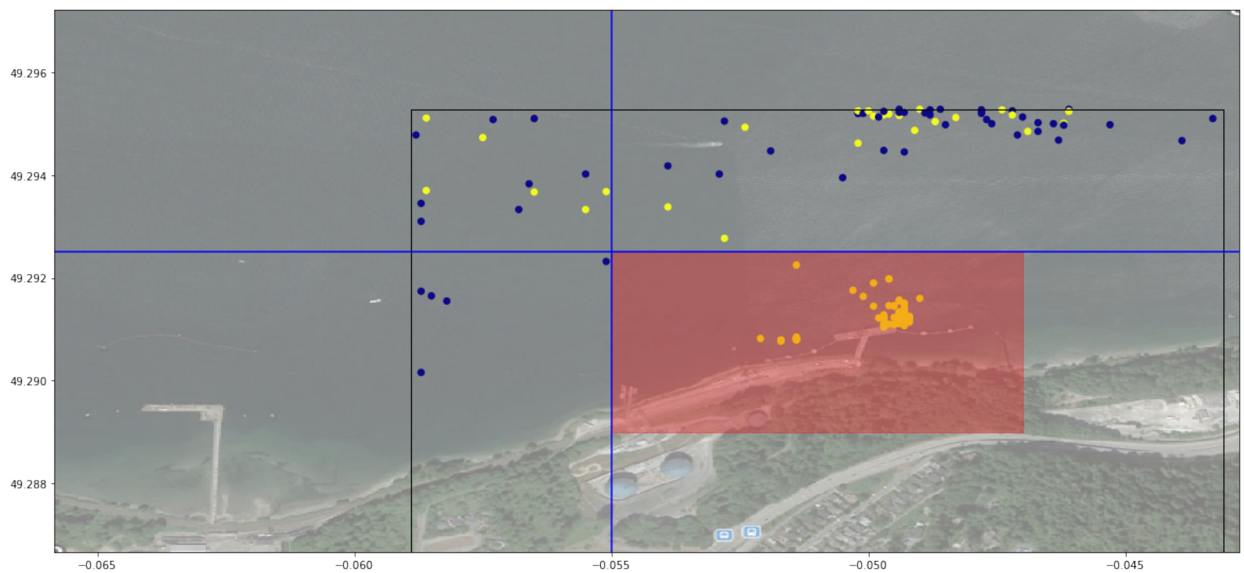

Figure A1: The set of 231 records identified within the initial bounding box (black line), and the 176 records (yellow dots) that either fell in a smaller bounding box (red) or were confirmed to have visited WMT by track analysis. Blue dots were confirmed to have not visited WMT and were excluded from the analysis.

We use those 176 departures as the sample for this report. It is worth noting that this dataset may not be a full accounting of tanker departures from WMT given that represents a lower rate than the ~60 tanker departures/year estimated by Kinder Morgan.[ii] Further work is needed to confirm the completeness of this dataset during this time period. This dataset includes a few articulated tug barges (ATBs, notably *Ocean Reliance* and *Pride*) that are or were listed as tankers on AIS and were returned in our Marine Traffic query. However this dataset is not a complete accounting of all tug or ATB traffic leaving WMT, for example it does not include ATB shipments to U.S. Oil in Tacoma identified by previous research.[iii] In addition to these outbound shipments, the WMT also receives ~1 barge shipment of jet fuel per month to supply the Vancouver airport via the Trans Mountain Jet Fuel pipeline.[iv]

To determine the routes of tankers leaving WMT, we requested AIS track data (~10 points per departure) from Marine Traffic, beginning upon departure from WMT and extending until the next port of call, for each of the 176 departures. In order to provide more resolution in the Salish Sea region, we supplemented that data with ~10 more AIS points per departure detailing the portion of the route from WMT to the exit of the Strait of Juan de Fuca.

For some tracks, the automated next port or next call field provided by Marine Traffic did not correctly indicate actual next destination of the vessel, and instead reflected a later, more distant port call. This may be due to a lack of AIS points within a specific defined region for a given port. We evaluated these tracks by hand and truncated them where necessary to indicate the correct next port.

We categorize each vessel track by its next primary port destination, as determined by Marine Traffic's automatic "next port" or "next call" fields, the AIS destination field entered by the ship's crew, or analysis of the track itself. These destination results are summarized in Table 1 and Figure 3. This dataset is not sufficient to determine which refinery in a particular destination region (if any) was the recipient of the transported oil. An analysis of volumes of oil delivered could be attempted using import data, but is beyond the scope of this report. The existing Trans Mountain pipeline does not exclusively carry tar sands (although TMEP will mostly carry heavy oil), and therefore it is not known which of these shipments were exclusively or primarily tar sands.

Vessel tracks cannot be perfectly represented with only a sample of AIS locations. The tracks in this report use ~20 points each and, as such, cannot perfectly capture every turn of the route. Some tracks seem to cross land due to a lack of data coverage for the entire route. In Figure 1, a number of tracks with missing data in the Salish Sea area made the map difficult to read. To provide visual clarity for that figure we augmented those departure tracks with additional points assuming the tankers stayed within the standard shipping channels while exiting the Salish Sea. Figure 2 shows only Marine Traffic provided points.

Simulated Tanker Tracks

To illustrate the projected increase in tanker traffic leaving WMT due to TMEP (from ~5/month to ~34/month), we generate simulated tanker tracks based on the historical AIS tracks from our dataset.

Figure 4b shows simulated tracks of tankers off the Pacific Coast after leaving the Strait of Juan de Fuca and heading to either Long Beach, San Francisco Bay or Asia/Hawaii. We don't simulate any tracks in the Salish Sea or Puget Sound area, or any Washington State destinations, because those shipments are confined to standard shipping channels. We also don't simulate any destinations in the "Other" category.

Assuming 408 total tanker departures per year (34 per month), and assuming the same proportion of destinations as is found in our historical AIS dataset, we simulate 218 tracks to Long Beach (53% of 408), 53 tracks to San Francisco Bay (13%), and 39 tracks to Asia/Hawaii (10%). Each track is constructed by sampling from the AIS points in our historical dataset. The procedure is as follows for each destination:

Long Beach

- Take as a first point the exit from the Strait of Juan de Fuca, (-124.973, 48.525)
- We group the historical AIS points (with the Long Beach area as destination) in six broad latitude bands: [45,48], [42,45], [39,42], [36,39], [33,36], and [30,33]. We also truncate AIS points that are outliers in longitude, and to avoid generating tracks that cross land.
- For each track we randomly sample one point from each of the six latitude bands, and add small offsets in longitude and latitude randomly sampled from a normal distribution ($\sigma = 0.3$).

- We then take Long Beach as the final point, (-118.21435, 33.75493)

San Francisco Bay

- Take as a first point the exit from the Strait of Juan de Fuca, (-124.973, 48.525)
- We group the historical AIS points (with SF Bay as destination) in four broad latitude bands: [45,48], [42,45], [39,42], and [36,39]. We also truncate AIS points that are outliers in longitude, and to avoid generating tracks that cross land.
- For each track we randomly sample one point from each of the four latitude bands, and add small offsets in longitude and latitude randomly sampled from a normal distribution ($\sigma = 0.3$).
- We then specify two points as the entrance into San Francisco Bay, (-122.670921, 37.771053) and (-122.383904, 37.862182).

Asia/Hawaii

- Take as a first point the exit from the Strait of Juan de Fuca, (-124.973, 48.525)
- We group the historical AIS points (with Asia or Hawaii as destination) with longitude in the range [-156,-130].
- For each track we randomly sample one point from the longitude band, and add a small offset in latitude randomly sampled from a normal distribution ($\sigma = 0.3$).

The result of this simulation is a projected set of tanker tracks that, by design, mirrors the geography of the historical AIS dataset, but illustrates what a projected seven-fold increase in tar sand shipments due to TMEP would look like. This figure is only a rough approximation of future tanker traffic and different model assumptions would naturally lead to different simulated results.

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[i] Historical AIS data purchased from Marine Traffic. [link]
[ii] Kinder Morgan. 2016. Marine Safety: Enhancements Already Underway in Local Waters. April 28. [link]
[iii] Felleman, F. 2016. *Tar Sands/Dilbit Crude Oil Movements Within the Salish Sea*. Friends of the Earth. [link]
[iv] Trans Mountain. 2013. Trans Mountain Pipeline System: Oil Sands Product Forum. April 16. [link]