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SPILL IMPACT ASSESSMENT – CRUDE OIL PIPELINE ERCB LICENSE NUMBER 3353-1

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ABSTRACT

Gibson Energy performed a liquid pipeline spill analysis on the approximately 1 kilometre long 168.3 mm Crude Oil pipeline near the Edmonton South Terminal. This pipeline crosses a sensitive tributary that drains into the North Saskatchewan River. The pipeline is currently not in operation, however is locked in with product. This spill analysis is unique in that the pipeline is under minimal pressure with no appreciable flow rate. As a result, the objective of this analysis was to illustrate the length of time required to perform drain down at various locations along the pipeline. The Spill Analysis consisted of modeling a potential liquid release scenario for overland flow modeling of a liquid release and reports both direct and indirect High Consequence Area (HCA) impacts. Additionally, data showing spill plume extents, final volumes and other GIS data was generated for map generation. This presentation will discuss the methods, data, parameters, and results of this analysis and the next steps in providing regulators sufficient information for a comprehensive contingency plan of the Edmonton terminal.

INTRODUCTION

A liquids spill impact assessment was conducted on Gibson Energy's 168.3mm OD Crude Oil pipeline ERCB license number 3353-1 located near the Edmonton South Terminal. This pipeline was selected due to its close proximity to the drainage tributary that enters the North Saskatchewan River. The pipeline is currently not flowing; however it is locked in with product and acts as a means of storage. This spill analysis is unique in that the pipeline is under minimal pressure with no appreciable flow rate. As a result, the objective of this analysis was to illustrate the length of time required to perform drain down at various release points along the pipeline.

Figure 1: Area of Interest shown in red - Edmonton Terminal. Image courtesy of Google Earth.

This paper discusses the methods, data, parameters, and results of this assessment. Although the detailed results of the spill impacts are not presented due to the confidential nature of the project, the authors did summarize the deliverables associated with the project as follows:

- MS-EXCEL spreadsheet with the drain down times for six (6) time based analyses
- Esri Personal Geodatabase (MS-ACCESS) containing:
    - Spill plume polygons containing overland spread results
    - Spill grid polygons with volume and impact time per grid cell
    - Pipeline centerline
    - Pipeline attribute with linear references
- Digital Elevation Models (DEMs) used in the analysis (ESRI Grid format)
- Alignment drawing with volume, time and overland spill results plotted on an Aerial image of the location
- Final report

NOMENCLATURE

The following nomenclature used in this paper is listed:

AB Energy Resources Conservation Board (ERCB)

Digital Elevation Model	(DEM)
Canadian National Hydrographic Network	(NHN)
Environmental Systems research Institute	(Esri)
Federal Emergency Management Agency	(FEMA)
Flo-2D™	(Flo-2D)
Gibson Energy	(Gibson's)
Light Detection And Ranging	(LiDAR)
National Resources Canada	(NRCAN)
New Century Software	(New Century)
Outside Diameter of pipe	(OD)
Spill Impact Analyst™	(SIA)
United States Geological Survey	(USGS)
USGS National Hydrographic Dataset	(NHD)
Wall Thickness of pipe	(WT)

In 2011 Gibson Energy contracted New Century to perform a spill impact analysis service on a single pipeline segment (totaling approximately 1 kilometer). New Century utilized its SIA software to perform the spill modeling. This process provides Gibson Energy with information on overland flow and drain down times along its pipeline.

The following source data to perform the spill modeling and report:

- Documents and drawings containing pipeline specifications (diameters, flow rate, media type, valve response time)
- Esri shp file of pipeline centerline
- Esri shp file of valve locations and shut off times
- Photos and descriptions of culverts
- 5m LiDAR data from Valtus
- Canadian NHN data sets

SIA is a computer leak simulation application specifically used to model the overland flow and channel flow of liquid hydrocarbon spilled on the ground. SIA runs as an extension to ArcGIS, to perform the spill modeling. SIA uses FLO-2D, a FEMA approved hydraulic model, as its overland flow modeling engine, while using ArcGIS to provide the spatial data pre- and post-processing and mapping of the FLO-2D results. FLO-2D is a wave front propagation algorithm that simulates the effect of overland, channel flow, and pooling over a three dimensional elevation model.

ArcGIS (version 9.3.1) suite of applications (ArcMap and ArcCatalog) with the SIA extension, as well as Microsoft Access and Excel, were used for visualizing and reviewing the input data for the spill model, running the spill model, and performing quality control (QC). These applications were also used for analyzing, plotting, and reporting the results.

DATA PREPARATION

A primary requirement of SIA is a digital elevation model (DEM) of the analysis region. Accurate overland flow modeling depends on the quality of the DEM data used to model the terrain surrounding the pipeline. DEM raster datasets are a representation of the ground surface topography or terrain in a grid structure with each grid element assigned an elevation value. Gibson Energy purchased 2010 vintage LiDAR data from Valtus. This LiDAR was available at 2-meter postings with an acquisition point density of approximately 1.14 meters. The horizontal and vertical accuracy are 50cm and 30cm, respectively. A 5m DEM was created from the LiDAR. The 5m resolution was chosen as it provides sufficient topographical detail to model overland flow outside of a tank farm without being too large to adversely impact processing.

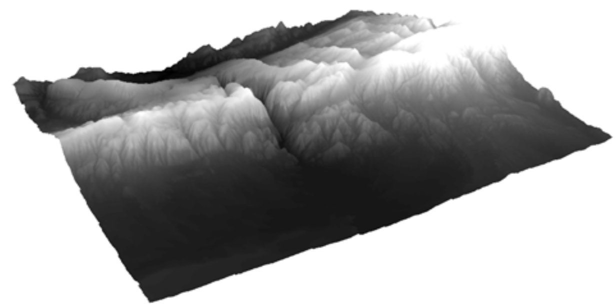

Figure 2: Example of 3-dimensional DEM raster file

PIPELINE ANALYSIS

These processes were used to ensure that the input data for the SIA application could be verified at various stages throughout the analysis process.

The pre-requisite pipeline data tables were built for SIA to operate. This included pipe segments (OD and WT), valve locations and shut-off times, and the pipeline's profile. The pipeline's profile was calculated using the DEM. This data was stored in an Esri personal geodatabase. The processes, including Quality Assurance/Quality Control steps are discussed below.

1. Pipeline Data Development

Pipeline data was obtained from Gibson Energy in the form of documents and shp files. These tables were populated to obtain the pre-requisite data for the SIA geodatabase.

- Route
- Series
- Profile
- Pipe Segment

2. Pipeline Centerline

The geographic location and shape of the ERCB pipeline license 3353-1 was obtained from Gibson Energy. A pipeline measure was assigned based on documentation provided by Gibson Energy. A profile was generated using an application called Centerline Design Toolkit, resulting in a table of points along the line at 10m intervals containing elevation values. This table is essential in modeling the drain down volumes along the pipeline.

3. Control Valves and Valve Times

Gibson Energy identified 2 (two) manually operated isolation shut-off valves along the pipeline at the following coordinates:

- 53.54846, -113.36618
- 53.54954, -113.36685

However, these coordinates did not fall in line with the analysis pipeline. Following confirmation with Gibson Energy field staff, the locations of these valves were adjusted to coincide with the begin/end of the shp file.

Two (2) valve times are required for input within the SIA database; response time and shutoff time. A response time and shut-off time of .01 seconds was used to simulate the locked-in nature of the pipeline.

4. Release Point Creation Process

Release points were then generated for the pipeline. Release points have a spatial location along the centerline, and for each release point an associated hydrograph is calculated that describes the time/flow rate relationship that results from a pipeline break, which in turn describes the resulting volume of media that is released. SIA calculates the total volume available for release based on the flow rate of the pipeline, the time it takes to respond and close down any shut-off valves, and the volume of media in the pipeline available for drain down after the valves around the break have been closed. The total spill volume is calculated as the sum of the volume released prior to shut-in (ramp up volume, full flow volume, and valve closure volume), plus the volume available for drain out after shut-in (drain down volume).

In Spill Impact Analyst, the ***locations of releases*** along a pipeline are automatically generated at intervals along the pipeline, with a spacing that should allow the spill results from each release point to overlap. This overlap indicates that if a release point were to be added between the two existing release points, it would provide little to no additional information on the potential impacts that could occur due to a break somewhere on the segment of pipe bounded by the original two release points. For each release point, a volume of product that will be released during the spill simulation is automatically calculated, based on the flow properties of the pipeline, the physical profile of the pipe (vertical variation of pipe along its length), and the response time of the operator to identify the problem, reach the valve, and shut it fully off. The volume of product to be applied over time to a release point is stored as a ***hydrograph***.

A conceptual figure of the hydrograph is shown below in Figure 3.

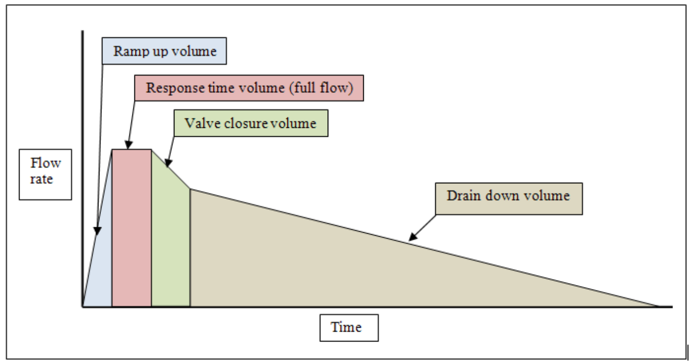

Figure 3: Conceptual SIA release point hydrograph

The released volume equals the combined total of the component volumes of the hydrograph. It is the sum of the volume during the initial ramp up time, the full flow volume, the valve closure volume, and the drain down volume.

In addition to the pipeline profile and dimensions, centerline, and bounding valve location and time information discussed previously, it is necessary to know the following information in order to create release points along the line:

- Media Properties
- Operating flow rate
- Percent of full flow rate at start of drain down
- Locations of bounding isolation valves and response times to close the valves
- Release point interval

The type of media being carried by the pipeline, sweet crude oil, was provided by Gibson Energy.

Due to the locked-in nature of this pipeline there was no appreciable flow rate available for modeling. However, it was important to Gibson Energy to understand the length of time required to drain down the pipeline at each release point. Therefore, it was decided to perform the analysis using six (6) flow rate based iterations (0.16 m3/hr, 0.79 m3/hr, 1.59m3, 2.38 m3/hr, 3.18 m3/hr, 3.97m3/hr)

The flow rate from the release point on the pipeline can be adjusted to include a gradual reduction in the flow rate during valve closure from the full flow rate of the pipeline. This is represented as a percent of full flow rate that is defined at the time that the valves are completely closed. A value of 100% was used (conservative assumption), thus full flow rate conditions from the release point will continue until the valves are completely closed.

A release point interval of 40 feet or 12.2m was selected for this project, additional release points at intersections of the pipeline centerlines with NHD tributaries (stream or river) were added. The 12.2m interval was determined by performing a series of test SIA simulations in order to determine at which interval the spill plumes would come closest to touching each other while still minimizing the total number of release points to be analyzed. It was determined that a 12.2m interval provided sufficient coverage of the pipeline. Due to the three-dimensional nature of the pipeline, a 12.2m interval thus does not correspond to a horizontal plane distance of 12.2m, but rather a measured 12.2m slope length on the pipeline.

After the input data was obtained and verified, release points were generated for the pipeline.

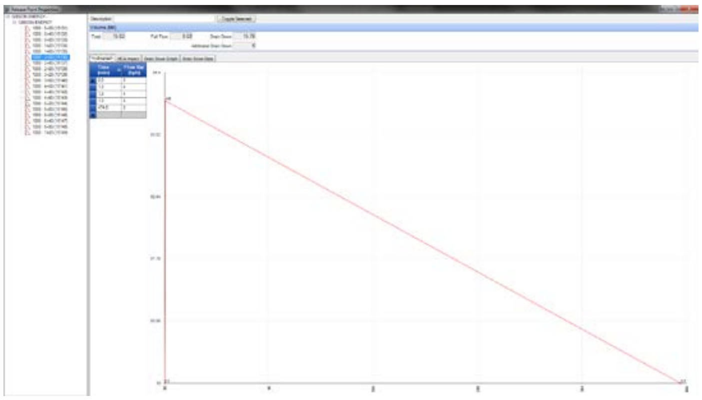

Figure 4: Release point 2+00 hydrograph

The hydrograph is a chart or table that represents the change of a hydrologic variable over time, in this case flow rate. Each release point has an associated hydrograph that completely describes the release of the product from the break point as a function of flow rate and time. Since the dependent variable is flow rate, the area under the curve is the volume. The area under the curve from time = 0 (when the leak is initiated) to the end of the ramp up time is the ramp up volume, from the end of the ramp up time until the system is shut in is the full flow volume and the area under the curve from shut-in until drain down is complete is the drain down volume.

Duration	Description
0 - 1 minute	Ramp up Time (Full Flow bbls/hr)
1 min – 1.01 minutes	Overland Flow (Full Flow)
1.01 minutes – 1.01 minutes	Valve Shut-In (Full Flow)
1.01 minutes - 99 hours	End simulation (Full Flow)

Table 1: 168.3mm OD Crude Oil pipeline ERCB license number 3353-1

The drain down volume is calculated based on the centerline profile of the pipeline, location of bounding valves, and depth of cover. An example drain down profile is shown in Figure 5.

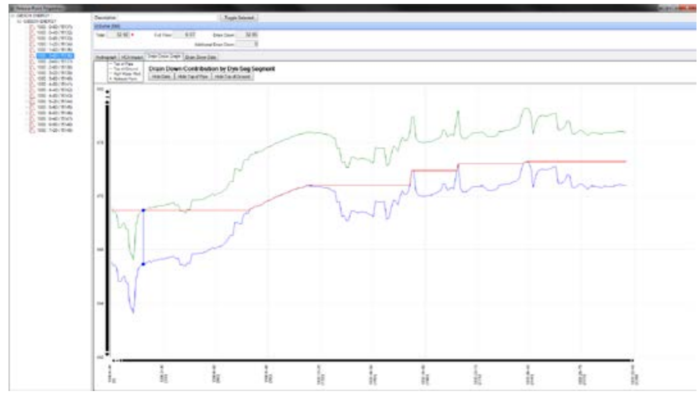

Figure 5: Release point 2+00 drain down profile

5. Simulation Parameters

Prior to the simulation, the following parameters were set up and verified. These values, once set and verified, are saved in the SIA settings and are kept constant throughout the duration of the simulation.

Media Settings

- Product Specific Gravity: 0.82
- Release Temperature: 15° C or 60° F
- Viscosity at low, medium, and high and values of these temperatures: 4.61 centiStokes (cSt) @ 15° C or 60° F

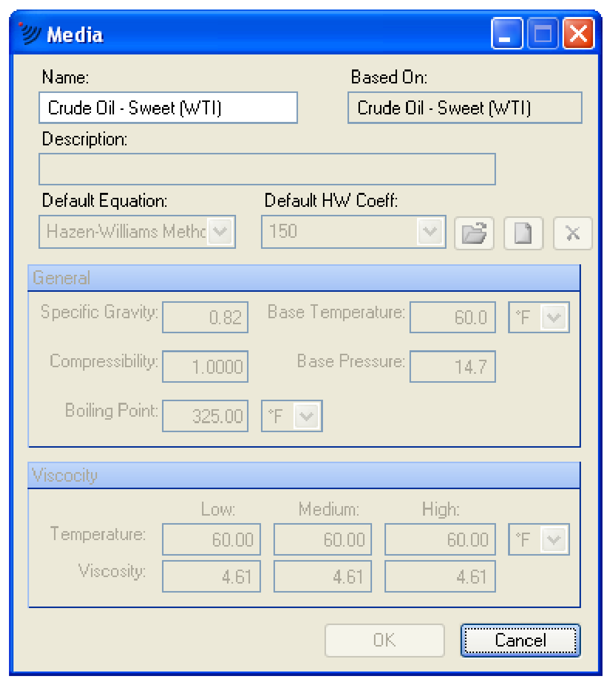

Figure 6: Media settings in the SIA Application

The Canadian NHN data was migrated into an USGS NHD geodatabase format, the NHD format is used by the SIA tool for channel flow analysis. This was necessary to ensure SIA could accurately trace the hydrographic data.

FLO 2-D Settings

The following default values were used in the analysis.

- Manning's n-value Roughness Coefficient. – Default 0.07
- Percent change in flow depth – Default 20%
- Dynamic wave stability coefficient – Default -0.25
- Ground Absorption properties – None (i.e., No volume was absorbed into the ground during overland flow - conservative assumption.)

Release Point Calculations

- Release Fixed Point Interval – 12.2 m interval
- Include level break sections in drain down volumes – Yes
- Assumed Depth of Cover – 1.2 m
- Elevation profile – Top of Ground
- Create release points at waterway crossings – Yes
- Hydrograph Ramp Time: – 1 minute
- Assumed Percent Flow at the start of drain down – 100%
- Assumed Percent Drain Down Released (100% means that all product that can drain out will) – 100%

Simulation Settings

- Simulation Time (The duration of the spill simulation, including overland flow, response time, valve shut off, drain down, NHD trace, and additional product settling time): 99 Hours

The simulation time was arbitrarily set high to ensure there was enough time to perform a complete drain down using the 6 variations in flow rate.

Other settings that had to be configured were the digital elevation models and NHD databases. These datasets were loaded into the SIA application and the settings saved. Afterward, the configuration settings were verified by reviewing the settings and confirming that each was correct and present. The simulations were then ready to be executed.

6. Simulations

After the preceding configurations were set and the release volumes were calculated, the SIA tool was then used to engage an overland flow simulation engine to perform the two-dimensional overland flow and water transport analysis. Simulations were then conducted for each of the release points. Output generated by SIA for each release point included spill plume outlines representing the outer boundary of the area impacted by the spilled media, plume grid cells which contain information on timing and volume for each impacted grid cell, and NHD traces showing the extent of the stream or river potentially impacted by transport of the media

OVERLAND FLOW ANALYSIS

The SIA application uses a proprietary version of FLO-2D modified specifically for routing shallow viscous fluid flows. SIA passes the necessary information to FLO-2D, allowing it to perform the overland flow simulation. SIA then process the results of the simulation to provide additional information useful to the pipeline operator as well as visualization of the results.

Flo-2D is a dynamic, 2-dimensional flood routing model that simulates unconfined overland flow. It is also used to predict the area of inundation associated with oil spills or any petroleum product. It simulates a flood over complex topography and roughness while reporting on volume conservation, the key to accurate flood distribution.

Overland flow is simulated using a dynamic flood routing model that was designed to simulate unconfined overland flow. FLO-2D can be used to simulate the flow of oil over complex topography and land roughness while maintaining volume conservation.

Flood routing in two dimensions is accomplished through a numerical integration of the equations of motion and the conservation of fluid volume for water flooding, mud and debris flows or oil spills. The equations of motion are the full dynamic wave momentum equation and the continuity equation (conservation of mass equation). The full dynamic wave equation includes both the local and convective acceleration terms. The inclusion of these two acceleration terms in the solution to the equations of motion means that the flow is both unsteady and non-uniform. The simulated flow can accelerate or decelerate in both time and space. Using the full dynamic wave momentum equation enables FLO-2D to simulate flow over complex topography with rapidly varying flow conditions that could not be modeled with the kinematic wave and diffusive wave approximations to the momentum equation. In fact, the kinematic wave and diffusive wave equations have become obsolete in flood routing models with the advent of fast personal computers.

The key to this accurate flood distribution is the use of the dynamic wave momentum equation and a centralized routing scheme that simulates flow in eight (8) potential flow directions. The flow directions use a system of square grid elements, derived from the DEM raster data cells used for the surface topography, to predict the progress of the flood hydrograph at each release point along the pipeline over time.

For more detail on the FLO-2D dynamic flood routing model, please refer to http://www.flo-2d.com/ for a general description of its use.

DIGITAL ELEVATION MODEL

The yellow pipeline center line shown in figure 7 is overlaid the hill shaded LiDAR DEM in the background and the NHD tributaries shown in blue. The North Saskatchewan River is indicated by the dark pixels in the upper left hand corner.

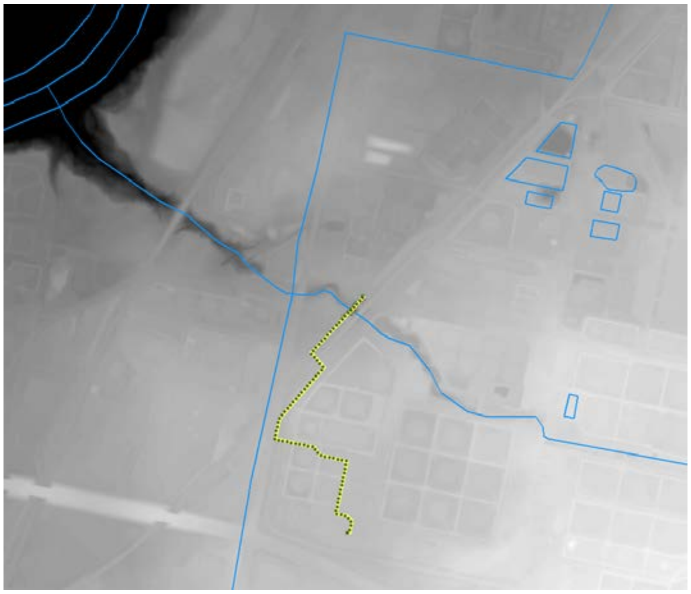

Figure 7: Hill shaded LiDAR DEM

Accurate overland flow modeling depends on the quality of the DEM data used to model the terrain surrounding the pipeline. SIA uses DEM raster data for terrain modeling. DEM raster datasets are essentially a snapshot of elevations in a grid structure with each grid element assigned an elevation. The grid element size of a dataset depends on the resolution of the source data and varies widely. The most commonly available resolution is 30 meter data, where each grid cell is a 30m x 30m square. For this project we chose to use off-the-shelf 5mx5m DEM as higher resolution DEM data would have meant and additional cost to Gibson Energy to capture LiDAR.

The quality of the results for overland flow is very sensitive to the granularity of the DEM data, as is the processing time. Oil spills from pipeline breaks tend to be low volume events, confined to relatively small areas, and the resulting depths are shallow. This means that the actual spill path is very sensitive to small variations in topography, such as elevated road beds or roadside ditches, as the spill plume expands. Relatively coarse DEM data, such as 30m, which may be fine for large flood events, will often mask topographical features that would have a significant effect on low volume, shallow flows such as pipeline breaks.

Conversely, as the granularity of the DEM data decreases, the number of grid elements in the analysis area increases, affecting processing time.

New Century Software has done extensive testing with Spill Impact Analyst using Flo-2D and DEM data across a range of resolutions. The results and recommendations are shown in the following table 2.

Resolution	Comments
> 30 meters	Blurring of significant topographical features produces unreliable results.
30 meters	Acceptable results. Very fast processing time. Upper limit of useable results for small volumes. Small spill volumes contained in as few as four grid elements. Major topographical features are preserved. Minor topographical features, such as elevated road beds and ditches can be masked, depending on width.
5 meters	Excellent results. Upper limit of acceptable processing time for large projects, such as entire lines at small release point intervals.
< 5 meters	Not practical for large projects. Very accurate analysis results. Suitable for detailed analysis of specific points of concern, such as tank ruptures, line crossings, etc.

Table 2: Table showing the various resolutions of DEM

The spill area of inundation (plume), volumes, and velocities of each grid cell in the plume, as well as NHD traces, were then stored in the geodatabase for further reporting and analysis.

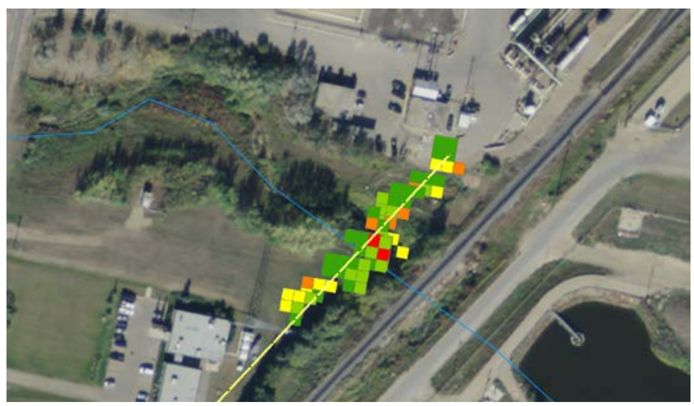

Figure 8: 5m x 5m grid cells color coded by impact time.

CHANNEL FLOW ANALYSIS

Channel flow modeling simulates the movement of spilled product as it travels downstream from the point of entry using a process called NHD Trace Analysis. SIA uses the U.S. Geological Survey (USGS) National Hydrographic Dataset (NHD) for stream trace analysis.

From the USGS NHD website: *"The National Hydrographic Dataset (NHD) is a comprehensive set of digital spatial data that contains information about surface water features such as lakes, ponds, streams, rivers, springs and wells. Within the NHD, surface water features are combined to* *form "reaches," which provide the framework for linking water-related data to the NHD surface water drainage network. These linkages enable the analysis and display of these water-related data in upstream and downstream order*."

The NHD is based upon the content of USGS Digital Line Graph (DLG) hydrographic data integrated with reach-related information from the EPA Reach File Version 3.

The NHD has the spatial information needed to find water features and the network information needed to trace streams and rivers once they've been located. The NHD is organized into watersheds which represent major geographic drainages.

If the plume contacts an NHD reach, the spill quantity and timing for the entry point are automatically transferred to the Channel Flow module and flow continues along the stream until the simulation time expires or the transported product is exhausted through losses due to bank retention and evaporation. Where the spill plume intersects the NHD stream reaches and is then transported downstream, SIA creates a stream trace polyline and stores it in the geodatabase as a feature class.

NHD Trace Analysis is done in two steps:

1. Contact detection
2. Transport analysis

Contact detection involves intersecting the spill plume with the NHD data to determine which, if any, waterways are contacted by the spill plume. A series of release points is shown below with their associated spill plumes. The blue polylines are NHD reach data and the red polyline is the result of the NHD trace for that release point. Once a spill plume is determined to intersect an NHD reach, calculations are performed to determine the time of contact and the volume to be transferred to the trace analysis engine.

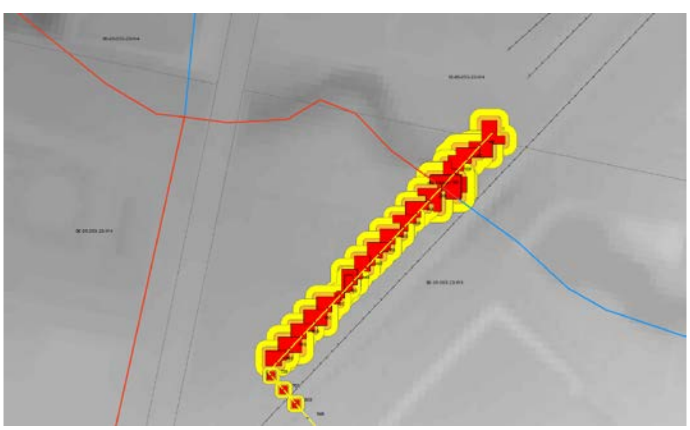

Figure 9: Spill plumes in red and NHD trace in red overlaid on 5m resolution DEM. The pool fire effects are also plotted as orange 10 kW and yellow 5 kW thermal radiation levels.

Transport analysis takes the volume transferred from contact detection and transports it by navigating downstream through the NHD reach network from the point of initial contact. Downstream transport moves at the flow rate specified for the configured hydrographic dataset (see NHD Configuration). As spilled product is transported downstream its volume diminishes due to factors such as bank retention and evaporation. The trace analysis engine continues stream tracing for a release point until one of four conditions is satisfied:

1. The simulation time expires
2. The transported volume goes to zero due to bank retention, etc.
3. The reach network terminates; or
4. The fixed distance length setting is reached

Once the trace analysis is complete an NHD trace is built. An NHD trace is a polyline that traces the reach network transport path over which the channel flow calculation determined spilled product would be transported. The trace polyline can then be used to intersect with consequence layers to determine if an impact occurred.

As an alternative to the aforementioned scenario, SIA also support fixed distance trace analysis. This option allows the operator to determine a minimum or maximum distance the trace will reach. This option may also be implemented to determine emergency response times or other "what if" scenarios.

7. Results

The results of this sophisticated flow model are paths that realistically widen and narrow as surface topography changes, rather than simply identifying the steepest downhill path. Overland flow processing continued until the simulation time expired.

If the plume contacted an NHD tributary, the spill quantity and timing for the entry point were automatically transferred to the Channel Flow module and flow continued along the stream for the full duration of the simulation, and incorporates an estimated attenuation rate for the product in channel flow conditions (water transport). Depending on the stream flow rate, this could greatly lengthen or shorten the extents of an NHD trace. SIA created a stream trace polyline and stored it in the geodatabase as a feature class.

After the simulation was completed a review of the database was performed to verify that all release points had been processed. A visual QA/QC process was performed to review the spill plumes, NHD traces, and drain down times.
A total of 1 line segment totaling approximately 1 kilometer of pipeline was analyzed.

Additional simulations were performed to answer what-if situations. It was determined that the oil would pass the road network impacting the river if the spill was greater than 635 m^3. Actual volumes available in the pipeline for drain down average less than 4 m^3. See Figure 10 for results of a 635 m3 spill simulation at release point 1+40.

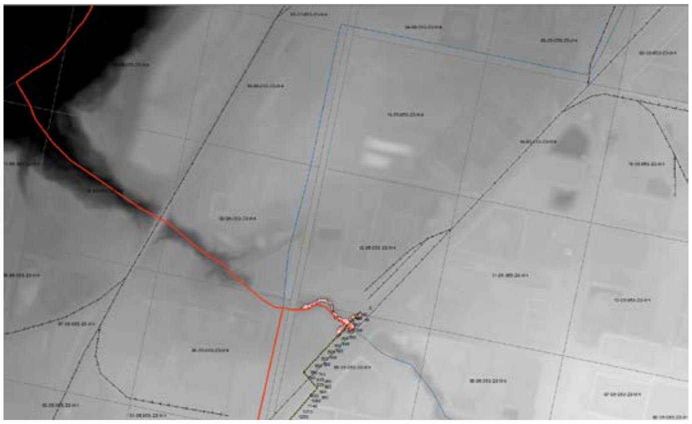

Figure 10: Exaggerated spill simulation of 635 m3 at release point 1+40. Notice the red NHD trace on the tributaries and North Saskatchewan River.

After careful review of the data, it was concluded that the actual simulated spills are large enough to drain into the intermittent tributary. The North Saskatchewan River would not be impacted from a spill of this magnitude by this locked in pipeline.

It was determined that the tributary is dammed by 17th Street NW and a corrugated steel pipe culvert exists under the road which would allow transport of the oil past 17th Street NW. see Figures 11, 12 and 13. If the tributary was flowing as in the case of spring runoff or after a larger rainstorm the simulated spill may be transported through the culverts and may reach the North Saskatchewan River.

Figure 11: Looking east from 17th street along tributary. Photo courtesy of Google Earth.

It was further field investigated and found that that there are four (4) culverts, each was clear of debris.

Figure 12: Downstream Culvert 1 under the Edmonton Terminal access road and CN railway. See Appendix B for culvert locations. Photo courtesy of Gibson Energy.

Figure 13: Upstream Culvert 2 under 17th Street NW. See Appendix B for culvert locations. Photo courtesy of Gibson Energy.

Gibson Energy is committed to protecting the environment and staged attenuation equipment preventing possible leaks to under pass the road network into the North Saskatchewan River. As such several weirs and booms are placed across the tributary at various strategic locations and are well maintained. See Appendix B for the locations of the weirs.

A summary of the drain down times relative to flow rate (0.16 m^3/hr, 0.79 m^3/hr, 1.59m^3, 2.38 m^3/hr, 3.18 m^3/hr, and 3.97m 3/hr) is presented in the tables in Appendix A.

SUMMARY

Gibson Energy and New Century performed the analyses on the 168.3mm OD Crude Oil pipeline ERCB license number 3353-1 line to determine the drain down time for locations along the pipeline based on varying six (6) flow rates:

1. 0.16 m3/hr
2. 0.79 m3/hr
3. 1.59 m3/hr
4. 2.38 m3/hr,
5. 3.18 m3/hr
6. 3.97 m3/hr

The final results of the analysis provide Gibson Energy with perspective on the amount of product that would be evacuated along the pipeline based on its profile. Also, by using the varying flow rates, Gibson Energy has more insight into the amount and length of time required to evacuate the drain down volumes along the pipeline. In conclusion the analysis proved that the spilled oil would not reach the North Saskatchewan River.

In summary the following tasks were performed during the project:

- ✓ Acquired 2 meter LiDAR data.
- ✓ Created 5 meter DEM.
- ✓ Migrated NRCAN NHN data into a USGS NHD
- ✓ Assigned cumulative measure and engineering stationing to valves provided by Gibson Energy.
- ✓ Loaded valve response and closure times into the SIA geodatabase using data supplied by Gibson Energy.
- ✓ Calculated release points and corresponding hydrographs at 12.2 meter intervals and at each NHD intersection.
- ✓ Entered analysis model parameters into SIA after discussions with Gibson Energy personnel
- ✓ Performed 6 (six) iterations of the spill analysis using various flow rates.
- ✓ Calculated overland spread grids and spread polygons.
- ✓ Calculated pool fire thermal impacts.
- ✓ Performed QC tests at important steps throughout the analysis process.
- ✓ Performed What-if scenarios to determine the impacts of higher volumes spilled.
- ✓ Reviewed output with Gibson Energy multiple times.
- ✓ Reviewed output personal geodatabase and prepared deliverables to Gibson Energy.
- ✓ Generated Excel spreadsheets showing individual release point volumes and drain down times.
- ✓ Created Integrity Management alignment map sheets showing release points, spill plumes, and elated spill data using its SheetCutter/Template Designer application.
- ✓ Created a Final Report of analysis methodology and results.

ACKNOWLEDGMENTS

Rich Henry Project Manager New Century Software
Dr. Jim O'Brien President and Creator of FLO-2D ™
Chuck Wright Sr. Software Engineer of Spill Impact Analyst ™

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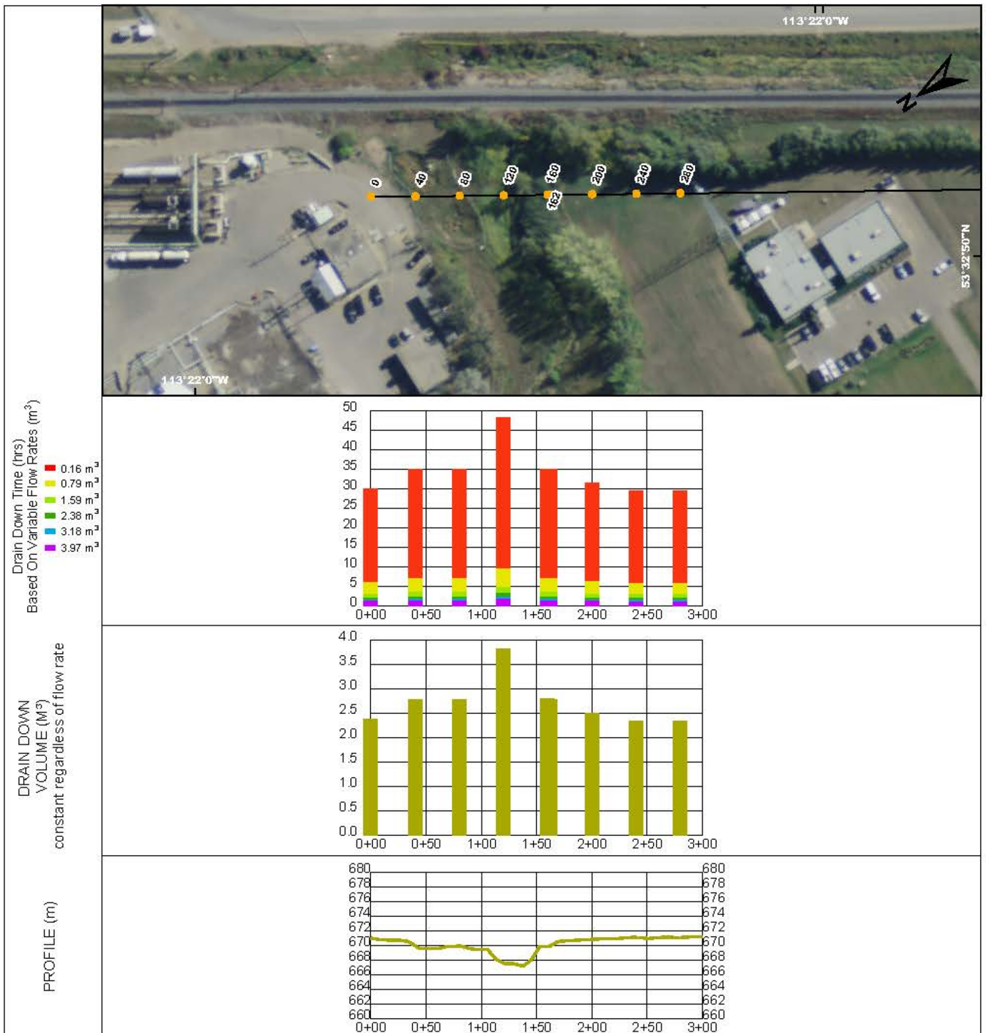
New Century Software website: http://www.newcenturysoftware.com/

Flo-2D website: http://www.flo-2d.com

APPENDIX A

ALIGNMENT MAP OF THE SIX (6) SPILL ANALYSES



DRAIN DOWN SUMMARY (six scenarios based on flow rate)

Measure	Flow Rate (m³)	Drain Down Vol (m³)	Drain Down Time (hr)	Measure	Flow Rate (m³)	Drain Down Vol (m³)	Drain Down Time (hr)
0+40	0.16	2.79	35.14	0+40	2.38	2.79	2.36
0+80	0.16	2.79	35.15	0+80	2.38	2.79	2.36
1+20	0.16	3.84	48.27	1+20	2.38	3.84	3.23
1+60	0.16	2.80	35.21	1+60	2.38	2.80	2.36
1+63	0.16	2.79	35.14	1+63	2.38	2.79	2.36
2+00	0.16	2.51	31.60	2+00	2.38	2.51	2.12
2+40	0.16	2.34	29.50	2+40	2.38	2.34	1.98
2+80	0.16	2.34	29.46	2+80	2.38	2.34	1.98

Measure	Flow Rate (m³)	Drain Down Vol (m³)	Drain Down Time (hr)	Measure	Flow Rate (m³)	Drain Down Vol (m³)	Drain Down Time (hr)
0+40	0.79	2.79	7.04	0+40	3.18	2.79	1.77
0+80	0.79	2.79	7.04	0+80	3.18	2.79	1.77
1+20	0.79	3.84	9.67	1+20	3.18	3.84	2.43
1+60	0.79	2.80	7.05	1+60	3.18	2.80	1.78
1+63	0.79	2.79	7.04	1+63	3.18	2.79	1.77
2+00	0.79	2.51	6.33	2+00	3.18	2.51	1.60
2+40	0.79	2.34	5.91	2+40	3.18	2.34	1.49
2+80	0.79	2.34	5.91	2+80	3.18	2.34	1.49

Measure	Flow Rate (m³)	Drain Down Vol (m³)	Drain Down Time (hr)	Measure	Flow Rate (m³)	Drain Down Vol (m³)	Drain Down Time (hr)
0+40	1.59	2.79	3.53	0+40	3.97	2.79	1.42
0+80	1.59	2.79	3.53	0+80	3.97	2.79	1.42
1+20	1.59	3.84	4.84	1+20	3.97	3.84	1.95
1+60	1.59	2.80	3.54	1+60	3.97	2.80	1.42
1+63	1.59	2.79	3.53	1+63	3.97	2.79	1.42
2+00	1.59	2.51	3.18	2+00	3.97	2.51	1.28
2+40	1.59	2.34	2.97	2+40	3.97	2.34	1.20
2+80	1.59	2.34	2.96	2+80	3.97	2.34	1.19

Gibson Energy
Pipeline Spill Analysis

06/16/11

APPENDIX B

LOCATION OF CULVERTS AND WEIR PLACEMENTS