Drill Cuttings, Drill Fluids, and Muds Discharge Modeling for

Burger S Well

Drilled by the Drill Ship Polar Pioneer

Located Offshore Chukchi Sea, Alaska

Prepared for:

Shell Alaska Venture
Anchorage, AK 99503

Prepared by:

3 Elm Street, Suite 2
Maynard, MA 01754
www.fluid-dynamix.com

September 10, 2014

Copyright **2014** by Fluid Dynamix. Company Confidential.

Report No.	Burger_S_SO10_POLAR_PIONEER

Author(s):	Alam Mohammed Senior Numeric Modeler Fluid Dynamix Boston, Massachusetts

Date:	Wednesday, September **10**, **2014**

Data Contributor(s):	Louis Brzuzy Senior Science Advisor Shell Alaska Venture Anchorage, AK **99503** Heather Ptak Environmental Engineer Shell Exploration & Production Anchorage, AK **99503** Ian Lewis Drilling Engineer Shell Exploration & Production Anchorage, AK **99503** Lana Davis Environmental Engineer Shell Exploration & Production Anchorage, AK **99503** Pete Nelson Schlumberger
Data Coordinator(s):	Barbara Bohn Senior Project Manager Olgoonik / Fairweather Anchorage, AK **99503**

Copyright **2014** by Fluid Dynamix. Company Confidential.

EXECUTIVE SUMMARY

The primary goal of this environmental numeric modeling was to simulate the dispersion and deposition of the cements, water based drill cuttings, drill fluids, and water based muds discharges from the drilling operation by the drill ship Polar Pioneer at the prospect well site Burger S located offshore Chukchi Sea using the Offshore Operators Committee Mud and Produced Water Discharge Model (OOC Model). The prospect well Burger S is located in block **6762** area of Posey. The depth of water is **44.0** meters (m). The dispersion and deposition numeric simulations were performed for the six discrete drilling intervals divided into two discharge scenarios: sea floor (**013**) and sea surface (**001**). The sea floor discharges occur from the drilling intervals **1**, **2**, and **3** and the sea surface discharges occur from the drilling intervals **4**, **5**, and **6**. The sea floor discharges occur at **1.83** m (or **6** feet) above the sea floor and the sea surface discharges occur at **8.53** m (or **28** feet) below the sea surface. Moreover, approximately **2**,**427** barrels (bbls) of the water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970**.**80** bbls per hour (bbls/hour) for **2**.**5** hours. These constitute discharges described in Permit no.: **AKG-28-8100** as discharge **013** (Muds, Cuttings, and Cements at the Seafloor) and discharge **001** (Water-Based Drilling Fluids and Drill Cuttings).

The cements, water based dill cuttings, and drill fluids mass discharge rate (effluent) for drilling intervals **1**, **2**, and **3** for the sea floor (**013**) discharges are: **68**.**83**, **116**.**30**, and **86**.**64** bbls/hour, respectively. These sediments will be pumped away via use of a pump at the sea floor. A flexible hose suction pipe will intake a large volume of sea water to move the cements, water based drill cuttings, and drill fluids from the seafloor and will discharge from a **12**.**0** inch internal diameter discharge pipe at **14**,**000** bbls/hour. This yields into **203**.**4**, **120.4**, and **161**.**6** pre-dilution factors before discharging into the ambient for the drilling intervals **1**, **2**, and **3**, respectively. The discharge pipe of the seafloor pump is located at **1**.**83** m (or **6** feet) above the seafloor and oriented horizontally aligned with the direction of the current, which is to the east.

The water based dill cuttings and drill fluids mass discharge rate (effluent) for drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharges are: **148**.**63**, **68**.**87**, and **26**.**47** bbls/hour, respectively. Sea water at a rate of **10**.**83** bbls/hour will be added to the drill cuttings and drill fluids before discharging into the ambient during the drilling of the bottom hole section i.e., the drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharge scenario. This yields into **1**.**1**, **1**.**2**, and **1**.**4** pre-dilution factors before discharging into the ambient for the drilling intervals **4**, **5**, and **6**, respectively. The pre-diluted water based dill cuttings and drill fluids discharge rate (effluent) for drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharges are: **159**.**46**, **79**.**70**, and **37**.**30** bbls/hour, respectively.

The outer diameter of the pipe for the sea surface discharge is **16**.**0** inches. It runs through the main deck of the drill rig Polar Pioneer and comes out on the bottom of the ship. The discharge pipe is located approximately **8**.**53** m below the water line. Therefore, the surface discharges occur at a depth of approximately **8**.**53** m from the sea surface. The internal pipe diameter of **15**.**25** inches was used for modeling the sea surface discharge scenario based on a **0**.**75** inches of total pipe wall thickness. The discharge pipe is oriented vertically downward with respect to the sea surface and discharges at approximately **8.53** m below the sea surface for modeling the sea surface discharge scenario.

The water based drill fluids for the top hole section i.e., the drilling intervals **1**, **2**, and **3**, for the sea floor (**013**) discharge scenario is composed of primarily sea water, which includes **30** pounds (lbs.) of bentonite, **0**.**5** lbs. of xanthan gum, and **0**.**03** lbs. of Gelex bentonite extender in each barrel of sea water.

The water based drill fluids for the bottom hole section i.e., the drilling intervals **4**, **5**, and **6**, for the sea surface (**001**) discharge scenario is composed of primarily sodium chloride (NaCl) brine system. Sodium chloride brine systems are single-salt solutions of sodium chloride and water. Saturated sodium chloride brine has a density of **1,198** kilograms per cubic meter **(**kg/m^3) or **10** lbs. per gallon (lb/gal**)** and used as a base drill fluids for the bottom hole section. Barite at the rate of **1**.**413** lb/gal is added to the base drill fluids to increase the weight of the drill fluids to **1,318.13** kg/m^3 (or **11** lb/gal**)** for drilling the interval **04** of the bottom hole section. Moreover, barite at

Copyright **2014** by Fluid Dynamix. Company Confidential.

the rate of **2.83** lb/gal is added to the base drill fluids to increase the weight of the drill fluids to **1,438** kg/m^3 (or **12** lb/gal) for drilling the intervals **05** and **06** of the bottom hole section.

The dispersion and deposition numeric simulations both for the sea floor (**013**) and the sea surface (**001**) discharge scenarios were performed for two sets of currents speed: mean currents and maximum currents. This provides a sensitivity analysis of the numeric model results to the model input parameter: currents speed. The current speed of **7** centimeters per second (cm/sec) was used as the mean value and **25** cm/sec was used as the maximum value in the OOC model.

The solids deposition on the seabed from the effluents discharged during the six discrete drilling intervals and the rig's surface pits were compiled using the Graphical User Interface Discharge Offshore (GUIDO, version **7.3**) software for the OOC model yielding the total solids deposition loading and total thickness distribution on the seabed from the drilling operation by the drill ship Polar Pioneer at the Burger S well site.

The OOC model predicted total amount of solids loading on the sea floor as a result of the discharge of the cements, water based drill cuttings, drill fluids, and water based muds at the mean currents are: (i) **100** kg/m^2 at **50** m, (ii) **10** kg/m^2 at **130** m, (iii) **1** kg/m^2 at **380** m, (iv) **0.1** kg/m^2 at **1,050** m, and (v) **0.01** kg/m^2 at **2,600** m distances approximately from the source towards the direction of the current.

The sea floor areas affected by solids deposit loading of more than **1000-, 100-, 10-, 1-, 0.1-,** and **0.01-**kg/m^2 at the mean currents are: **0.108**, **0.268**, **0.598**, **4.243**, **17.429**, and **126.801** hectares (ha), respectively.

The OOC model predicted maximum deposit thickness at the mean currents is **201.7** cm, which occurs at **10** m to the east and **30** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **105** m to the east from the discharge location.

The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **130** m x **40** m rectangle area (or **0.510** ha) at the mean currents. The sea floor areas affected by deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0.102**, **0.195**, and **0.510** ha, respectively.

The OOC model predicted total amount of solids loading on the sea floor as a result of the discharge of the cements, water based drill cuttings, drill fluids, and water based muds at the maximum currents are: (i) **100** kg/m^2 at **80** m, (ii) **10** kg/m^2 at **275** m, (iii) **1** kg/m^2 at **825** m, and (iv) **0.1** kg/m^2 at **1,950** m distances approximately from the source towards the direction of the current.

The sea floor areas affected by solids deposit loading of more than **1000**-, **100**-, **10**-, **1**-, **0.1**-, and **0.01**-kg/m^2 at the maximum currents are: **0.106**, **0.340**, **1.280**, **3.450**, **15.080**, and **125.133** ha, respectively.

The OOC model predicted maximum deposit thickness at the maximum currents is **160.2** cm, which occurs at **10** m to the east and **30** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **235** m to the east from the discharge location.

The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **250** m x **40** m rectangle area (or **1.048** ha) at the maximum currents. The sea floor areas affected by deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0.098**, **0.277**, and **1.048** ha, respectively.

The OOC model predicted fate and transport of the TSS concentrations show that the TSS concentrations attain a value of less than **0.1** mg/l at: **6** to **24** hours after the cessation of the discharge during the mean currents and **4** to **6** hours after the cessation of the discharge during the maximum currents. The maximum duration to attain less than **0.1** mg/l of TSS concentration is **24** hours after the cessation of the discharge.

The impacts on the ambient from the drilling operations at the Burger S well in terms of solids deposit thickness of **1** cm or larger is limited to an area: **0.510** ha at the mean currents and **1.048** ha at the maximum currents. The

Copyright **2014** by Fluid Dynamix. Company Confidential.

impacts at **100** m from the discharge source are: solids deposit thickness in the range of **1** to **3** cm at the mean currents and **3** to **10** cm at the maximum currents on the seabed. The impacts on the ambient water in terms of the TSS concentrations at **100** m from the discharge source are: **6.0** to **233.2** mg/l at the mean currents and **14.0** to **205.0** mg/l at the maximum currents. The impacts at **300** m from the source are: solids deposit thickness of less than **1** cm on the seabed both for the mean and maximum currents. The impacts on the ambient water in terms of the TSS concentrations at **300** m from the discharge source are: **1.6** to **109.0** mg/l at the mean currents and **3.2** to **92.7** mg/l at the maximum currents. The overall impacts on the ambient from the drilling operations at the Burger S well by the drill ship Polar Pioneer can be classified as low.

Copyright **2014** by Fluid Dynamix. Company Confidential.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
TABLE OF FIGURES v
TABLE OF TABLES ix
TABLE OF ACRONYMS x
SECTION 1.0 INTRODUCTION 1
1.1 THE OOC MODEL 4
1.2 SETTLING VELOCITY DISTRIBUTION FOR SOLIDS IN DRILL CUTTINGS AND FLUIDS 5
SECTION 2.0 AMBIENT CHARACTERISTICS 7
2.1 DEPTH OF WATER 7
2.2 TEMPERATURE AND SALINITY 7
2.3 CURRENT SPEED 7
2.4 WINDS SPEED AND WAVE HEIGHT 8
SECTION 3.0 EFFLUENT CHARACTERISTICS 11
3.1 DISCHARGE SCENARIOS 11
3.2 DRILLING INTERVALS, DRILLING DURATIONS, AND EFFLUENT DISCHARGE RATES 11
3.3 DISCHARGE PIPE SIZE AND HEIGHT 13
3.4 FALL VELOCITY CLASSES FOR WATER BASED DRILL CUTTINGS 13
3.5 FALL VELOCITY CLASSES FOR WATER BASED MUDS 13
3.6 EFFLUENT DENSITIES 15
SECTION 4.0 MODEL DOMAIN 18
SECTION 5.0 DISPERSION AND DEPOSITION MODELING – MEAN CURRENTS 19
5.1 MODEL RESULTS FOR SEA FLOOR DISCHARGE SCENARIO – DRILLING INTERVAL 01 21
5.2 MODEL RESULTS FOR SEA FLOOR DISCHARGE SCENARIO – DRILLING INTERVAL 02 30
5.3 MODEL RESULTS FOR SEA FLOOR DISCHARGE SCENARIO – DRILLING INTERVAL 03 39
5.4 MODEL RESULTS FOR SEA SURFACE DISCHARGE SCENARIO – DRILLING INTERVAL 04 48
5.5 MODEL RESULTS FOR SEA SURFACE DISCHARGE SCENARIO – DRILLING INTERVAL 05 57
5.6 MODEL RESULTS FOR SEA SURFACE DISCHARGE SCENARIO – DRILLING INTERVAL 06 65
5.7 MODEL RESULTS FOR SEA SURFACE DISCHARGE SCENARIO – RIGS SURFACE PITS 77
5.8 COMBINED MODEL RESULTS - SEA FLOOR AND SEA SURFACE DISCHARGES, BURGER S 87
SECTION 6.0 DISPERSION AND DEPOSITION MODELING – MAXIMUM CURRENTS 96
6.1 MODEL RESULTS FOR SEA FLOOR DISCHARGE SCENARIO – DRILLING INTERVAL 01 98
6.2 MODEL RESULTS FOR SEA FLOOR DISCHARGE SCENARIO – DRILLING INTERVAL 02 110
6.3 MODEL RESULTS FOR SEA FLOOR DISCHARGE SCENARIO – DRILLING INTERVAL 03 122
6.4 MODEL RESULTS FOR SEA SURFACE DISCHARGE SCENARIO – DRILLING INTERVAL 04 134
6.5 MODEL RESULTS FOR SEA SURFACE DISCHARGE SCENARIO – DRILLING INTERVAL 05 146
6.6 MODEL RESULTS FOR SEA SURFACE DISCHARGE SCENARIO – DRILLING INTERVAL 06 158
6.7 MODEL RESULTS FOR SEA SURFACE DISCHARGE SCENARIO – RIGS SURFACE PITS 168
6.8 COMBINED MODEL RESULTS - SEA FLOOR AND SEA SURFACE DISCHARGES, BURGER S 180
SECTION 7.0 SENSITIVITY ANALYSIS 189
SECTION 8.0 SUMMARY AND CONCLUSION 193
SECTION 9.0 REFERENCES 196

Copyright **2014** by Fluid Dynamix. Company Confidential.

TABLE OF FIGURES

Figure 1-1: Location of the Burger Field 2
Figure 2-1: Ambient temperature for open water season, Burger Field, Chukchi Sea 8
Figure 2-2: Ambient salinity for open water season, Burger Field, Chukchi Sea 9
Figure 2-3: Wind speed for open water season, Burger Field, Chukchi Sea 9
Figure 2-4: Wave height for open water season, Burger Field, Chukchi Sea 10
Figure 4-1: Model domain for the prospect well Burger S 18
Figure 5-1: Trajectory of the discharge plume at mean currents, Drilling Interval 01 21
Figure 5-2: Shape and width of the discharge plume at mean currents, Drilling Interval 01 22
Figure 5-3a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 01 23
Figure 5-3b: TSS concentrations during the mean currents at 72 h (or 6 h after the cessation of release) 24
Figure 5-3c: TSS concentrations during the mean currents at 78 h (or 12 h after the cessation of release) 25
Figure 5-3d: TSS concentrations during the mean currents at 84 h (or 18 h after the cessation of release) 26
Figure 5-4: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 01 27
Figure 5-5a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 01 28
Figure 5-5b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 01 29
Figure 5-6: Trajectory of the discharge plume at mean currents, Drilling Interval 02 30
Figure 5-7: Shape and width of the discharge plume at mean currents, Drilling Interval 02 31
Figure 5-8a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 02 32
Figure 5-8b: TSS concentrations during the mean currents at 11.2 h (or 6 h after the cessation of release) 33
Figure 5-8c: TSS concentrations during the mean currents at 17.2 h (or 12 h after the cessation of release) 34
Figure 5-8d: TSS concentrations during the mean currents, at 23.2 h (or 18 h after the cessation of release) 35
Figure 5-9: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 02 36
Figure 5-10a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 02 37
Figure 5-10b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 02 38
Figure 5-11: Trajectory of the discharge plume at mean currents, Drilling Interval 03 39
Figure 5-12: Shape and width of the discharge plume at mean currents, Drilling Interval 03 40
Figure 5-13a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 03 41
Figure 5-13b: TSS concentrations during the mean currents at 40.4 h (or 6 h after the cessation of release) 42
Figure 5-13c: TSS concentrations during the mean currents at 46.4 h (or 12 h after the cessation of release) 43
Figure 5-13d: TSS concentrations during the mean currents at 52.4 h (or 18 h after the cessation of release) 44
Figure 5-14: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 03 45
Figure 5-15a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 03 46
Figure 5-15b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 03 47
Figure 5-16: Trajectory of the discharge plume at mean currents, Drilling Interval 04 48
Figure 5-17: Shape and width of the discharge plume at mean currents, Drilling Interval 04 49
Figure 5-18a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 04 50
Figure 5-18b: TSS concentrations during the mean currents at 29.3 h (or 6 h after the cessation of release) 51
Figure 5-18c: TSS concentrations during the mean currents at 35.3 h (or 12 h after the cessation of release) 52
Figure 5-18d: TSS concentrations during the mean currents at 41.3 h (or 18 h after the cessation of release) 53
Figure 5-19: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 04 54
Figure 5-20a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 04 55
Figure 5-20b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 04 56
Figure 5-21: Trajectory of the discharge plume at mean currents, Drilling Interval 05 57
Figure 5-22: Shape and width of the discharge plume at mean currents, Drilling Interval 05 58
Figure 5-23a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 05 59
Figure 5-23b: TSS concentrations during the mean currents at 35 h (or 6 h after the cessation of release) 60
Figure 5-23c: TSS concentrations during the mean currents at 41 h (or 12 h after the cessation of release) 61
Figure 5-24: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 05 62
Figure 5-25a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 05 63
Figure 5-25b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 05 64

Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-26: Trajectory of the discharge plume at mean currents, Drilling Interval 06 65
Figure 5-27: Shape and width of the discharge plume at mean currents, Drilling Interval 06.....66
Figure 5-28a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 06 67
Figure 5-28b: TSS concentrations during the mean currents at 38.2 h (or 1 h after the cessation of release).....68
Figure 5-28c: TSS concentrations during the mean currents at 39.2 h (or 2 h after the cessation of release) 69
Figure 5-28d: TSS concentrations during the mean currents at 40.2 h (or 3 h after the cessation of release).....70
Figure 5-28e: TSS concentrations during the mean currents at 41.2 h (or 4 h after the cessation of release).....71
Figure 5-28f: TSS concentrations during the mean currents at 42.2 h (or 5 h after the cessation of release).....72
Figure 5-28g: TSS concentrations during the mean currents at 43.2 h (or 6 h after the cessation of release) 73
Figure 5-29: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 06 74
Figure 5-30a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 06 75
Figure 5-30b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 06 76
Figure 5-31: Trajectory of the discharge plume at mean currents, Rig's Surface Pits 77
Figure 5-32: Shape and width of the discharge plume at mean currents, Rig's Surface Pits 78
Figure 5-33a: Total suspended solids concentrations in water column at mean currents, Rig's Surface Pits.....79
Figure 5-33b: TSS concentrations during the mean currents at 8.5 h (or 6 h after the cessation of release).....80
Figure 5-33c: TSS concentrations during the mean currents at 14.5 h (or 12 h after the cessation of release) 81
Figure 5-33d: TSS concentrations during the mean currents at 20.5 h (or 18 h after the cessation of release).....82
Figure 5-34: Amount of deposition of the solids on seabed at mean currents, Rig's Surface Pits 84
Figure 5-35a: Spatial extent of solids thickness distribution on seabed at mean currents, Rig's Surface Pits 85
Figure 5-35b: Spatial extent of solids thickness distribution on seabed at mean currents, Rig's Surface Pits.....86
Figure 5-36a: Total amount of deposition of the solids on seabed at mean currents, Burger S 88
Figure 5-36b: Total amount of deposition of the solids on seabed at mean currents, Burger S (zoom view) 89
Figure 5-37a: Spatial extent of total solids thickness distribution on seabed at mean currents, Burger S 91
Figure 5-37b: Spatial extent of total solids thickness distribution on seabed at mean currents, Burger S.....92
Figure 5-38: Sea floor area affected by solids thickness distribution at mean currents, Burger S 93
Figure 6-1: Trajectory of the discharge plume at maximum currents, Drilling Interval 01 98
Figure 6-2: Shape and width of the discharge plume at maximum currents, Drilling Interval 01 99
Figure 6-3a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 01 ...100
Figure 6-3b: TSS concentrations during the maximum currents at 67 h (or 1 h after the cessation of release).....101
Figure 6-3c: TSS concentrations during the maximum currents at 68 h (or 2 h after the cessation of release) 102
Figure 6-3d: TSS concentrations during the maximum currents at 69 h (or 3 h after the cessation of release).....103
Figure 6-3e: TSS concentrations during the maximum currents at 70 h (or 4 h after the cessation of release).....104
Figure 6-3f: TSS concentrations during the maximum currents at 71 h (or 5 h after the cessation of release) 105
Figure 6-3g: TSS concentrations during the maximum currents at 72 h (or 6 h after the cessation of release).....106
Figure 6-4: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 01.....107
Figure 6-5a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 01 ..108
Figure 6-5b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 01 ..109
Figure 6-6: Trajectory of the discharge plume at maximum currents, Drilling Interval 02 110
Figure 6-7: Shape and width of the discharge plume at maximum currents, Drilling Interval 02 111
Figure 6-8a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 02 ...112
Figure 6-8b: TSS concentrations during the maximum currents at 6.2 h (or 1 h after the cessation of release).....113
Figure 6-8c: TSS concentrations during the maximum currents at 7.2 h (or 2 h after the cessation of release) 114
Figure 6-8d: TSS concentrations during the maximum currents at 8.2 h (or 3 h after the cessation of release).....115
Figure 6-8e: TSS concentrations during the maximum currents at 9.2 h (or 4 h after the cessation of release).....116
Figure 6-8f: TSS concentrations during the maximum currents at 10.2 h (or 5 h after the cessation of release) 117
Figure 6-8g: TSS concentrations during the maximum currents at 11.2 h (or 6 h after the cessation of release) 118
Figure 6-9: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 02.....119
Figure 6-10a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 02 120
Figure 6-10b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 02 121
Figure 6-11: Trajectory of the discharge plume at maximum currents, Drilling Interval 03 122
Figure 6-12: Shape and width of the discharge plume at maximum currents, Drilling Interval 03 123
Figure 6-13a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 03 .124

Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-13b: TSS concentrations during the maximum currents at 35.4 h (or 1 h after the cessation of release)..125
Figure 6-13c: TSS concentrations during the maximum currents at 36.4 h (or 2 h after the cessation of release)..126
Figure 6-13d: TSS concentrations during the maximum currents at 37.4 h (or 3 h after the cessation of release)..127
Figure 6-13e: TSS concentrations during the maximum currents at 38.4 h (or 4 h after the cessation of release)..128
Figure 6-13f: TSS concentrations during the maximum currents at 39.4 h (or 5 h after the cessation of release) ..129
Figure 6-13g: TSS concentrations during the maximum currents at 40.4 h (or 6 h after the cessation of release)..130
Figure 6-14: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 03.....131
Figure 6-15a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 03 132
Figure 6-15b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 03 133
Figure 6-16: Trajectory of the discharge plume at maximum currents, Drilling Interval 04 134
Figure 6-17: Shape and width of the discharge plume at maximum currents, Drilling Interval 04.....135
Figure 6-18a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 04 .136
Figure 6-18b: TSS concentrations during the mean currents at 24.3 h (or 1 h after the cessation of release).....137
Figure 6-18c: TSS concentrations during the mean currents at 25.3 h (or 2 h after the cessation of release) 138
Figure 6-18d: TSS concentrations during the mean currents at 26.3 h (or 3 h after the cessation of release).....139
Figure 6-18e: TSS concentrations during the mean currents at 27.3 h (or 4 h after the cessation of release).....140
Figure 6-18f: TSS concentrations during the mean currents at 28.3 h (or 5 h after the cessation of release).....141
Figure 6-18g: TSS concentrations during the mean currents at 29.3 h (or 6 h after the cessation of release) 142
Figure 6-19: Amount of deposition of the solids on the seabed at maximum currents, Drilling Interval 04 143
Figure 6-20a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 04 144
Figure 6-20b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 04 145
Figure 6-21: Trajectory of the discharge plume at maximum currents, Drilling Interval 05 146
Figure 6-22: Shape and width of the discharge plume at maximum currents, Drilling Interval 05.....147
Figure 6-23a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 05 .148
Figure 6-23b: TSS concentrations during the maximum currents at 30 h (or 1 h after the cessation of release).....149
Figure 6-23c: TSS concentrations during the maximum currents at 31 h (or 2 h after the cessation of release) 150
Figure 6-23d: TSS concentrations during the maximum currents at 32 h (or 3 h after the cessation of release).....151
Figure 6-23e: TSS concentrations during the maximum currents at 33 h (or 4 h after the cessation of release).....152
Figure 6-23f: TSS concentrations during the maximum currents at 34 h (or 5 h after the cessation of release).....153
Figure 6-23g: TSS concentrations during the maximum currents at 35 h (or 6 h after the cessation of release) 154
Figure 6-24: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 05.....155
Figure 6-25a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 05 156
Figure 6-25b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 05 157
Figure 6-26: Trajectory of the discharge plume at maximum currents, Drilling Interval 06 158
Figure 6-27: Shape and width of the discharge plume at maximum currents, Drilling Interval 06.....159
Figure 6-28a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 06 .160
Figure 6-28b: TSS concentrations during the maximum currents at 38.2 h (or 1 h after the cessation of release)..161
Figure 6-28c: TSS concentrations during the maximum currents at 39.2 h (or 2 h after the cessation of release) ..162
Figure 6-28d: TSS concentrations during the maximum currents at 40.2 h (or 3 h after the cessation of release)..163
Figure 6-28e: TSS concentrations during the maximum currents at 41.2 h (or 4 h after the cessation of release)..164
Figure 6-29: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 06.....165
Figure 6-30a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 06 166
Figure 6-30b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 06 167
Figure 6-31: Trajectory of the discharge plume at maximum currents, Rig's Surface Pits 168
Figure 6-32: Shape and width of the discharge plume at maximum currents, Rig's Surface Pits 169
Figure 6-33a: Total suspended solids concentrations in water column at maximum currents, Rig's Surface Pits....170
Figure 6-33b: TSS concentrations during the maximum currents at 3.5 h (or 1 h after the cessation of release)....171
Figure 6-33c: TSS concentrations during the maximum currents at 4.5 h (or 2 h after the cessation of release) 172
Figure 6-33d: TSS concentrations during the maximum currents at 5.5 h (or 3 h after the cessation of release)....173
Figure 6-33e: TSS concentrations during the maximum currents at 6.5 h (or 4 h after the cessation of release)....174
Figure 6-33f: TSS concentrations during the maximum currents at 7.5 h (or 5 h after the cessation of release) 175
Figure 6-33g: TSS concentrations during the maximum currents at 8.5 h (or 6 h after the cessation of release)....176
Figure 6-34: Amount of deposition of the solids on seabed at maximum currents, Rig's Surface Pits.....177

Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-35a: Spatial extent of solids thickness distribution on seabed at maximum currents, Rig's Surface Pits ...178
Figure 6-35b: Spatial extent of solids thickness distribution on seabed at maximum currents, Rig's Surface Pits ...179
Figure 6-36a: Total amount of deposition of the solids on seabed at maximum currents, Burger S 181
Figure 6-36b: Total amount of deposition of the solids on seabed at maximum currents, Burger S (zoom view) ...182
Figure 6-37a: Spatial extent of total solids thickness distribution on seabed at maximum currents, Burger S 184
Figure 6-37b: Spatial extent of total solids thickness distribution on seabed at maximum currents, Burger S 185
Figure 6-38: Sea floor area affected by solids thickness distribution at maximum currents, Burger S 186

Copyright **2014** by Fluid Dynamix. Company Confidential.

TABLE OF TABLES

Table 1-1: Location of the Prospect Well Burger S 2
Table 1-2: Drilling Operation for Burger S 3
Table 1-3: Fall Velocity Classes for Water Based Mud Cuttings (Brandsma and Smith, 1999) 5
Table 1-4: Fall Velocity Classes for Water Based Mud (Brandsma and Smith, 1999) 6
Table 1-5: Fall Velocities for Different Sediment Particle Size and Classes (Keith Dyer, 1986) 6
Table 2-1: Ambient Water Characteristics for the Burger Field, for the planned drilling period 7
Table 3-1: Drilling Operation for Burger S 12
Table 3-2: Fall Velocity Classes and Volume Fractions for Water Based Drill Cuttings, Burger S 14
Table 3-3: Fall Velocity Classes and Volume Fractions for Water Based Drilling Fluids, Burger S 14
Table 3-4a: Computations of Solids Density and Solids Volume Fractions for Burger S 16
Table 3-4b: Computations of Effluent Bulk Density for Burger S 17
Table 5-1: Total Simulation Time, Model Time Step, and Discharge Rates for Burger S 19
Table 5-2: Total Solids Deposition on the Seabed at Mean Currents 94
Table 5-3: Total Suspended Solids (TSS) Concentrations in the Water Column at Mean Currents 95
Table 6-1: Total Simulation Time, Model Time Step, and Discharge Rates for Burger S 96
Table 6-2: Total Solids Deposition on the Seabed at Maximum Currents 187
Table 6-3: Total Suspended Solids (TSS) Concentrations in the Water Column at Maximum Currents 188
Table 7-1: Mean and Maximum Currents Speed for the Burger Field, for July through October 189
Table 7-2: The OOC Model Predicted Solids Deposition at the Mean and the Maximum Currents Speed 190
Table 7-3: The OOC Model Predicted TSS Concentrations at the Mean and the Maximum Currents Speed 191
Table 7-4: Model Predicted Drill Cutting Deposition Thickness at Mean Currents Speed 192
Table 7-5: Model Predicted Drill Cutting Deposition Thickness at Maximum Currents Speed 192

Copyright **2014** by Fluid Dynamix. Company Confidential.

TABLE OF ACRONYMS

bbls	Barrels
bbls/hour	Barrels per hour
cc	Cubic centimeter
cm	Centimeters
cm/sec	Centimeters per second
°C	Degrees Celsius
ft	Feet
g	Grams
g/cc	Grams per cubic centimeter
gal	Gallons
h	Hours
ha	Hectares
kg	Kilograms
kg/m^2	Kilograms per square meter
kg/m^3	Kilograms per cubic meter
km	Kilometers
lb	Pounds
lb/gal	Pounds per gallon
m	Meters
m/s	Meters per second
mg	Milligrams
mg/l	Milligrams per liter
psu	Practical salinity scale unit
sec	Seconds
TSS	Total suspended solids

Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 1.0 INTRODUCTION

The numeric simulations for the cements, water based drill cuttings, drill fluids, and water based muds discharges from the drilling operation by the drill ship Polar Pioneer at the prospect well site Burger S located offshore Chukchi Sea were performed using the Offshore Operators Committee Mud and Produced Water Discharge Model (OOC Model). The prospect well Burger S is located in block **6762** area of Posey. The depth of water is **44.0** meters (m). The location of the well Burger S, within the burger field offshore the Chukchi Sea is presented in **Figure 1-1**. The Burger S well coordinates: easting-northing and latitude-longitude are presented in **Table 1-1**. The dispersion and deposition numeric simulations were performed for the six discrete drilling intervals divided into two discharge scenarios: sea floor (**013**) and sea surface (**001**). The sea floor discharges occur from the drilling intervals **1**, **2**, and **3** and the sea surface discharges occur from the drilling intervals **4**, **5**, and **6**. The sea floor discharges occur at **1.83** m (or **6** feet) above the sea floor and the sea surface discharges occur at **8.53** m (or **28** feet) below the sea surface. Moreover, approximately **2**,**427** barrels (bbls) of the water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970**.**80** bbls per hour (bbls/hour) for **2**.**5** hours. These constitute discharges described in Permit no.: **AKG-28-8100** as discharge **013** (Muds, Cuttings, and Cements at the Seafloor) and discharge **001** (Water-Based Drilling Fluids and Drill Cuttings).

The dispersion and deposition numeric simulations both for the sea floor (**013**) and the sea surface (**001**) discharge scenarios as listed below were performed for two sets of currents speed: mean currents and maximum currents. This provides a sensitivity analysis of the numeric model results to the model input parameter: currents speed. The modeled discharge scenarios are:

- **Discharge Scenario 1a**: **Sea Floor Discharges (013) at Mean Currents**
  Muds, cuttings, and cements discharges prior to the installation of the riser near the sea floor.

- **Discharge Scenario 1b: Sea Surface Discharges (001) at Mean Currents**
  Water based drill fluids and drill cuttings discharges after the installation of the riser near the sea surface. Moreover, approximately **2**,**427** bbls of water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970**.**80** bbls/hour for **2**.**5** hours.

- **Discharge Scenario 2a**: **Sea Floor Discharges (013) at Maximum Currents**
  Muds, cuttings, and cements discharges prior to the installation of the riser near the sea floor.

- **Discharge Scenario 2b: Sea Surface Discharges (001) at Maximum Currents**
  Water based drill fluids and drill cuttings discharges after the installation of the riser near the sea surface. Moreover, approximately **2**,**427** bbls of water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970**.**80** bbls/hour for **2**.**5** hours.

The drilling operations for the Burger S well would be conducted by the drill ship Polar Pioneer. The drilling operation for each discharge scenario (sea floor and sea surface) would be conducted in three different intervals yielding a total of six (**2** discharge scenarios × **3** drilling intervals per scenario) drilling intervals as presented in **Table 1-2**.

Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 1-1: Location of the Burger Field
Prospect Well: Burger S

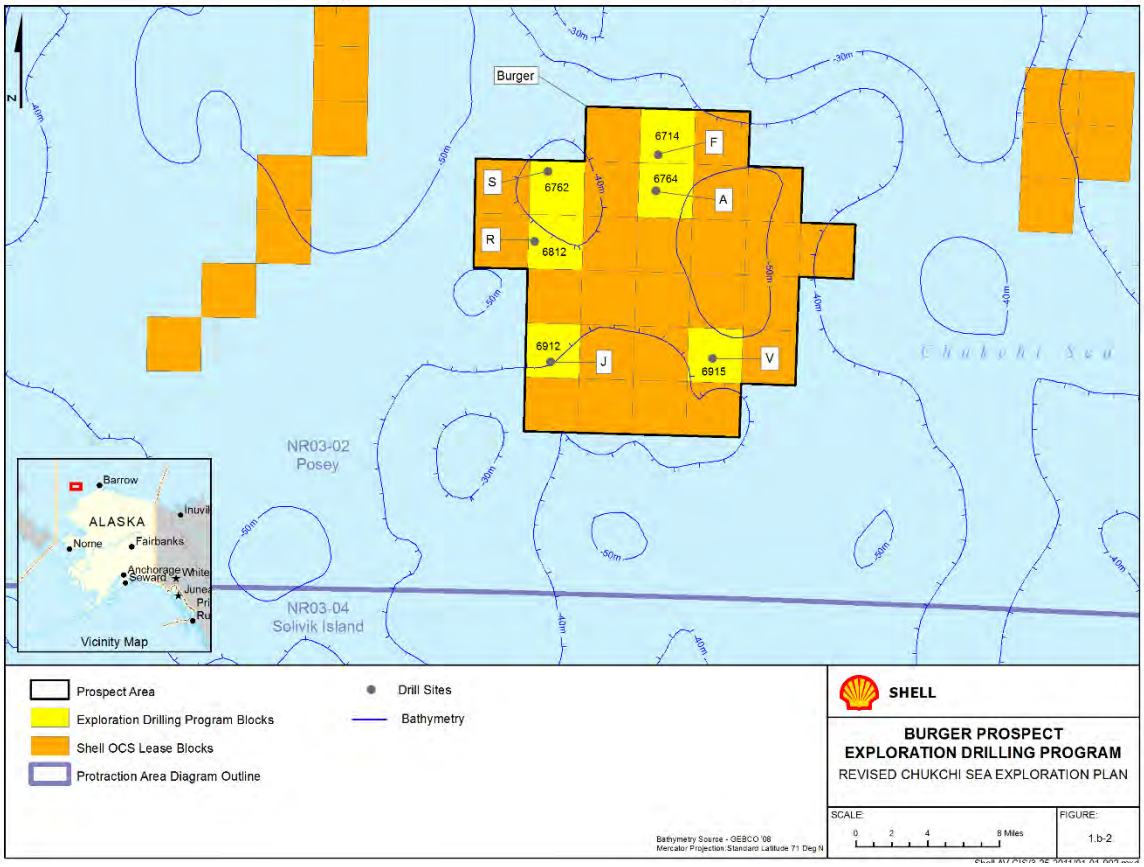


Table 1-1: Location of the Prospect Well Burger S

Prospect Well	Area	Block	Coordinates				Water Depth (m)
			Easting (m)	Northing (m)	Latitude	Longitude	
Burger S	Posey	6762	554,390.64	7,914,198.48	N71° 19' 25.79"	W163° 28' 40.84"	44.0

Table **1**-**2** presents the detailed drilling operation and the effluent data for the prospect well Burger S. This table presents the following data: discharge scenarios, drilling intervals, durations of drilling, footage drilled, volume of total water based drill cuttings including washout, volume of total water based drill fluids, volume of total effluent, effluent (or cuttings mass) discharge rate, volume of seawater added, volume of total pre-diluted effluent, and the pre-diluted effluent discharge rate. The estimated volumes of the water based drill cuttings including fifty percent (**50** %) washout and the drill fluids for the six drilling intervals vary from a low of **604.75** bbls to a high of **4,542.86** bbls. The durations of drilling vary from a low of **5.2** hours to a high of **66.0** hours. The effluent or cuttings mass discharge rates vary from a low of **26.47** to a high of **148.63** bbls/hour. Cement is discharged only for the sea floor discharge scenario during the drilling intervals **2** and **3**. It is included in the volume of the drill cuttings. Moreover, approximately **2,427** bbls of the water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970.8** bbls/hour for **2.5** hours.

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 1-2: Drilling Operation for Burger S

DISCHARGE SCENARIOS, DRILLING INTERVALS, VOLUMES OF DRILL CUTTINGS, AND EFFLUENT DISCHARGE RATES

Discharge Scenario	Drilling Intervals	Durations of Drilling or Pumping	Footage Drilled	Total Water Based Drill Cuttings including 50% Washout[1]	Total Water Based Drill Fluids[2]	Total Effluent (water based drill cuttings + drill fluids)	Effluent Discharge Rate	Seawater Added to the Effluent	Total Pre-diluted Effluent (water based drill cuttings + drill fluids + seawater)	Pre-diluted Effluent Discharge Rate
		(Hours)	(feet)	(bbls)	(bbls)	(bbls)	(bbls/hour)	(bbls)	(bbls)	(bbls/hour)
Sea Floor	1	66.00	40	3,702.86	840.00	4,542.86	68.83	919,457.14	924,000.00	14000.00
	2	5.20	123	232.37	372.37	604.75	116.30	72,195.25	72,800.00	14000.00
	3	34.40	1,086	1,070.17	1,910.17	2,980.34	86.64	478,619.66	481,600.00	14000.00
Sea Surface	4	23.30	1,763	577.17	2,885.86	3,463.04	148.63	252.34	3,715.37	159.46
	5	29.00	2,075	332.86	1,664.32	1,997.19	68.87	314.07	2,311.26	79.70
	6	37.20	2,125	164.12	820.62	984.75	26.47	402.88	1,387.62	37.30
	Discharge from Rig's Surface Pits	2.50	-	-	2,427.00	-	970.80	-	2,427.00	970.80

Notes to Table 1-2:

1: Cement is discharged during the drilling intervals **2** and **3**. It is included in the volume of drill cuttings.

2: Volume of the water based muds discharges from the rig's surface pits.

The cements, water based dill cuttings, and drill fluids mass discharge rate (effluent) for drilling intervals **1**, **2**, and **3** for the sea floor (**013**) discharges are: **68.83**, **116.30**, and **86.64** bbls/hour, respectively. These sediments will be pumped away via use of a pump at the sea floor. A flexible hose suction pipe will intake a large volume of sea water to move the cements, water based drill cuttings, and drill fluids from the seafloor and will discharge from a **12.0** inch internal diameter discharge pipe at **14,000** bbls/hour. This yields into **203.4**, **120.4**, and **161.6** pre-dilution factors before discharging into the ambient for the drilling intervals **1**, **2**, and **3**, respectively. The discharge pipe of the seafloor pump is located at **1.83** m (or **6** feet) above the seafloor and oriented horizontally aligned with the direction of the current, which is to the east.

The water based dill cuttings and drill fluids mass discharge rate (effluent) for drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharges are: **148.63**, **68.87**, and **26.47** bbls/hour, respectively. Sea water at a rate of **10.83** bbls/hour will be added to the drill cuttings and drill fluids before discharging into the ambient during the drilling of the bottom hole section i.e., the drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharge scenario. This

Copyright **2014** by Fluid Dynamix. Company Confidential.

yields into **1**.**1**, **1**.**2**, and **1**.**4** pre-dilution factors before discharging into the ambient for the drilling intervals **4**, **5**, and **6**, respectively. The pre-diluted water based dill cuttings and drill fluids discharge rate (effluent) for drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharges are: **159**.**46**, **79**.**70**, and **37**.**30** bbls/hour, respectively.

The outer diameter of the pipe for the sea surface discharge is **16**.**0** inches. It runs through the main deck of the drill rig Polar Pioneer and comes out on the bottom of the ship. The discharge pipe is located approximately **8**.**53** m below the water line. Therefore, the surface discharges occur at a depth of approximately **8**.**53** m from the sea surface. The internal pipe diameter of **15**.**25** inches was used for modeling the sea surface discharge scenario based on a **0**.**75** inches of total pipe wall thickness. The discharge pipe is oriented vertically downward with respect to the sea surface and discharges at approximately **8.53** m below the sea surface for modeling the sea surface discharge scenario.

The water based drill fluids for the top hole section i.e., the drilling intervals **1**, **2**, and **3**, for the sea floor (**013**) discharge scenario is composed of primarily sea water, which includes **30** pounds (lbs.) of bentonite, **0**.**5** lbs. of xanthan gum, and **0**.**03** lbs. of Gelex bentonite extender in each barrel of sea water.

The water based drill fluids for the bottom hole section i.e., the drilling intervals **4**, **5**, and **6**, for the sea surface (**001**) discharge scenario is composed of primarily sodium chloride (NaCl) brine system. Sodium chloride brine systems are single-salt solutions of sodium chloride and water. Saturated sodium chloride brine has a density of **1,198** kilograms per cubic meter **(**kg/m^3) or **10** lbs. per gallon (lb/gal**)** and used as a base drill fluids for the bottom hole section. Barite at the rate of **1**.**413** lb/gal is added to the base drill fluids to increase the weight of the drill fluids to **1,318.13** kg/m^3 (or **11** lb/gal**)** for drilling the interval **04** of the bottom hole section. Moreover, barite at the rate of **2**.**83** lb/gal is added to the base drill fluids to increase the weight of the drill fluids to **1,438** kg/m^3 (or **12** lb/gal) for drilling the intervals **05** and **06** of the bottom hole section.

1.1 The OOC Model

The Offshore Operators Committee (OOC), a consortium of companies operating in the waters of the Gulf of Mexico, sponsored development of a model to predict the fate of the effluents discharged offshore (Brandsma and Smith, **1999** and Alam and Brandsma, **2013**). The OOC model predicts the fate of drilling mud, cuttings, or produced water discharged from a single pipe. The effluent may contain up to **12** classes of particulates. Particulates may be solids or oil droplets. The model predicts the concentrations of particulates and liquid effluents in the water column and the deposition of solid particles on the sea floor. There are no restrictions on the nature of the receiving environment simulated by the OOC model. The ambient bathymetry may be variable or constant depth. Currents and hydrography may change spatially and temporally. Sea state may change temporally. The model couples an integral plume model of initial dilution and dynamic spreading with a far-field cloud-tracking model.

The OOC model has been validated against laboratory and field data (O'Reilly et al., **1989**; Smith et al, **1994**; and Smith et al., **2004**). The OOC model is maintained with the aid of an automated validation system. The validation system produces an HTML report documenting the results of simulating **681** experiments in twenty-five laboratory studies and four field studies (Brandsma, **2004**), including a field study of cuttings deposition on the sea floor. The model has been used by several major oil companies around the globe, universities, MMS, and EPA. The model has been applied to offshore Brazil, Gulf of Mexico, Nigeria, North Sea, and Pacific Ocean.

The Graphical User Interface Discharge Offshore (GUIDO), version **7**.**3** software (Alam and Brandsma, **2013**) for the OOC model performs pre- and post-processing for the FORTRAN based OOC model. It allows the user to prepare inputs in convenient systems of units, checks and, if necessary, adjusts inputs for consistency and submits the inputs for execution by the OOC model, in interactive or batch mode.

Copyright **2014** by Fluid Dynamix. Company Confidential.

1.2 Settling Velocity Distribution for Solids in Drill Cuttings and Fluids

The solids in drilling discharges have a range of particle sizes (Brandsma and Smith, **1999**). As a result, the settling behavior of the effluent solids is described by a distribution of settling velocities rather than a single settling velocity. The Report and User Guide (Brandsma and Smith, **1999**) of the OOC Model presents examples of solids fall velocity data sets for the water-based mud, water-based mud cuttings, and oil-based mud cuttings. The Report and User Guide states that these data sets can be used for modeling studies in cases where no site specific data are available on the fall velocity distribution of the effluent solids.

The dispersion and deposition numeric simulations of the cements, water based drill cuttings, and drill fluids discharges for both the sea floor and sea surface discharge scenarios were performed using the fall velocity classes for the water based mud cuttings presented in the OOC model Report and User Guide (Brandsma and Smith, **1999**) for the prospect well Burger S. The volume fractions of the fall velocity classes were adjusted for the effluent for each drilling intervals based on the actual volume of the total cuttings solids present in the volumes of the total effluent. The fall velocity classes for the water based mud cuttings from the Report and User Guide is presented in **Table 1-3**. The actual value of the density for the solids was used in the numeric simulations for each drilling intervals.

The dispersion and deposition numeric simulations of the water based muds discharges from the rig's surface pits were performed using the fall velocity classes for the water based mud presented in the OOC model Report and User Guide (Brandsma and Smith, **1999**) for the prospect well Burger S. The volume fractions of the fall velocity classes were adjusted based on the actual volume of the total solids such as barite present in the volume of the total effluent. The fall velocity classes for the water based mud from the Report and User Guide is presented in **Table 1-4**. The actual value of the density for the solids was used in the numeric modeling of the water based muds discharges from the rig's surface pits.

The fall velocities for different sediment particle sizes and classes are presented in **Table 1-5** (Keith Dyer, **1986**).

The ambient and the effluent characteristics used in the OOC models for the Burger S well are described in detailed in **Sections 2** and **3**. The model domain is described in **Section 4**. The model results at the mean and maximum currents are described in details in **Sections 5** and **6. Section 7** presents the sensitivity analysis**. Section 8** describes the summary and conclusion. **Section 9** lists the references cited in this technical report.

Table 1-3: Fall Velocity Classes for Water Based Mud Cuttings (Brandsma and Smith, 1999)

Class	Density (g/cc)	Volume Fraction	Fall Velocity (feet/s)	Fall Velocity (cm/s)
1	2.65	0.04272	0.000004430	0.0001350264
2	2.65	0.03204	0.000055300	0.0016855440
3	2.65	0.03738	0.000716000	0.0218236800
4	2.65	0.01602	0.007638000	0.2328062400
5	2.65	0.01068	0.047480000	1.4471904000
6	2.65	0.09612	0.131600000	4.0111680000
7	2.65	0.08544	0.321400000	9.7962720000
8	2.65	0.08010	0.443500000	13.5178800000
9	2.65	0.13350	0.852200000	25.9750560000

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 1-4: Fall Velocity Classes for Water Based Mud (Brandsma and Smith, 1999)

Class	Density	Volume Fraction	Fall Velocity	
	(g/cc)		(feet/s)	(cm/s)
1	3.377000	0.000530000	3.68000E-02	1.1216640000
2	3.377000	0.002110000	1.40000E-02	0.4267200000
3	3.377000	0.010160000	2.70000E-03	0.0822960000
4	3.377000	0.010160000	2.10000E-03	0.0640080000
5	3.377000	0.007000000	1.68000E-03	0.0512064000
6	3.377000	0.007000000	1.43000E-03	0.0435864000
7	3.377000	0.005280000	9.85000E-04	0.0300228000
8	3.377000	0.002640000	4.85000E-04	0.0147828000
9	3.377000	0.004220000	2.00000E-04	0.0060960000
10	3.377000	0.003700000	9.00000E-05	0.0027432000

Table 1-5: Fall Velocities for Different Sediment Particle Size and Classes (Keith Dyer, 1986)

Sediment Size Class	Particle Size (mm)	Fall Velocity (cm/s)
		Keith Dyer (1986)
Chunks	> 2.0	65
Sand	0.062 - 2.0	32
Coarse Silt	0.016 - 0.062	0.32
Fine Silt	0.004 - 0.016	0.027
Clay	< 0.004	< 0.01

Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 2.0 AMBIENT CHARACTERISTICS

The OOC model was used for the numeric simulations of the dispersion and deposition of the cements, water based drill cuttings, drill fluids, and water based muds discharges from the prospect well Burger S located offshore Chukchi Sea. The required model input data for the ambient are described in this section.

2.1 DEPTH OF WATER

The ambient water characteristics data set presented in **Table 2-1** for the planned drilling period was used for the dispersion and deposition numeric simulations of the cements, water based drill cuttings, drill fluids, and water based muds discharges using the OOC model for both the sea floor and sea surface discharge scenarios. The ambient water depth at the Burger S well site is **44.0** m. The planned drilling period is within the open water season of July thru October.

2.2 TEMPERATURE AND SALINITY

The stratification of the ambient temperature and salinity for the open water season is presented in **Figures 2-1** and **2-2**, respectively. The temperature of the ambient water varies from **4** degrees Celsius (°C) at the surface stratum to - **0.5** °C at the bottom stratum, with a significant stratification occurring at **15** m depth. The salinity of the ambient water varies from **30** Practical Salinity Scale Unit (psu) at the surface stratum to **32** psu at the bottom stratum.

Table 2-1: Ambient Water Characteristics for the Burger Field, for the planned drilling period

Water Depth	Temperature	Salinity	Mean Current		Maximum Current	
			Speed	Direction (from True North)	Speed	Direction (from True North)
m	°C	psu	cm/s	°T	cm/s	°T
0.0	4.00	30.0	7.0	90	25.0	90
15.0	3.50	30.5	7.0	90	25.0	90
20.0	-0.25	31.5	7.0	90	25.0	90
43.9-45.7	-0.50	32.0	7.0	90	25.0	90

2.3 CURRENT SPEED

The report "Physical Oceanographic Measurements in the Klondike and Burger Survey Areas of the Chukchi Sea: **2008** and **2009**" (Figures **2** and **3**, Weingartner and Danielson, **2010**) for the year **2008** states the following: Mean current speeds within the Herald and Barrow Canyons are swift (**25** centimeters per second (cm/s)), more moderate in the Central Channel (**10** cm/s), and generally < **5** cm/s elsewhere. The prospect well Burger S is located in **71°** N and **163°** W. It can be seen from Figure **3** (Weingartner and Danielson, **2010**) that the mean flow vectors (blue arrows) in the vicinity of **71°** N and **163°** W are approximately in the range of **3** cm/s to **10** cm/s.

Therefore, the current speed of **7** cm/sec is used in the model as the average value. The current speed of **25** cm/sec is used as the maximum value in the OOC model. The currents turn eastward to enter the Barrow Canyon at **71°** N (Ref: Page **4**, Physical oceanographic measurements in the Klondike and Burger prospects of the Chukchi Sea: **2008** and **2009**). The current speed is distributed uniformly with the depth with a prevailing direction of flow to the east for the planned drilling period in the OOC model.

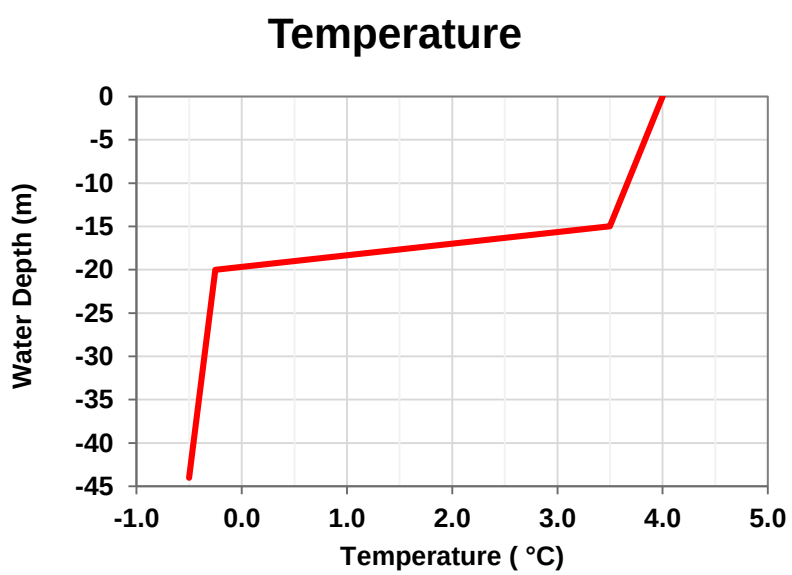
Copyright **2014** by Fluid Dynamix. Company Confidential.

2.4 Winds Speed and Wave Height

The wind speed during the open water season steadily increases from July through October as presented in **Figure 2-3**. The approximate values for the **50**-percentile rank wind speeds for July, August, September, and October are **6.8**, **7.8**, **9.5**, and **10.3** meters per second (m/s), respectively. The tentative drilling period for Burger S is beginning of August to mid-September. The average value for **50**-percentile rank wind speeds for the month of August and September i.e., **8.7** m/s was used for the Burger S well.

The wave height during the open water season also steadily increases from July through October as presented in **Figure 2-4**. The approximate values for the **50**-percentile rank wave heights for July, August, September, and October are **1.2**, **1.4**, **1.8**, and **1.9** m, respectively. The average value for **50**-percentile rank wave height for the month of August and September i.e., **1.6** m was used for the Burger S well.

Figure 2-1: Ambient temperature for open water season, Burger Field, Chukchi Sea



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 2-2: Ambient salinity for open water season, Burger Field, Chukchi Sea

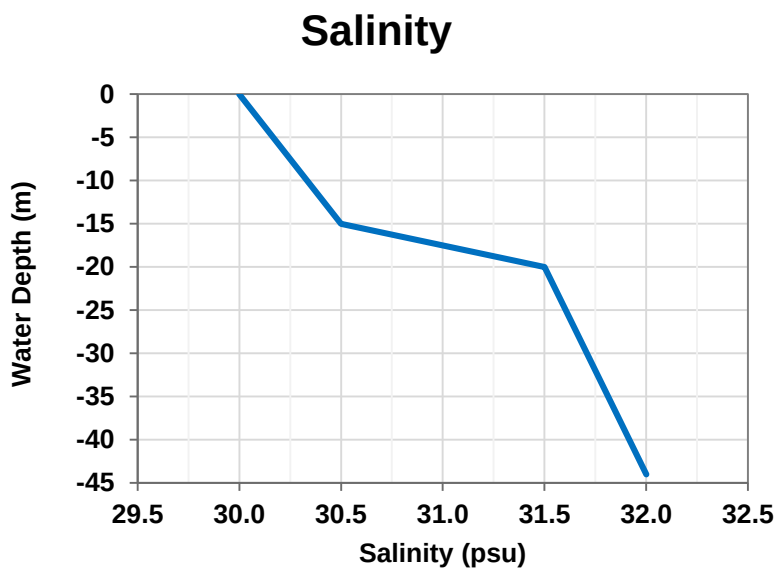
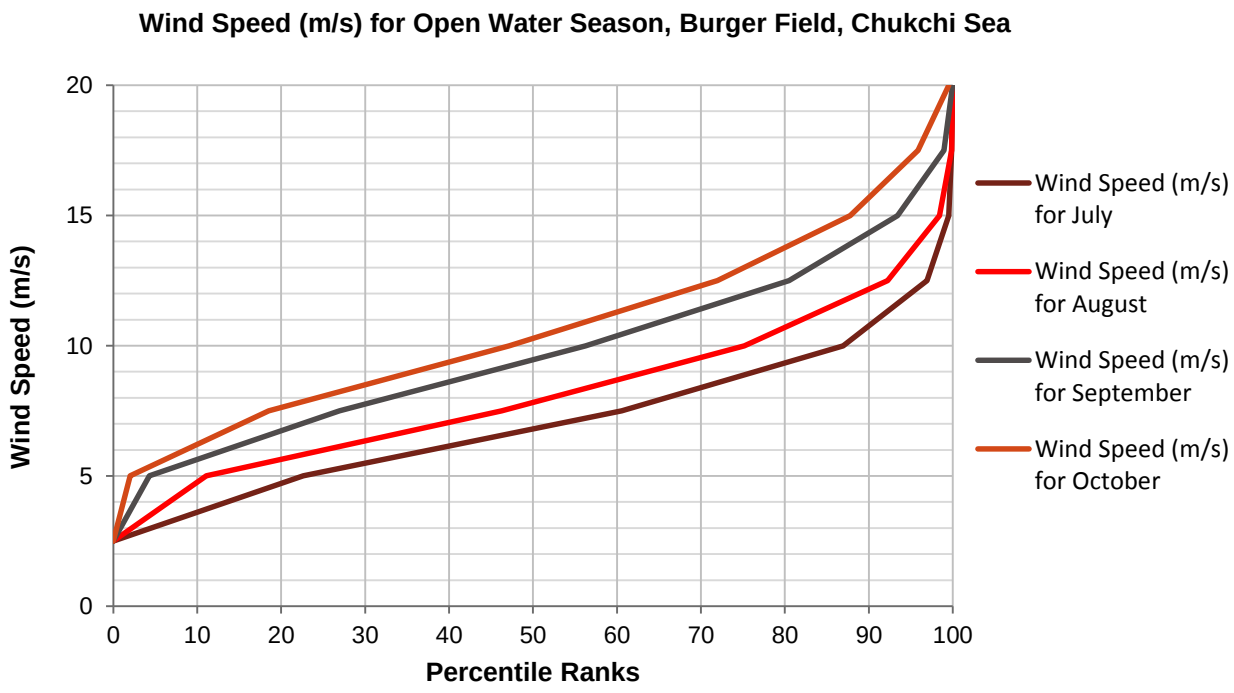
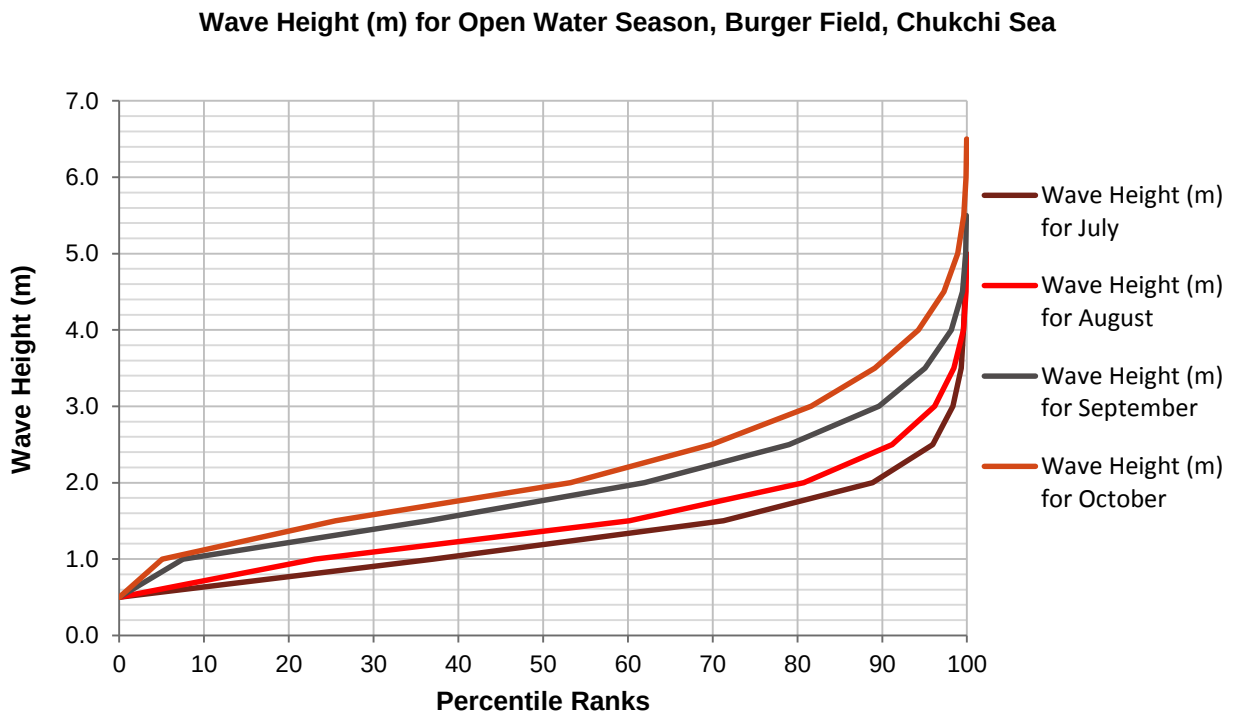


Figure 2-3: Wind speed for open water season, Burger Field, Chukchi Sea



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 2-4: Wave height for open water season, Burger Field, Chukchi Sea



Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 3.0 EFFLUENT CHARACTERISTICS

The OOC model was used for the numeric simulations for the dispersion and deposition of the cements, water based drill cuttings, drill fluids, and water based muds discharges from the drilling operation at the prospect well Burger S located offshore Chukchi Sea. The required model input data for the effluent are described in this section.

3.1 DISCHARGE SCENARIOS

The dispersion and deposition numeric simulations both for the sea floor (**013**) and the sea surface (**001**) discharge scenarios as listed below were performed for two sets of currents speed: mean currents and maximum currents. This provides a sensitivity analysis of the numeric model results to the model input parameter: currents speed. The modeled discharge scenarios are:

- **Discharge Scenario 1a**: **Sea Floor Discharges (013) at Mean Currents**
  Muds, cuttings, and cements discharges prior to the installation of the riser near the sea floor.

- **Discharge Scenario 1b: Sea Surface Discharges (001) at Mean Currents**
  Water based drill fluids and drill cuttings discharges after the installation of the riser near the sea surface. Moreover, approximately **2**,**427** bbls of water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970**.**80** bbls/hour for **2**.**5** hours.

- **Discharge Scenario 2a**: **Sea Floor Discharges (013) at Maximum Currents**
  Muds, cuttings, and cements discharges prior to the installation of the riser near the sea floor.

- **Discharge Scenario 2b: Sea Surface Discharges (001) at Maximum Currents**
  Water based drill fluids and drill cuttings discharges after the installation of the riser near the sea surface. Moreover, approximately **2**,**427** bbls of water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970**.**80** bbls/hour for **2**.**5** hours.

3.2 DRILLING INTERVALS, DRILLING DURATIONS, AND EFFLUENT DISCHARGE RATES

The drilling operation for the Burger S well would be conducted by the drill ship Polar Pioneer. The drilling operation for each discharge scenario (sea floor and sea surface) would be conducted in three different intervals yielding a total of six (**2** discharge scenarios × **3** drilling intervals per scenario) drilling intervals. Moreover, approximately **2,427** bbls of the water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970**.**80** bbls/hour for **2.5** hours.

The effluent characteristics from the drilling operation are presented in details in **Table 3-1** for each of the six drilling intervals and the rig's surface pits for the prospect well Burger S. This table presents the following data: discharge scenarios, drilling intervals, durations of drilling, footage drilled, volume of total water based drill cuttings including washout, volume of total water based drill fluids, volume of total effluent, effluent (or cuttings mass) discharge rate, volume of seawater added, volume of total pre-diluted effluent, and the pre-diluted effluent discharge rate. The estimated volumes of the water based drill cuttings including fifty percent (**50** %) washout and the drill fluids for the six drilling intervals vary from a low of **604.75** bbls to a high of **4,542.86** bbls. The durations of drilling vary from a low of **5.2** hours to a high of **66.0** hours. The effluent or cuttings mass discharge rates vary from a low of **26.47** to a high of **148.63** bbls/hour. Cement is discharged only for the sea floor discharge scenario during the drilling intervals **2** and **3**. It is included in the volume of the drill cuttings.

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 3-1: Drilling Operation for Burger S

DISCHARGE SCENARIOS, DRILLING INTERVALS, DURATIONS OF DRILLING AND EFFLUENT DISCHARGE RATES

Discharge Scenario	Drilling Intervals	Durations of Drilling or Pumping	Footage Drilled	Total Water Based Drill Cuttings including 50% Washout[1]	Total Water Based Drill Fluids[2]	Total Effluent (water based drill cuttings + drill fluids)	Effluent Discharge Rate	Seawater Added to the Effluent	Total Pre-diluted Effluent (water based drill cuttings + drill fluids + seawater)	Pre-diluted Effluent Discharge Rate
		(Hours)	(feet)	(bbls)	(bbls)	(bbls)	(bbls/hour)	(bbls)	(bbls)	(bbls/hour)
Sea Floor	1	66.00	40	3,702.86	840.00	4,542.86	68.83	919,457.14	924,000.00	14000.00
	2	5.20	123	232.37	372.37	604.75	116.30	72,195.25	72,800.00	14000.00
	3	34.40	1,086	1,070.17	1,910.17	2,980.34	86.64	478,619.66	481,600.00	14000.00
Sea Surface	4	23.30	1,763	577.17	2,885.86	3,463.04	148.63	252.34	3,715.37	159.46
	5	29.00	2,075	332.86	1,664.32	1,997.19	68.87	314.07	2,311.26	79.70
	6	37.20	2,125	164.12	820.62	984.75	26.47	402.88	1,387.62	37.30
	Discharge from Rig's Surface Pits	2.50	-	-	2,427.00	-	970.80	-	2,427.00	970.80

Notes to Table 3-1:

1: Cement is discharged during the drilling intervals **2** and **3**. It is included in the volume of drill cuttings.

2: Volume of the water based muds discharges from the rig's surface pits.

The water based drill fluids for the top hole section i.e., the drilling intervals **1**, **2**, and **3**, for the sea floor (**013**) discharge scenario is composed of primarily sea water, which includes **30** lbs. of bentonite, **0.5** lbs. of xanthan gum, and **0.03** lbs. of Gelex bentonite extender in each barrel of sea water.

The water based drill fluids for the bottom hole section i.e., the drilling intervals **4**, **5**, and **6**, for the sea surface (**001**) discharge scenario is composed of primarily sodium chloride (NaCl) brine system. Sodium chloride brine systems are single-salt solutions of sodium chloride and water. Saturated sodium chloride brine has a density of **1,198** kg/m^3 (or **10** lb/gal**)** and used as a base drill fluids for the bottom hole section. Barite at the rate of **1.413** lb/gal is added to the base drill fluids to increase the weight of the drill fluids to **1,318.13** kg/m^3 (or **11** lb/gal) for drilling the interval **04** of the bottom hole section. Moreover, barite at the rate of **2.83** lb/gal is added to the base drill fluids to increase the weight of the drill fluids to **1,438** kg/m^3 (or **12** lb/gal) for drilling the intervals **05** and **06** of the bottom hole section.

Copyright **2014** by Fluid Dynamix. Company Confidential.

3.3 Discharge Pipe Size and Height

A pump will be used at the sea floor during the drilling of the top hole section i.e., the drilling intervals **1**, **2**, and **3** for the sea floor (**013**) discharges. A flexible hose suction pipe will intake a large volume of sea water to move the cements, water based drill cuttings, and drill fluids from the seafloor and will discharge from a **12**.**0** inch internal diameter discharge pipe at **14**,**000** bbls/hour. The discharge pipe of the seafloor pump is located at **1**.**83** m (or **6** feet) above the seafloor and oriented horizontally aligned with the direction of the current, which is to the east.

The outer diameter of the pipe for the sea surface discharge is **16**.**0** inches. It runs through the main deck of the drill rig Polar Pioneer and comes out on the bottom of the ship. The discharge pipe is located approximately **8**.**53** m below the water line. Therefore, the surface discharges occur at a depth of approximately **8**.**53** m from the sea surface. The internal pipe diameter of **15**.**25** inches was used for modeling the sea surface discharge scenario based on a **0**.**75** inches of total pipe wall thickness. The discharge pipe is oriented vertically downward with respect to the sea surface and discharges at approximately **8.53** m below the sea surface for modeling the sea surface discharge scenario.

3.4 Fall Velocity Classes for Water Based Drill Cuttings

The dispersion and deposition numeric simulations of the cements, water based drill cuttings, and drill fluids discharges for both the sea floor and sea surface discharge scenarios were performed using the fall velocity classes for the water based mud cuttings presented in the OOC model Report and User Guide (Brandsma and Smith, **1999**) for the prospect well Burger S. The volume fractions of the fall velocity classes were adjusted for the effluent classes for each drilling intervals based on the actual volume of the total cuttings solids present in the effluent. The fall velocity classes and volume fractions for the water based drill cuttings used for the Burger S well is presented in **Table 3-2**. The solids density varies from **2**.**65** grams per cubic centimeter (g/cc) to **3**.**07** g/cc, depending on the quantities of drill cuttings, bentonite, and barite present in the effluent.

3.5 Fall Velocity Classes for Water Based Muds

The dispersion and deposition numeric simulation of the water based muds discharges from the rig's surface pits was performed using the fall velocity classes for the water based mud presented in the OOC model Report and User Guide (Brandsma and Smith, **1999**) for the prospect well Burger S. The volume fractions of the fall velocity classes were adjusted based on the actual volume of the total solids namely barite present in the effluent. The fall velocity classes and volume fractions for the water based muds used for the Burger S well is presented in **Table 3-3**. The actual value of the density for barite (**4**.**1** g/cc) was used in the numeric modeling.

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 3-2: Fall Velocity Classes and Volume Fractions for Water Based Drill Cuttings, Burger S

Well ID	Sediment Class in Drill Cuttings	Solids Density	Estimated Particle Diameter	Fall Velocity	Volume Fractions For Drilling Intervals					
		(g/cc)	micro meter (µm)	(cm/s)	1	2	3	4	5	6
Burger S	1	Varies from 2.65 to 3.07	1	0.0001350264	0.0003229	0.0002686	0.0001880	0.0149939	0.0162778	0.0133684
	2		4	0.0016855440	0.0002422	0.0002014	0.0001410	0.0112454	0.0122083	0.0100263
	3		15	0.0218236800	0.0002826	0.0002350	0.0001645	0.0131196	0.0142431	0.0116973
	4		50	0.2328062400	0.0001211	0.0001007	0.0000705	0.0056227	0.0061042	0.0050131
	5		125	1.4471904000	0.0000807	0.0000671	0.0000470	0.0037485	0.0040694	0.0033421
	6		250	4.0111680000	0.0007266	0.0006043	0.0004231	0.0337362	0.0366250	0.0300788
	7		500	9.7962720000	0.0006459	0.0005372	0.0003761	0.0299877	0.0325556	0.0267367
	8		1000	13.5178800000	0.0006055	0.0005036	0.0003526	0.0281135	0.0305208	0.0250657
	9		3600	25.9750560000	0.0010092	0.0008393	0.0005876	0.0468559	0.0508681	0.0417761

Table 3-3: Fall Velocity Classes and Volume Fractions for Water Based Drilling Fluids, Burger S

Well ID	Sediment Class in Drilling Fluids	Solids Density	Estimated Particle Diameter	Fall Velocity	Volume Fractions
		(g/cc)	micro meter (µm)	(cm/s)	Discharge from Rig's Surface Pit
Burger S	1	4.1	75.0	1.121664	0.00082876183
	2		50.0	0.426720	0.00329941031
	3		20.0	0.082296	0.01588720795
	4		18.0	0.064008	0.01588720795
	5		16.0	0.051206	0.01094591099
	6		15.0	0.043586	0.01094591099
	7		12.5	0.030023	0.00825634429
	8		8.0	0.014783	0.00412817214
	9		5.0	0.006096	0.00659882062
	10		3.5	0.002743	0.00578569581

Copyright **2014** by Fluid Dynamix. Company Confidential.

3.6 Effluent Densities

The sea water density was computed using the Equation of State presented by Crowley (Crowley, **1986**). The computations for the solids density, solids volume fractions, and effluent bulk density for the water based drill cuttings and water based muds for the prospect well Burger S are presented in **Tables 3-4a** and **3-4b**.

Density of sea water at the surface = **1**,**023**.**80** kg/m^3.
Density of sea water at the bottom = **1**,**025**.**77** kg/m^3
Density of drill cuttings = **2**,**650**.**00** kg/m^3.
Density of drilling fluid for drilling intervals **01**, **02**, and **03** (top hole section) = **1**,**076**.**13** kg/m^3.
Density of drilling fluid for drilling interval **04** (bottom hole section) = **1**,**318**.**13** kg/m^3.
Density of drilling fluid for drilling intervals **05** and **06** (bottom hole section) = **1**,**437**.**87** kg/m^3.

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 3-4a: Computations of Solids Density and Solids Volume Fractions for Burger S

Drilling Interval	Drill Fluids				Total Cuttings Solids[1]				Total Solids Mass	Total Solids Volume	Solids Density		Volume Fraction of Solids in Effluent
	Density	Volume		Mass	Density	Volume		Mass					
	kg/m³	bbls	m³	kg	kg/m³	bbls	m³	kg	kg	m³	kg/m³	g/cc	
1	1,076.18	840	134	143,724	2,650	3,703	589	1,560,074	1,571,304.80	593.03	2,649.64	2.65	0.00403683
2	1,076.18	372	59	63,713	2,650	232	37	97,903	102,881.26	38.86	2,647.54	2.65	0.00335738
3	1,076.18	1,910	304	326,829	2,650	1,070	170	450,880	476,418.75	179.97	2,647.27	2.65	0.00235040
4	1,318.13	2,886	459	604,778	2,650	577	92	243,172	320,856.54	110.71	2,898.16	2.90	0.18742341
5	1,437.87	1,664	265	380,470	2,650	333	53	140,241	229,813.12	74.77	3,073.68	3.07	0.20347227
6	1,437.87	821	130	187,598	2,650	164	26	69,148	113,313.42	36.87	3,073.68	3.07	0.16710448
Rig's Surface Pits	1,198.30	2,227	354	424,203	4,100	200	32	130,618	130,618.22	31.86	4,100.00	4.10	0.0825634

Note to Table 3-4a:

1: The water based muds discharged from the rig's surface pits contains barite solids and the corresponding density, volume, and mass presented above under "Total Cuttings Solids" are for barite and not for sea floor cuttings.

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 3-4b: Computations of Effluent Bulk Density for Burger S

Drilling Interval	Drill Fluids				Total Cuttings Solids [1]				Sea Water				Computation of Density of Effluent (Bulk Density)			
	Density	Volume		Mass	Density	Volume		Mass	Density	Volume		Mass	Total Mass	Total Volume	Bulk Density	
	kg/m³	bbls	m³	kg	kg/m³	bbls	m³	kg	kg/m³	bbls	m³	kg	kg	m³	kg/m³	lbs/gal
1	1,076.18	840	134	143,724	2,650	3,703	589	1,560,074	1,025.77	919,457	146,182	149,948,589	151,652,387	146,904	1,032.32	8.62
2	1,076.18	372	59	63,713	2,650	232	37	97,903	1,025.77	72,195	11,478	11,773,878	11,935,494	11,574	1,031.21	8.61
3	1,076.18	1,910	304	326,829	2,650	1,070	170	450,880	1,025.77	478,620	76,094	78,055,126	78,832,835	76,568	1,029.58	8.59
4	1,318.13	2,886	459	604,778	2,650	577	92	243,172	1,023.80	252	40	41,074	889,024	591	1,505.04	12.56
5	1,437.87	1,664	265	380,470	2,650	333	53	140,241	1,023.80	314	50	51,122	571,833	367	1,556.18	12.99
6	1,437.87	821	130	187,598	2,650	164	26	69,148	1,023.80	403	64	65,577	322,323	221	1,461.02	12.19
Rig's Surface Pits	1,198.30	2,227	354	424,203	4,100	200	32	130,618	-	-	-	-	554,821	386	1,437.87	12.00

Note to Table 3-4b:

1: The water based muds discharged from the rig's surface pits contains barite solids and the corresponding density, volume, and mass presented above under "Total Cuttings Solids" are for barite and not for sea floor cuttings.

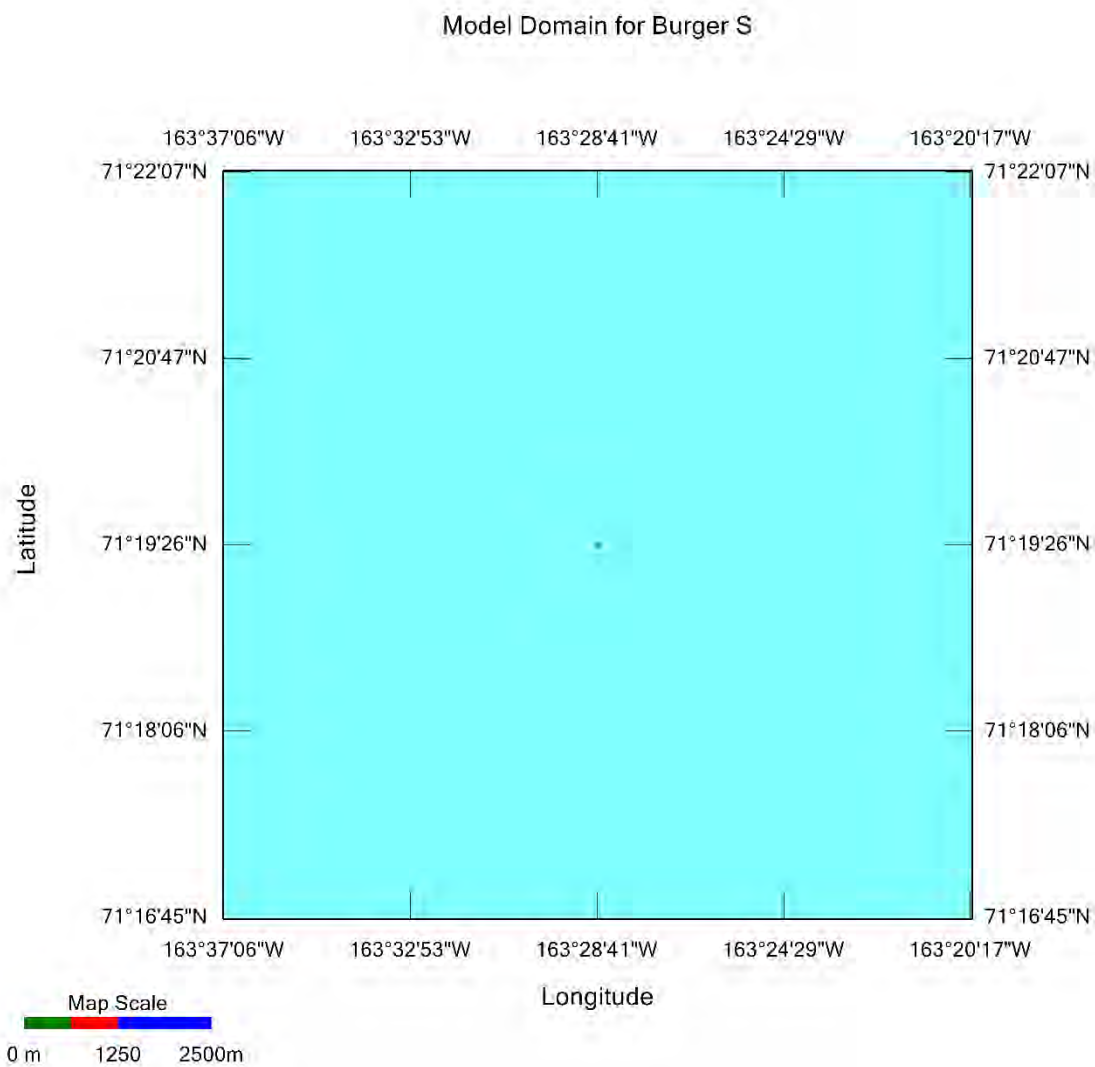
Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 4.0 MODEL DOMAIN

The dispersion and deposition numeric simulations of the cements, water based drill cuttings, drill fluids, and water based muds discharges for both the sea floor and sea surface discharge scenarios were performed using the OOC model as described in **Section 1**.

The model domain extends **5**,**000** m or **5.0** kilometers (km) in all directions from the discharge source. The model consists of **500** cells in the west-east direction and **500** cells in the north-south direction as well. Each cell is a **20** m × **20** m square. The well is located at the center of the model domain shown by a gray dot in **Figure 4-1**.

Figure 4-1: Model domain for the prospect well Burger S



Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 5.0 DISPERSION AND DEPOSITION MODELING – MEAN CURRENTS

The dispersion and deposition numeric simulations of the cements, water based drill cuttings, and drill fluids discharges from the drilling operation at the Burger S well site for both the sea floor **(D013)** and sea surface **(D001)** discharge scenarios at the mean currents were performed using the OOC model. The numeric simulations were carried out for the six drillings intervals for the actual drilling durations: **66.0**, **5.2**, **34.4**, **23.3**, **29.0**, and **37.2** hours as presented in **Table 5-1**. Moreover, numeric simulation was also carried out for the surface discharge of the water based muds at the end of the drilling of the well from the rig's surface pits at a rate of **970.80** bbls/hour for **2.5** hours. A **360**-second model time step (Δt) was used for the computer simulations of all discharges listed in Table **5-1**. The solids deposition on the seabed from the below listed discharges from the six discrete drilling intervals and the rig's surface pits were compiled using the GUIDO **7** software for the OOC model yielding the total solids deposition loading and thickness distribution on the seabed from the drilling operation at the Burger S well site.

Table 5-1: Total Simulation Time, Model Time Step, and Discharge Rates for Burger S

Well ID	Discharge Scenario	Drilling Intervals	Durations of Drilling (Discharge)		The OOC Numeric Model Simulation			Depth of Water	Depth of Discharge	Effluent (Cuttings + Drilling Fluids) Mass Discharge Rate	Pre-diluted Effluent Discharge Rate
					Total Simulation Time	Model Time Step (Δt)	Count of Total Model Steps				
			Hours	Seconds	Seconds	Seconds		m	m	bbls/hour	bbls/hour
Burger S	Sea Floor	1	66.00	237,600	237,600	360	660	44.00	42.17	68.83	14,000
		2	5.20	18,720	18,720	360	52	44.00	42.17	116.30	14,000
		3	34.40	123,840	123,840	360	344	44.00	42.17	86.64	14,000
	Sea Surface	4	23.30	83,880	83,880	360	233	44.00	8.53	148.63	159.46
		5	29.00	104,400	104,400	360	290	44.00	8.53	68.87	79.70
		6	37.20	133,920	133,920	360	372	44.00	8.53	26.47	37.30
		Rig's Surface Pits	2.50	9,000	9,000	360	25	44.00	8.53	970.80	970.80

Copyright **2014** by Fluid Dynamix. Company Confidential.

The OOC model predictions for the dispersion and deposition of the cements, water based drill cuttings, drill fluids, and water based muds in the near-field and far-field receiving water are presented in this technical report by the following effluent characteristics:

- Trajectory and shape of the discharge plume
- Total suspended solids (TSS) concentrations in milligrams per liter (mg/l) in the water column
- Amount of deposition of the discharged solids in kilograms per square meter (kg/m^2) on the seabed
- Spatial extent of deposition (i.e., solids thickness distribution) in centimeter (cm) of the discharged solids on the seabed

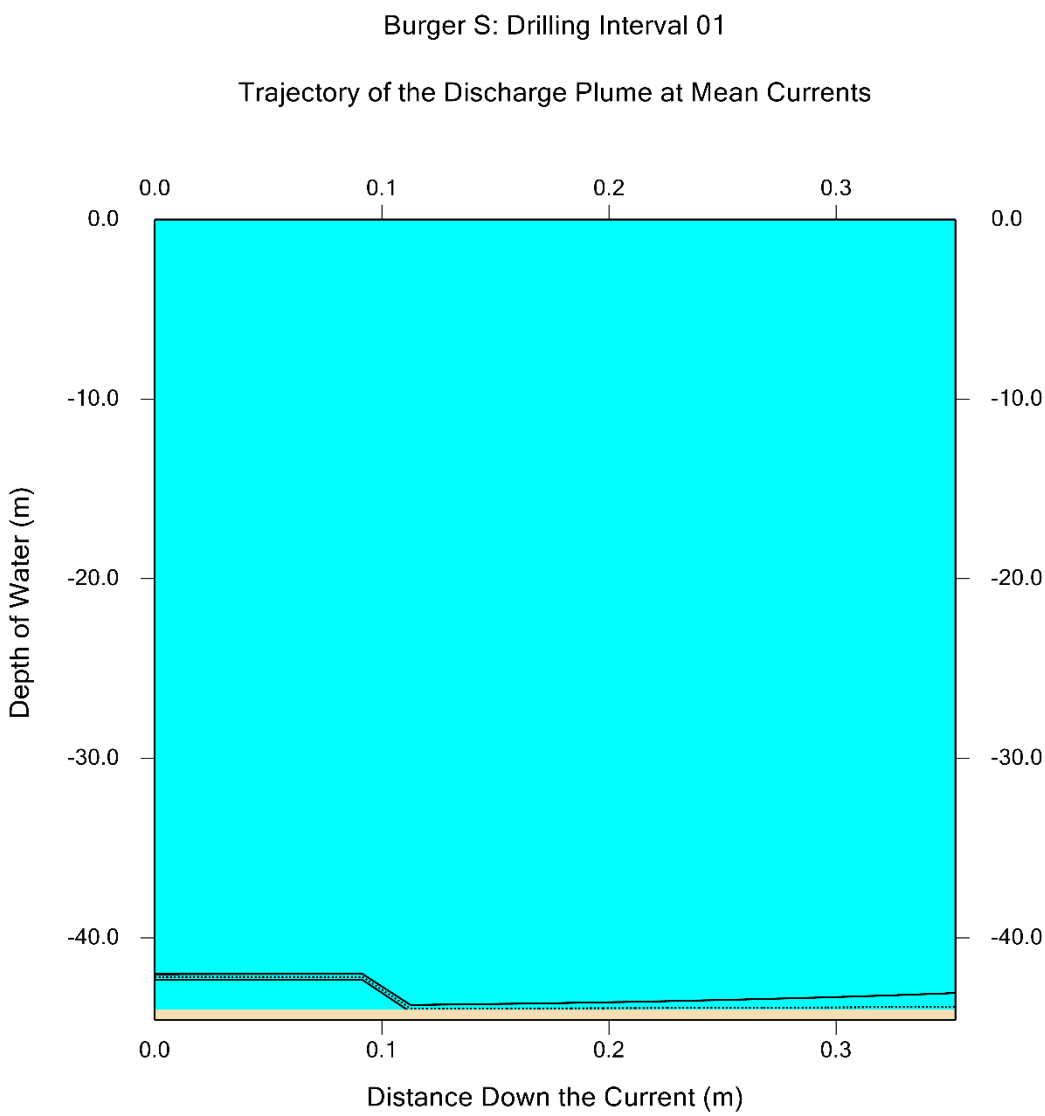
Copyright **2014** by Fluid Dynamix. Company Confidential.

5.1 Model Results for Sea Floor Discharge Scenario – Drilling Interval 01

Trajectory and Shape of the Discharge Plume

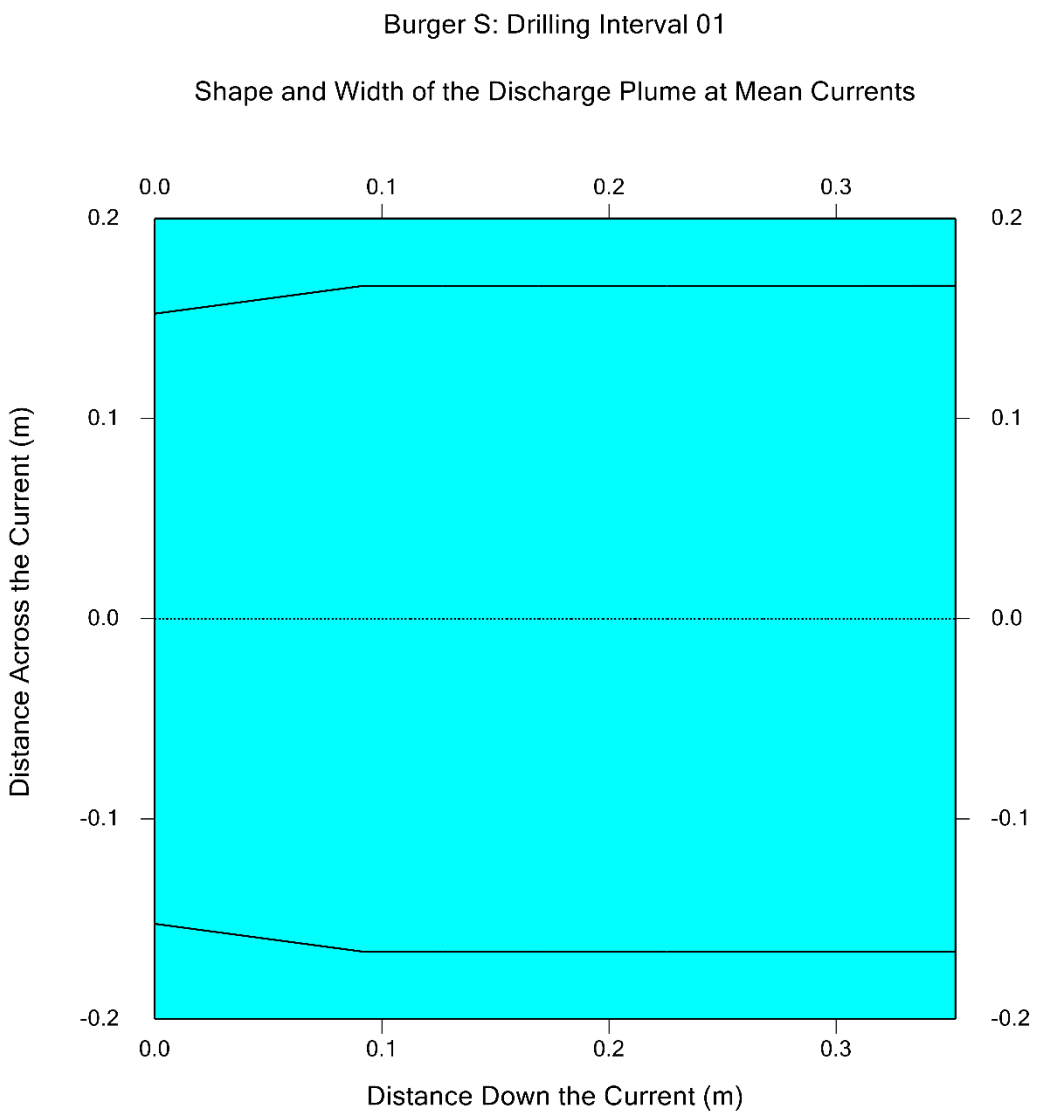
The trajectory of the discharge plume is presented in **Figure 5-1**. The depth of water is **44.0** m and the discharge occurs at a depth of **42.17** m from a **12.0** inches internal diameter discharge pipe of the sea floor pump at **14,000** bbls/hour. A flexible hose suction pipe of this sea floor pump moves the water based drill cuttings and drill fluids from the drill strings and discharges at **1.83** m (or **6** feet) above the seafloor. The discharge pipe is oriented horizontally aligned with the direction of the current, which is to the east. Therefore, the heavier discharge plume attempts to shoot horizontally as seen in Figure **5**-**1** and travels to the east to a distance approximately **0**.**35** m only from the discharge location before collapsing onto the sea floor due to the proximity of the plume near the sea floor. The shape and width of the discharge plume is presented in **Figure 5**-**2**. The width of the plume is approximately **0**.**35** m at a distance **0**.**35** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **5**-**1** and **5**-**2**.

Figure 5-1: Trajectory of the discharge plume at mean currents, Drilling Interval 01



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-2: Shape and width of the discharge plume at mean currents, Drilling Interval 01



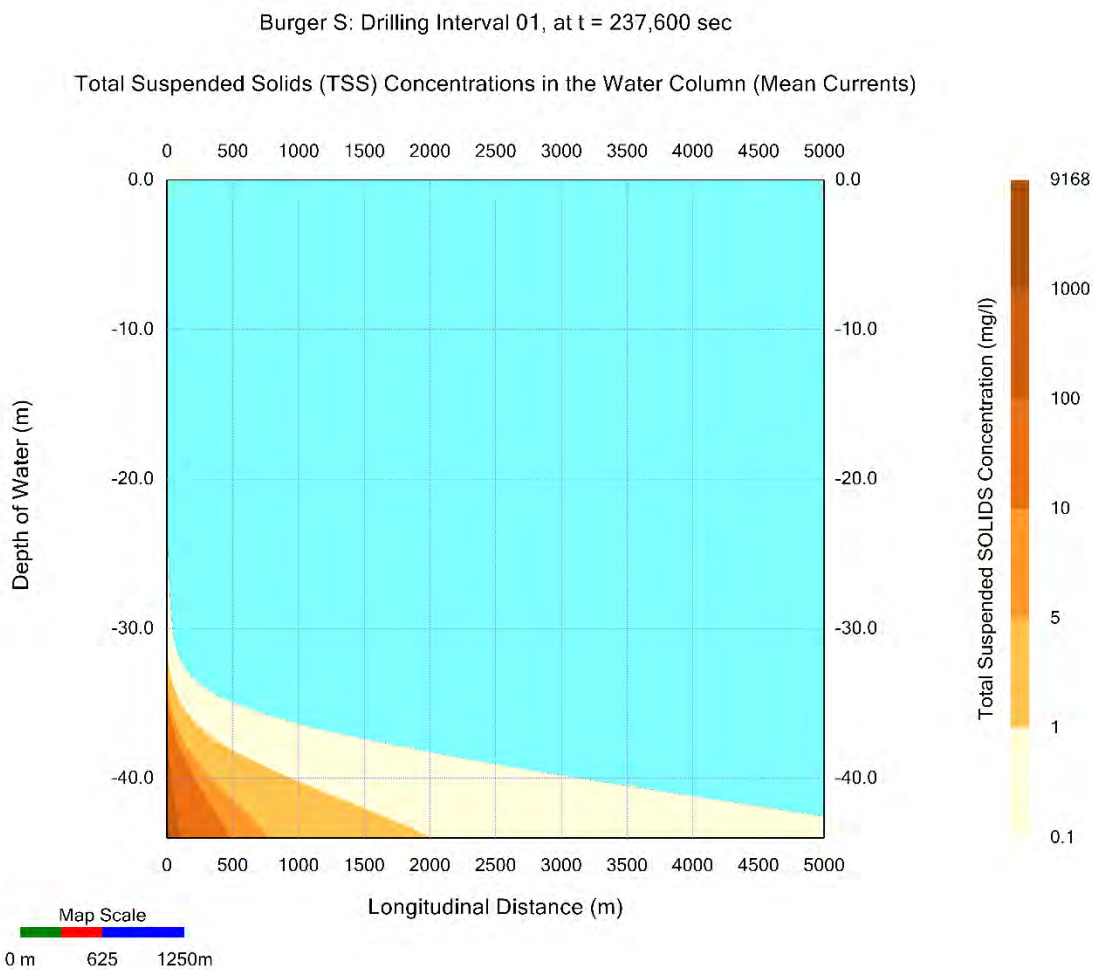
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **237,600** sec (or **66.0** hours) which is the discharge duration for this drilling interval is presented in **Figure 5-3**a. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **42**.**17** m from a **12.0** inches internal diameter discharge pipe. Figure **5-3**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **9**,**168** mg/l occurs at the discharge location. It decreases to a value of **100** mg/l and **10** mg/l at distances approximately **95** m and **475** m, respectively from the discharge location. It varies from **10** to **5** mg/l approximately between **475** and **750** m distances from the discharge location. It varies from **5** to **1** mg/l between **750** and **2**,**000** m distances from the source. It is less than **1** mg/l beyond **2**,**000** m from the discharge location. The effect of the sea floor pump is visible in this Figure **5**-**3**. The discharge plume is spreading farther horizontally to the east along the direction of the current than vertically. The TSS concentration is less than **1** mg/l at a depth approximately **30** m at or near the discharge location. It is less than **5** mg/l at a depth approximately **40** m at **500** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **1**,**085**.**8**, **383**.**6**, **96**.**1**, **20**.**3**, and **3**.**3** mg/l, respectively.

Figure 5-3a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 01

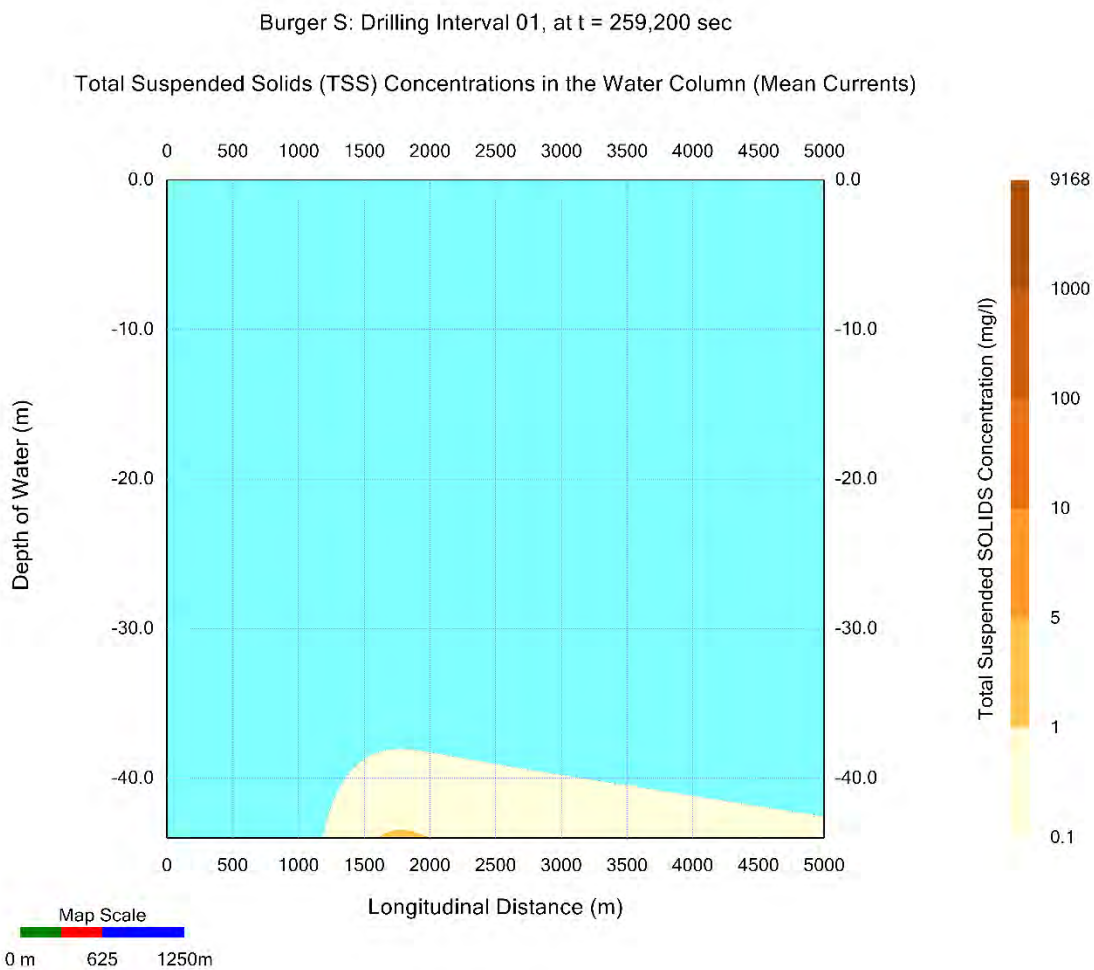


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

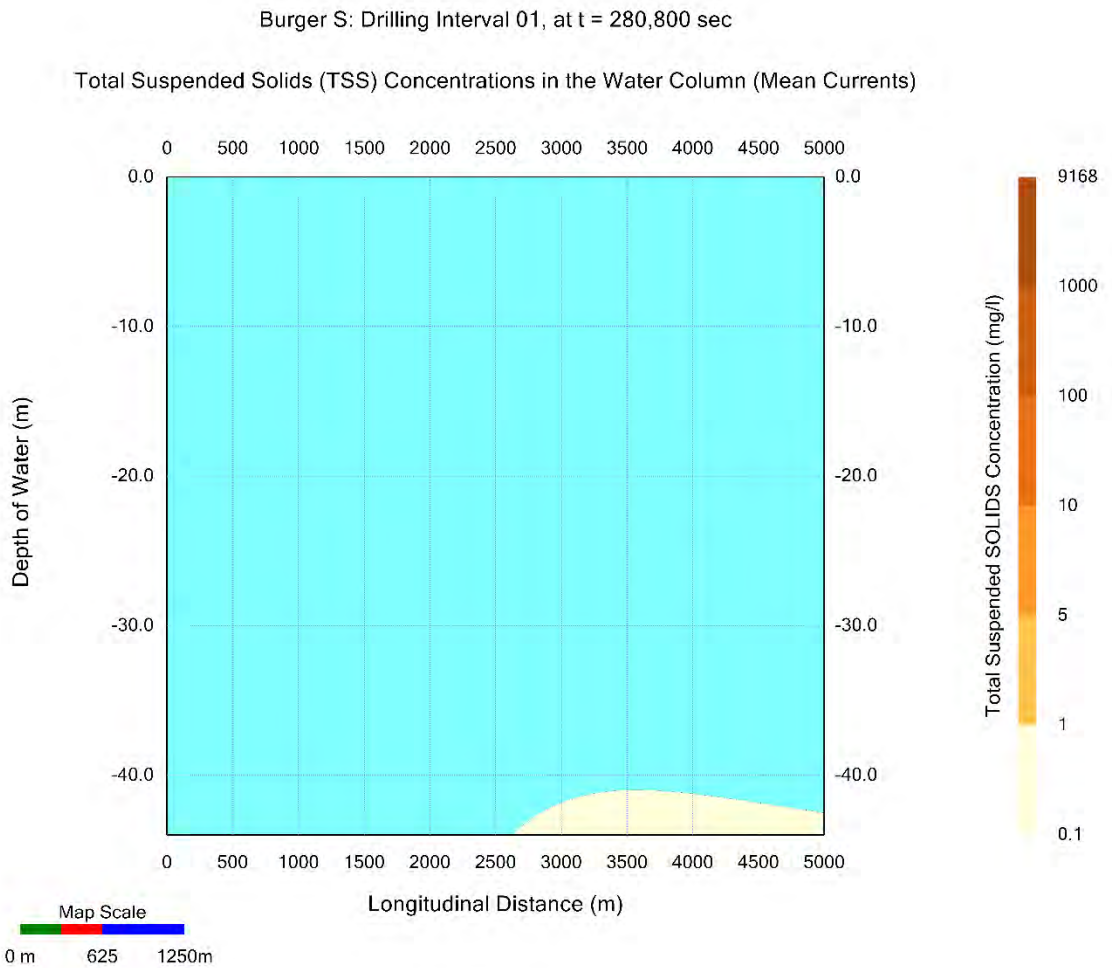
The discharge of the water based drill cuttings and drill fluids ceases at time, t = **237**,**600** sec (or **66.0** hours). The fate and transport of the discharged solids at times **6**, **12**, and **18** hours (h) after the cessation of the discharge are presented by **Figures 5-3**b**, 5-3**c**,** and **5-3**d. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **5** mg/l or less at **6** h, **1** mg/l or less at **12** h, and less than **0.1** mg/l at **18** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **12** and **18** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0.1** mg/l within the model domain.

Figure 5-3b: TSS concentrations during the mean currents at 72 h (or 6 h after the cessation of release)



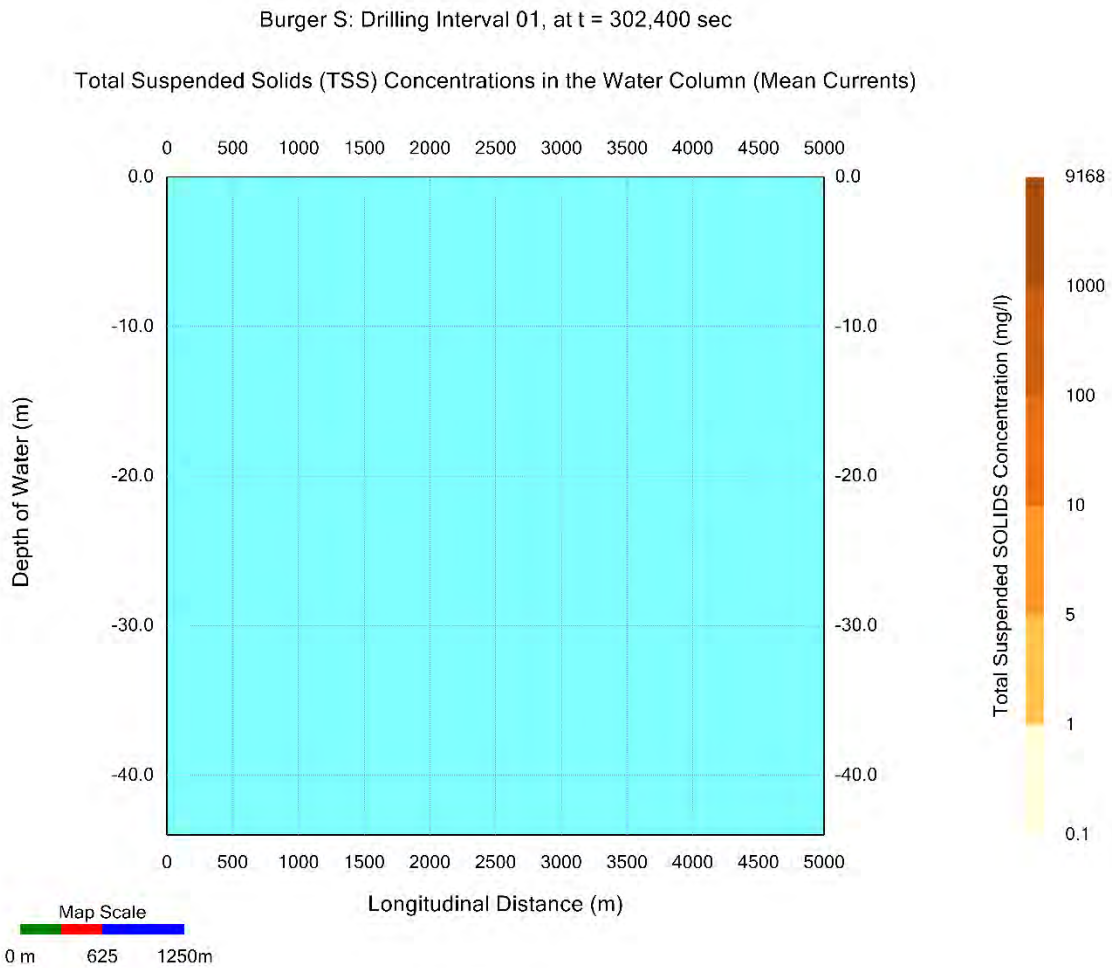
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-3c: TSS concentrations during the mean currents at 78 h (or 12 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-3d: TSS concentrations during the mean currents at 84 h (or 18 h after the cessation of release)



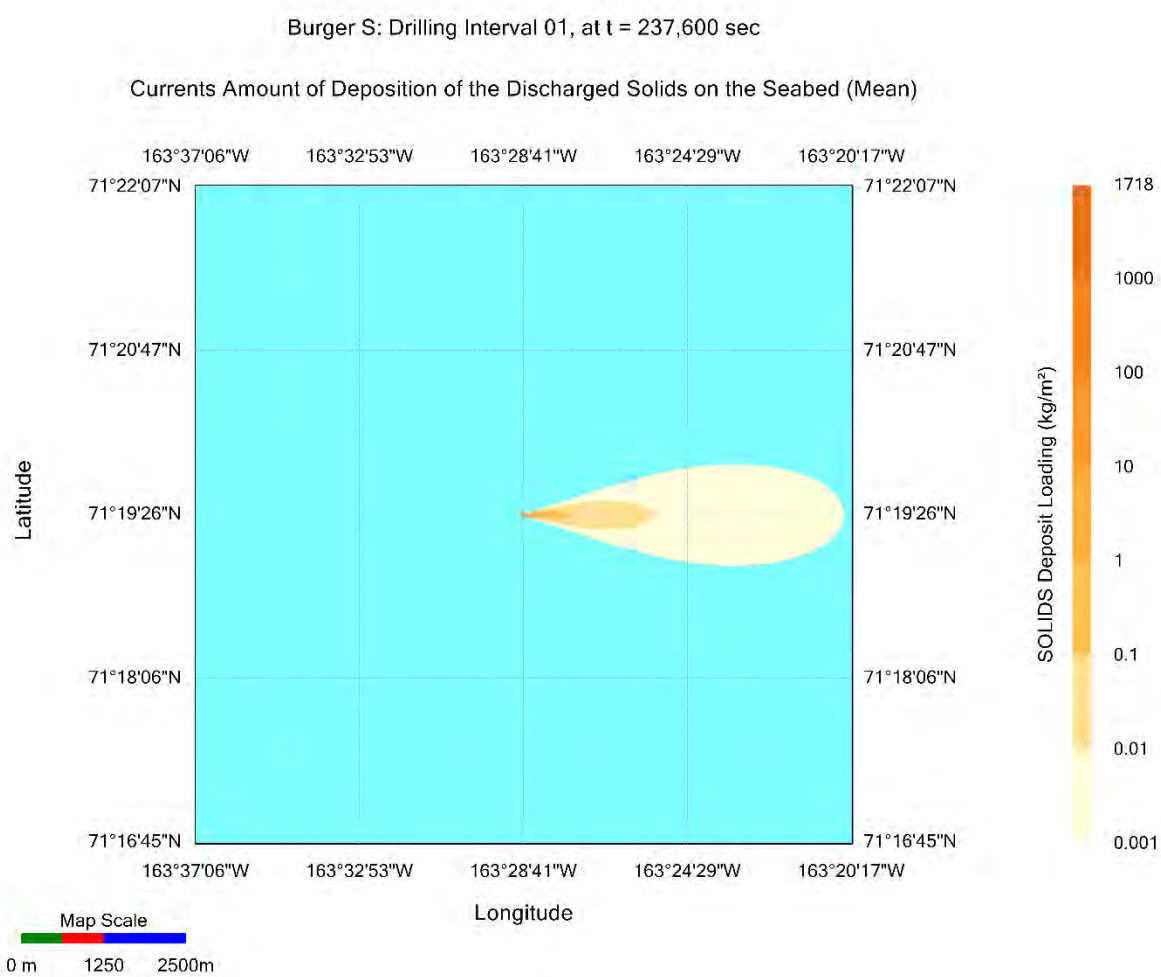
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **237**,**600** sec (or **66**.**0** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 5-4**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **5**-**4**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **1,717** kg/m^2 occurs at **10** m to the east and **10** m to the south from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **50** m and **265** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **265** and **710** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **710** and **2,000** m distances from the discharge location. The loading is less than **0**.**01** kg/m^2 beyond **2,000** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **1000**-, **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**098**, **0**.**120**, **0**.**277**, **1**.**147**, **6**.**850**, and **60**.**162** hectares (ha), respectively.

Figure 5-4: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 01



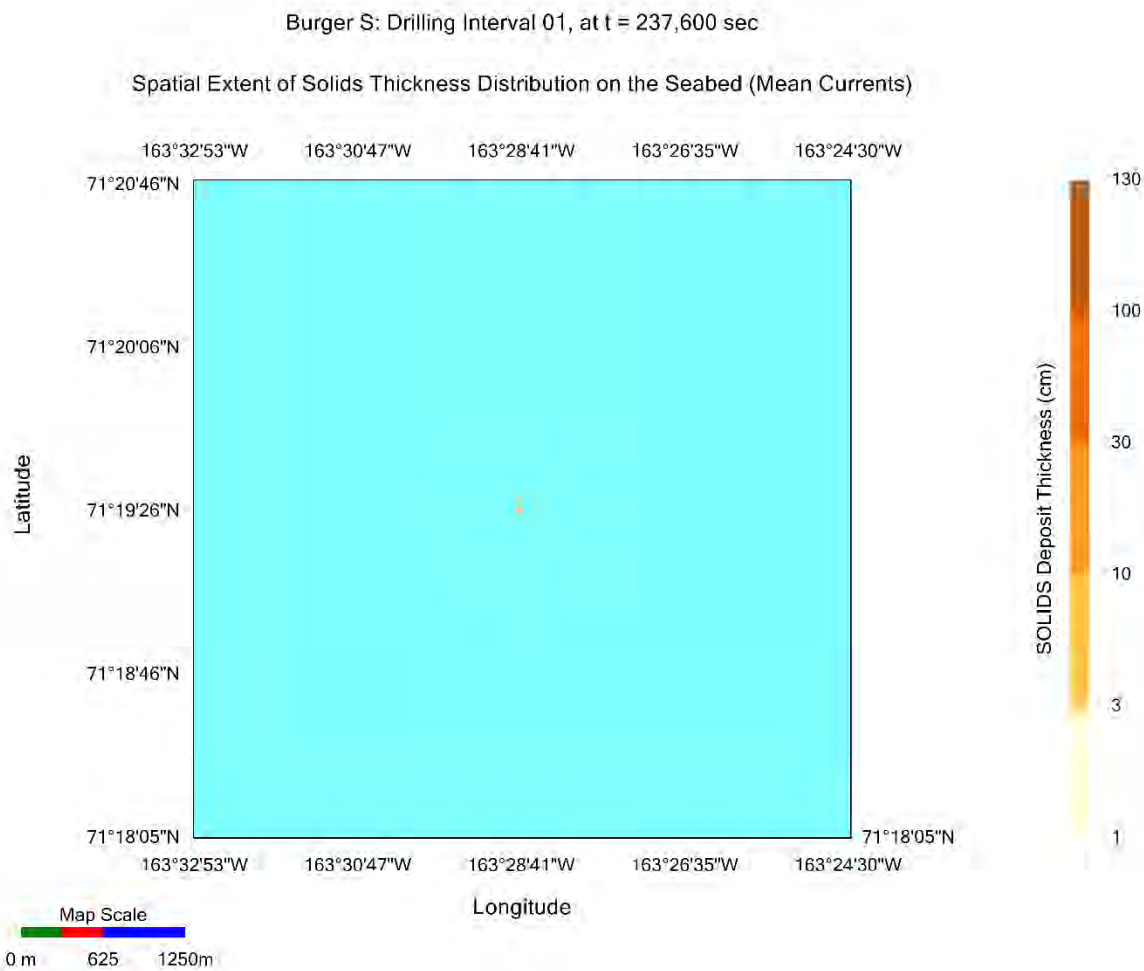
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **237**,**600** sec (or **66**.**0** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 5-5a** and **5-5b.** The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **5**-**5**a. The same result is presented in Figure **5**-**5**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **129**.**6** cm occurs at **10** m to the east and **10** m to the south from the discharge location. It decreases to a value of **1** cm at a distance approximately **45** m from the discharge location.

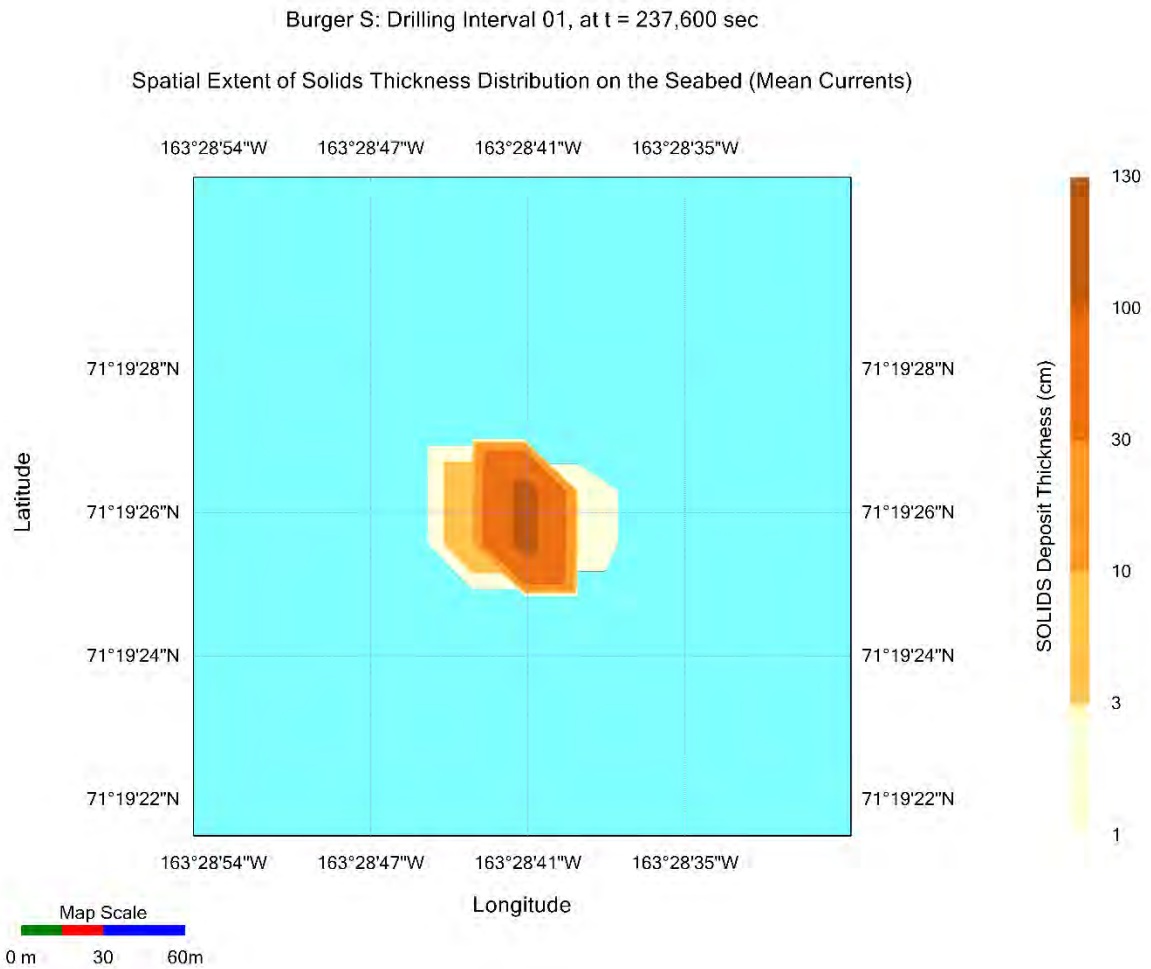
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **70** m x **40** m rectangle area (or **0**.**271** ha) as presented in Figure **5**-**5**b. The sea floor areas affected by deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0**.**090**, **0**.**119**, and **0**.**271** ha, respectively.

Figure 5-5a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 01



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-5b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 01 (Zoom In View)



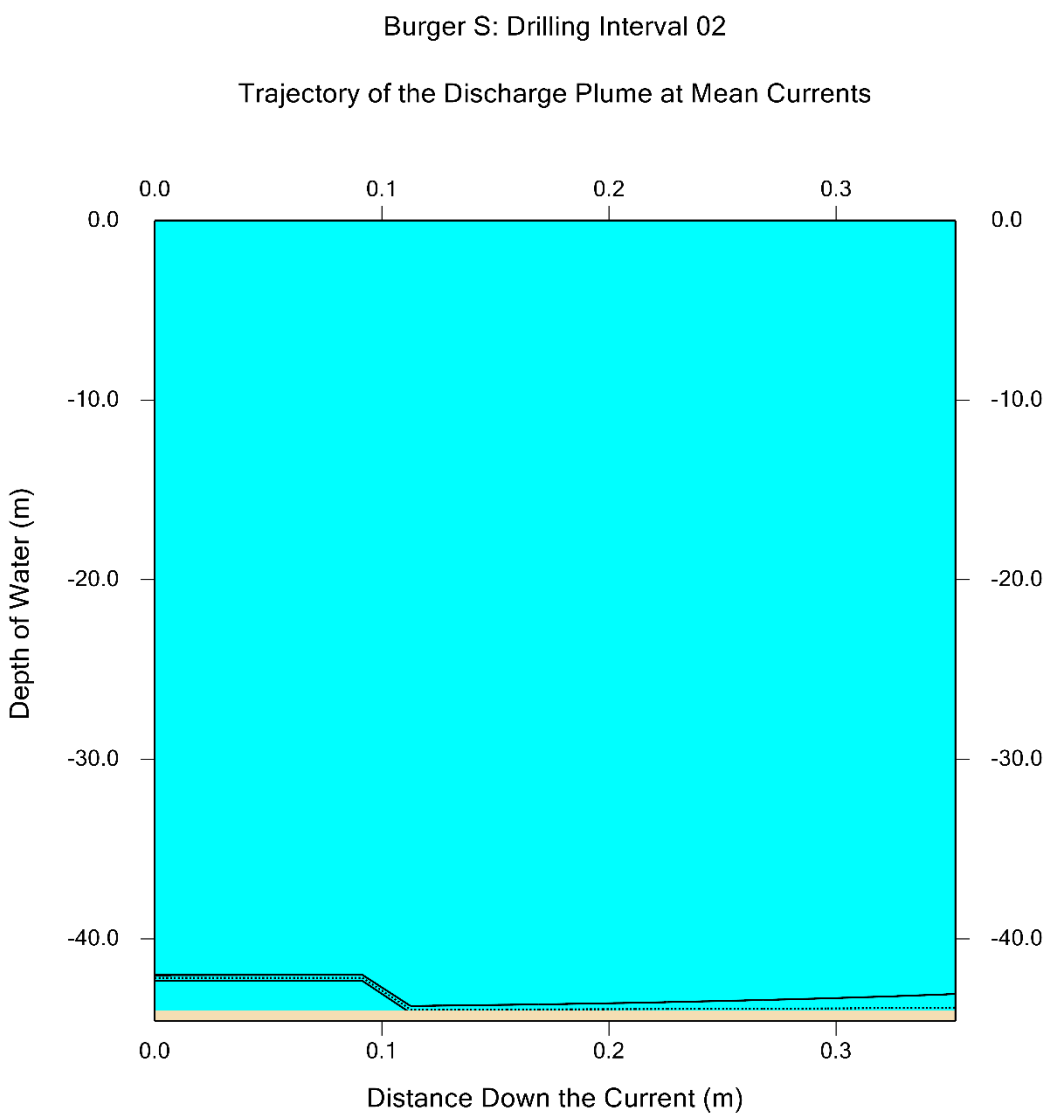
Copyright **2014** by Fluid Dynamix. Company Confidential.

5.2 Model Results for Sea Floor Discharge Scenario – Drilling Interval 02

Trajectory and Shape of the Discharge Plume

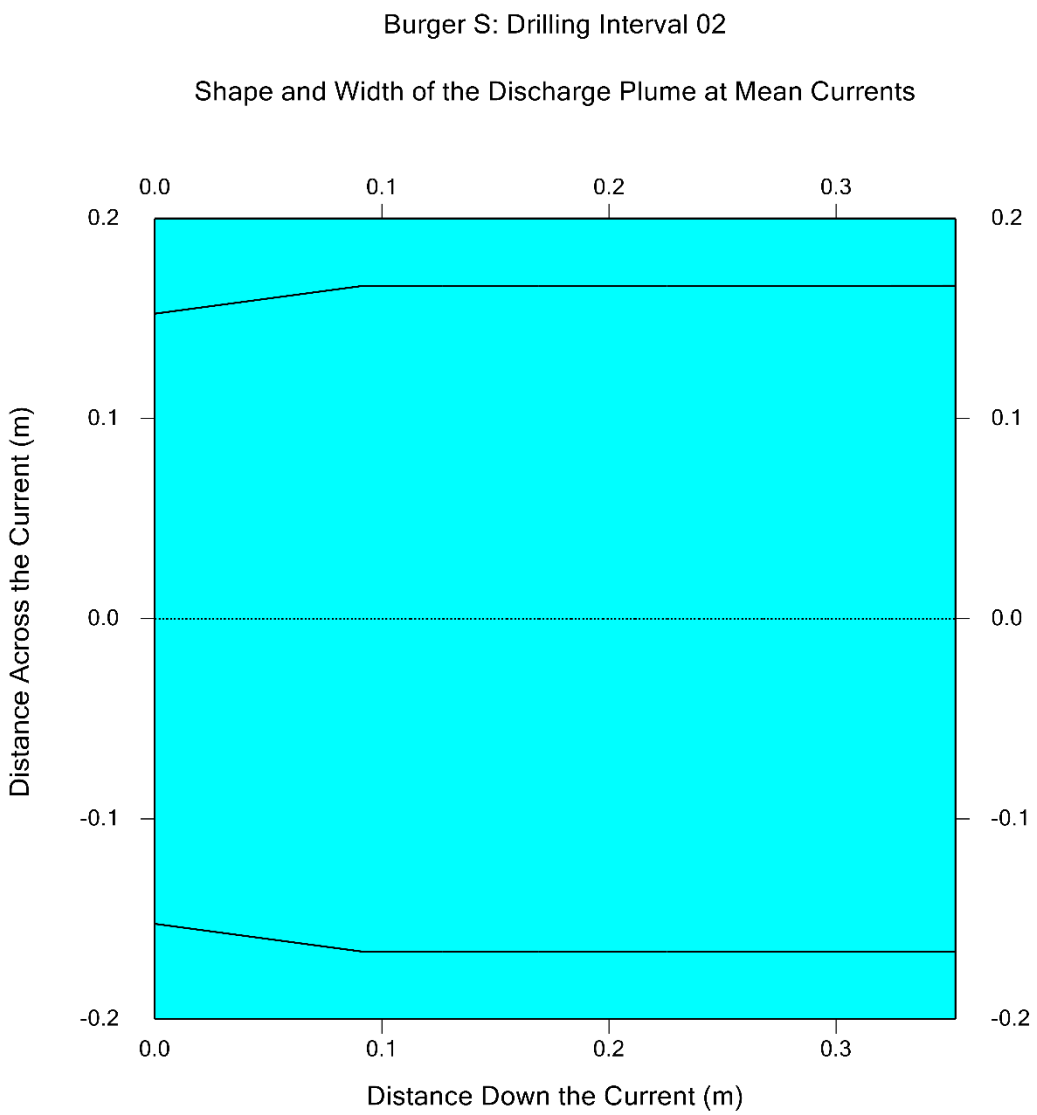
The trajectory of the discharge plume is presented in **Figure 5-6**. The depth of water is **44.0** m and the discharge occurs at a depth of **42.17** m from a **12.0** inches internal diameter discharge pipe of the sea floor pump at **14,000** bbls/hour. A flexible hose suction pipe of this sea floor pump moves the cements, water based drill cuttings, and drill fluids from the drill strings and discharges at **1.83** m (or **6** feet) above the seafloor. The discharge pipe is oriented horizontally aligned with the direction of the current, which is to the east. Therefore, the heavier discharge plume attempts to shoot horizontally as seen in Figure **5-6** and travels to the east to a distance approximately **0.35** m only from the discharge location before collapsing onto the sea floor due to the proximity of the plume near the sea floor. The shape and width of the discharge plume is presented in **Figure 5-7**. The width of the plume is approximately **0.35** m at a distance **0.35** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **5-6** and **5-7**.

Figure 5-6: Trajectory of the discharge plume at mean currents, Drilling Interval 02



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-7: Shape and width of the discharge plume at mean currents, Drilling Interval 02



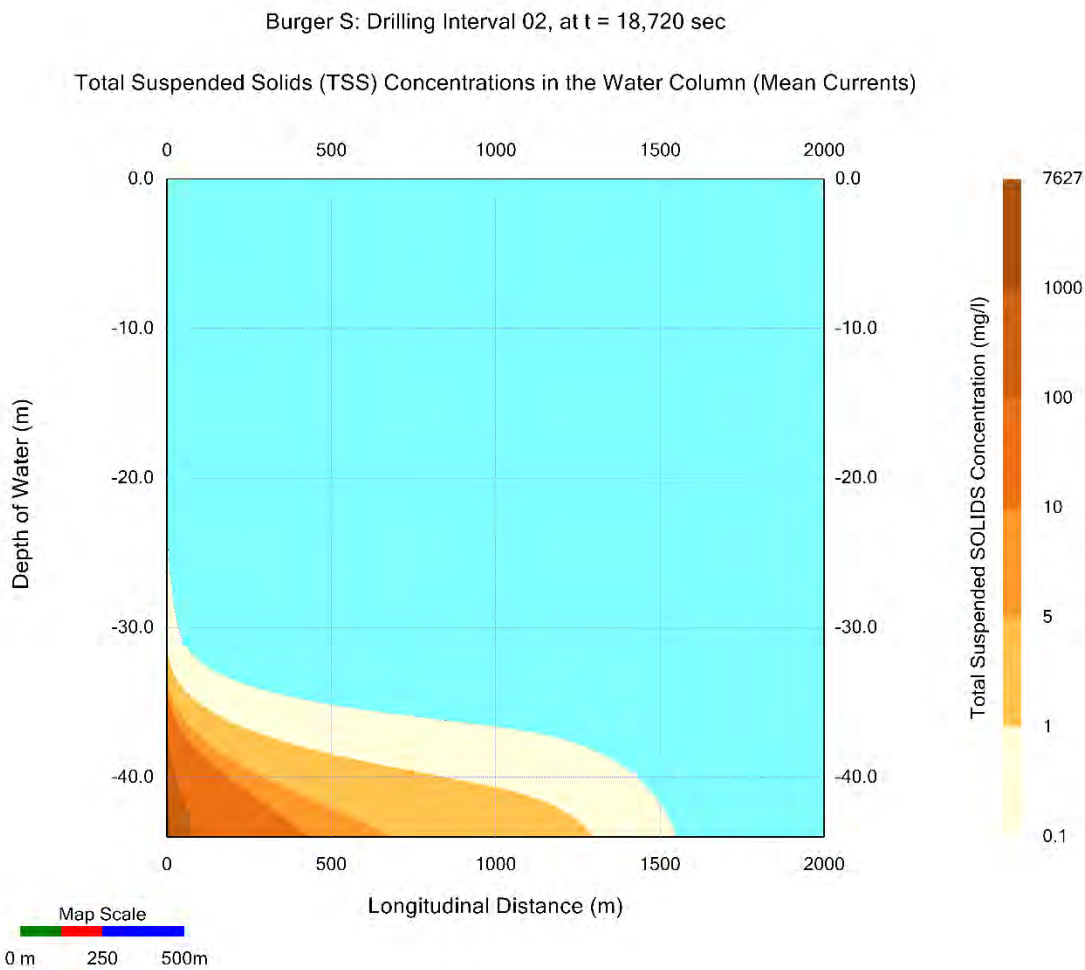
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **18**,**720** sec (or **5**.**2** hours) which is the discharge duration for this drilling interval is presented in **Figure 5-8**a. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **42**.**17** m from a **12.0** inches internal diameter discharge pipe. Figure **5-8**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **7**,**627** mg/l occurs at the discharge location. It decreases to a value of **100** mg/l and **10** mg/l at distances approximately **85** m and **425** m, respectively from the discharge location. It varies from **10** to **5** mg/l approximately between **425** and **675** m distances from the discharge location. It varies from **5** to **1** mg/l between **675** and **1**,**300** m distances from the discharge location. It is less than **1** mg/l beyond **1**,**300** m from the discharge location. The effect of the sea floor pump is visible in this Figure **5**-**8a**. The discharge plume is spreading farther horizontally to the east along the direction of the current than vertically. The TSS concentration is less than **1** mg/l at a depth approximately **30** m at or near the discharge location. It is less than **5** mg/l at a depth approximately **40** m at **500** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **868.5**, **295.0**, **81.1**, **16.9**, and **2.7** mg/l, respectively.

Figure 5-8a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 02

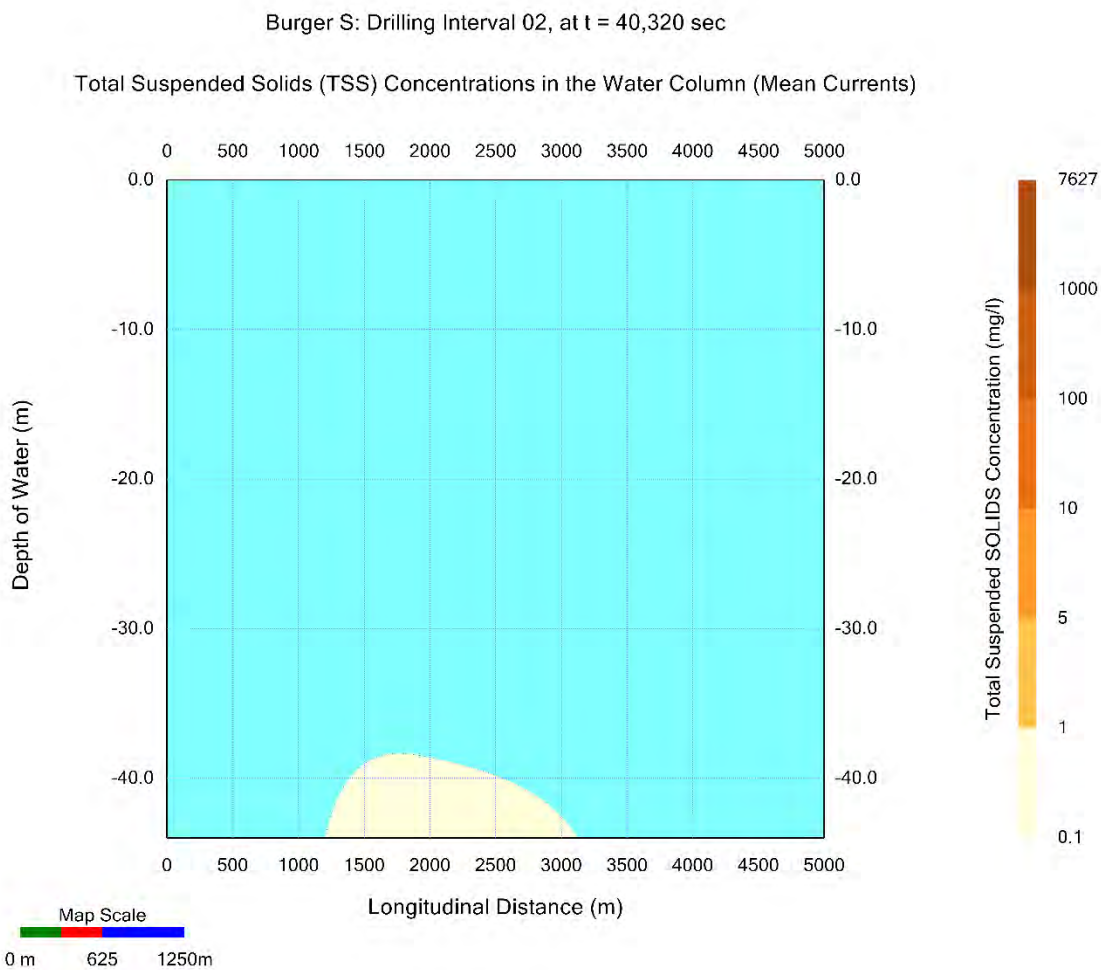


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

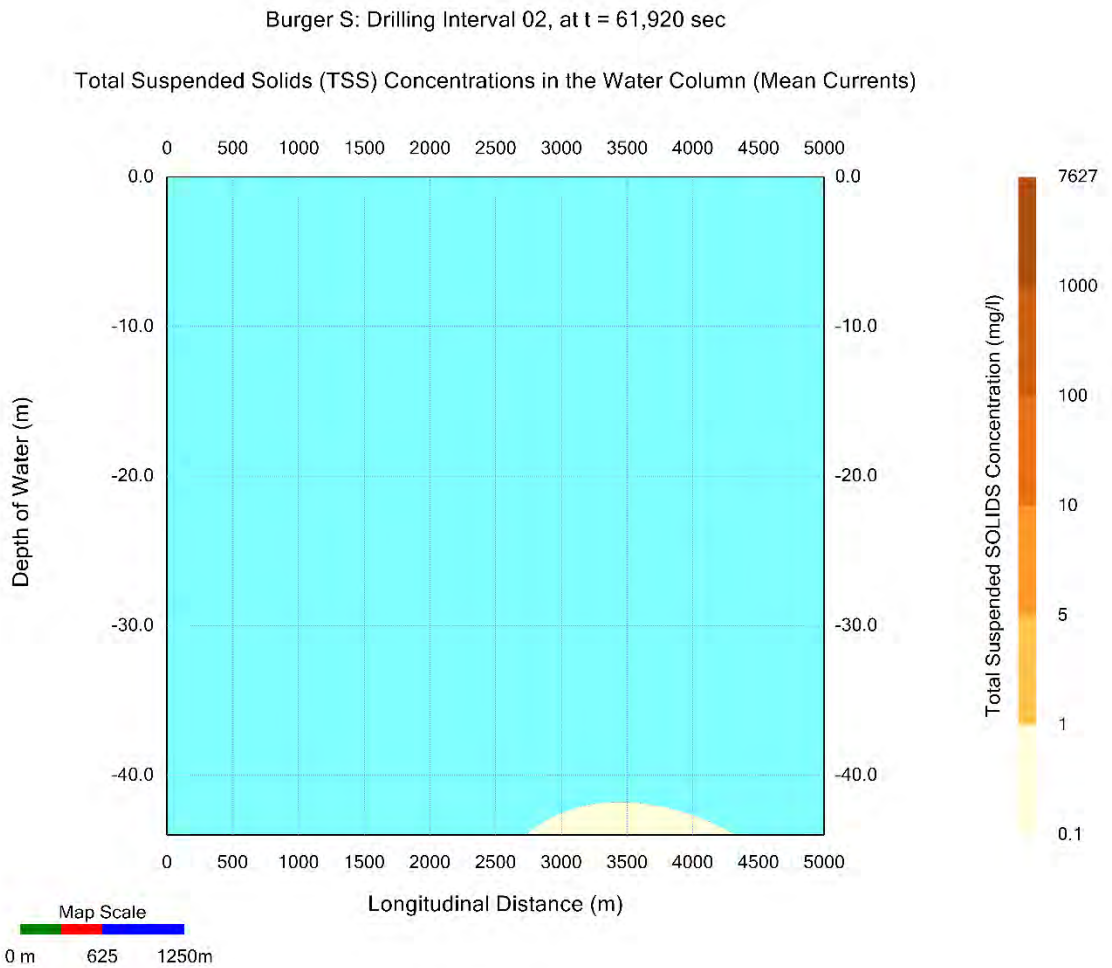
The discharge of the cements, water based drill cuttings, and drill fluids ceases at time, t = **18**,**720** sec (or **5**.**2** hours). The fate and transport of the discharged solids at times **6**, **12**, and **18** h after the cessation of the discharge are presented by **Figures 5-8**b**, 5-8**c**,** and **5-8**d. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **1** mg/l or less at **6** h, **1** mg/l or less at **12** h, and less than **0**.**1** mg/l at **18** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **12** and **18** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 5-8b: TSS concentrations during the mean currents at 11.2 h (or 6 h after the cessation of release)



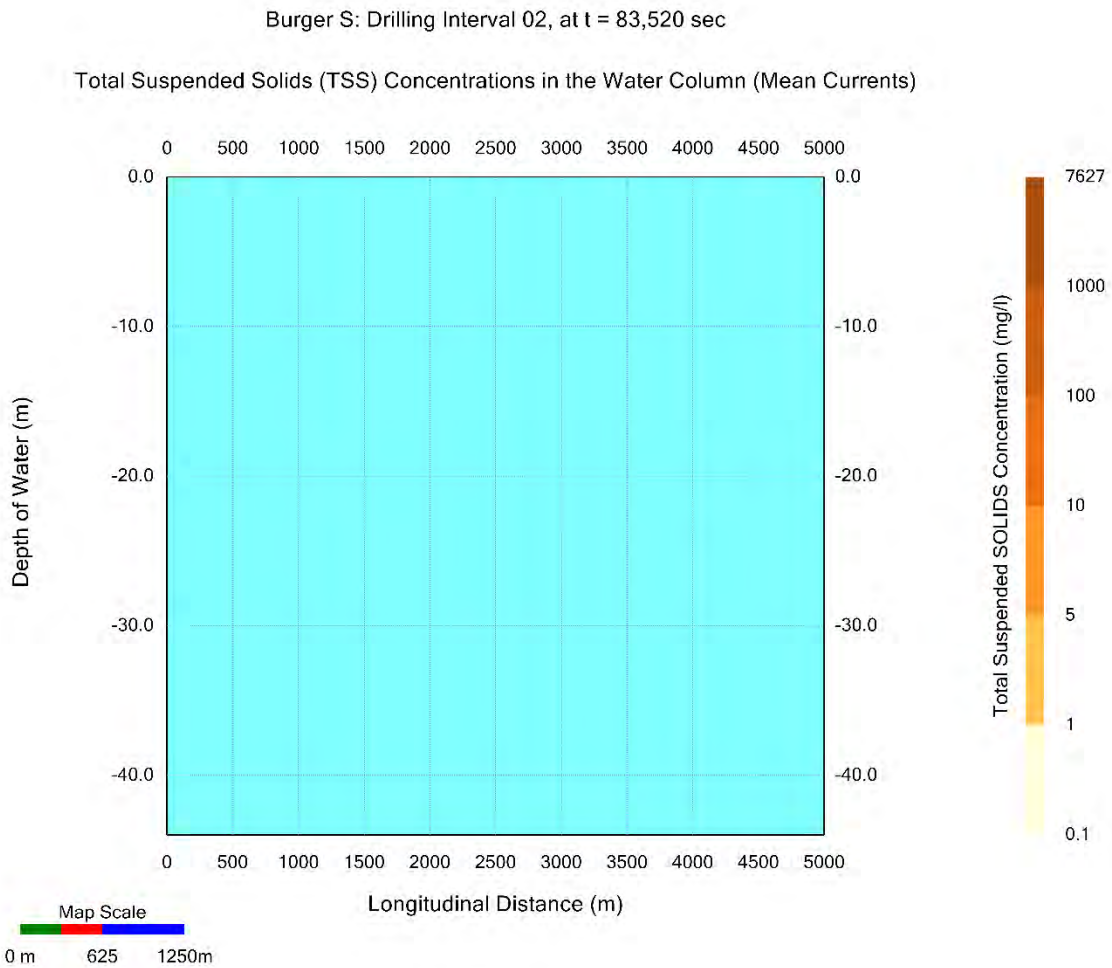
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-8c: TSS concentrations during the mean currents at 17.2 h (or 12 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-8d: TSS concentrations during the mean currents, at 23.2 h (or 18 h after the cessation of release)



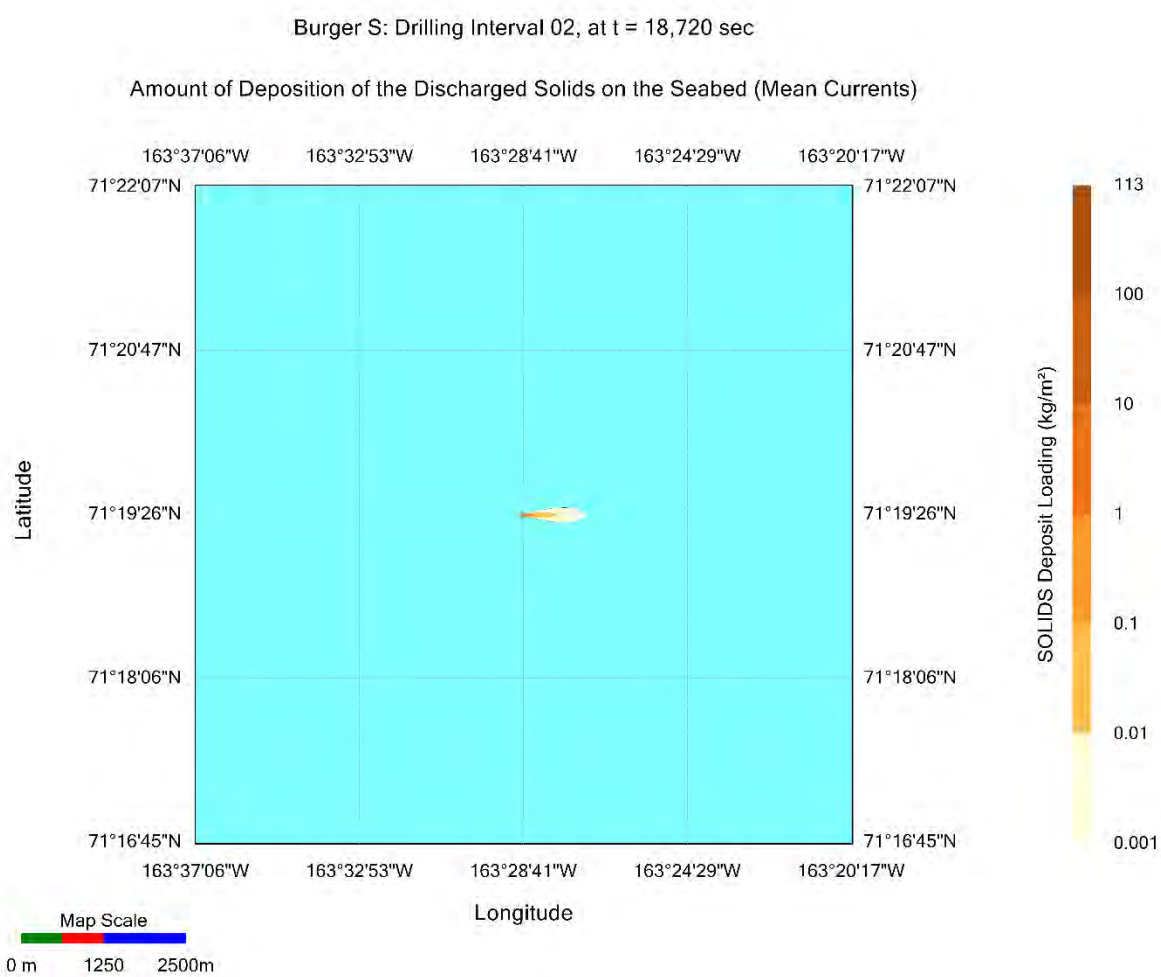
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **18**,**720** sec (or **5**.**2** hours) as a result of the discharge of the cements, water based drill cuttings, and drill fluids on a plan view is presented in **Figure 5-9**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **5**-**9**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading of **112** kg/m^2 occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **30** m and **45** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **45** and **190** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **190** and **500** m distances from the discharge location. The loading is less than **0**.**01** kg/m^2 beyond **520** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**085**, **0**.**119**, **0**.**266**, **0**.**882**, and **3**.**309** ha, respectively.

Figure 5-9: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 02



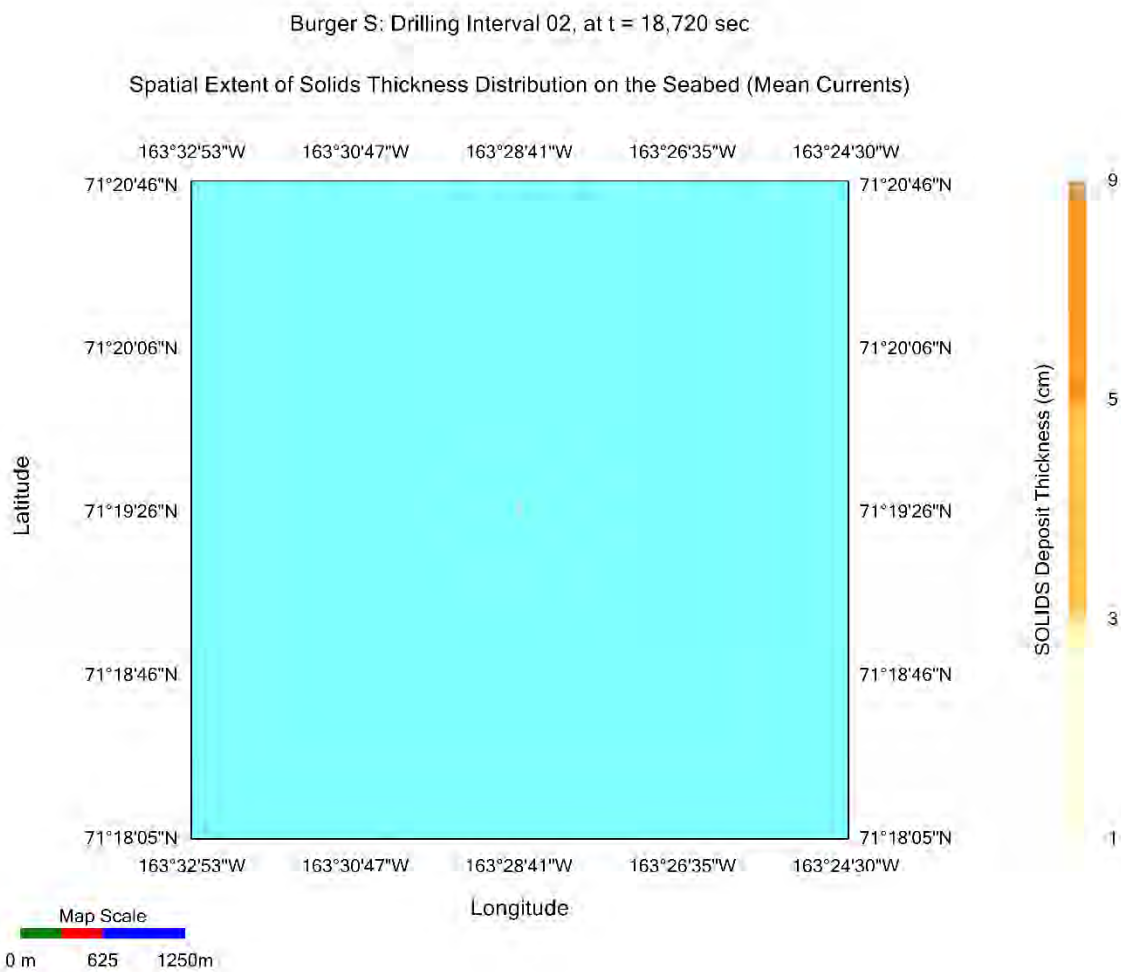
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **18**,**720** sec (or **5**.**2** hours) as a result of the discharge of the cements, water based drill cuttings, and drill fluids on a plan view is presented in **Figures 5-10a** and **5-10b.** The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. But the solids deposit on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **5**-**10**a. The same result is presented in Figure **5**-**10**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **8.5** cm occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **30** m from the discharge location.

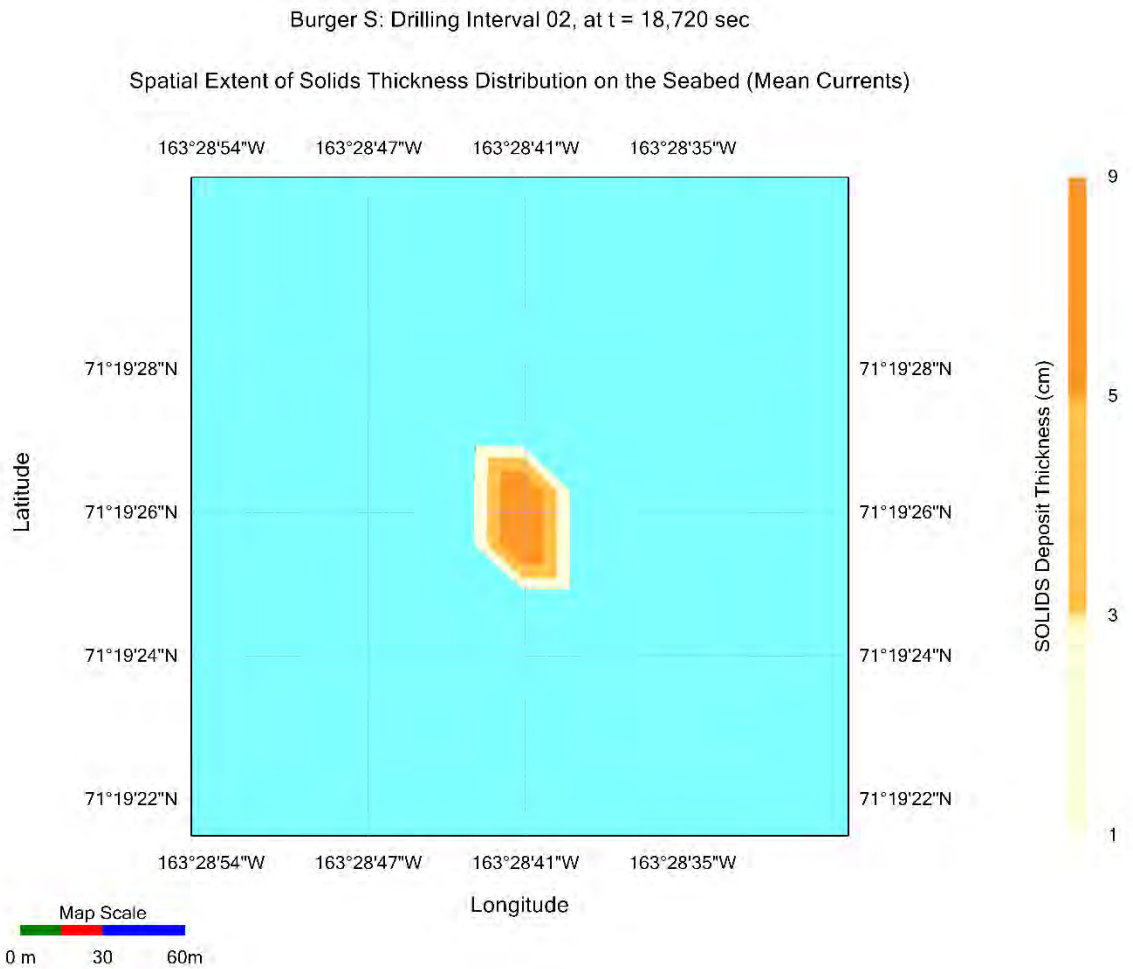
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **30** m x **40** m square area (or **0**.**117** ha) as presented in Figure **5**-**10**b. The sea floor areas affected by deposit thickness larger than **1**-cm is: **0**.**117** ha.

Figure 5-10a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 02



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-10b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 02 (Zoom In View)



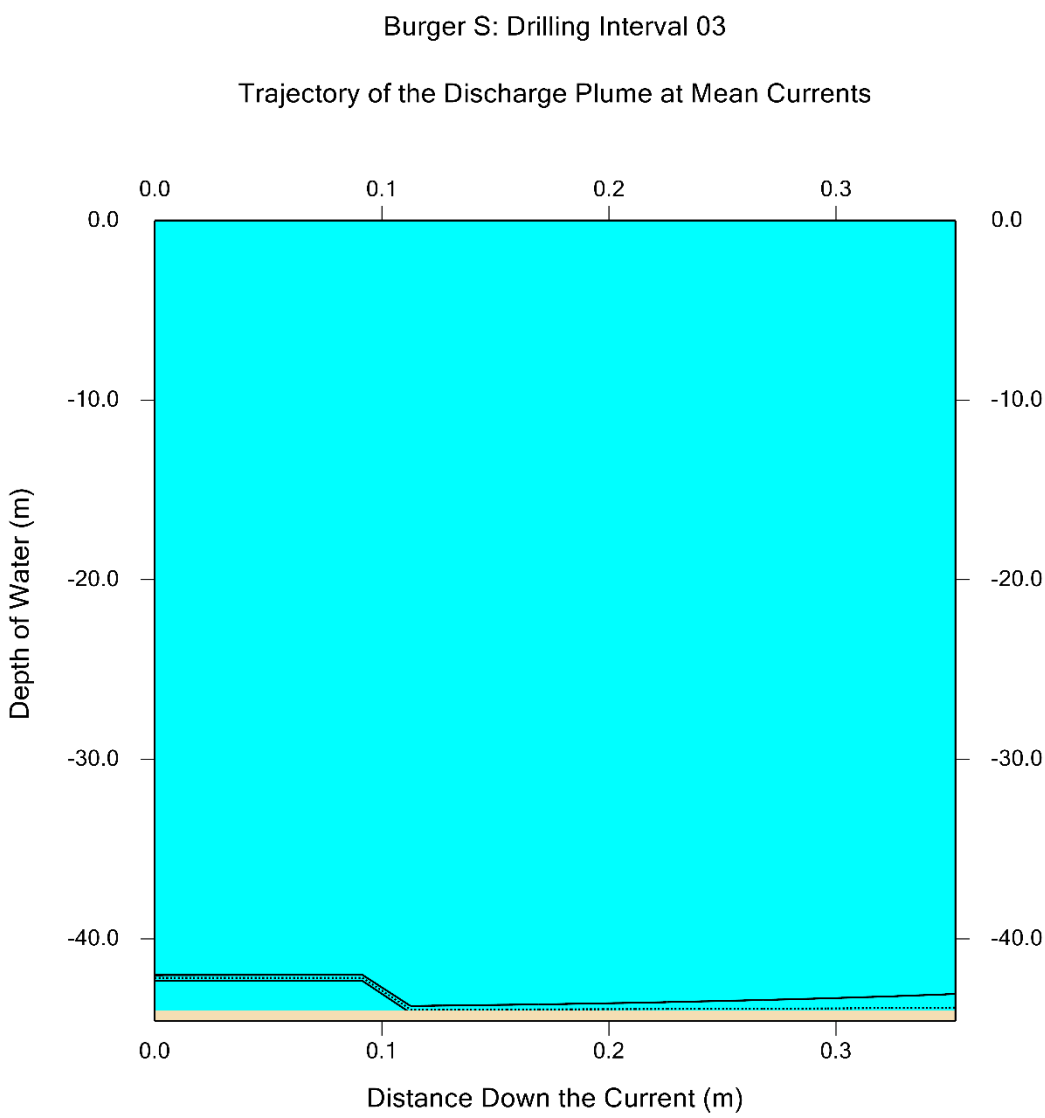
Copyright **2014** by Fluid Dynamix. Company Confidential.

5.3 Model Results for Sea Floor Discharge Scenario – Drilling Interval 03

Trajectory and Shape of the Discharge Plume

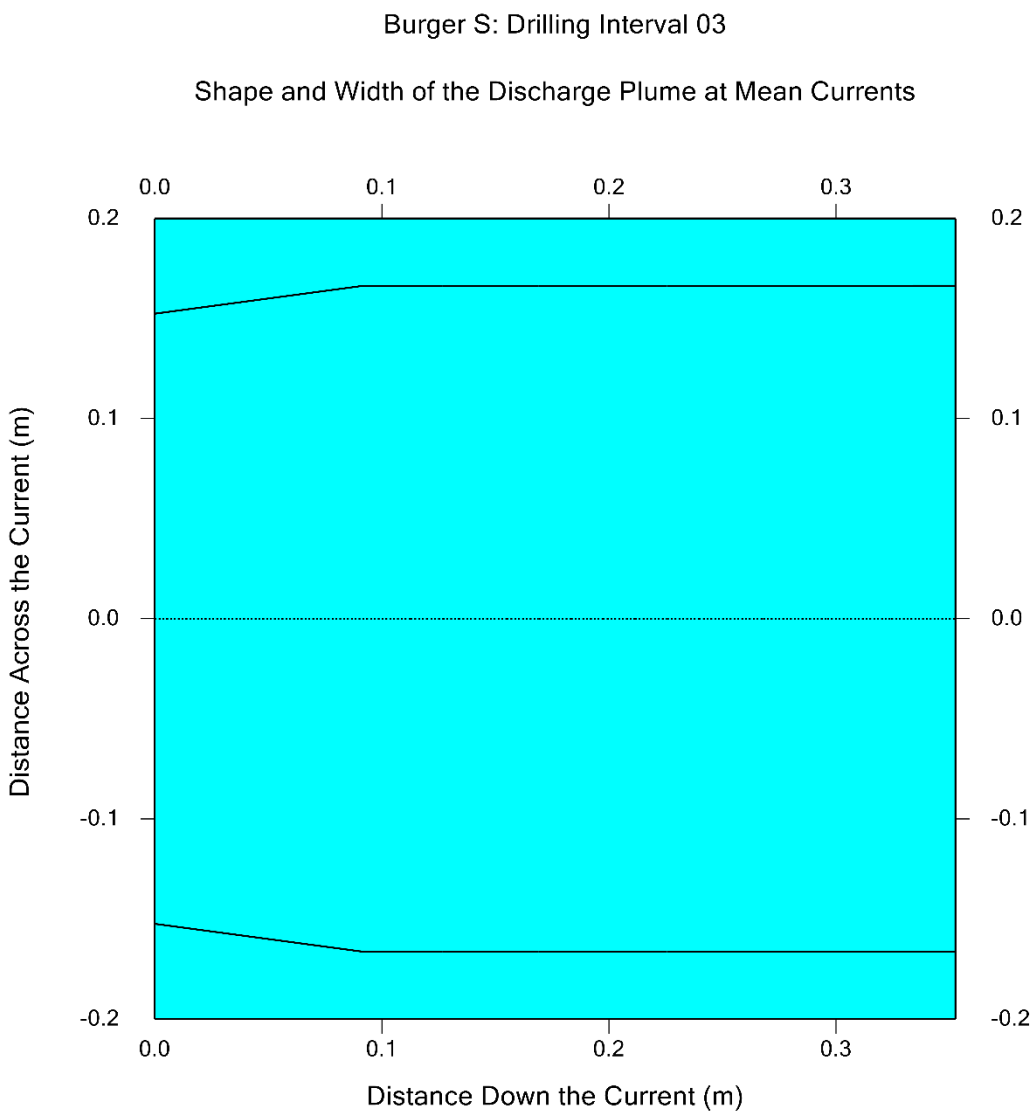
The trajectory of the discharge plume is presented in **Figure 5-11**. The depth of water is **44.0** m and the discharge occurs at a depth of **42.17** m from a **12.0** inches internal diameter discharge pipe of the sea floor pump at **14,000** bbls/hour. A flexible hose suction pipe of this sea floor pump moves the cements, water based drill cuttings, and drill fluids from the drill strings and discharges at **1.83** m (or **6** feet) above the seafloor. The discharge pipe is oriented horizontally aligned with the direction of the current, which is to the east. Therefore, the heavier discharge plume attempts to shoot horizontally as seen in figure below and travels to the east to a distance approximately **0.35** m only from the discharge location before collapsing onto the sea floor due to the proximity of the plume near the sea floor. The shape and width of the discharge plume is presented in **Figure 5-12**. The width of the plume is approximately **0.35** m at a distance **0.35** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **5-11** and **5-12**.

Figure 5-11: Trajectory of the discharge plume at mean currents, Drilling Interval 03



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-12: Shape and width of the discharge plume at mean currents, Drilling Interval 03



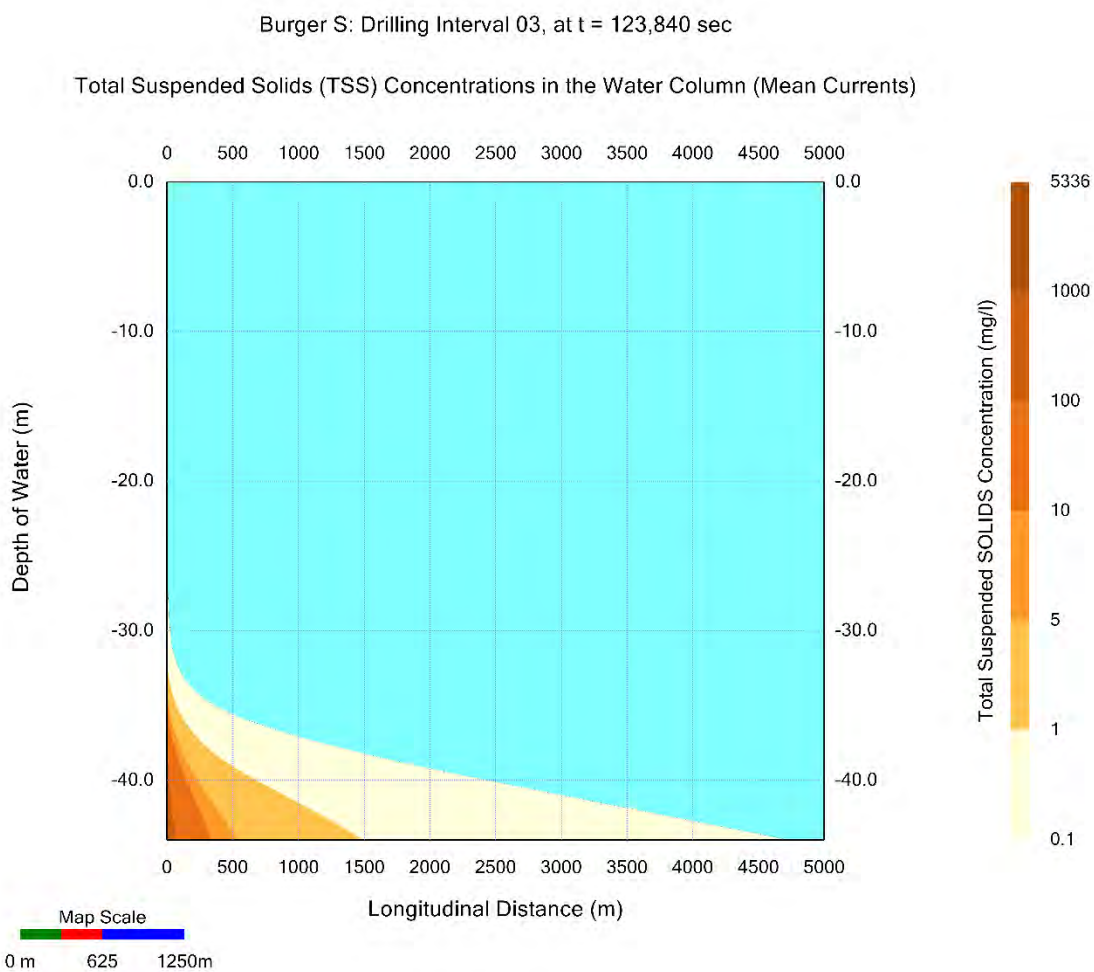
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **123**,**840** sec (or **34**.**4** hours) which is the discharge duration for this drilling interval is presented in **Figure 5-13**a. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **42**.**17** m from a **12.0** inches internal diameter discharge pipe. Figure **5-13**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **5**,**336** mg/l occurs at the source. It decreases to a value of **100** mg/l at a distance approximately **60** m from the discharge location. It varies from **100** to **10** mg/l between **60** and **325** m distances from the discharge location. It varies from **10** to **5** mg/l between **325** and **525** m distances from the discharge location. It varies from **5** to **1** mg/l between **525** and **1**,**500** m distances approximately from the discharge location. It is less than **1** mg/l beyond **1**,**500** m from the discharge location. The effect of the sea floor pump is visible in this Figure **5**-**13a**. The discharge plume is spreading farther horizontally to the east along the direction of the current than vertically. The TSS concentration is less than **1** mg/l at a depth approximately **30** m at or near the discharge location. It is less than **5** mg/l at a depth approximately **40** m at **500** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **556.4**, **208.0**, **57.1**, **11**.**8**, and **1**.**9** mg/l, respectively.

Figure 5-13a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 03

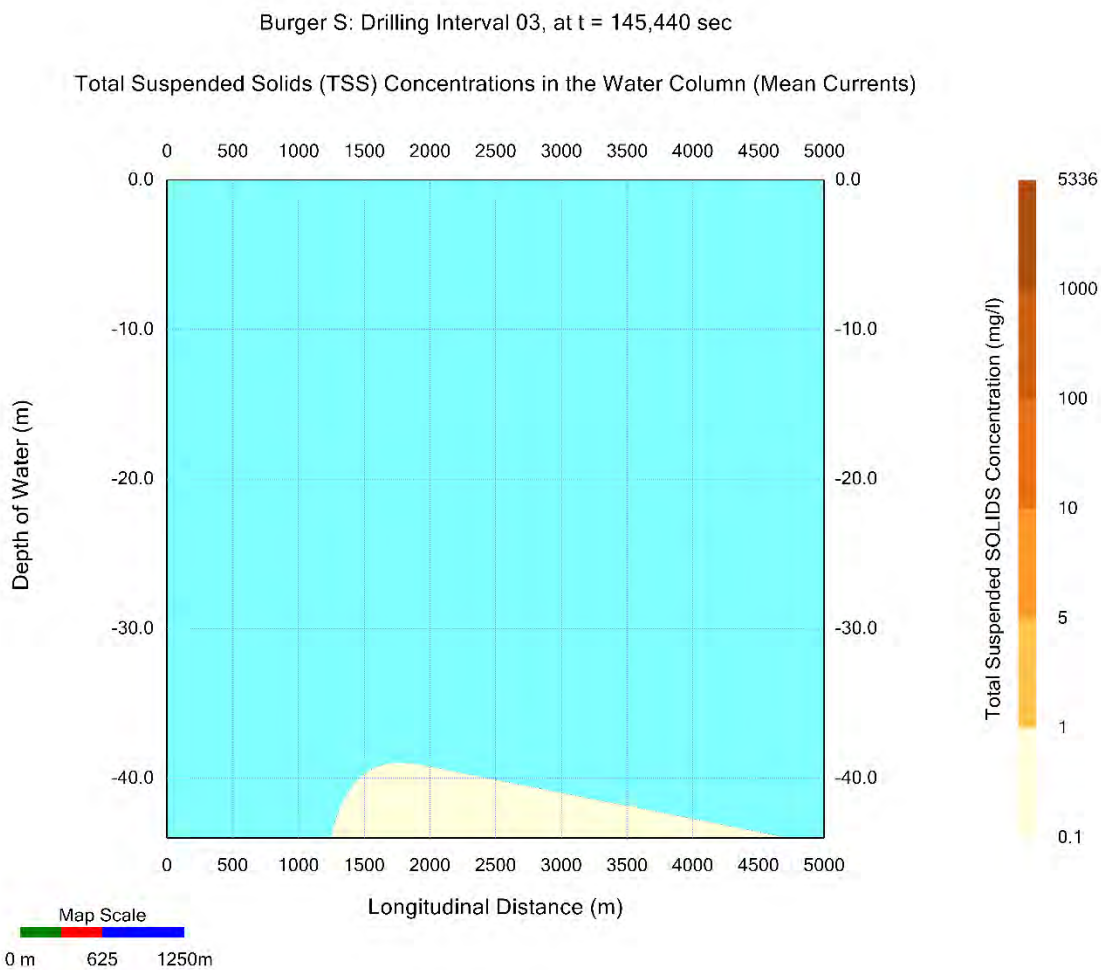


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

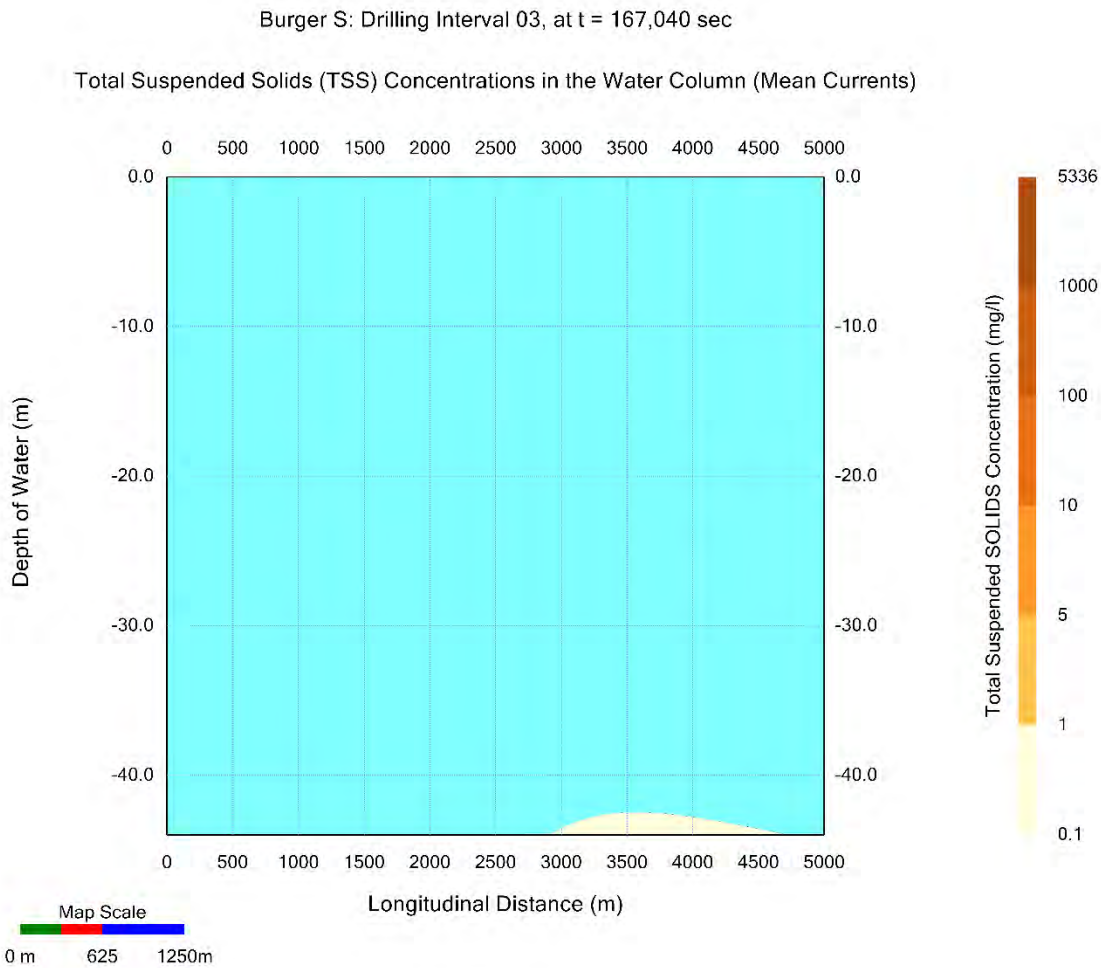
The discharge of the cements, water based drill cuttings, and drill fluids ceases at time, t = **123**,**840** sec (or **34**.**4** hours). The fate and transport of the discharged solids at times **6**, **12**, and **18** h after the cessation of the discharge are presented by **Figures 5-13**b**, 5-13**c**,** and **5-13**d. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **1** mg/l or less at **6** h, **1** mg/l or less at **12** h, and less than **0**.**1** mg/l at **18** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **12** and **18** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 5-13b: TSS concentrations during the mean currents at 40.4 h (or 6 h after the cessation of release)



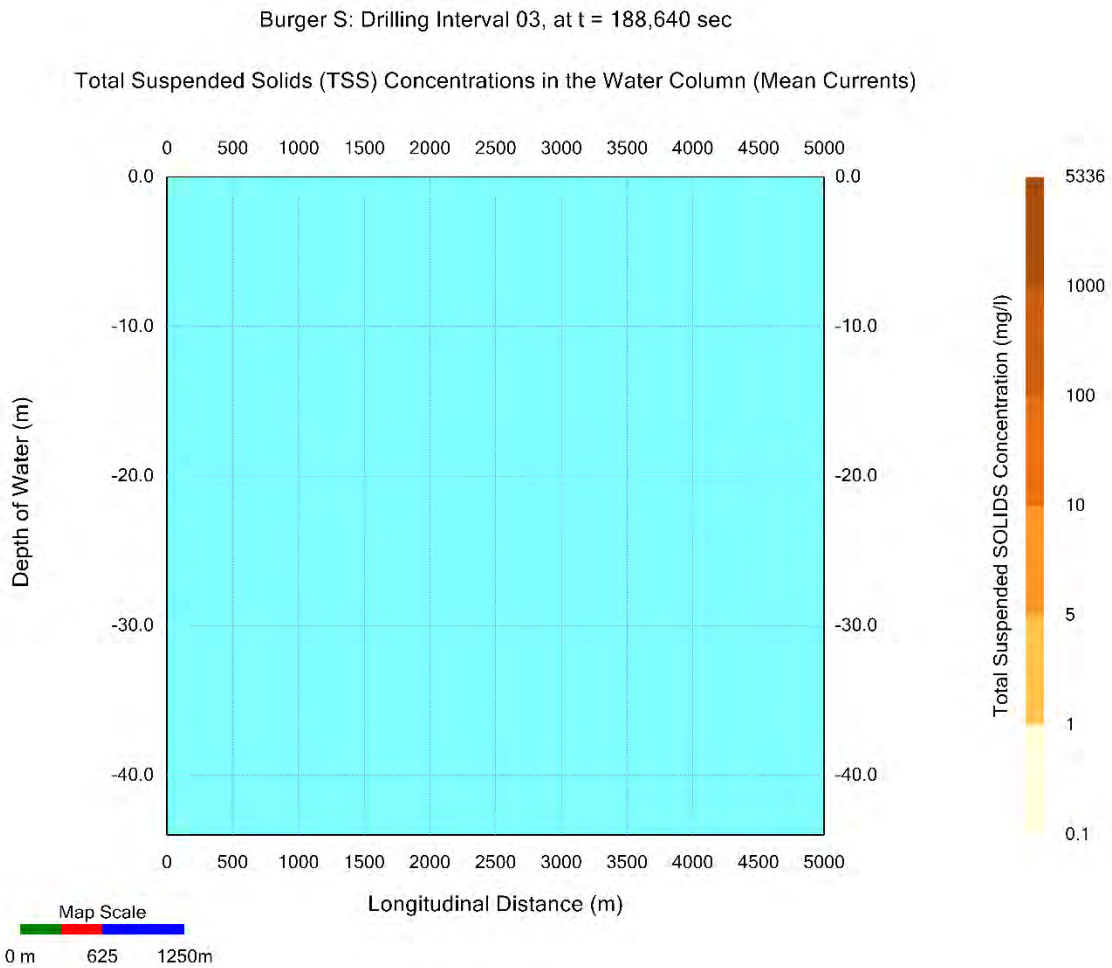
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-13c: TSS concentrations during the mean currents at 46.4 h (or 12 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-13d: TSS concentrations during the mean currents at 52.4 h (or 18 h after the cessation of release)



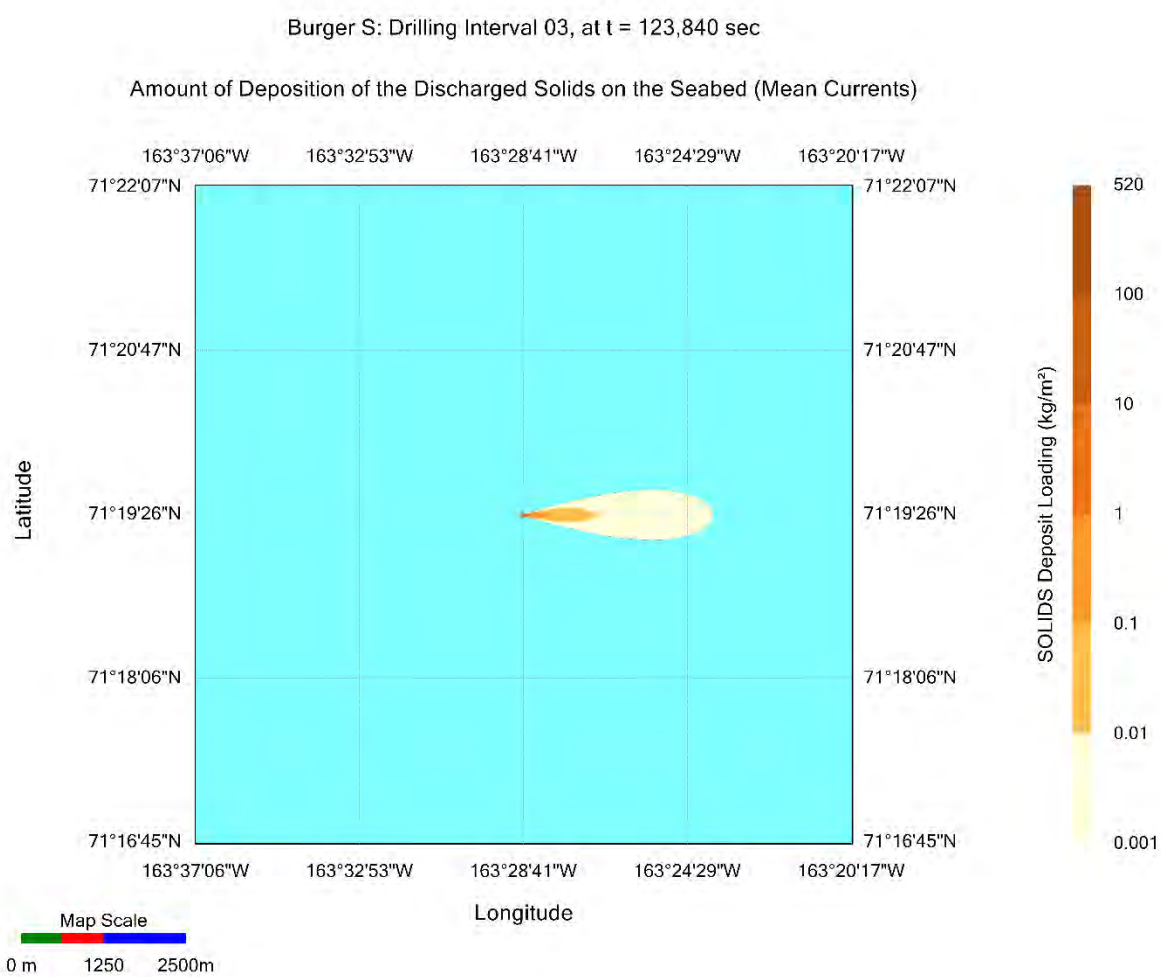
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **123**,**840** sec (or **34**.**4** hours) as a result of the discharge of the cements, water based drill cuttings, and drill fluids on a plan view is presented in **Figure 5-14**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **5**-**14**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **520** kg/m^2 occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **30** m and **110** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **110** and **430** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **430** and **1**,**125** m distances from the discharge location. It is less than **0**.**01** kg/m^2 beyond **1**,**125** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**114**, **0**.**197**, **0**.**519**, **3**.**359**, and **17**.**427** ha, respectively.

Figure 5-14: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 03



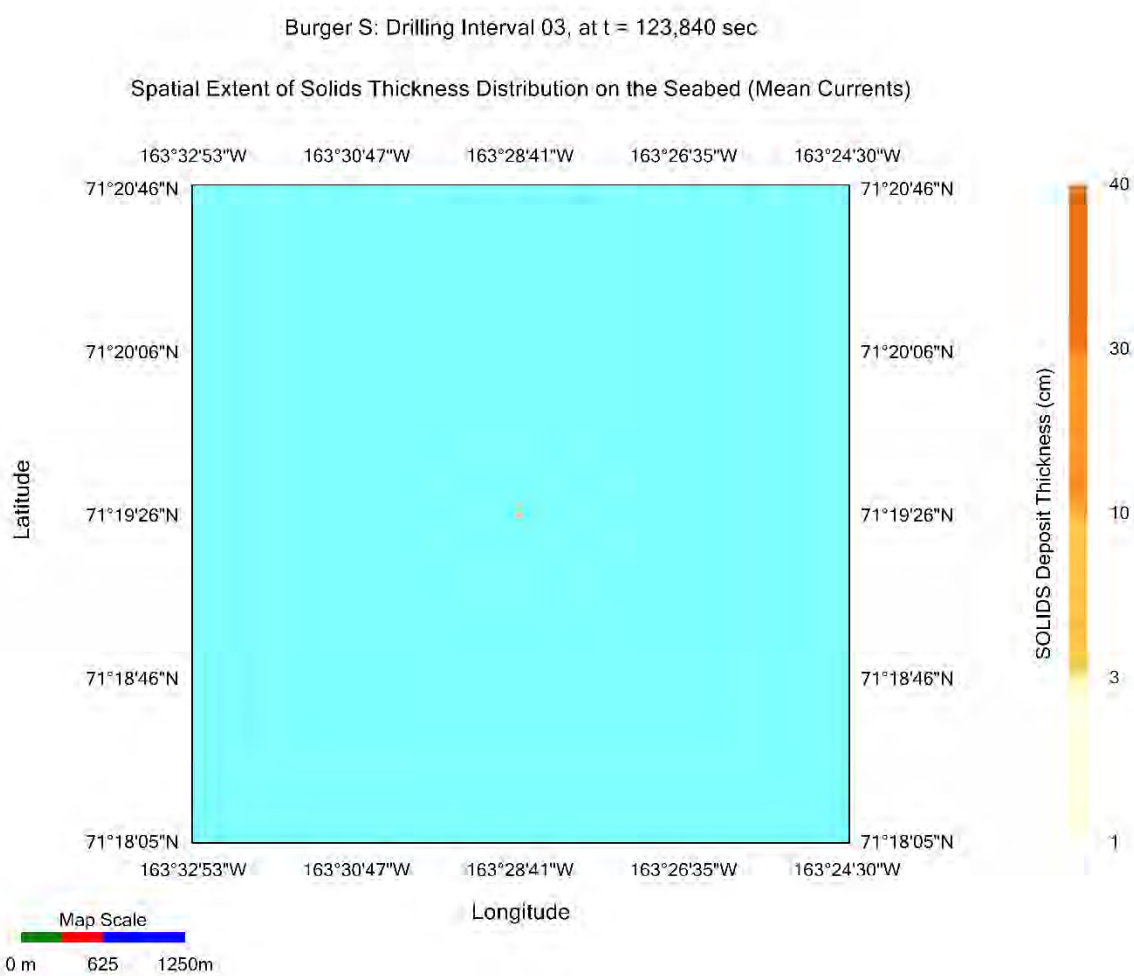
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **123**,**840** sec (or **34**.**4** hours) as a result of the discharge of the cements, water based drill cuttings, and drill fluids on a plan view is presented in **Figures 5-15a** and **5-15b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **5**-**15**a. The same result is presented in Figure **5**-**15**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **39**.**3** cm occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **30** m from the discharge location.

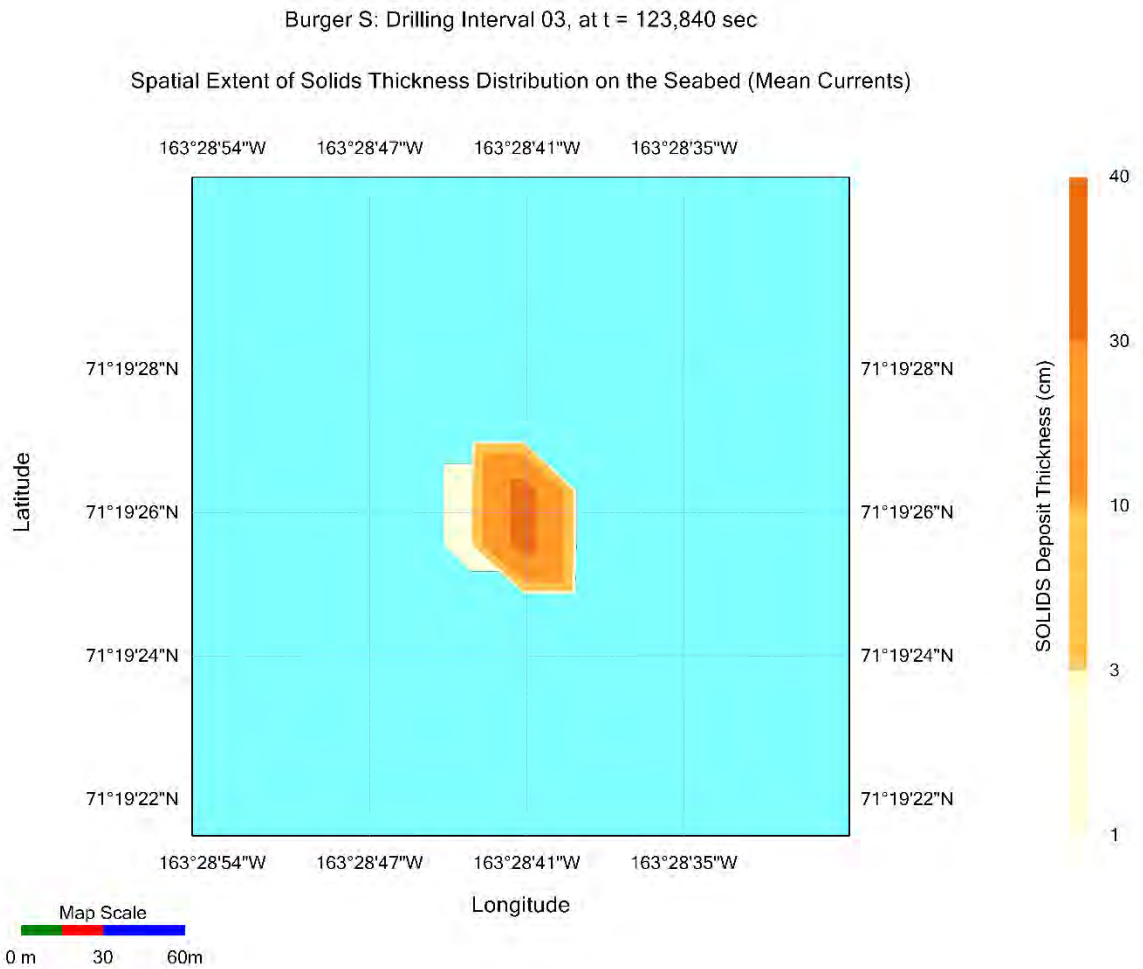
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **50** m x **40** m rectangle area (or **0**.**191** ha) as presented in Figure **5**-**15**b. The sea floor areas affected by deposit thickness larger than **10**- and **1**-cm are: **0**.**112** and **0**.**191** ha, respectively.

Figure 5-15a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 03



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-15b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 03 (Zoom In View)



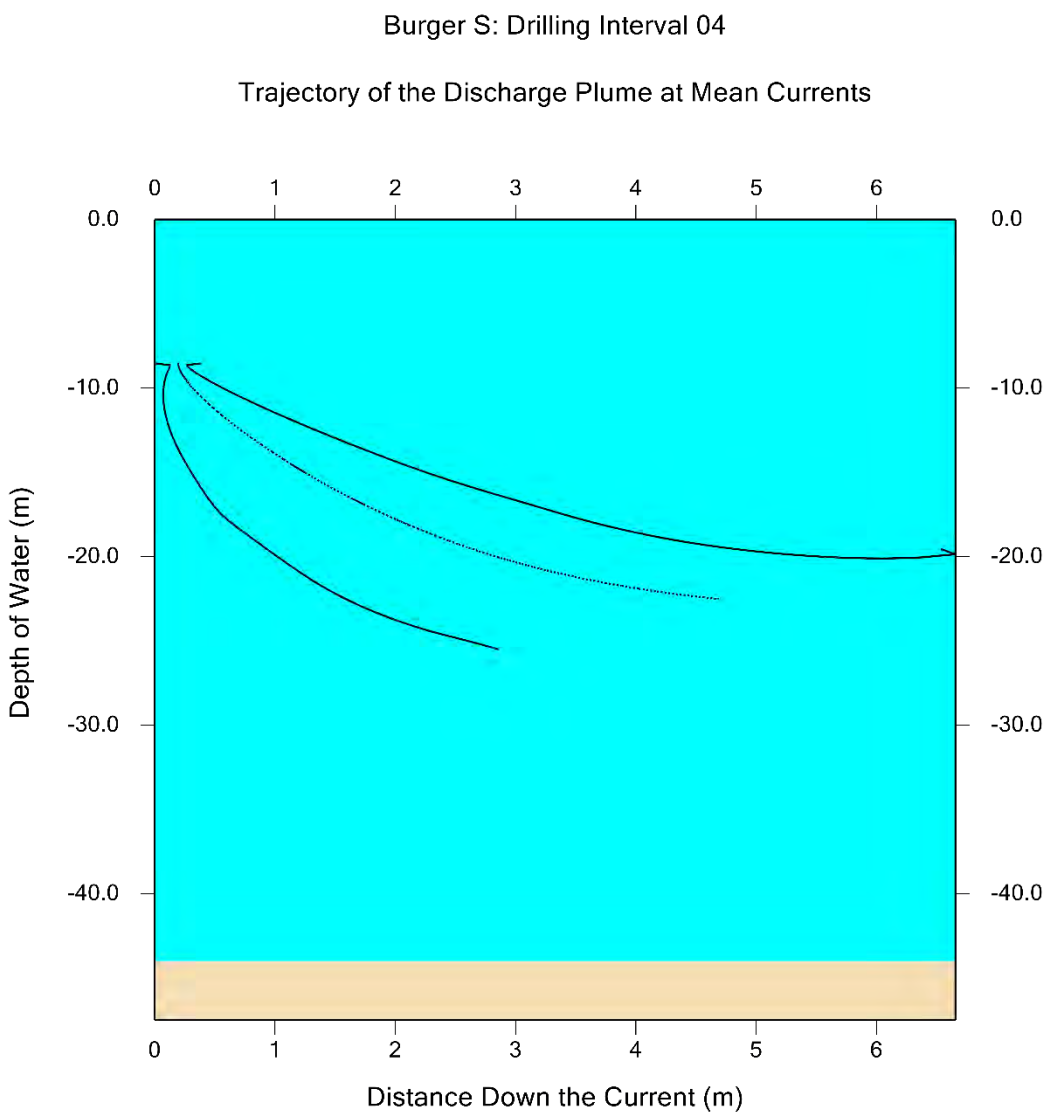
Copyright **2014** by Fluid Dynamix. Company Confidential.

5.4 Model Results for Sea Surface Discharge Scenario – Drilling Interval 04

Trajectory and Shape of the Discharge Plume

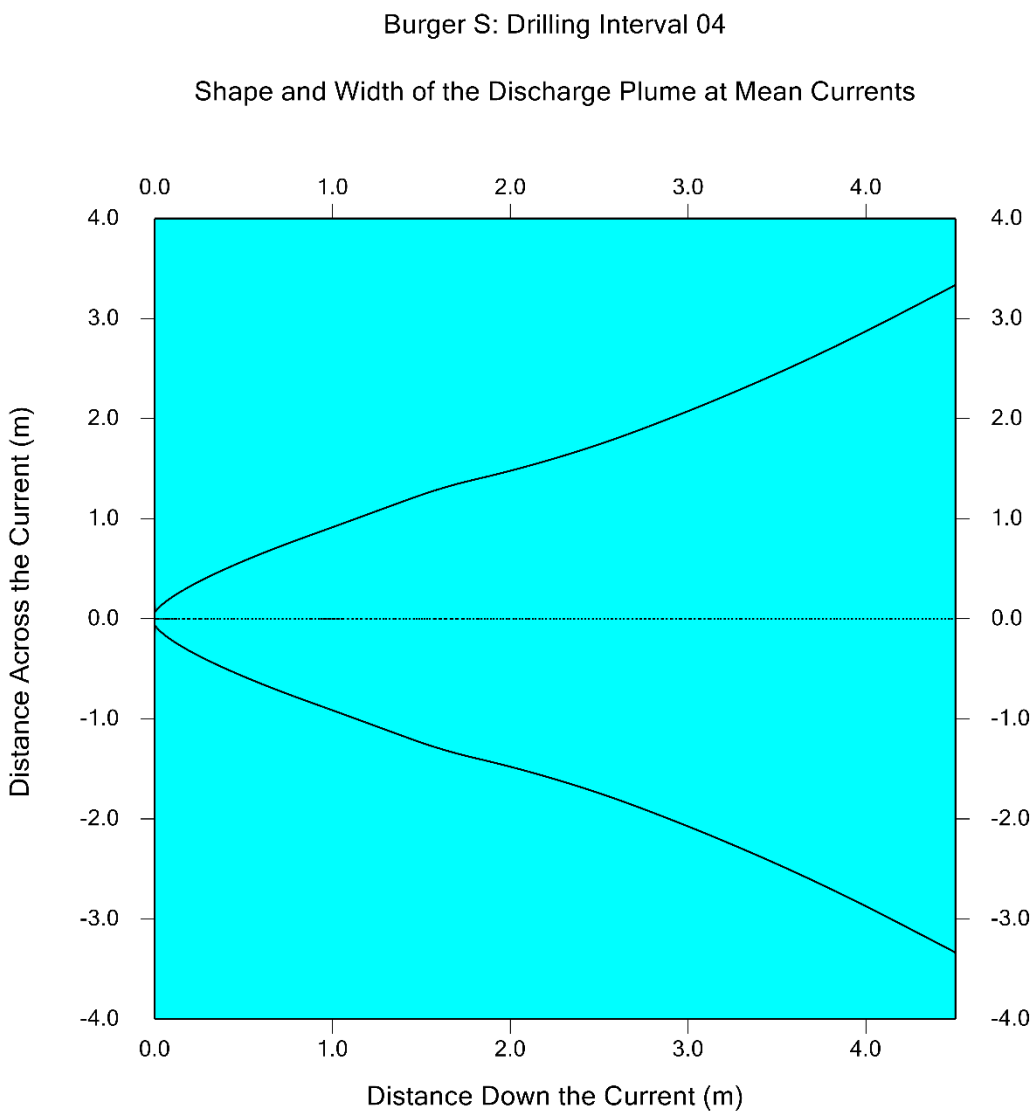
The trajectory of the discharge plume is presented in **Figure 5-16**. The depth of water is **44.0** m and the discharge occurs at a depth of **8.53** m below the sea surface. The heavier plume travels approximately **4.5** m from the discharge location before collapsing into the ambient sea water due to the higher density of the discharge plume. The shape and width of the discharge plume is presented in **Figure 5-17**. The width of the plume is approximately **6.6** m at a distance **4.5** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **5-16** and **5-17**.

Figure 5-16: Trajectory of the discharge plume at mean currents, Drilling Interval 04



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-17: Shape and width of the discharge plume at mean currents, Drilling Interval 04



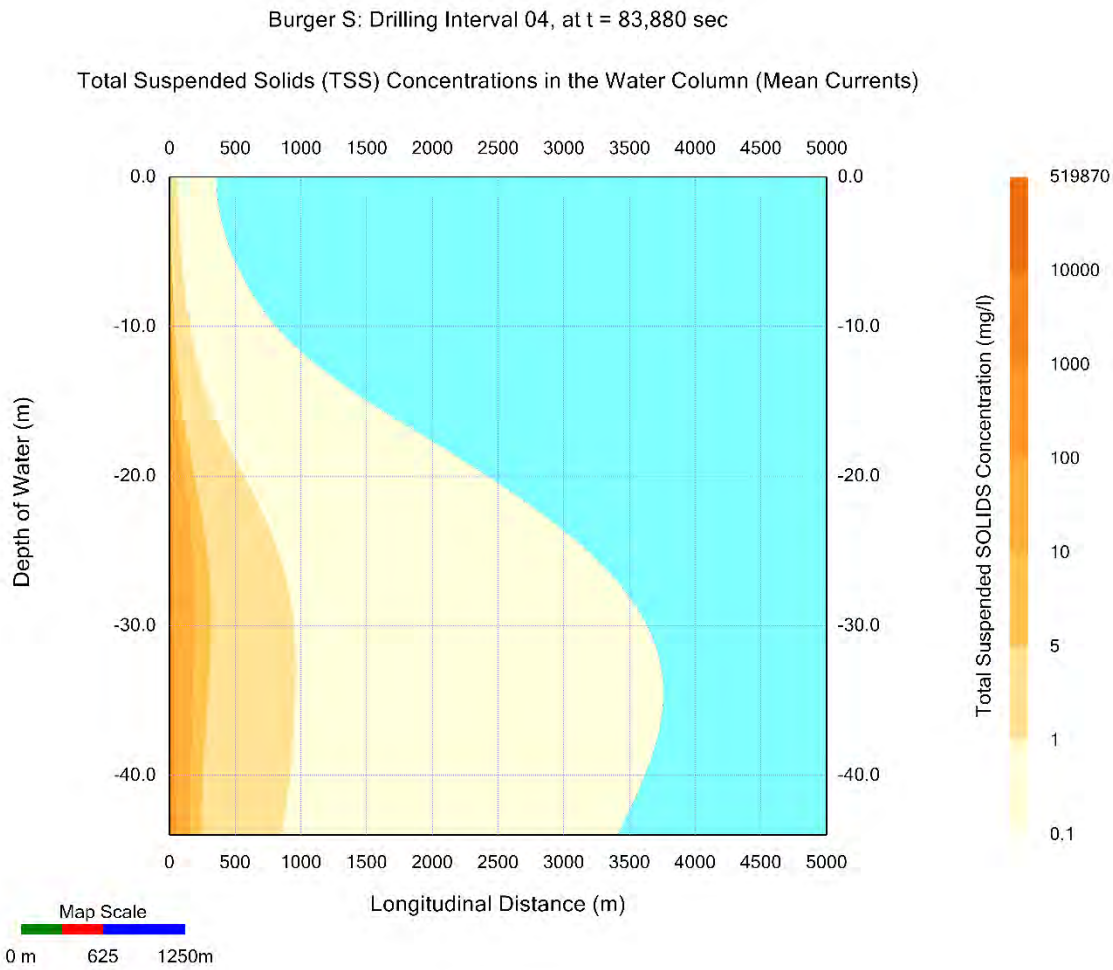
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **83**,**880** sec (or **23**.**3** hours) which is the discharge duration for this drilling interval is presented in **Figure 5-18**a. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **8.53** m from a **15.25** inches internal diameter discharge pipe. Figure **5-18**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **519,870** mg/l occurs at the discharge location. It decreases to a value of **100** and **10** mg/l at distances approximately: **50** and **200** m, respectively from the discharge location. It varies from **10** to **5** mg/l between **200** and **325** m distances from the discharge location. It varies from **5** to **1** mg/l between **325** and **1**,**000** m distances from the source. It is less than **1** mg/l beyond **1**,**000** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **713.3**, **202.4**, **23.9**, **5.5**, and **0.9** mg/l, respectively.

Figure 5-18a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 04

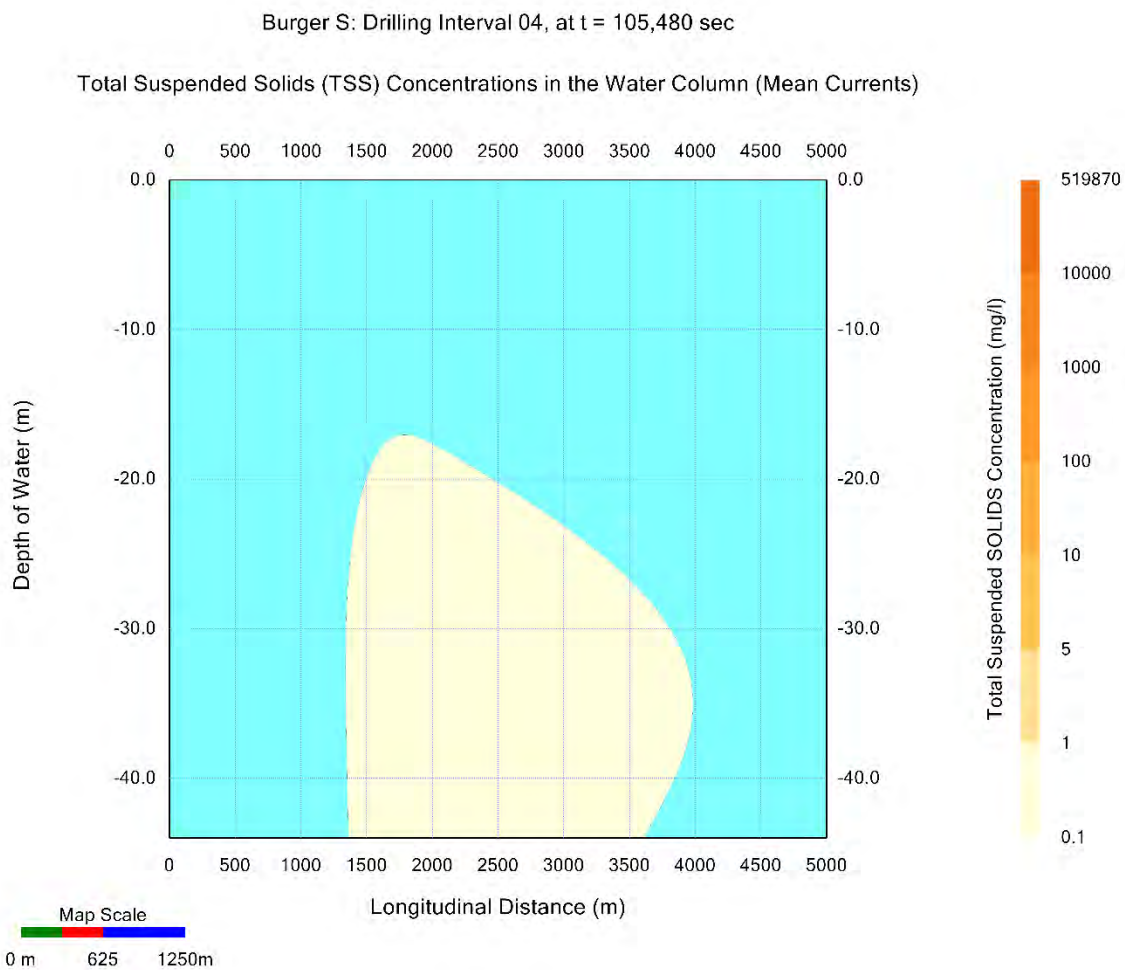


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

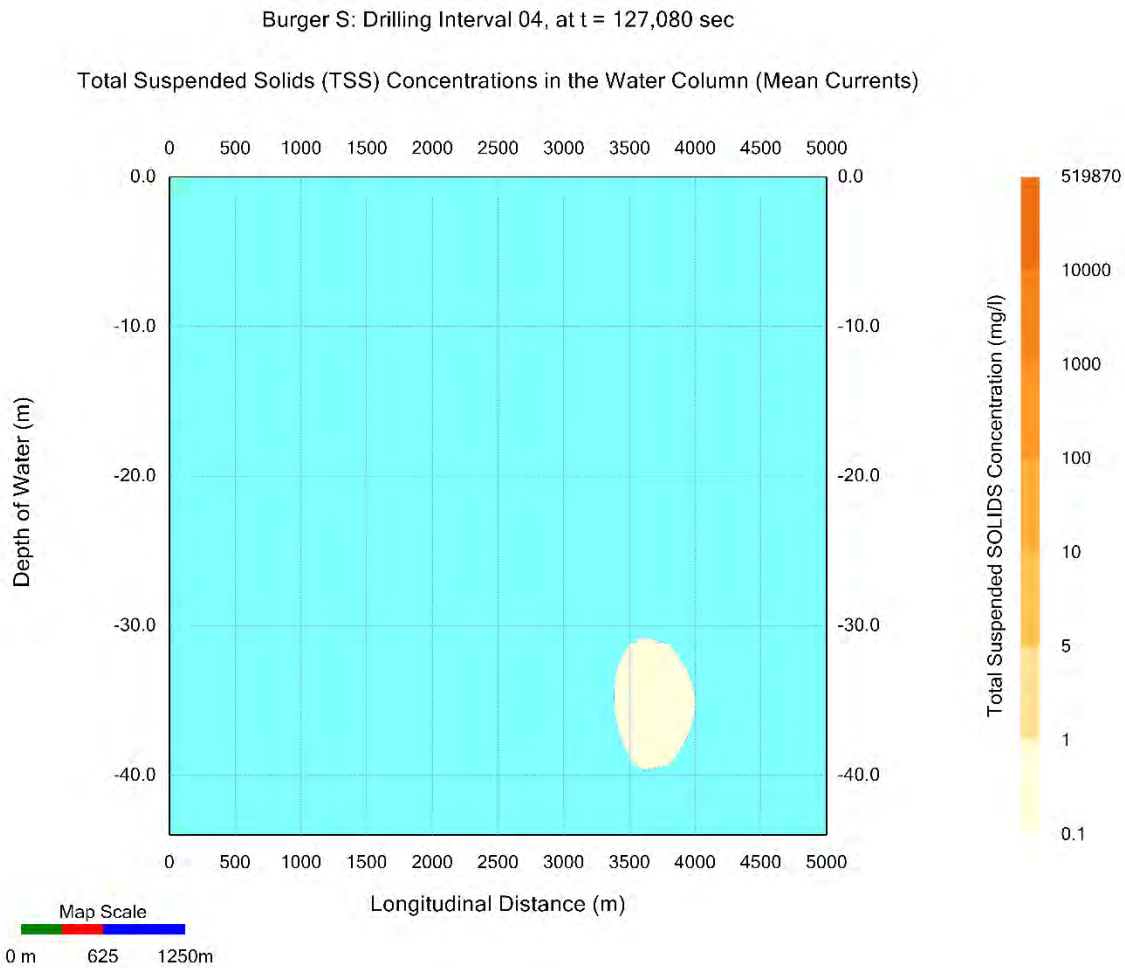
The discharge of the water based drill cuttings and drill fluids ceases at time, t = **83**,**880** sec (or **23**.**3** hours). The fate and transport of the discharged solids at times **6**, **12**, and **18** h after the cessation of the discharge are presented by **Figures 5-18**b**, 5-18**c**,** and **5-18**d. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **1** mg/l or less at **6** h, **1** mg/l or less at **12** h, and less than **0**.**1** mg/l at **18** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **12** and **18** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 5-18b: TSS concentrations during the mean currents at 29.3 h (or 6 h after the cessation of release)



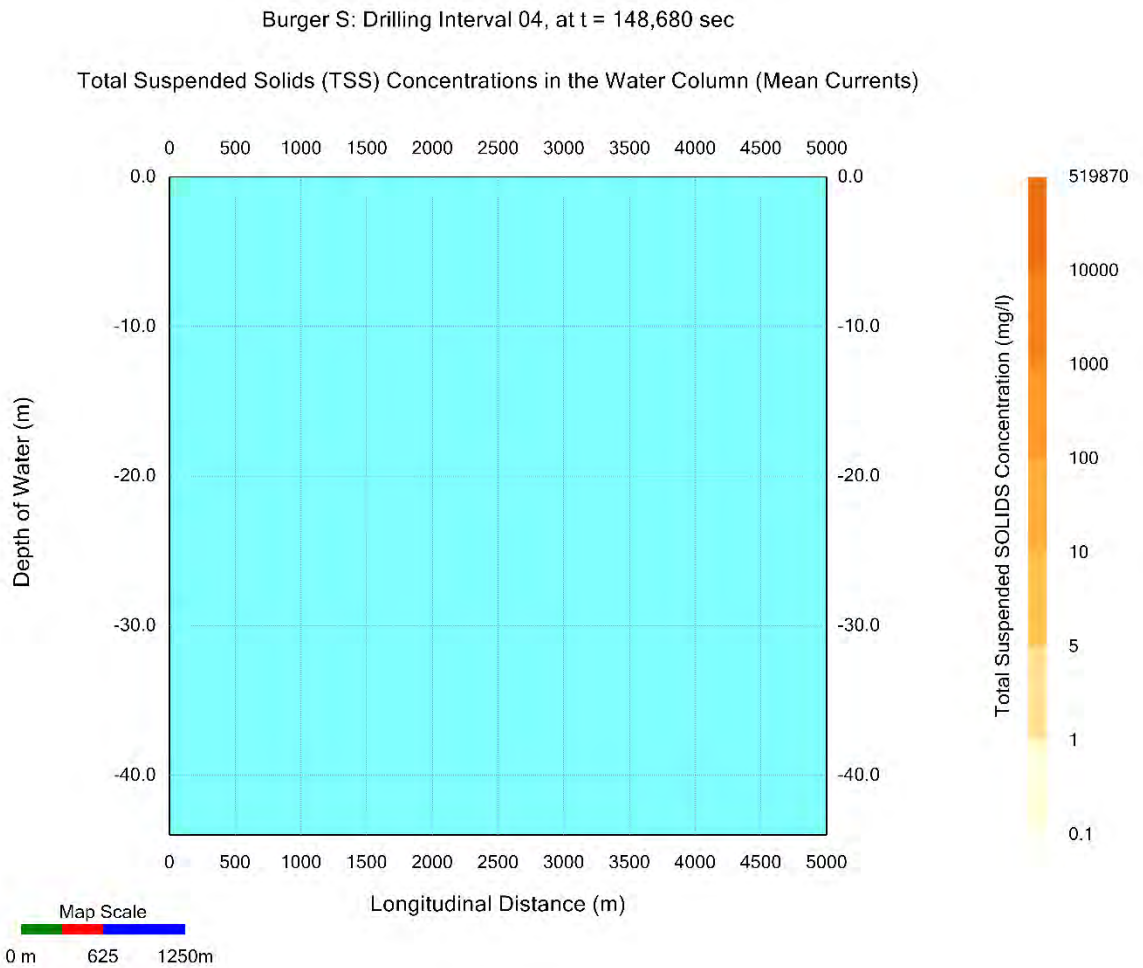
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-18c: TSS concentrations during the mean currents at 35.3 h (or 12 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-18d: TSS concentrations during the mean currents at 41.3 h (or 18 h after the cessation of release)



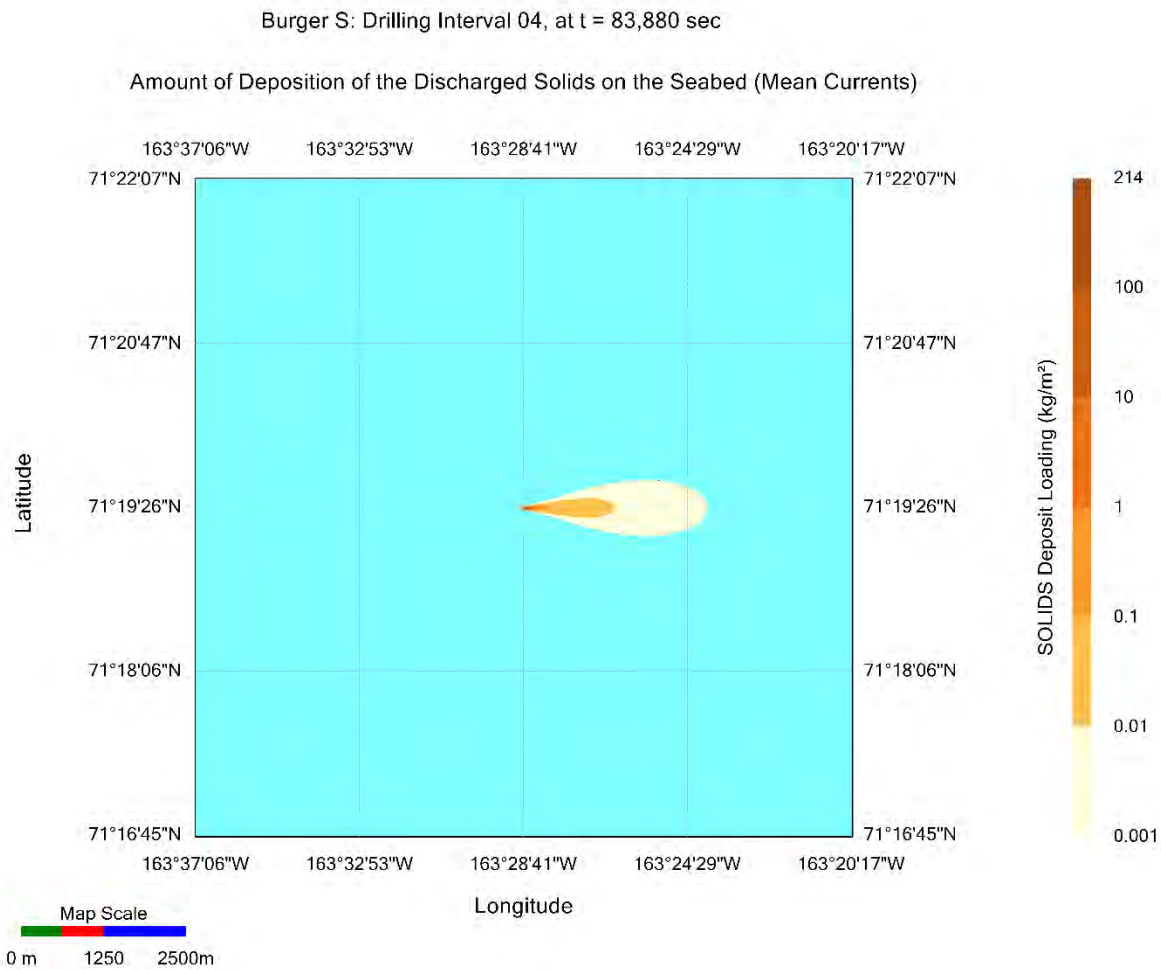
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **83,880** sec (or **23.3** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented **in Figure 5-19.** The model domain extends to **5.0** km in all directions from the discharge location as shown in Figure **5-19**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **213** kg/m^2 occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **75** m and **200** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0.1** kg/m^2 approximately between **200** and **450** m distances from the discharge location. It varies from **0.1** kg/m^2 to **0.01** kg/m^2 approximately between **450** m and **1,425** m distances from the discharge location. It is less than **0.01** kg/m^2 beyond **1,425** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **100**-, **10**-, **1**-, **0.1**-, and **0.01**-kg/m^2 are: **0.114**, **0.330**, **0.808**, **4.783**, and **28.907** ha, respectively.

Figure 5-19: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 04



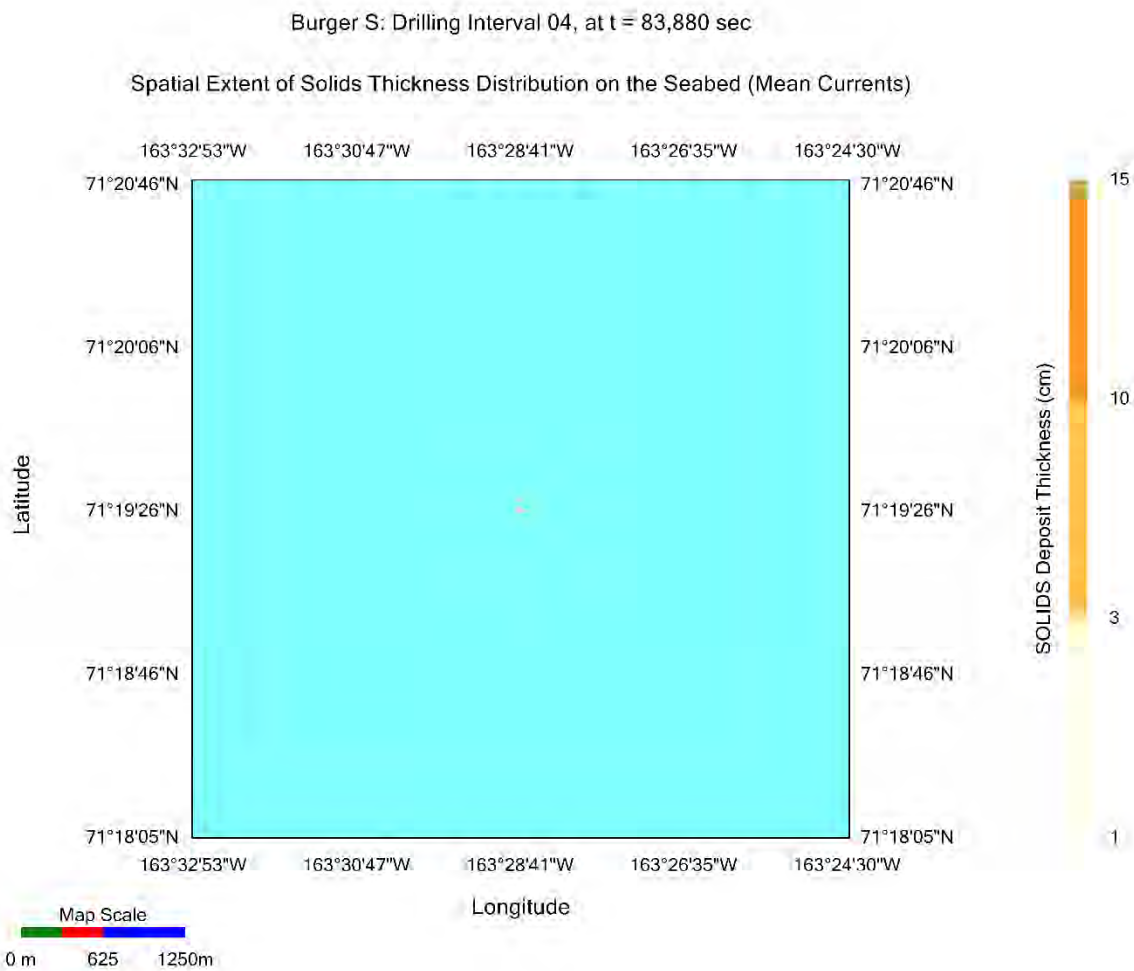
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **83,880** sec (or **23.3** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 5-20a** and **5-20b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5.0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **5-20**a. The same result is presented in Figure **5-20**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **14.7** cm occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **75** m from the discharge location.

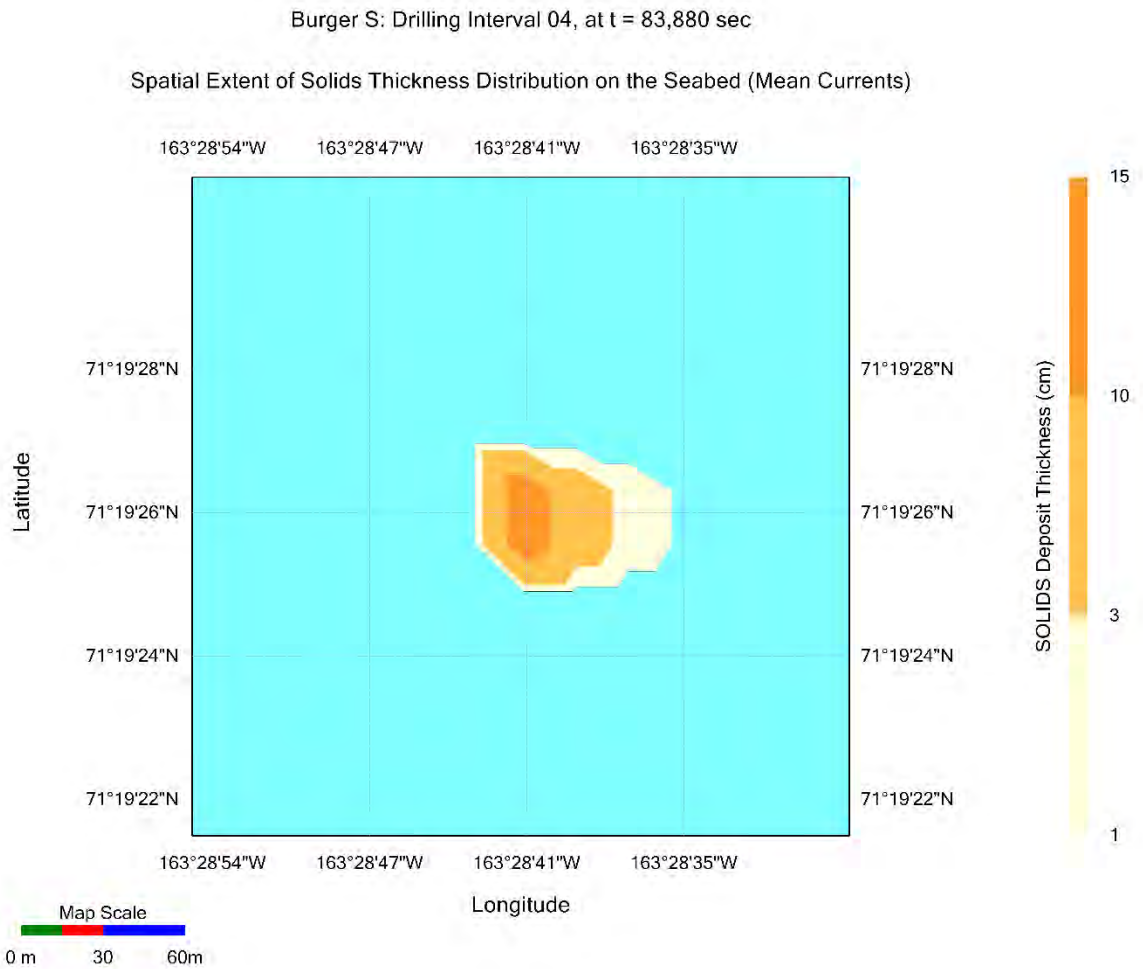
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **75** m x **40** m rectangle area (or **0.274** ha) as presented in Figure **5-20**b. The sea floor areas affected by deposit thickness larger than **10**- and **1**-cm are: **0.100** and **0.274** ha, respectively.

Figure 5-20a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 04



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-20b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 04 (Zoom In View)



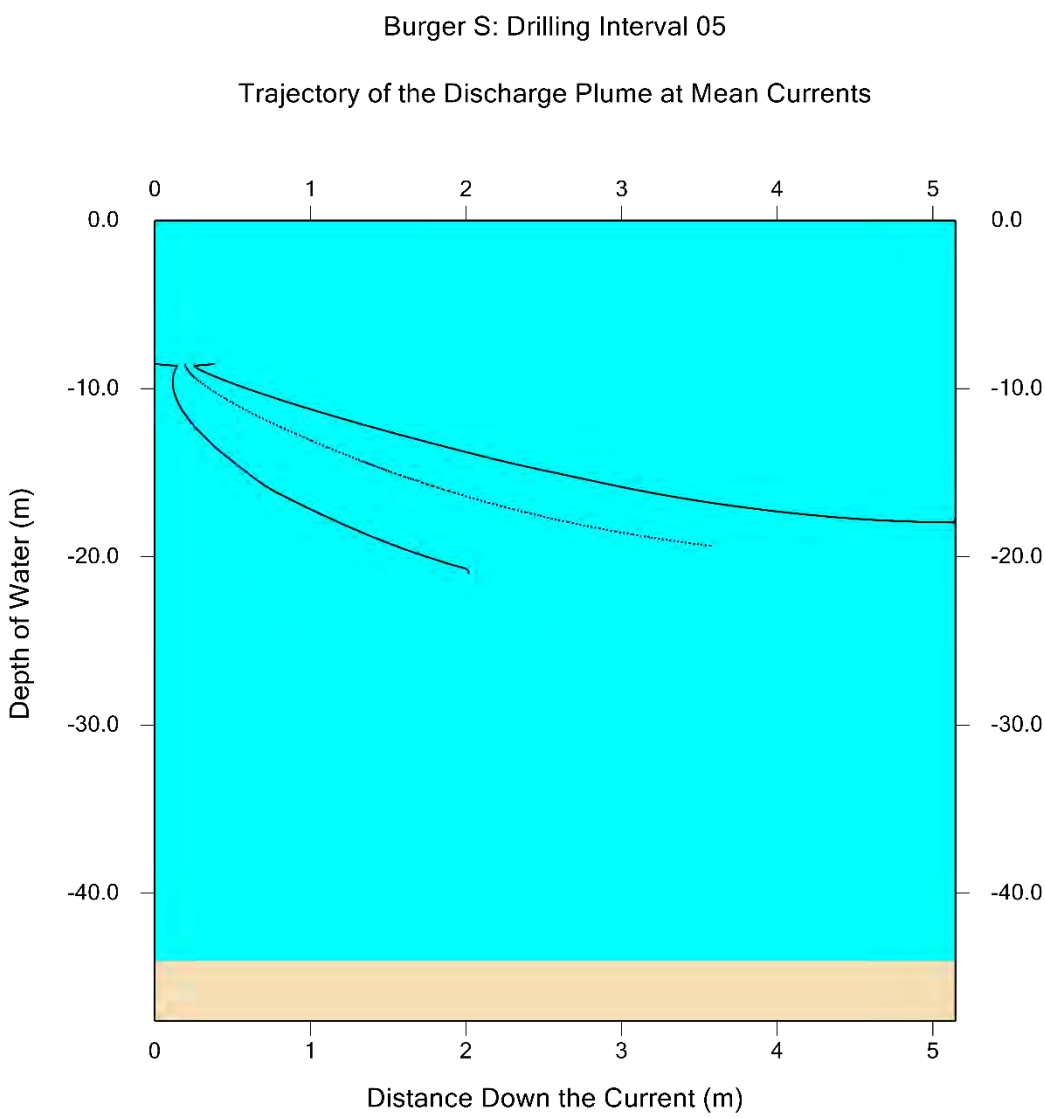
Copyright **2014** by Fluid Dynamix. Company Confidential.

5.5 Model Results for Sea Surface Discharge Scenario – Drilling Interval 05

Trajectory and Shape of the Discharge Plume

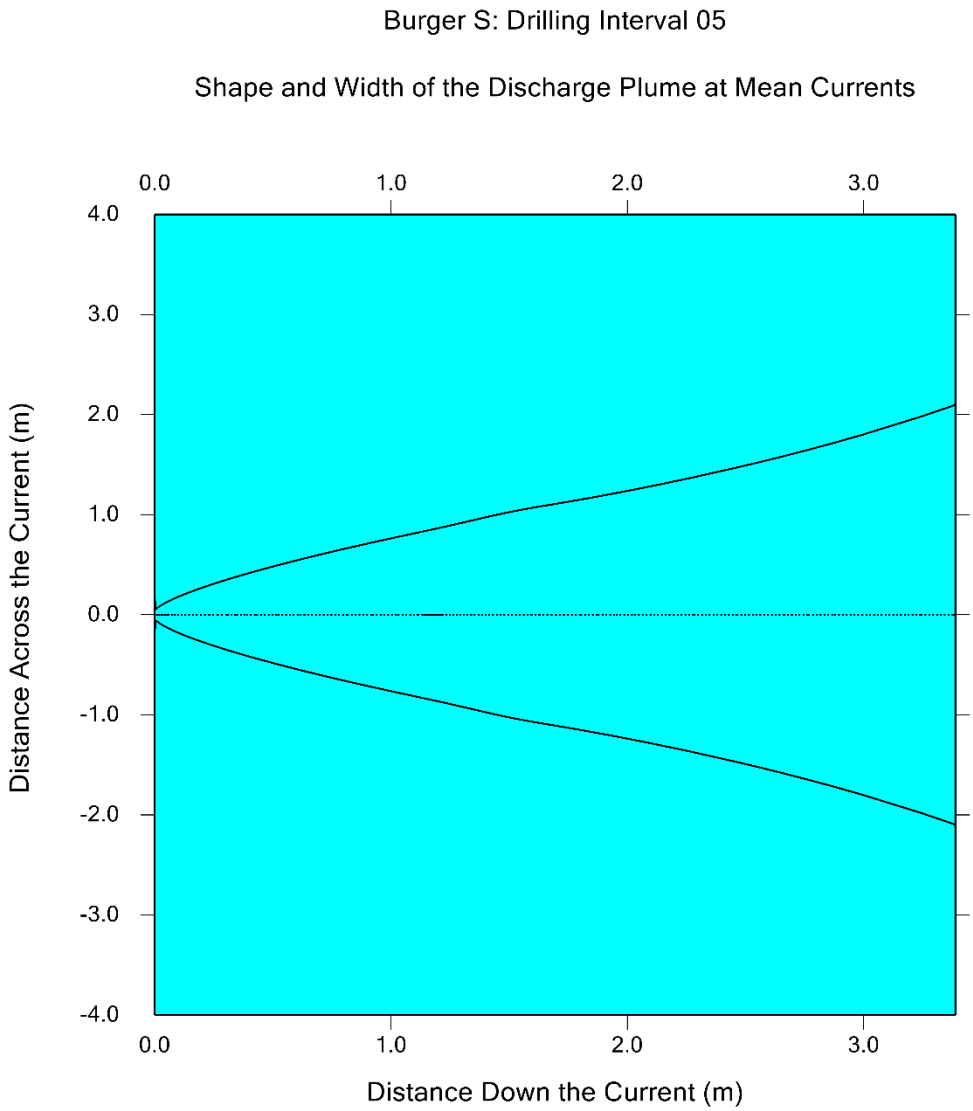
The trajectory of the discharge plume is presented in **Figure 5-21**. The depth of water is **44.0** m and the discharge occurs at a depth of **8.53** m below the sea surface. The heavier plume travels approximately **3.5** m from the discharge location before collapsing into the ambient sea water due to the higher density of the discharge plume. The shape and width of the discharge plume is presented in **Figure 5-22**. The width of the plume is approximately **4.2** m at a distance **3.5** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **5-21** and **5-22**.

Figure 5-21: Trajectory of the discharge plume at mean currents, Drilling Interval 05



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-22: Shape and width of the discharge plume at mean currents, Drilling Interval 05



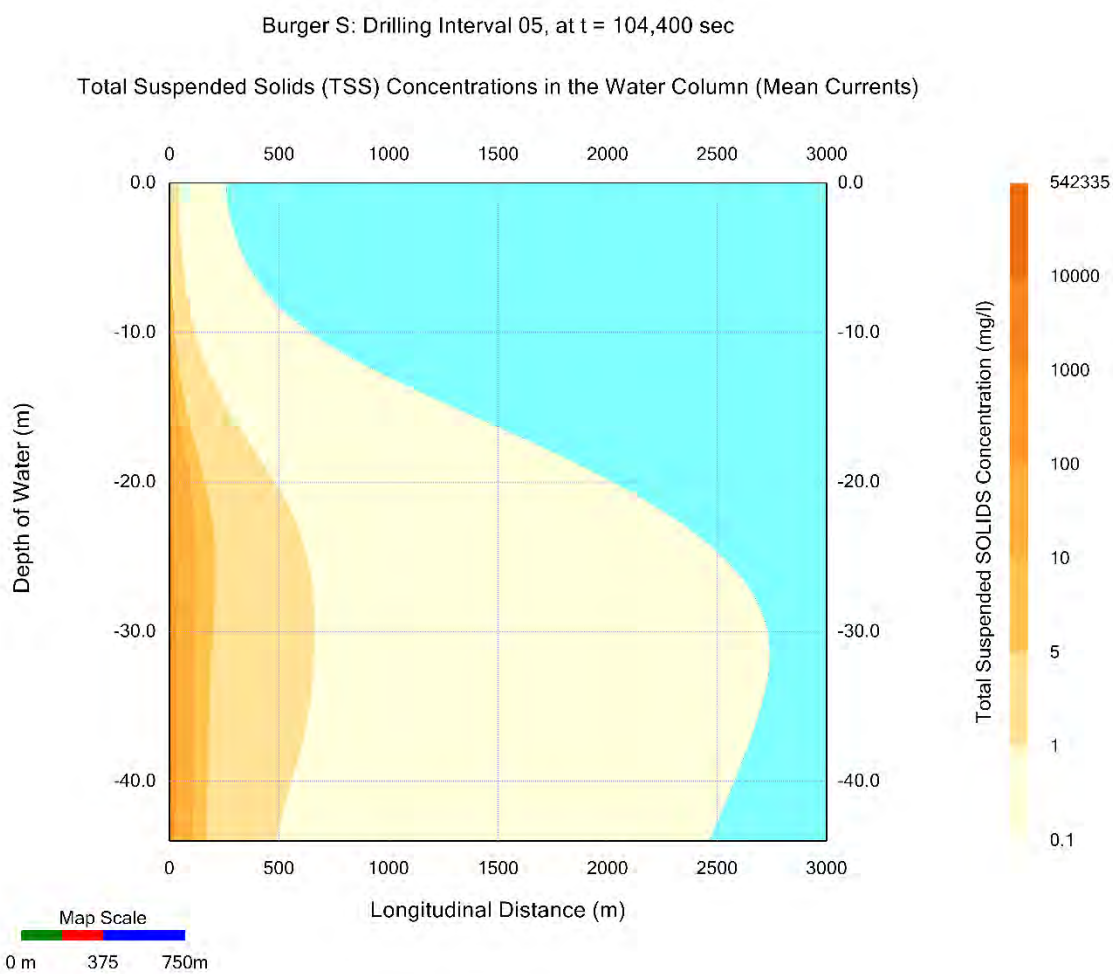
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **104**,**400** sec (or **29**.**0** hours) which is the discharge duration for this drilling interval is presented in **Figure 5-23**a. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **8.53** m from a **15.25** inches internal diameter discharge pipe. Figure **5-23**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **594,489** mg/l occurs at the discharge location. It decreases to a value of **100** and **10** mg/l at distances approximately: **40** and **125** m, respectively from the discharge location. It varies from **10** to **5** mg/l between **125** and **225** m distances from the discharge location. It varies from **5** to **1** mg/l between **225** and **675** m distances from the source. It is less than **1** mg/l beyond **675** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **443.0**, **111.7**, **13.0**, **3**.**1**, and **0**.**5** mg/l, respectively.

Figure 5-23a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 05

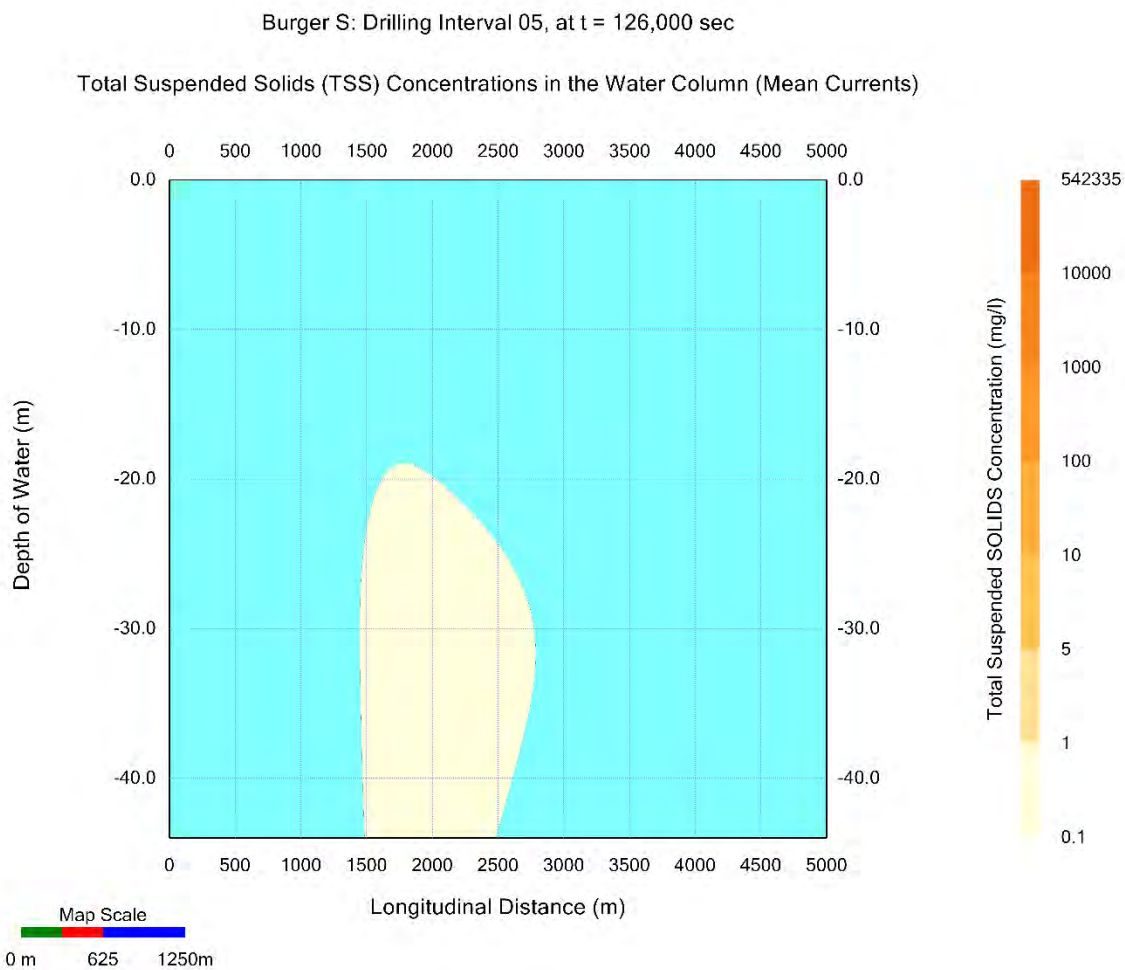


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

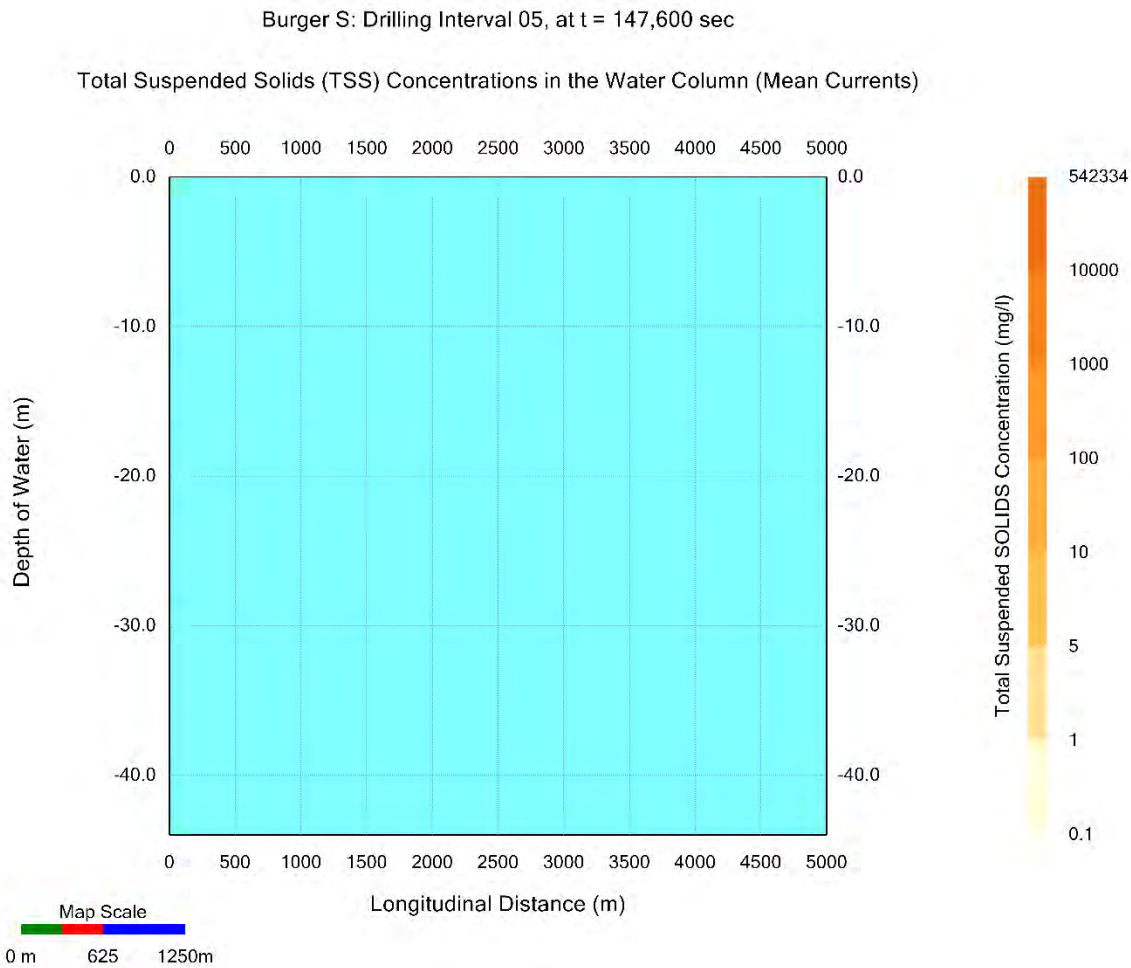
The discharge of the water based drill cuttings and drill fluids ceases at time, t = **104**,**400** sec (or **29**.**0** hours). The fate and transport of the discharged solids at times **6** and **12** h after the cessation of the discharge are presented by **Figures 5-23**b and **5-23**c. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **1** mg/l or less at **6** h and less than **0**.**1** mg/l at **12** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **6** and **12** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 5-23b: TSS concentrations during the mean currents at 35 h (or 6 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-23c: TSS concentrations during the mean currents at 41 h (or 12 h after the cessation of release)



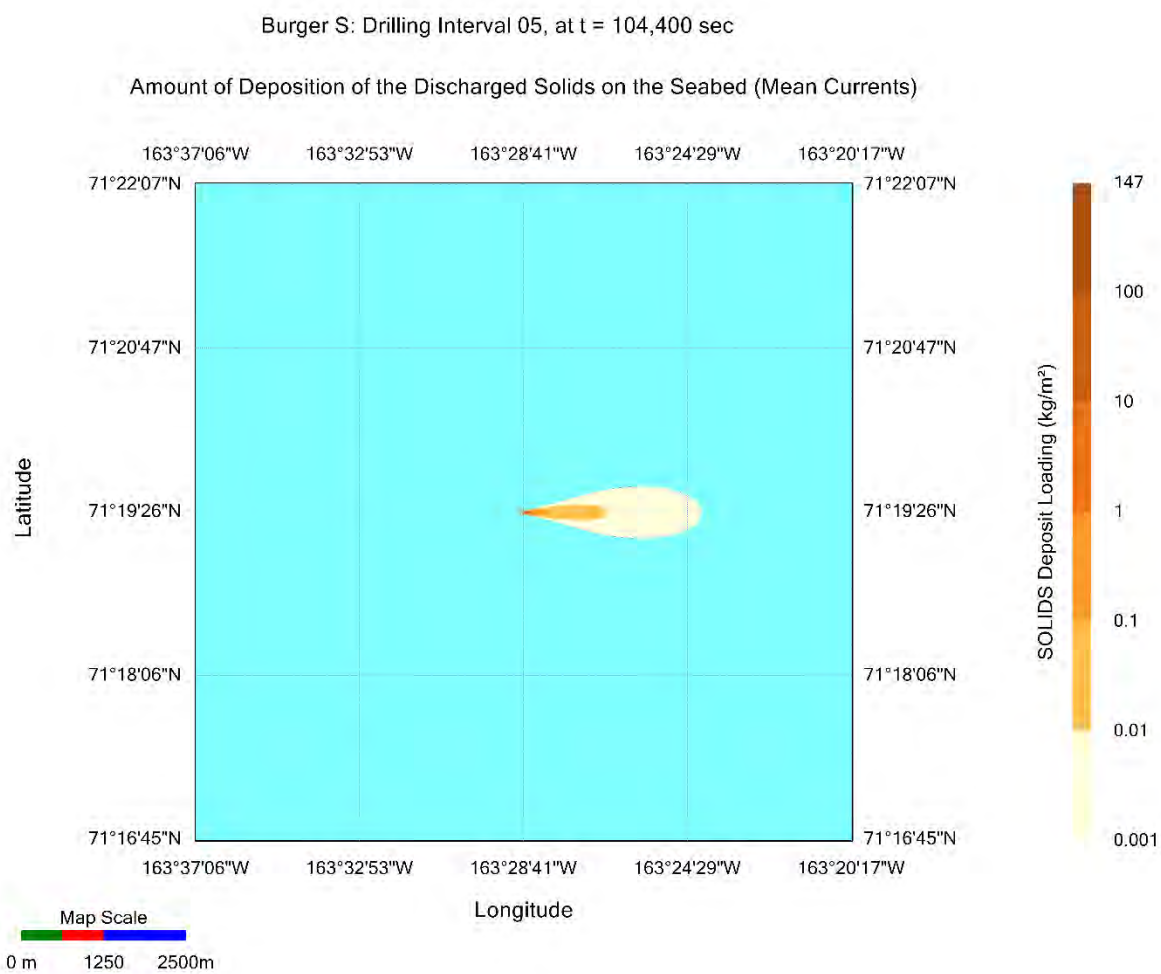
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **104**,**400** sec (or **29**.**0** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figure 5-24**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **5**-**24**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **147** kg/m^2 occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **70** m and **175** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **175** and **400** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **400** and **1**,**300** m distances from the discharge location. The loading is less than **0**.**01** kg/m^2 beyond **1**,**300** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**101**, **0**.**277**, **0**.**730**, **4**.**068**, and **22**.**653** ha, respectively.

Figure 5-24: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 05



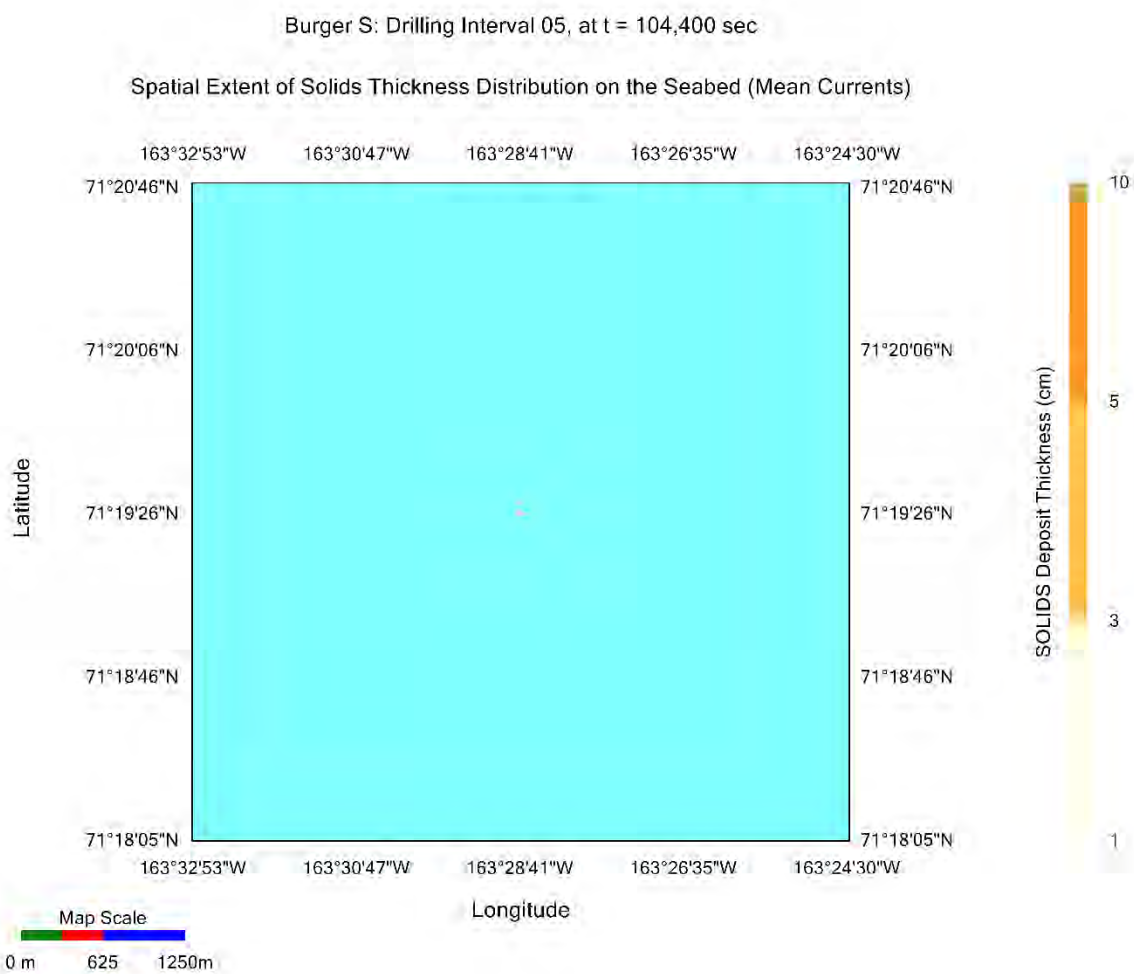
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **104**,**400** sec (or **29**.**0** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 5-25a** and **5-25b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **5**-**25**a. The same result is presented in Figure **5**-**25**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **9**.**6** cm occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **60** m from the discharge location.

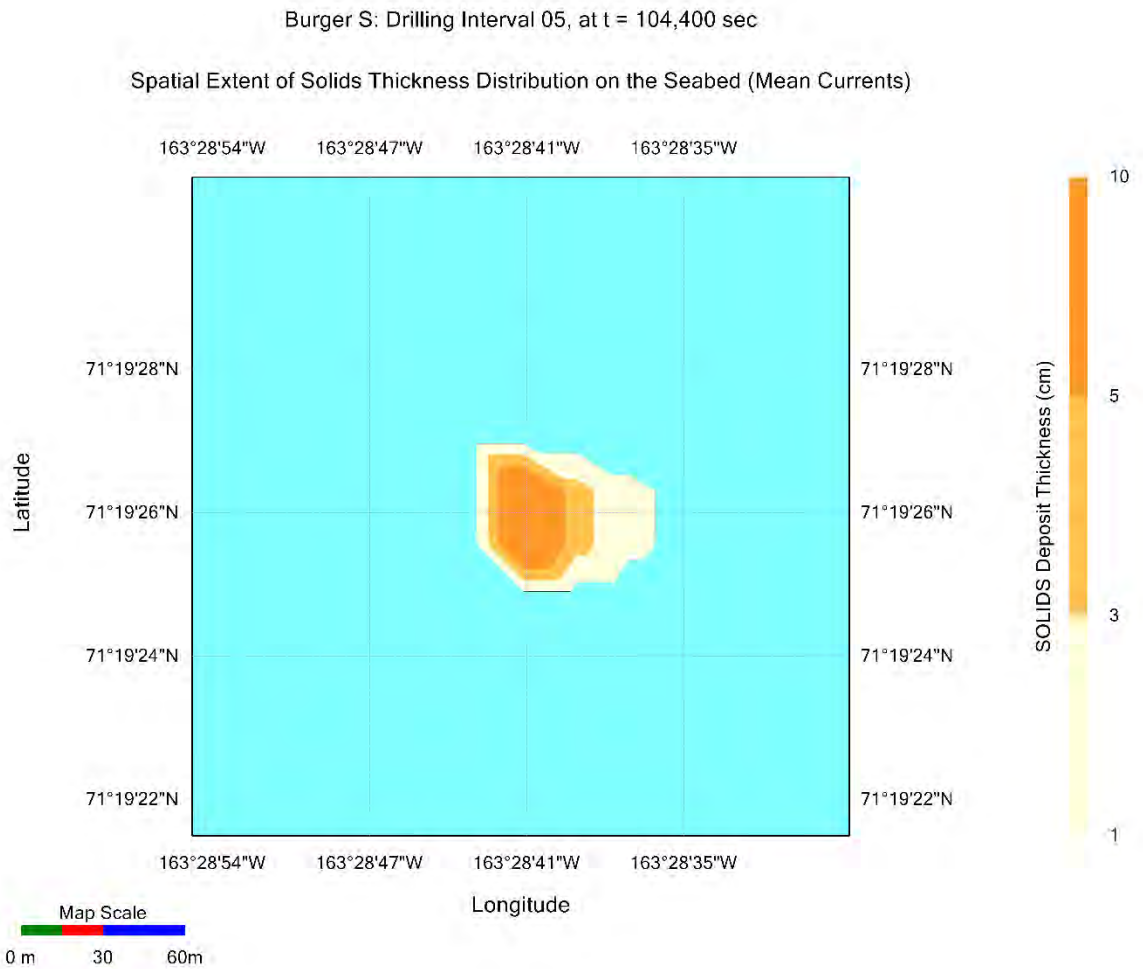
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **70** m x **40** m rectangle area (or **0**.**261** ha) as presented in Figure **5**-**25**b.

Figure 5-25a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 05



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-25b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 05 (Zoom In View)



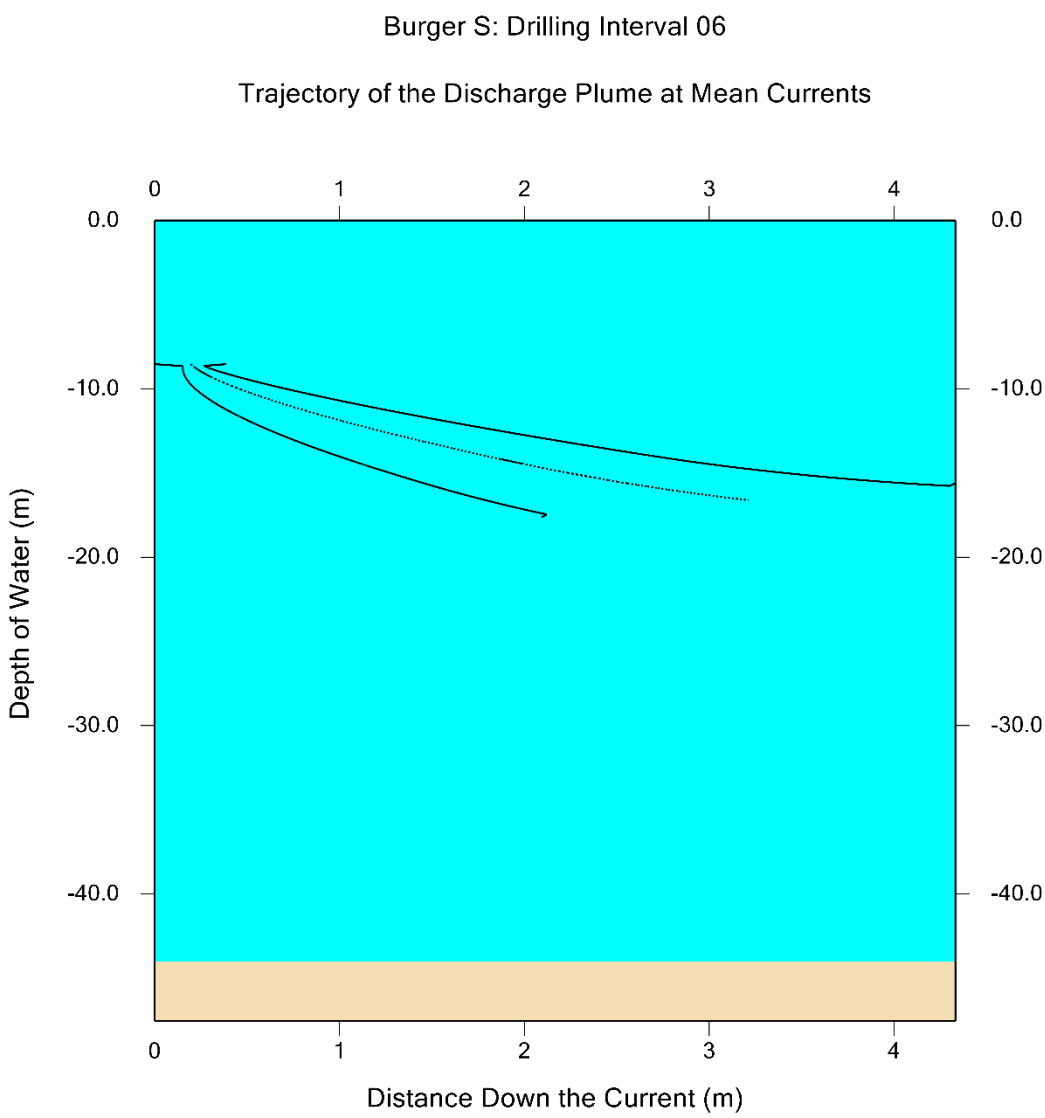
Copyright **2014** by Fluid Dynamix. Company Confidential.

5.6 Model Results for Sea Surface Discharge Scenario – Drilling Interval 06

Trajectory and Shape of the Discharge Plume

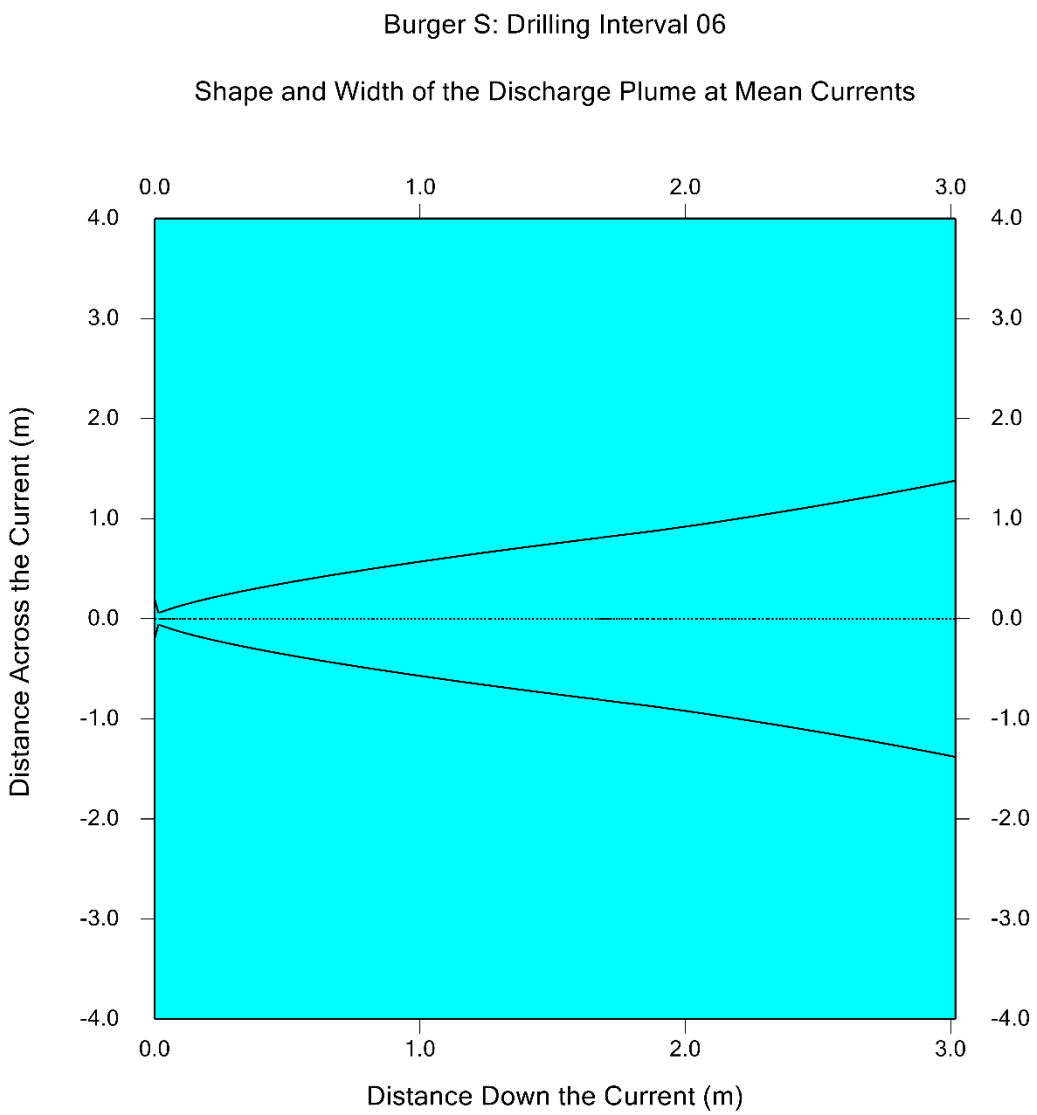
The trajectory of the discharge plume is presented in **Figure 5-26**. The depth of water is **44.0** m and the discharge occurs at a depth of **8.53** m below the sea surface. The heavier plume travels approximately **3.0** m from the discharge location before collapsing into the ambient sea water due to the higher density of the discharge plume. The shape and width of the discharge plume is presented in **Figure 5-27**. The width of the plume is approximately **2.8** m at a distance **3.0** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **5-26** and **5-27**.

Figure 5-26: Trajectory of the discharge plume at mean currents, Drilling Interval 06



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-27: Shape and width of the discharge plume at mean currents, Drilling Interval 06



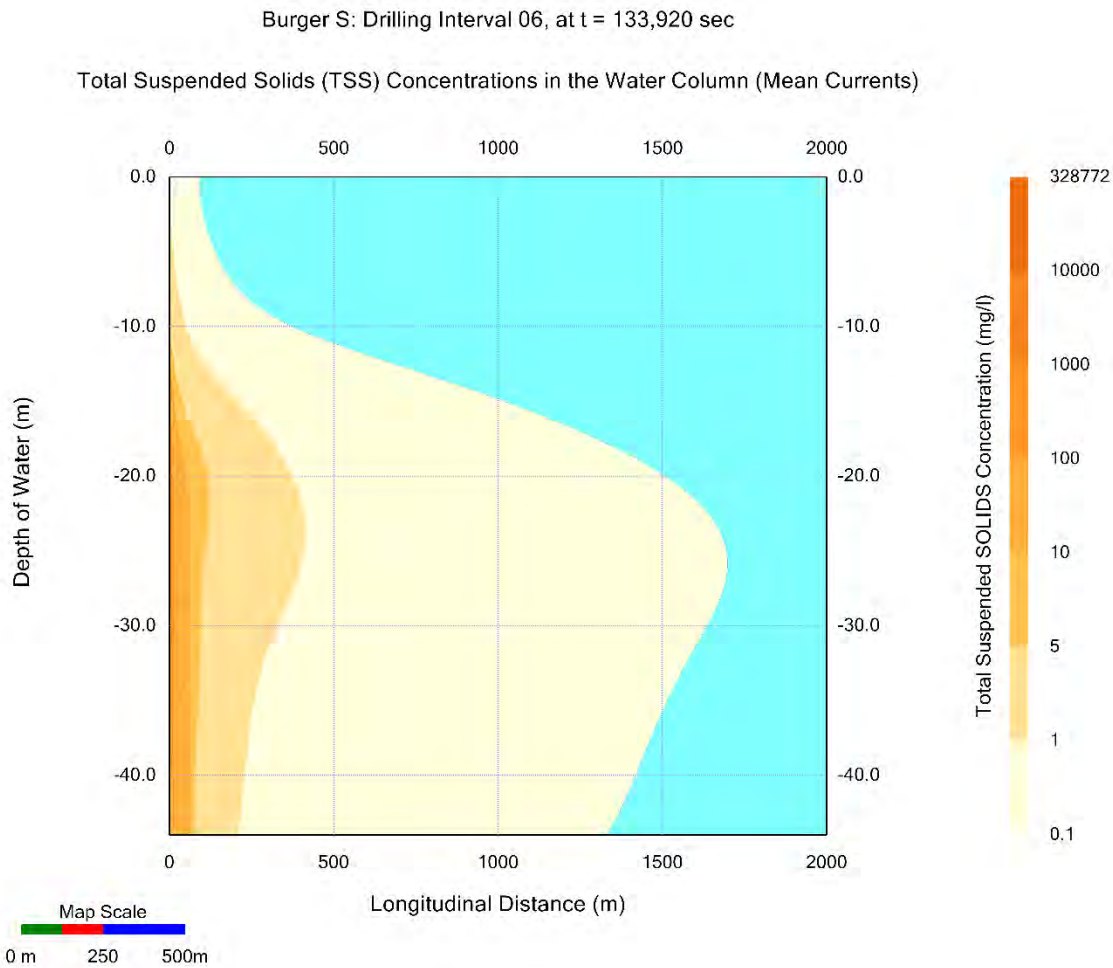
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **133**,**920** sec (or **37**.**2** hours) which is the discharge duration for this drilling interval is presented in **Figure 5-28**a. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **8.53** m from a **15.25** inches internal diameter discharge pipe. Figure **5-28**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **328,772** mg/l occurs at the discharge location. It decreases to a value of **100** and **10** mg/l at distances approximately: **20** and **60** m, respectively from the discharge location. It varies from **10** to **5** mg/l between **60** m and **100** m distances from the discharge location. It varies from **5** to **1** mg/l between **100** m and **410** m distances from the discharge location. It is less than **1** mg/l beyond **410** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **185.6**, **43.3**, **6.0**, **1**.**6**, and **0**.**2** mg/l, respectively.

Figure 5-28a: Total suspended solids concentrations in water column at mean currents, Drilling Interval 06

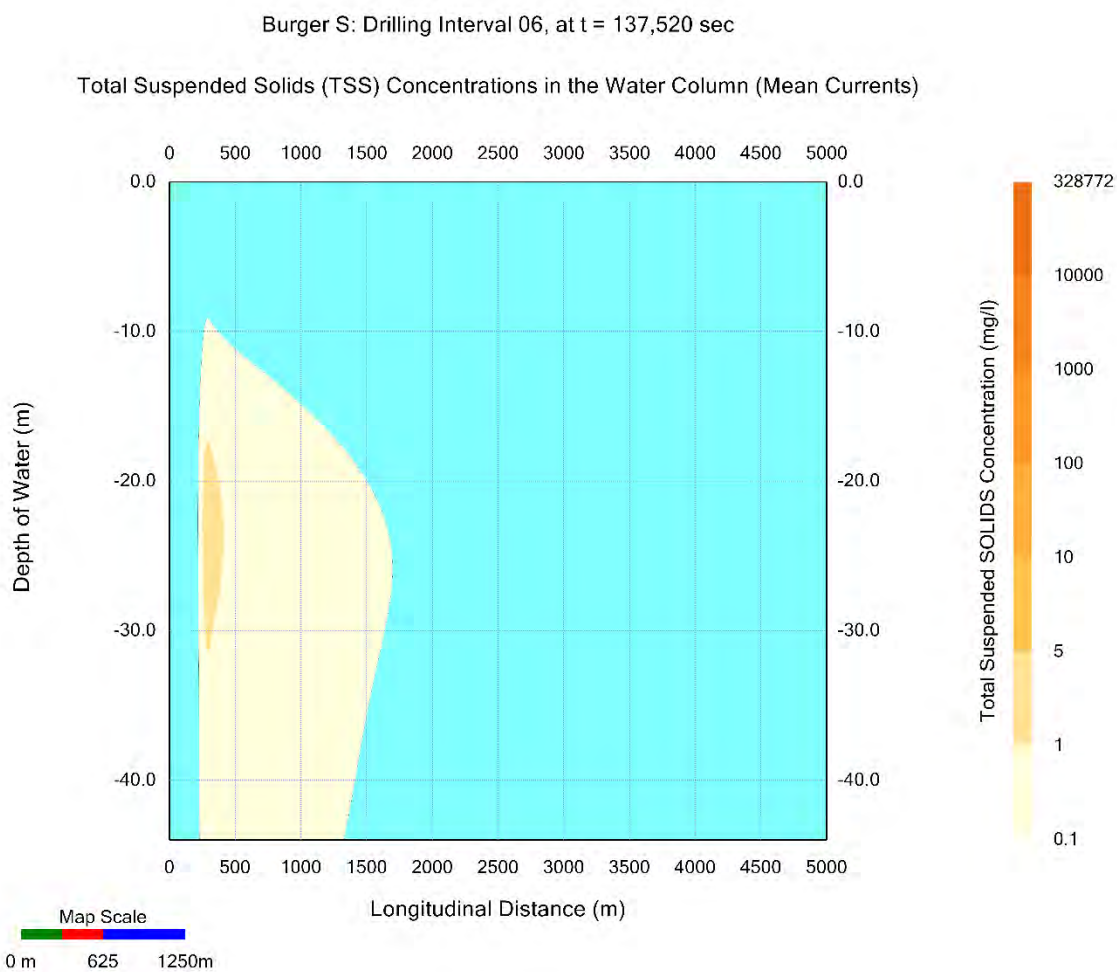


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

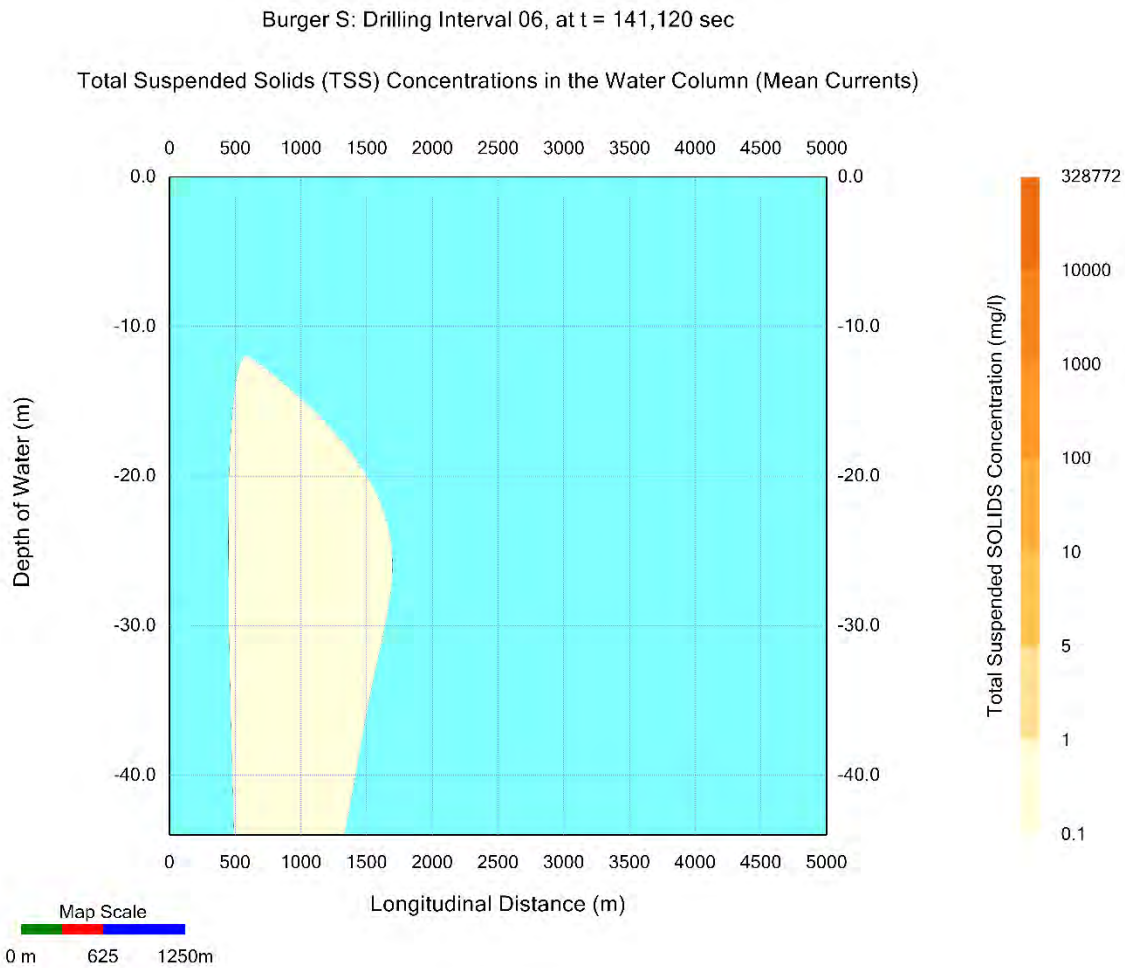
The discharge of the water based drill cuttings and drill fluids ceases at time, t = **133**,**920** sec (or **37**.**2** hours). The fate and transport of the discharged solids at times **1**, **2**, **3**, **4**, **5**, and **6** h after the cessation of the discharge are presented by **Figures 5-28**b**, 5-28**c**, 5-28**d**, 5-28**e**, 5-28**f**,** and **5-28g**. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **5** mg/l or less at **1** h, **1** mg/l or less at **2** h, **1** mg/l or less at **3** h, **1** mg/l or less at **4** h, **1** mg/l or less at **5** h, and less than **0**.**1** mg/l at **6** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **5** and **6** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 5-28b: TSS concentrations during the mean currents at 38.2 h (or 1 h after the cessation of release)



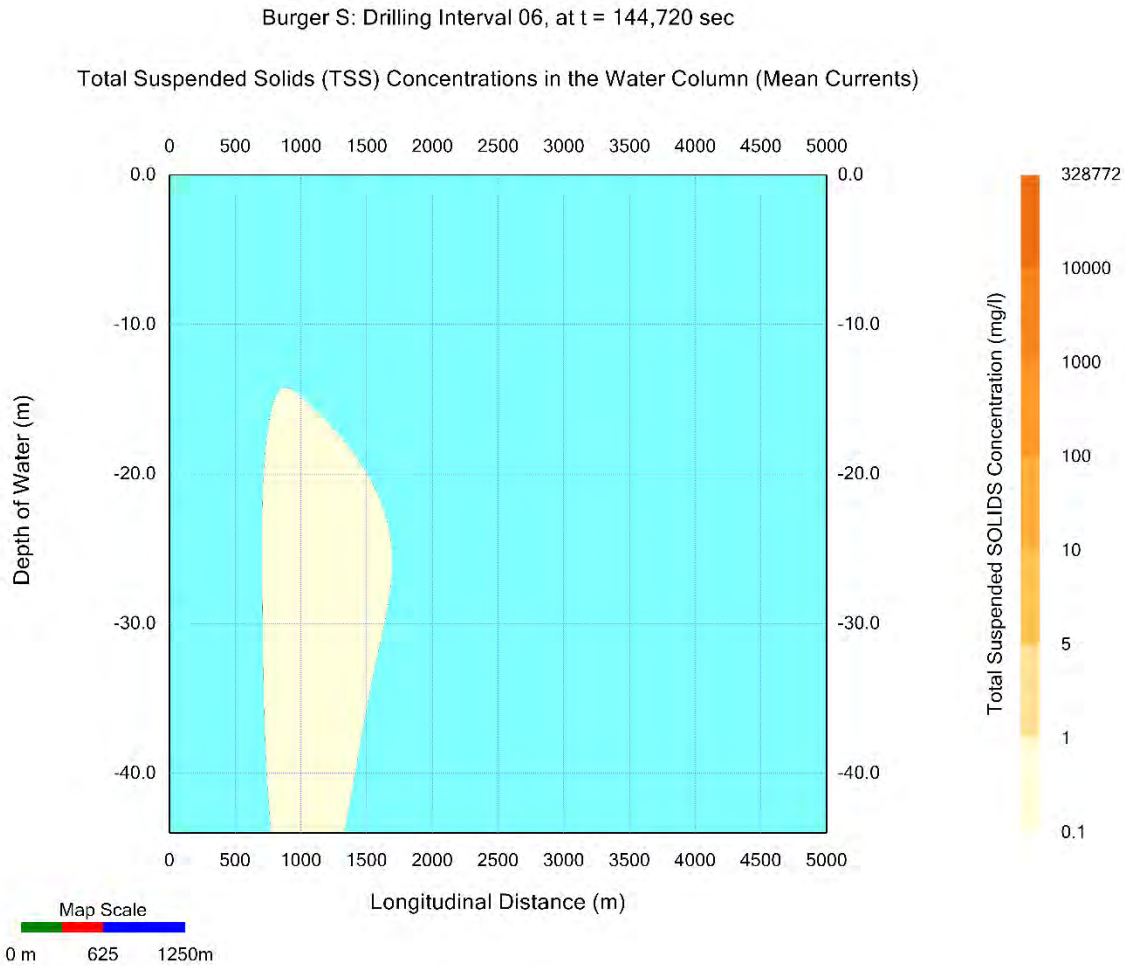
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-28c: TSS concentrations during the mean currents at 39.2 h (or 2 h after the cessation of release)



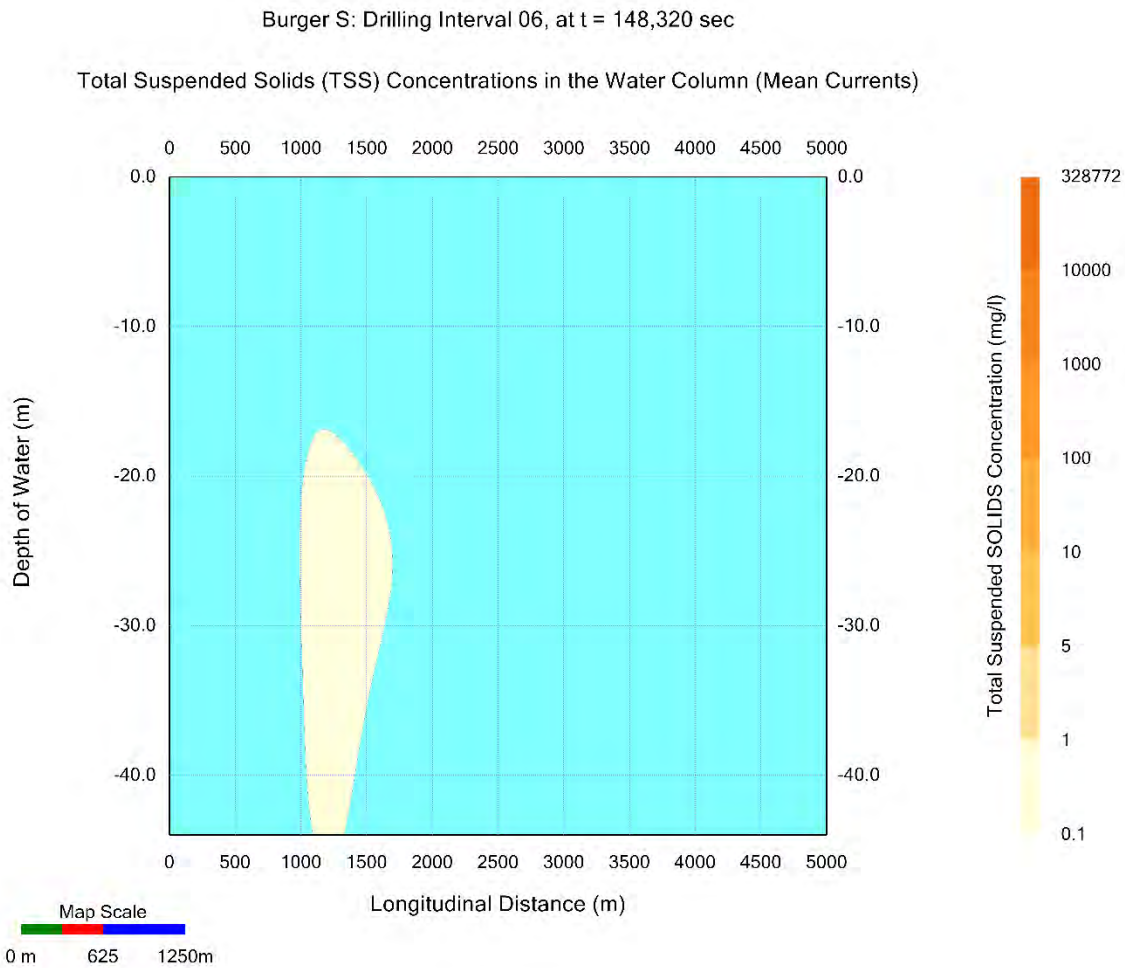
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-28d: TSS concentrations during the mean currents at 40.2 h (or 3 h after the cessation of release)



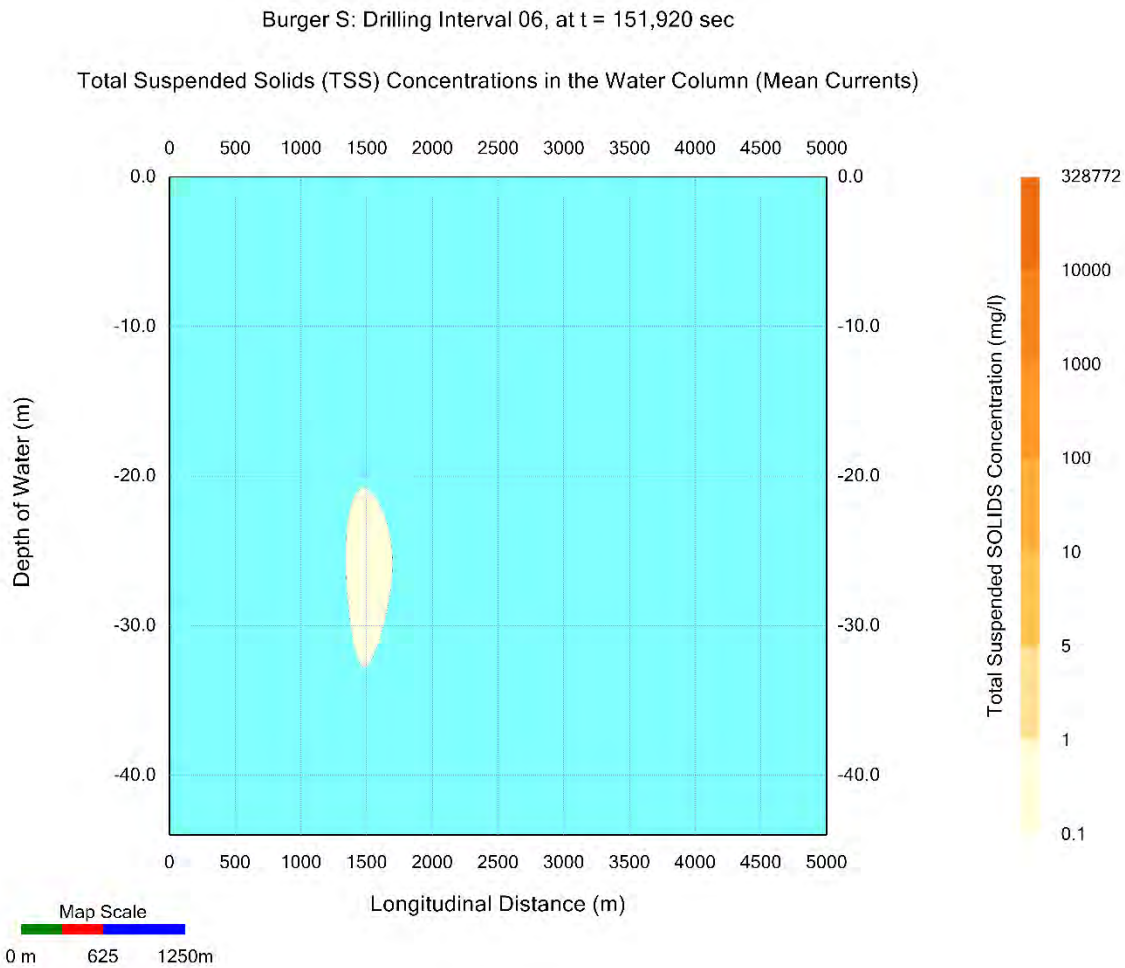
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-28e: TSS concentrations during the mean currents at 41.2 h (or 4 h after the cessation of release)



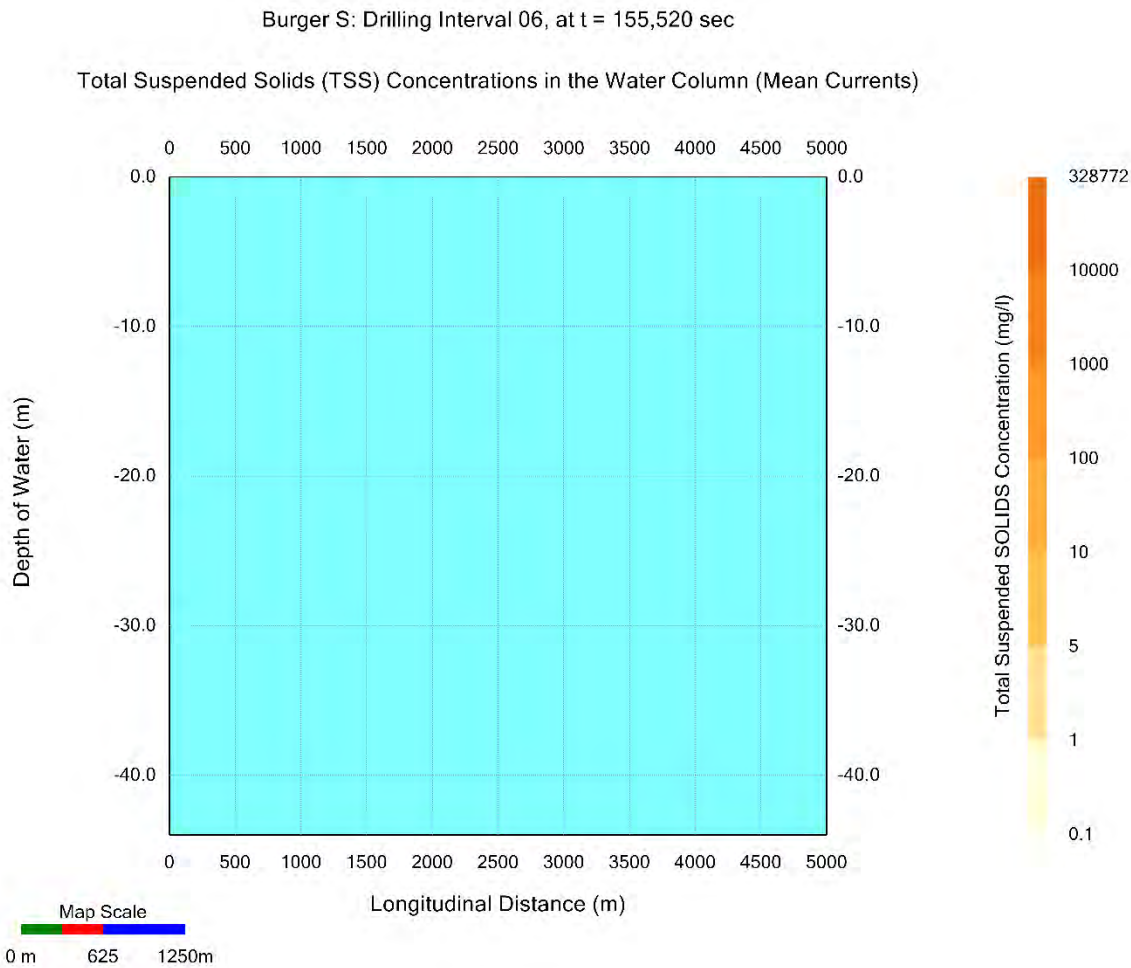
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-28f: TSS concentrations during the mean currents at 42.2 h (or 5 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-28g: TSS concentrations during the mean currents at 43.2 h (or 6 h after the cessation of release)



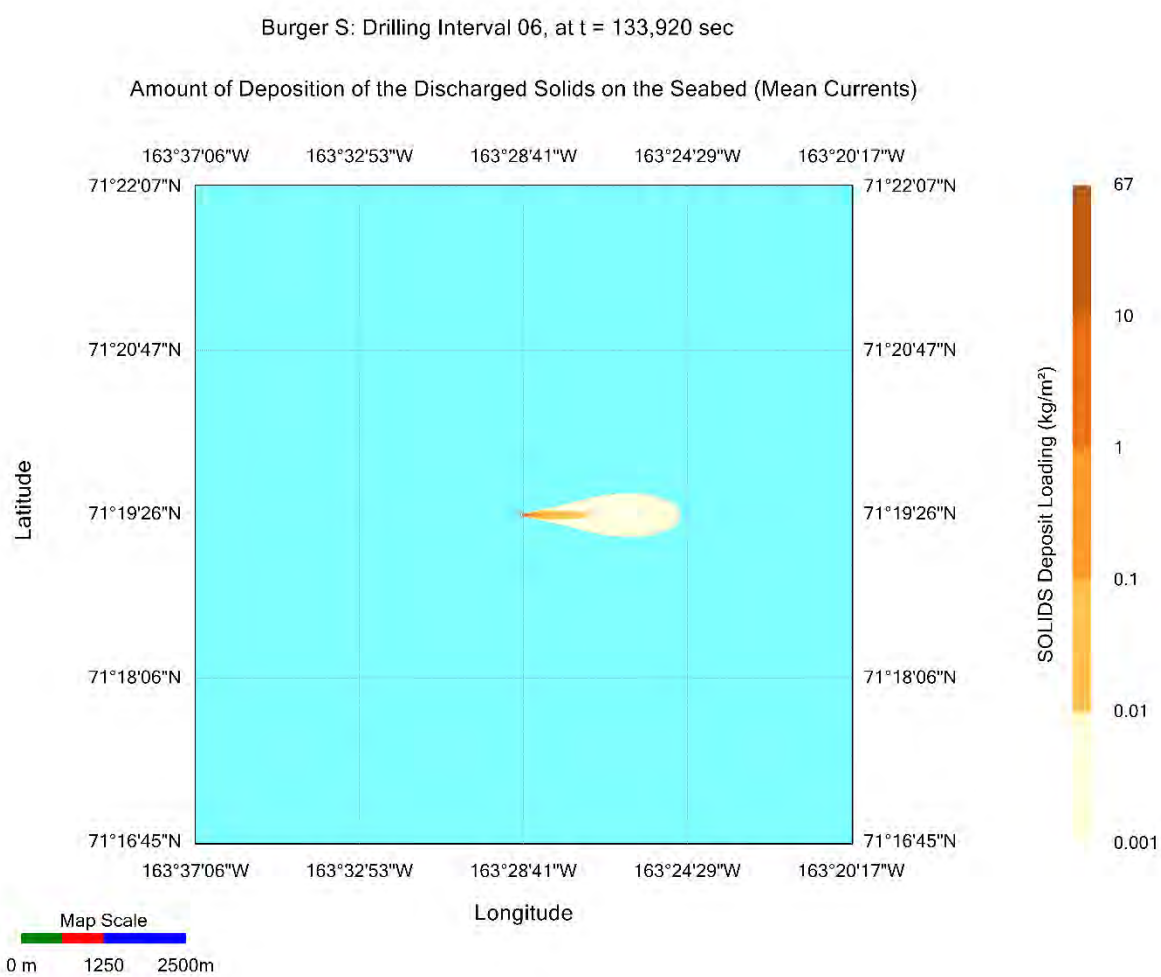
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **133**,**920** sec (or **37**.**2** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figure 5-29**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **5**-**29**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **66** kg/m^2 occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **55** m and **140** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **140** and **325** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **325** and **1,000** m distances from the discharge location. The loading is less than **0**.**01** kg/m^2 beyond **1,000** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**251**, **0**.**575**, **1**.**516**, and **11**.**608** ha, respectively.

Figure 5-29: Amount of deposition of the solids on seabed at mean currents, Drilling Interval 06



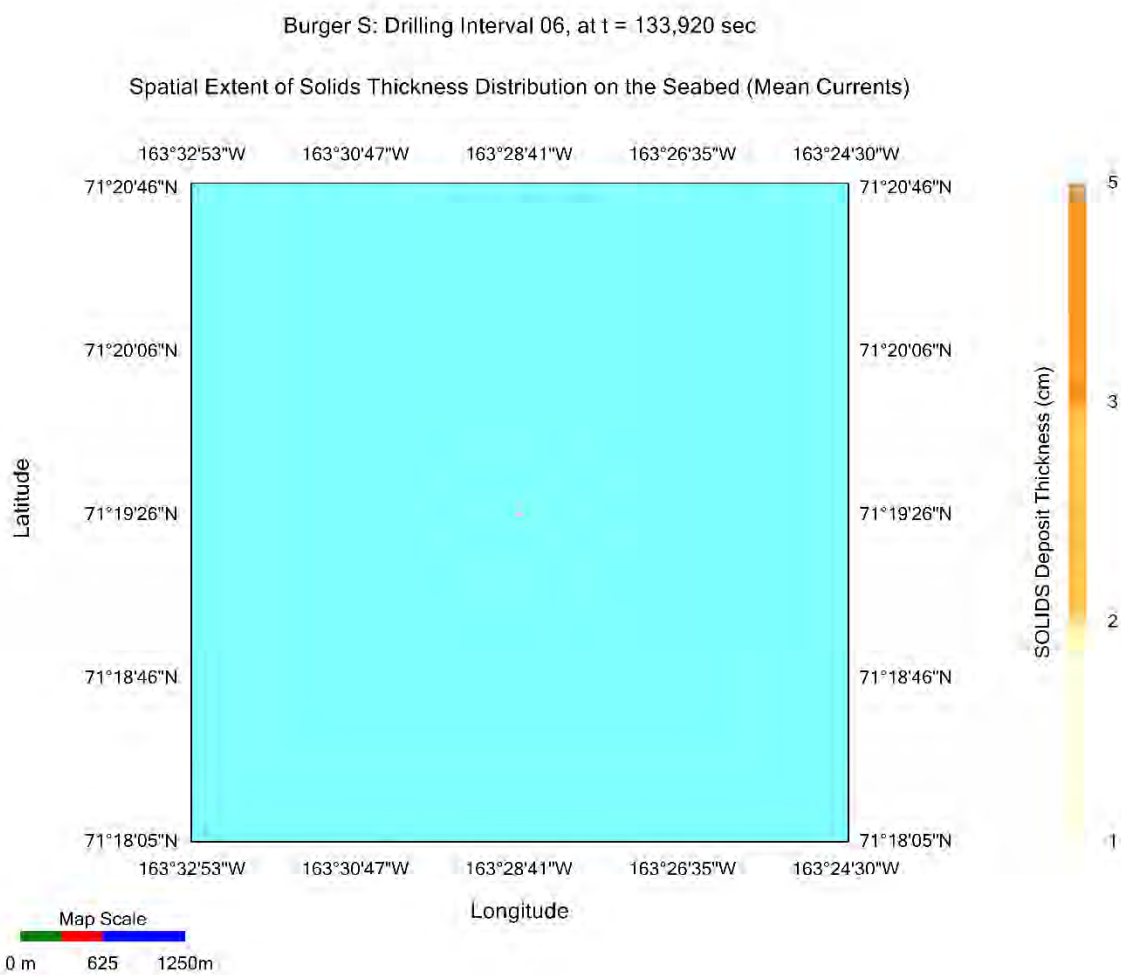
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **133**,**920** sec (or **37**.**2** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 5-30a** and **5-30b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **5**-**30**a. The same result is presented in Figure **5**-**30**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **4.3** cm occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **45** m from the discharge location.

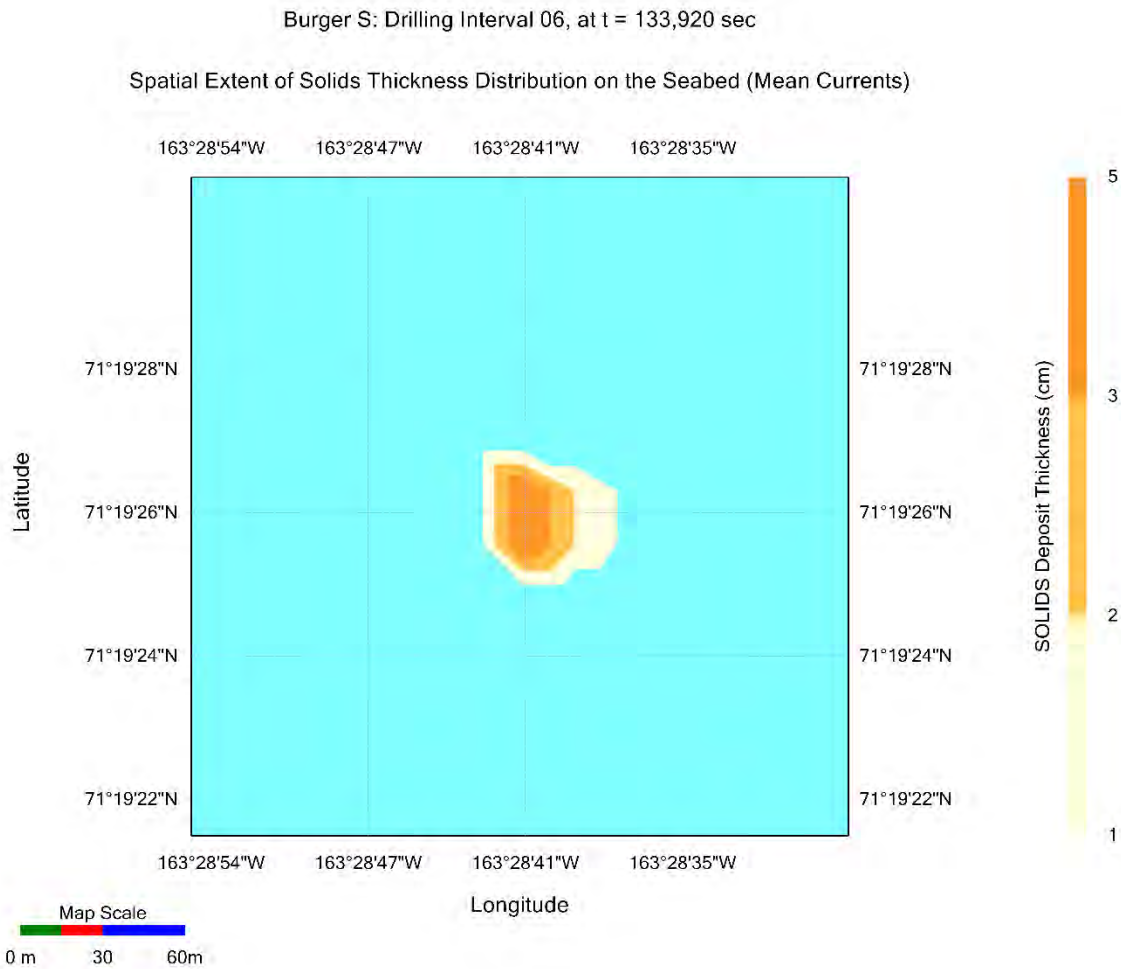
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **50** m x **40** m rectangle area or **0**.**192** ha as presented in Figure **5**-**30**b.

Figure 5-30a: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 06



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-30b: Spatial extent of solids thickness distribution on seabed at mean currents, Drilling Interval 06 (Zoom In View)



Copyright **2014** by Fluid Dynamix. Company Confidential.

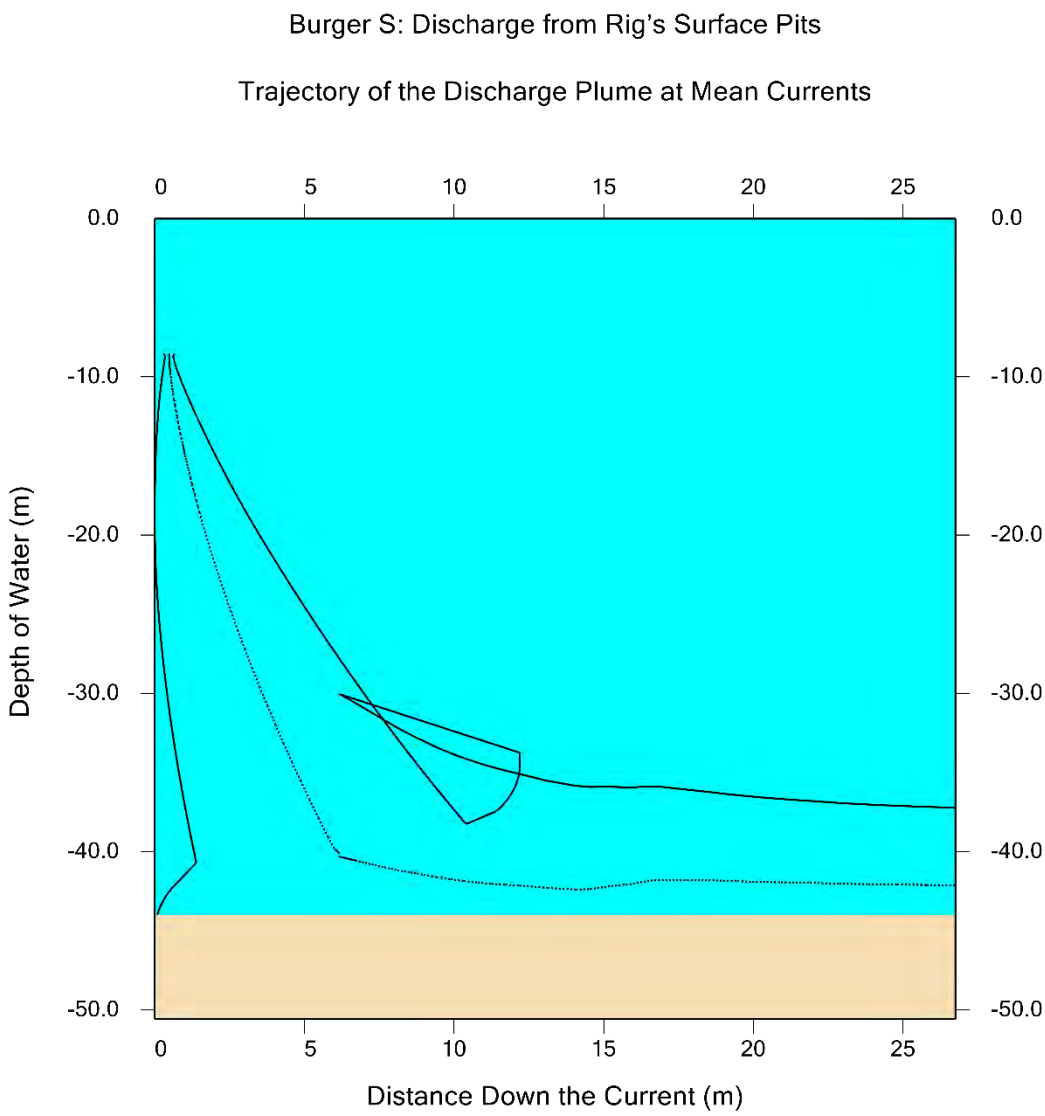
5.7 Model Results for Sea Surface Discharge Scenario – Rigs Surface Pits

Water Based Muds Discharge from Rigs Surface Pits at the end of the Drilling Operation

Trajectory and Shape of the Discharge Plume

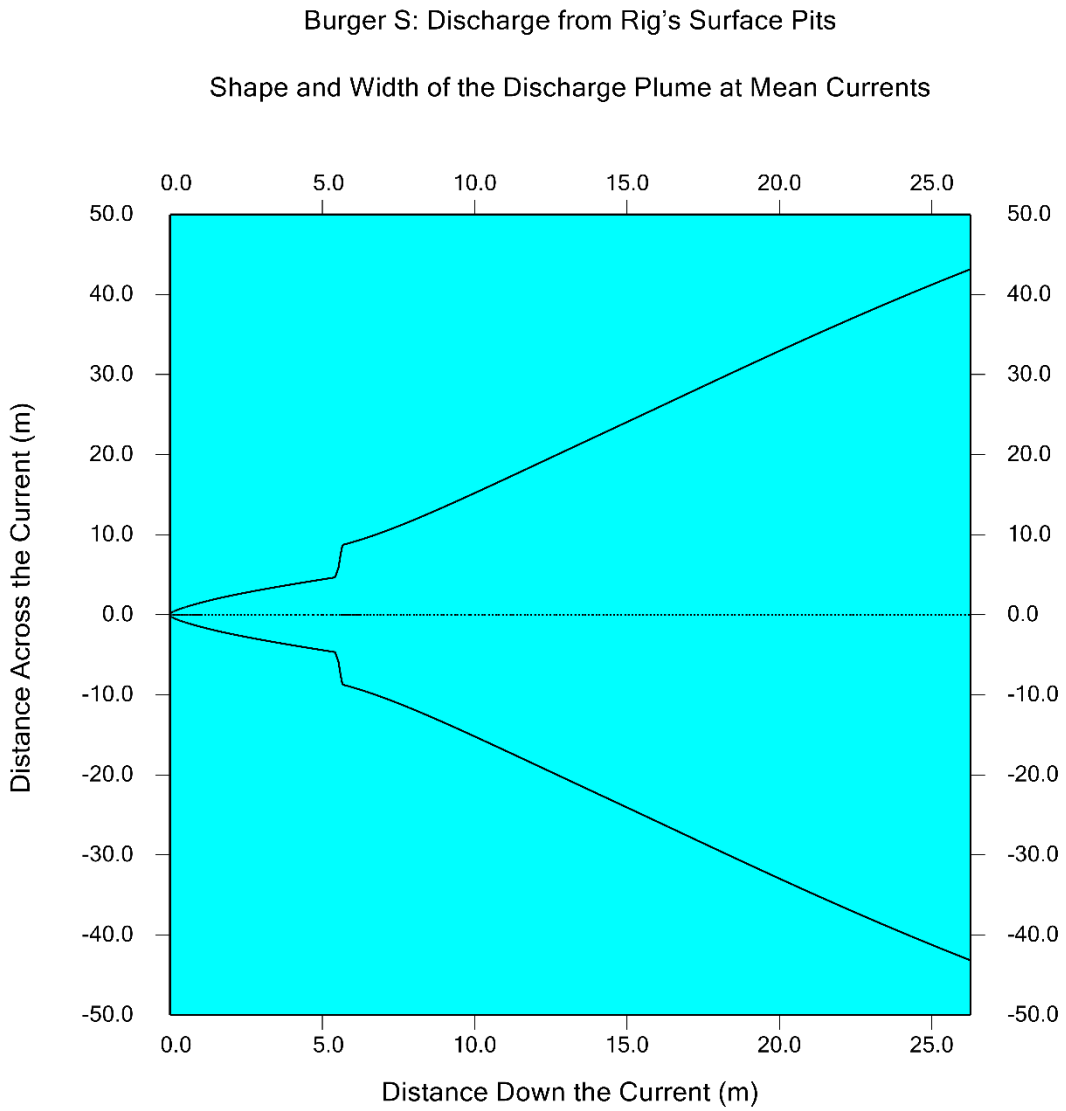
The trajectory of the discharge plume is presented in Figure **5-31**. The depth of water is **44.0** m and the discharge occurs at a depth of **8.53** m below the sea surface. The heavier plume travels approximately **26.0** m from the discharge location before collapsing into the ambient sea water due to the higher density of the discharge plume. The shape and width of the discharge plume is presented in Figure **5-32**. The width of the plume is approximately **86.0** m at a distance **26.0** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **5-31** and **5-32**. The OOC model exhibits numerical oscillations or instability, which leads to the formation of a triangular loop in the upper boundary of the plume. But it dissipates and the upper boundary smoothed out after the numerical solution stabilized.

Figure 5-31: Trajectory of the discharge plume at mean currents, Rig's Surface Pits



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-32: Shape and width of the discharge plume at mean currents, Rig's Surface Pits



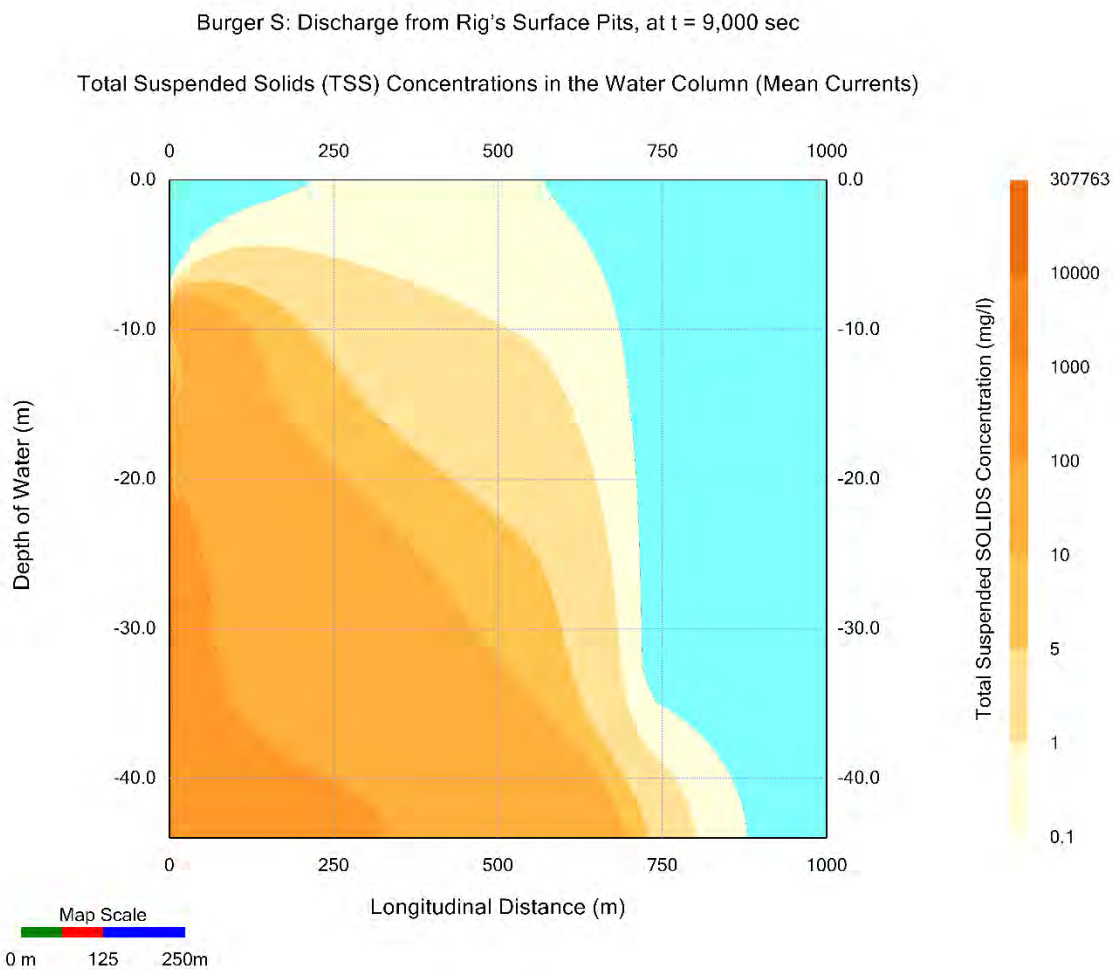
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentration in the water column at time, t = **9,000** sec (or **2.5** hours) which is the discharge duration for the water based muds from the rig's surface pits is presented in **Figure 5-33**a. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **8.53** m from a **15.25** inches internal diameter discharge pipe. Figure **5-33**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **307,763** mg/l occurs at the discharge location. It decreases rapidly to a value of **100** mg/l at a distance approximately **325** m from the discharge location. It varies from **100** to **10** mg/l between **325** m and **700** m distances from the discharge location. It varies from **10** to **5** mg/l between **700** m and **725** m distances from the discharge location. It varies from **5** to **1** mg/l between **725** m and **800** m distances from the source. It is less than **1** mg/l beyond **800** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **608.5**, **428.3**, **232.2**, **109.0**, and **0.0** mg/l, respectively.

Figure 5-33a: Total suspended solids concentrations in water column at mean currents, Rig's Surface Pits

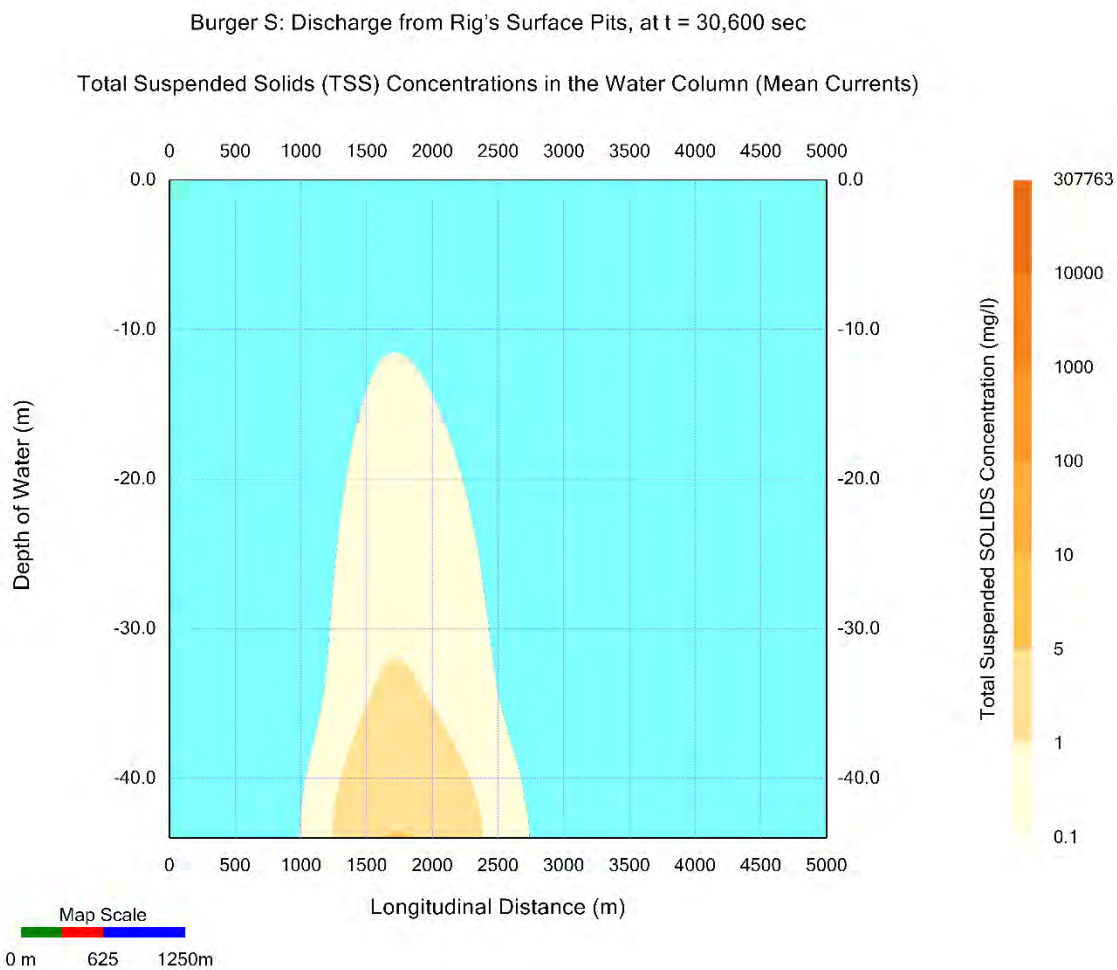


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

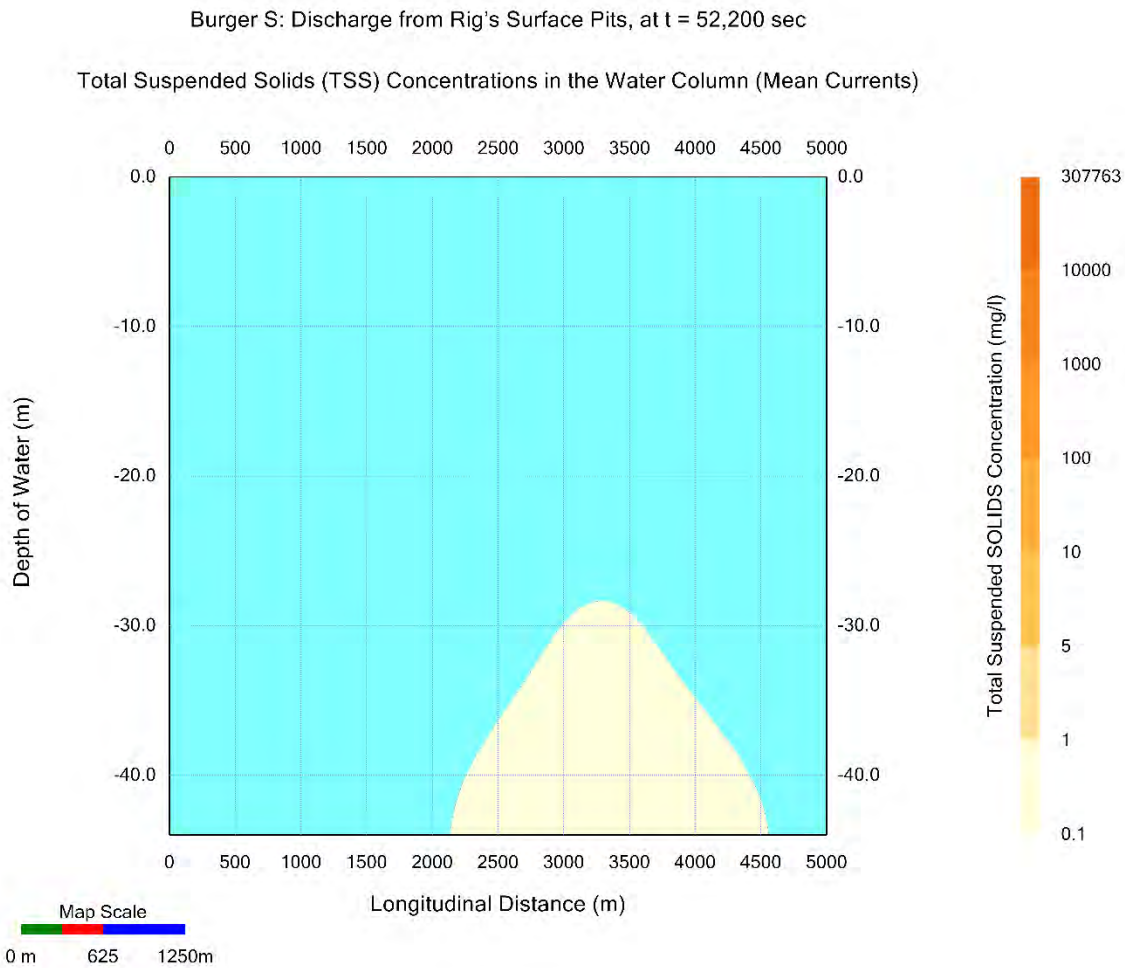
The discharge of the water based muds ceases at time, t = **9,000** sec (or **2.5** hours). The fate and transport of the discharged solids at times **6**, **12**, **18**, and **24** h after the cessation of the discharge are presented by **Figures 5-33**b**, 5-33**c**, 5-33**d and **5-33**e. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **10** mg/l or less at **6** h, **1** mg/l or less at **12** h, **1** mg/l or less at **18** h, and less than **0.1** mg/l at **24** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **18** and **24** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0.1** mg/l within the model domain.

Figure 5-33b: TSS concentrations during the mean currents at 8.5 h (or 6 h after the cessation of release)



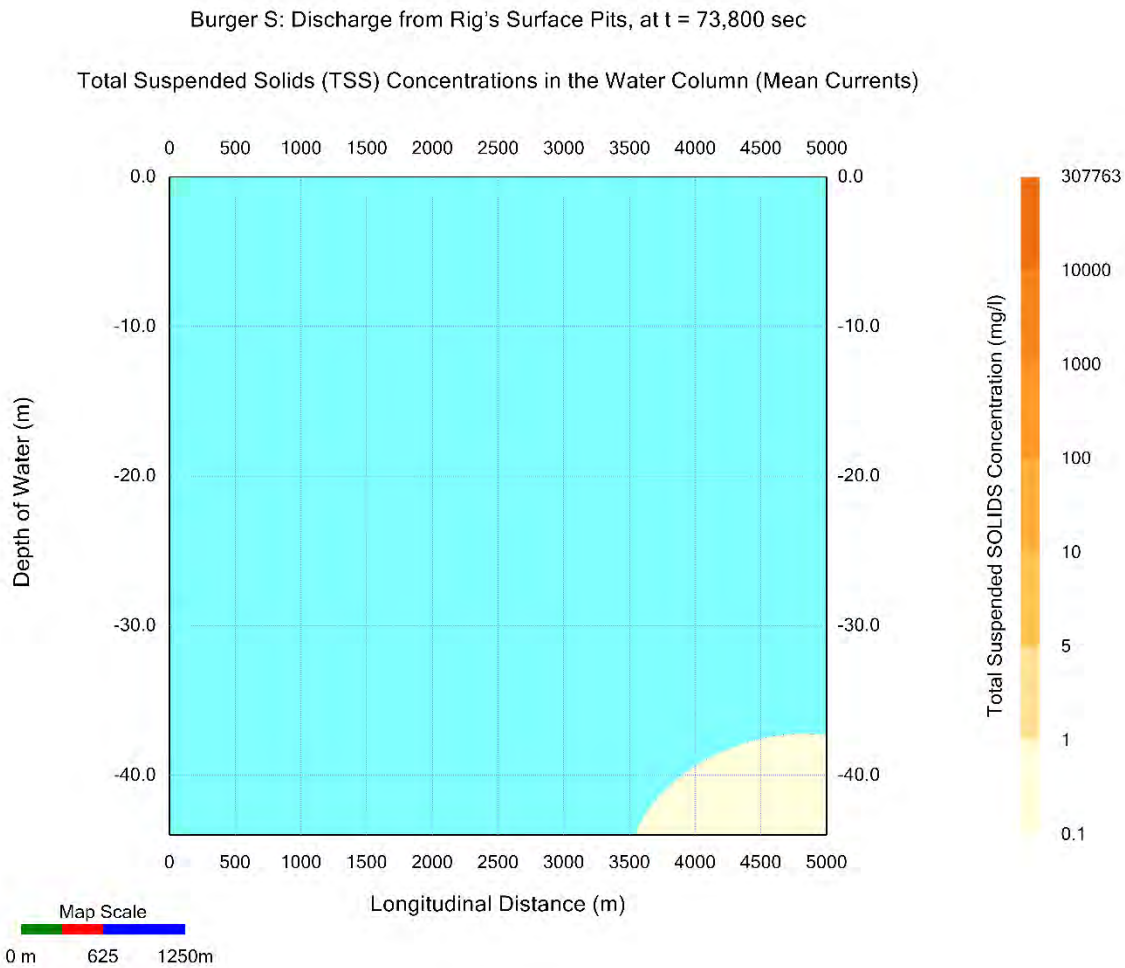
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-33c: TSS concentrations during the mean currents at 14.5 h (or 12 h after the cessation of release)



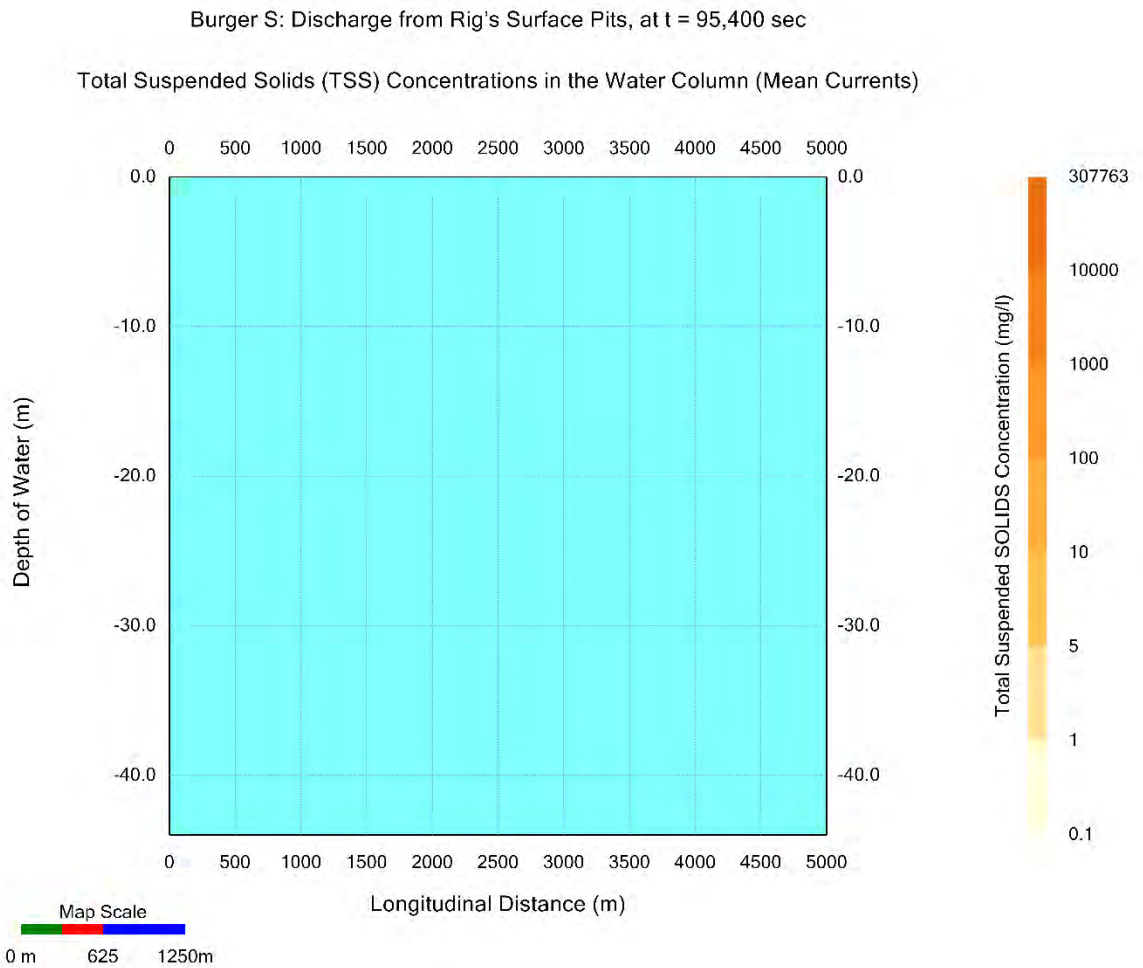
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-33d: TSS concentrations during the mean currents at 20.5 h (or 18 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-33e: TSS concentrations during the mean currents at 26.5 h (or 24 h after the cessation of release)



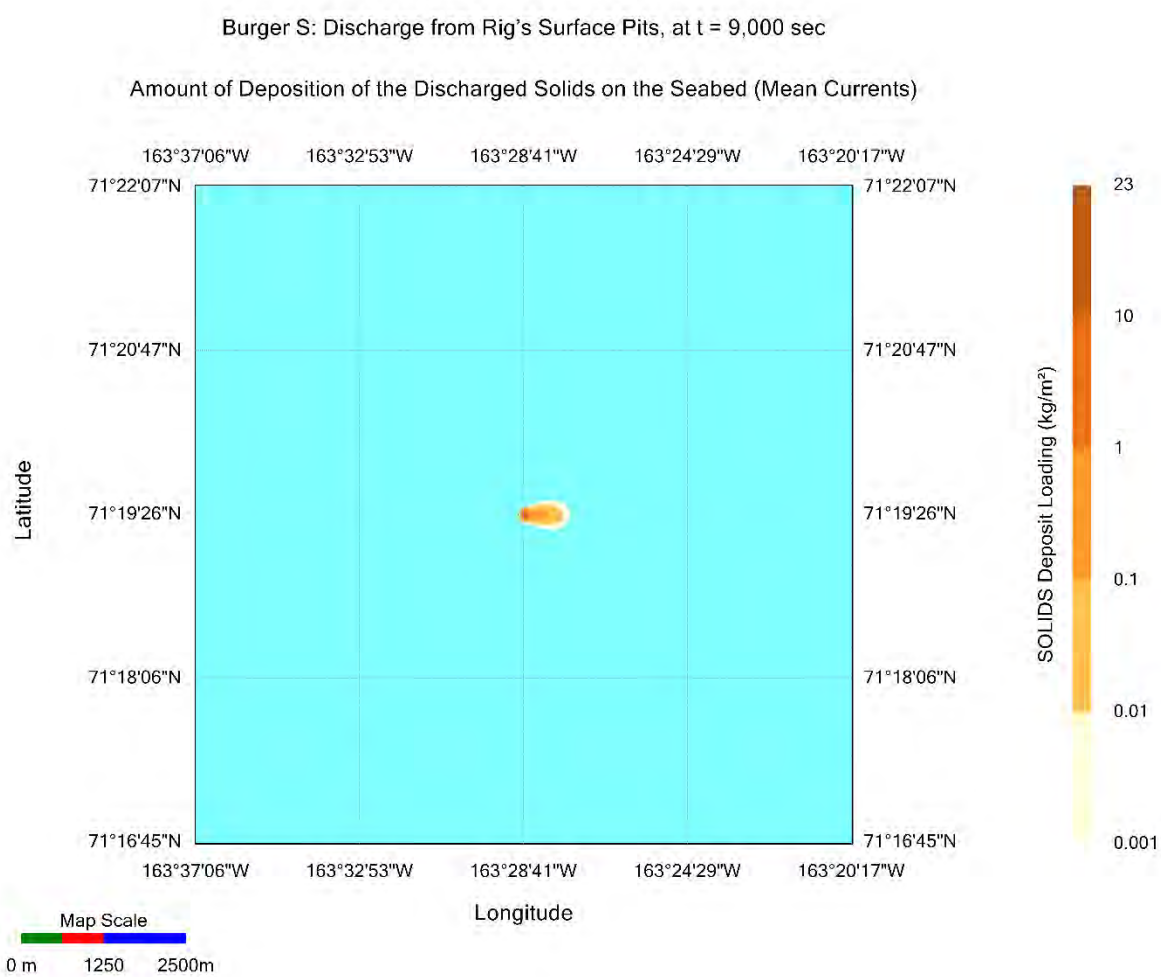
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **9,000** sec (or **2.5** hours) as a result of the discharge of the water based muds from the rig's surface pits on a plan view is presented in **Figure 5-34**. The model domain extends to **5.0** km in all directions from the discharge location as shown in Figure **5-34**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **23** kg/m^2 occurs at **30** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **60** m and **90** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0.1** kg/m^2 between distances approximately **90** m and **410** m, respectively from the discharge location. It varies from **0.1** kg/m^2 to **0.01** kg/m^2 between distances approximately **410** m and **625** m, respectively from the discharge location. It is less than **0.01** kg/m^2 beyond **625** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **10**-, **1**-, **0.1**-, and **0.01**-kg/m^2 are: **0.250**, **0.837**, **5.840**, and **15.813** ha, respectively.

Figure 5-34: Amount of deposition of the solids on seabed at mean currents, Rig's Surface Pits



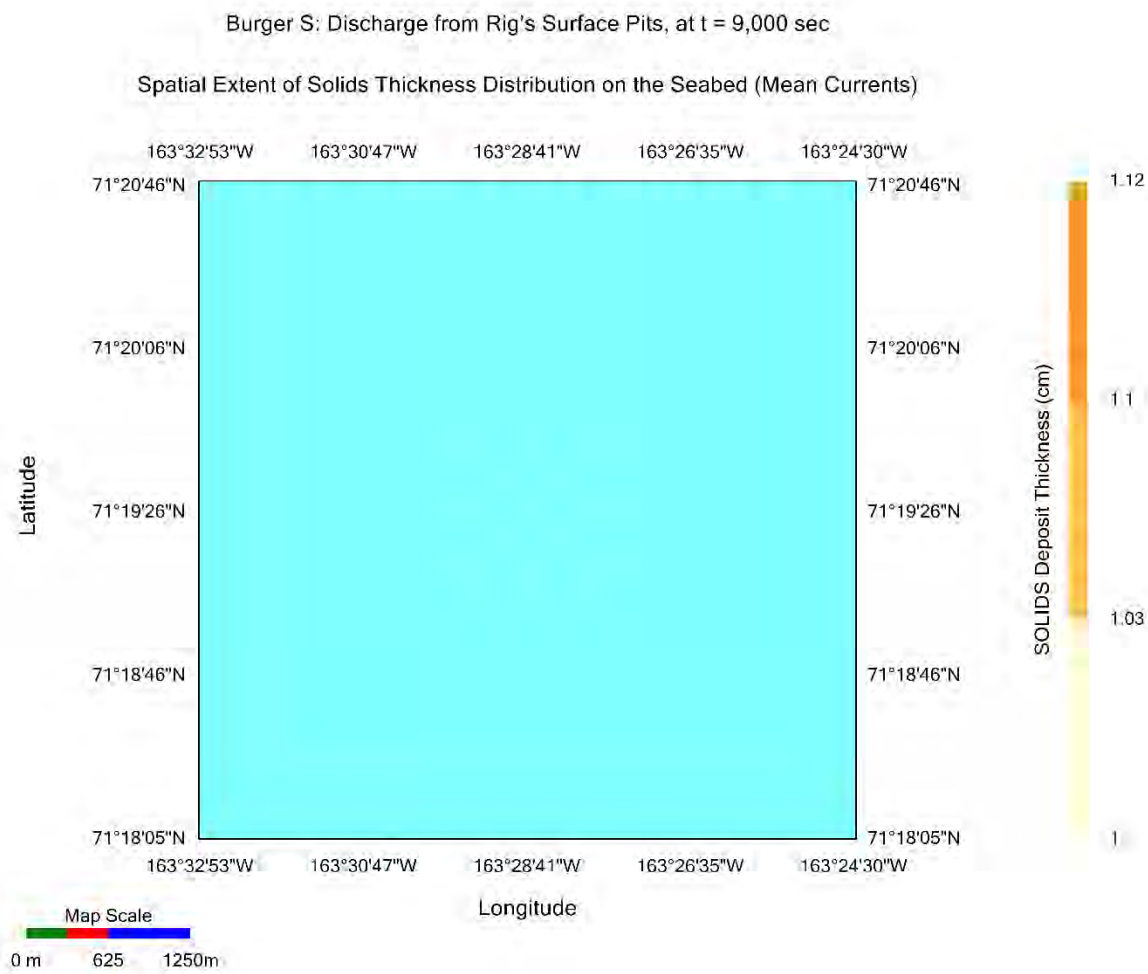
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness deposited on the sea floor at time, t = **9,000** sec (or **2.5** hours) as a result of the discharge of the water based muds from the rig's surface pits on a plan view is presented in **Figures 5-35a** and **5-35b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5.0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **5-35**a. The same result is presented in Figure **5-35**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **1.1** cm occurs at **30** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **35** m from the discharge location.

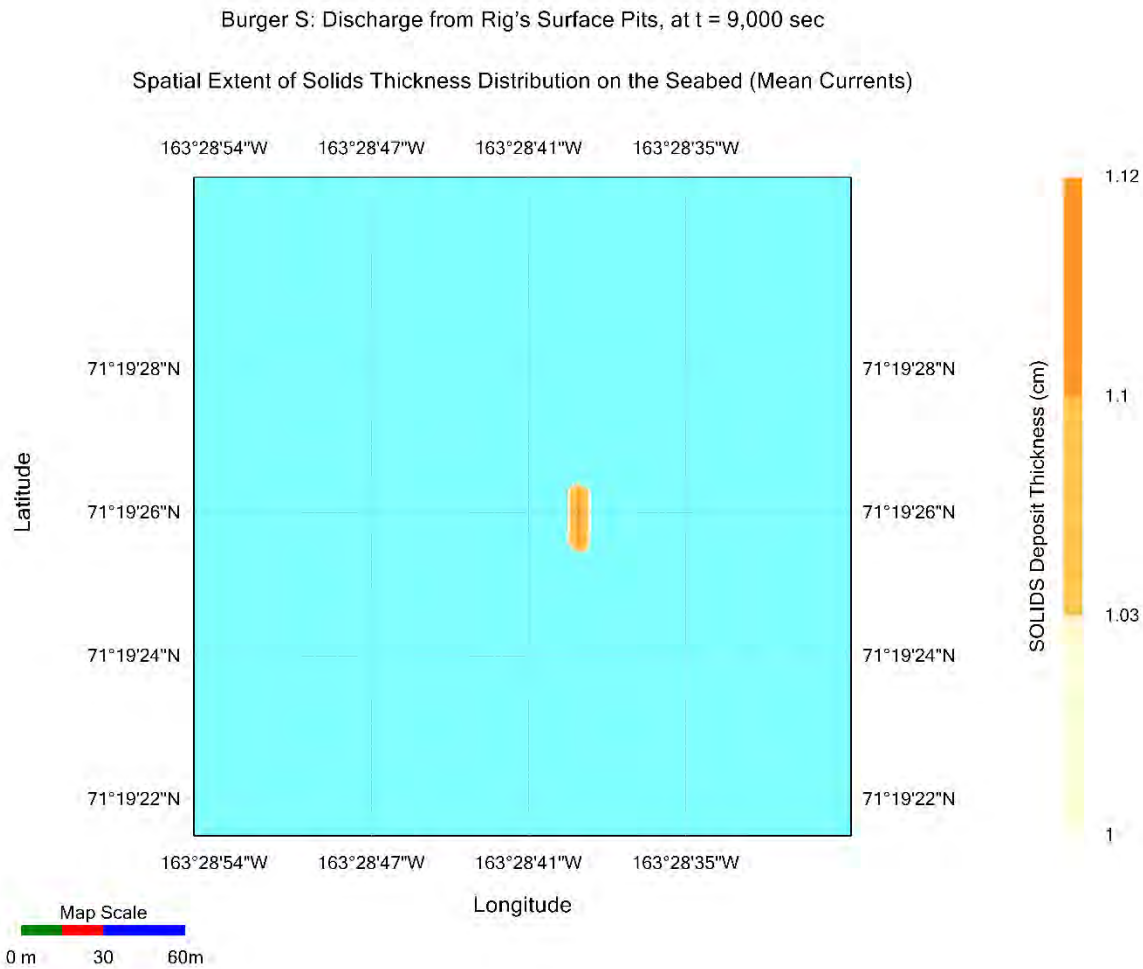
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **10** m x **20** m rectangle area (or **0.091** ha) as presented in Figure **5-35**b.

Figure 5-35a: Spatial extent of solids thickness distribution on seabed at mean currents, Rig's Surface Pits



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-35b: Spatial extent of solids thickness distribution on seabed at mean currents, Rig's Surface Pits (Zoom In View)



Copyright **2014** by Fluid Dynamix. Company Confidential.

5.8 Combined Model Results - Sea Floor and Sea Surface Discharges, Burger S

The spatial extent of the total amount of deposition of the discharged solids on the seabed from the six discrete drilling intervals (**01**, **02**, **03**, **04**, **05**, and **06**) and the rig's surface pits were compiled using the GUIDO **7** (version **7**.**3**) for the OOC model yielding the total solids deposition loading and thickness distribution on the seabed from the drilling operation at the Burger S well site.

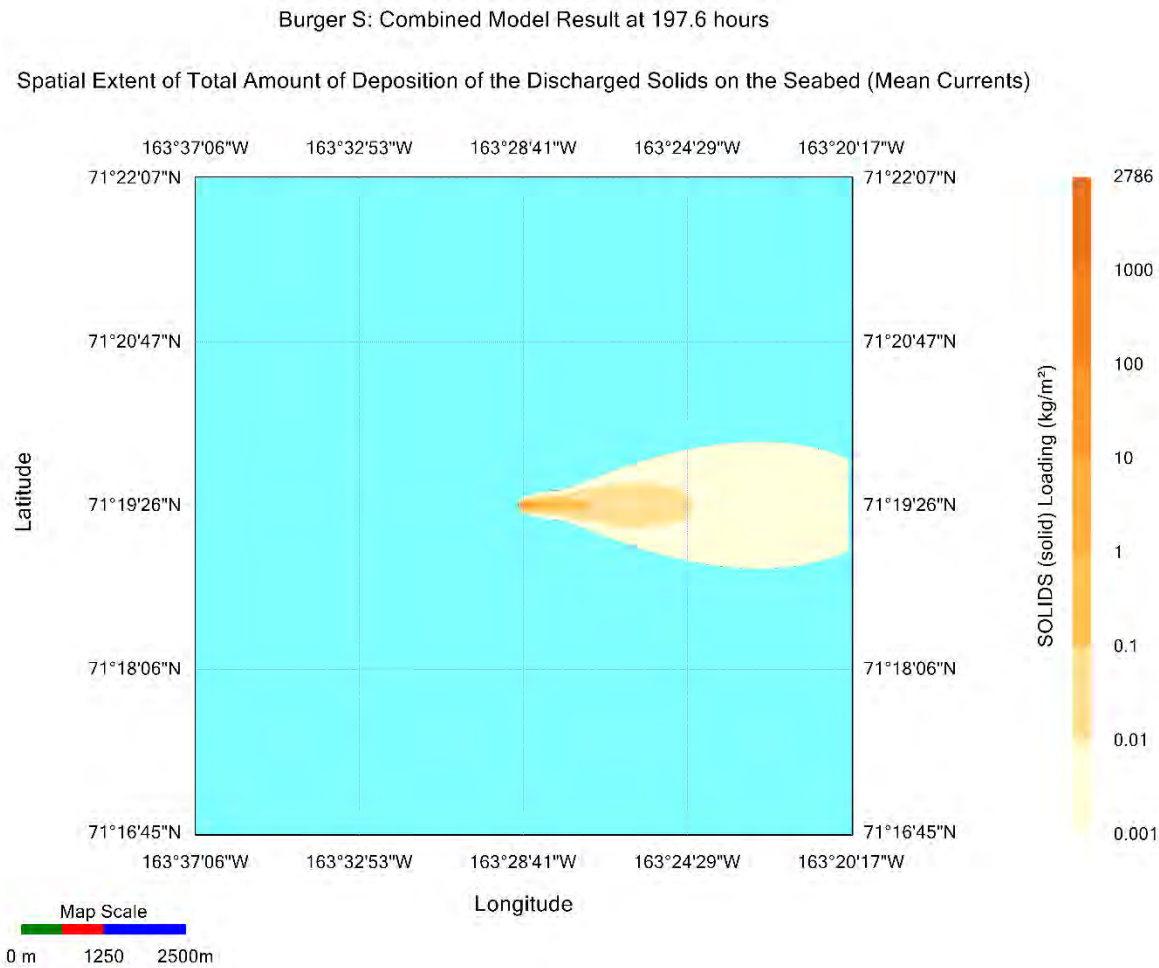
Total Amount of Deposition of the Discharged Solids on the Seabed

The spatial extent of the total amount of solids loading at time t = **197**.**6** hours as a result of the discharge of the cements, water based drill cuttings, drill fluids, and water based muds on a plan view is presented in **Figures 5-36a** and **5-36b**. The model domain extends to **5**.**0** km in all directions from the discharge location as presented in Figure **5**-**36**a. Figure **5**-**36**b presents a zoom in view of the model results, which shows only **2** km x **2** km area of the seabed. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The prevailing current direction is to the east. Therefore, the fate and transport of the discharge plume is towards the east only from the discharge location. The maximum loading of **2**,**786** kg/m^2 occurs at **10** m to the east and **30** m to the north from the discharge location. It decreases to a value of **100** kg/m^2 at a distance approximately **50** m from the discharge location as shown in Figure **5**-**36**b. It decreases: **100** kg/m^2 to **10** kg/m^2 between **50** m and **130** m; **10** kg/m^2 to **1** kg/m^2 between **130** m and **380** m; **1** kg/m^2 to **0**.**1** kg/m^2 between **380** m and **1**,**050** m; and **0.1** kg/m^2 to **0.01** kg/m^2 between **1,050** m and **2,600** m distances approximately from the discharge location. The loading is less than **0**.**01** kg/m^2 beyond **2**,**600** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **1000**-, **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**108**, **0**.**268**, **0**.**598**, **4**.**243**, **17**.**429**, and **126**.**801** ha, respectively.

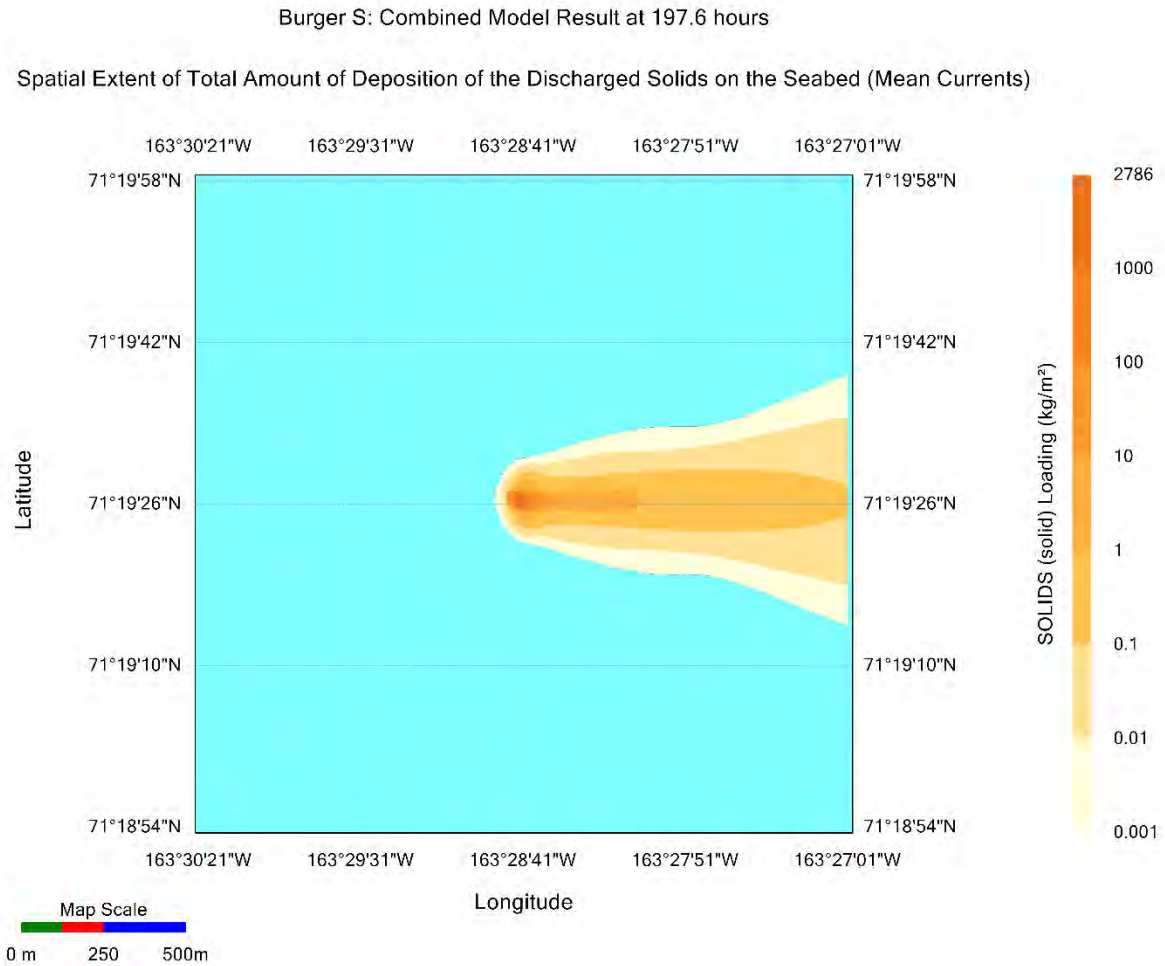
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-36a: Total amount of deposition of the solids on seabed at mean currents, Burger S



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-36b: Total amount of deposition of the solids on seabed at mean currents, Burger S (zoom view)



Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

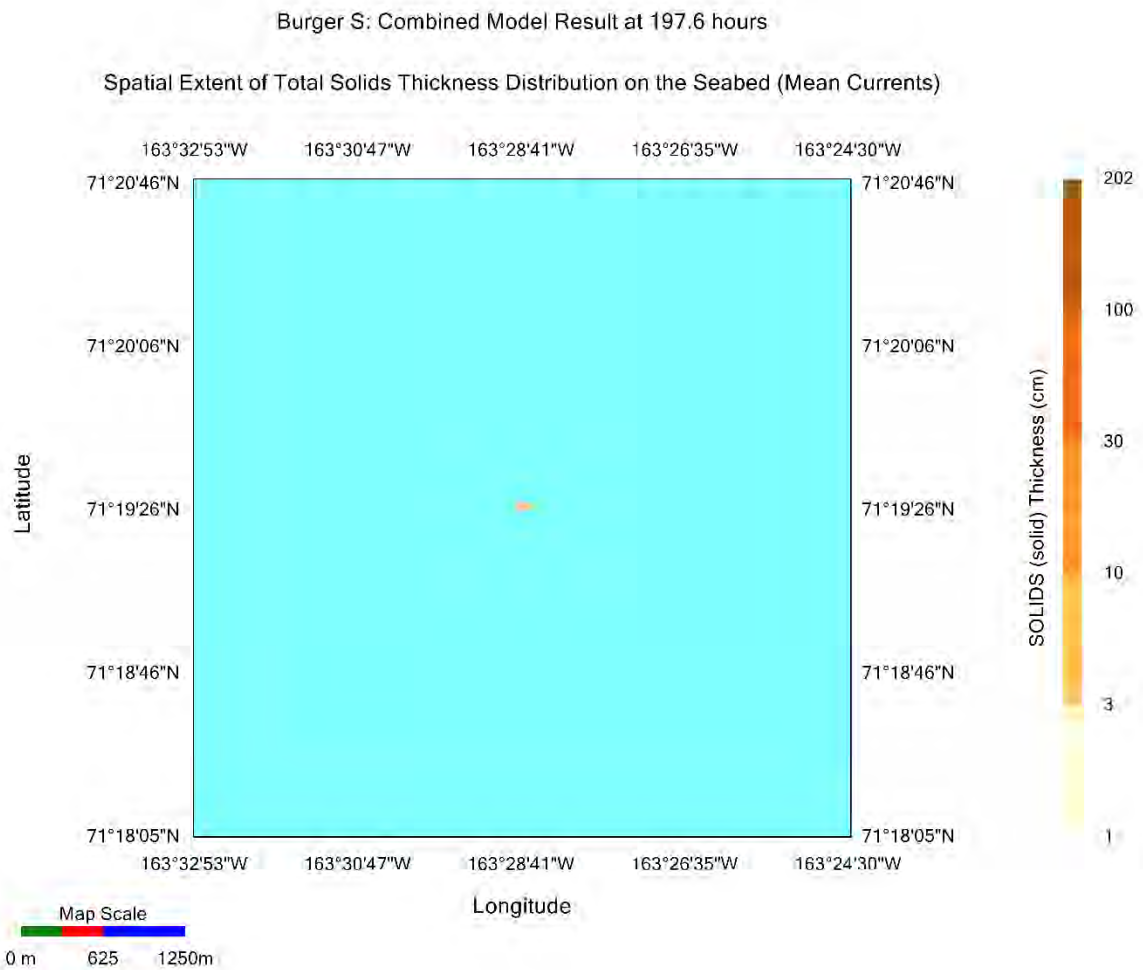
The spatial extent of the total solids thickness of **1** cm or larger deposited on the sea floor at time t = **197**.**6** hours as a result of the discharge of the cements, water based drill cuttings, drill fluids, and water based muds on a plan view is presented in **Figures 5-37a** and **5-37b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger occurs on a small surface area compare to the **5** km x **5** km map surface area shown in Figure **5**-**37**a. The same result is presented in Figure **5**-**37**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The prevailing current direction is to the east. Therefore, the fate and transport of the discharge plume is towards the east only from the discharge location. The maximum deposit thickness of **201.7** cm occurs at **10** m to the east and **30** m to the north from the discharge location. It decreases to a value of **100** cm at a distance approximately **20** m from the discharge location as shown in Figure **5**-**37**b. It decreases: **100** cm to **30** cm between **20** m and **30** m; **30** cm to **10** cm between **30** m and **45** m; **10** cm to **3** cm between **45** m and **70** m; and **3** cm to **1** cm between **70** m and **105** m distances approximately from the discharge location. It is less than **1** cm beyond **105** m approximately to the east from the discharge location.

The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **130** m x **40** m rectangle area (or **0**.**510** ha) as presented in Figure **5**-**37**b.

The sea floor areas affected by deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0**.**102**, **0**.**195**, and **0**.**510** ha, respectively. The sea floor areas affected by solids deposit thickness is presented graphically in **Figure 5-38**.

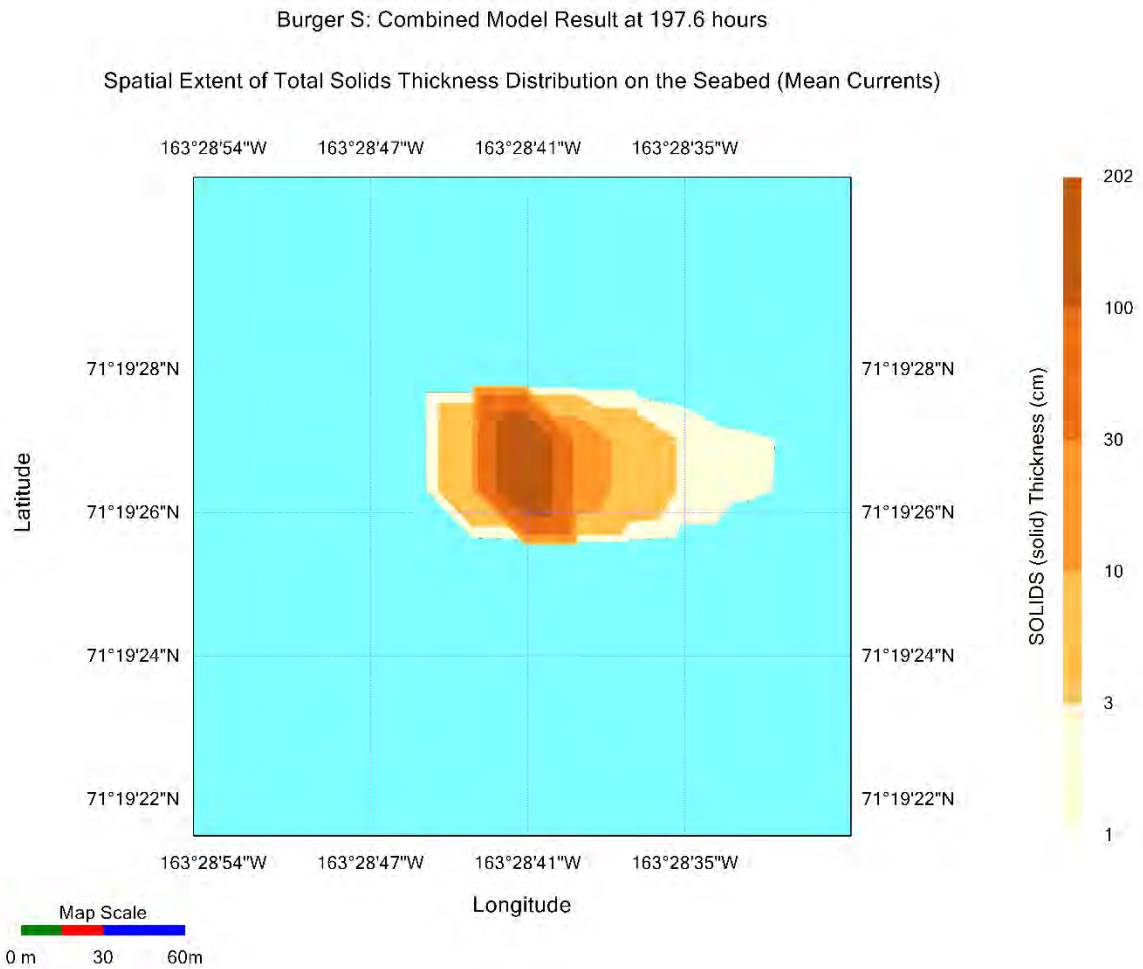
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-37a: Spatial extent of total solids thickness distribution on seabed at mean currents, Burger S



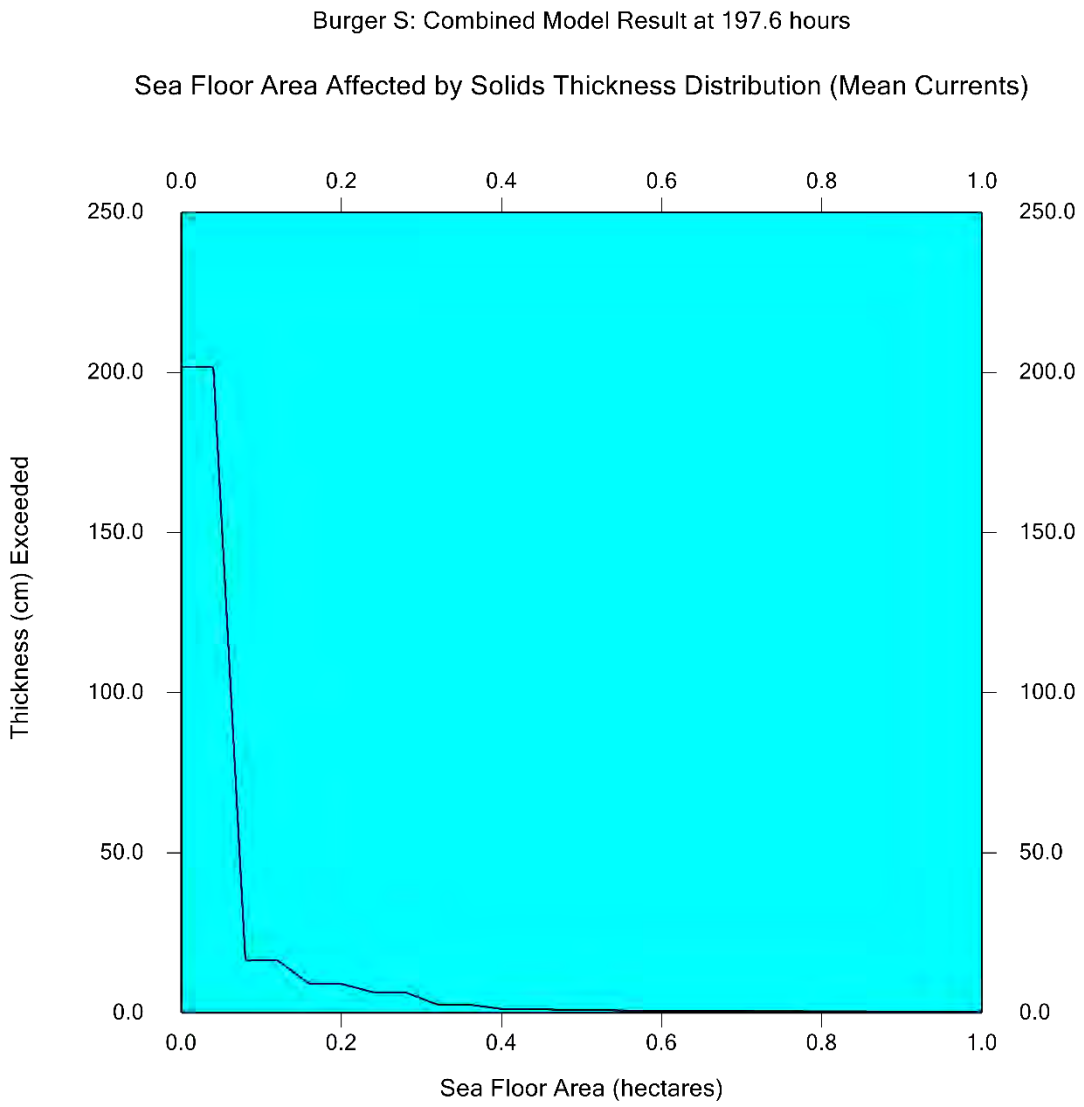
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-37b: Spatial extent of total solids thickness distribution on seabed at mean currents, Burger S (Zoom In View)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 5-38: Sea floor area affected by solids thickness distribution at mean currents, Burger S



Copyright **2014** by Fluid Dynamix. Company Confidential.

The OOC model predictions for the solids deposition on the seabed from the cements, water based drill cuttings, drill fluids, and water based muds discharges from the six discrete drilling intervals and the rig's surface pits at the mean currents speeds were compiled using the GUIDO **7** software yielding the total solids deposition loading and thickness distribution on the seabed from the drilling operation at the Burger S well site and are presented in **Table 5-2**. The sea floor areas affected at the end of the drilling operation at the Burger S well site by the solids deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0.102**, **0.195**, and **0.510** ha, respectively as presented in Table **5-2**.

The total suspended solids (TSS) concentrations in the water column are presented in **Table 5-3**. The TSS concentrations during the drilling operations are: **6.0** to **232.2** mg/l at **100** m; **1.6** to **109.0** mg/l at **300** m; and **0.0** to **3.3** mg/l at **1000** m distances from the source.

Table 5-2: Total Solids Deposition on the Seabed at Mean Currents

The OOC Model Predictions at Mean Currents											
Well ID	Discharge Scenario	Drilling Intervals	Durations of Discharge	Depth of Water	Depth of Discharge	Effluent Discharge Rate	Pre-diluted Effluent Discharge Rate	Solids Deposition on the Seabed			
								Total Area (ha) Covered by Solids Thickness larger than 100-, 10-, and 1-cm			Maximum Deposit Thickness
			Hours	m	m	bbls/hour	bbls/hour	100 cm	10 cm	1 cm	cm
Burger S	Sea Floor	1	66.00	44.00	42.17	68.83	14,000.00	0.090	0.119	0.271	129.63
		2	5.20	44.00	42.17	116.30	14,000.00	-	-	0.117	8.48
		3	34.40	44.00	42.17	86.64	14,000.00	-	0.112	0.191	39.28
	Sea Surface	4	23.30	44.00	8.53	148.63	159.46	-	0.100	0.274	14.71
		5	29.00	44.00	8.53	68.87	79.70	-	-	0.261	9.55
		6	37.20	44.00	8.53	26.47	37.30	-	-	0.192	4.30
		Rig's Surface Pits	2.50	44.00	8.53	970.80	970.80	-	-	0.091	1.12
	At the end of the Drilling Operation							0.102	0.195	0.510	201.74

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 5-3: Total Suspended Solids (TSS) Concentrations in the Water Column at Mean Currents

The OOC Model Predictions at Mean Currents												
Well ID	Discharge Scenario	Drilling Intervals	Durations of Discharge	Depth of Water	Depth of Discharge	Effluent Discharge Rate	Pre-diluted Effluent Discharge Rate	Total Suspended Solids (TSS) Concentrations (mg/l) in Water Column at 10-, 30-, 100-, 300-, and 1000-m from the Source				
			Hours	m	m	bbls/hour	bbls/hour	10 m	30 m	100 m	300 m	1000 m
Burger S	Sea Floor	1	66.00	44.00	42.17	68.83	14,000.00	1,085.8	383.6	96.1	20.3	3.3
		2	5.20	44.00	42.17	116.30	14,000.00	868.5	295.0	81.1	16.9	2.7
		3	34.40	44.00	42.17	86.64	14,000.00	556.4	208.0	57.1	11.8	1.9
	Sea Surface	4	23.30	44.00	8.53	148.63	159.46	713.3	202.4	23.9	5.5	0.9
		5	29.00	44.00	8.53	68.87	79.70	443.0	111.7	13.0	3.1	0.5
		6	37.20	44.00	8.53	26.47	37.30	185.6	43.3	6.0	1.6	0.2
		Rig's Surface Pits	2.50	44.00	8.53	970.80	970.80	608.5	428.3	232.2	109.0	0.0

Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 6.0 DISPERSION AND DEPOSITION MODELING – MAXIMUM CURRENTS

The dispersion and deposition numeric simulations of the cements, water based drill cuttings, and drill fluids discharges from the drilling operation at the Burger S well site for both the sea floor (**D013**) and sea surface (**D001**) discharge scenarios at the maximum currents were performed using the OOC model. The numeric simulations were carried out for the six drillings intervals for the actual drilling durations: **66.0**, **5.2**, **34.4**, **23.3**, **29.0**, and **37.2** hours as presented in **Table 6-1**. Moreover, numeric simulation was also carried out for the surface discharge of the water based muds at the end of the drilling of the well from the rig's surface pits at a rate of **970.80** bbls/hour for **2.5** hours. A **360**-second model time step (Δt) was used for the computer simulations of all discharges listed in Table **6-1**. The solids deposition on the seabed from the below listed discharges from the six discrete drilling intervals and the rig's surface pits were compiled using the GUIDO **7** software for the OOC model yielding the total solids deposition loading and thickness distribution on the seabed from the drilling operation at the Burger S well site.

Table 6-1: Total Simulation Time, Model Time Step, and Discharge Rates for Burger S

Well ID	Discharge Scenario	Drilling Intervals	Durations of Drilling (Discharge)		The OOC Numeric Model Simulation			Depth of Water	Depth of Discharge	Effluent (Cuttings + Drilling Fluids) Mass Discharge Rate	Pre-diluted Effluent Discharge Rate
					Total Simulation Time	Model Time Step (Δt)	Count of Total Model Steps				
			Hours	Seconds	Seconds	Seconds		m	m	bbls/hour	bbls/hour
Burger S	Sea Floor	1	66.00	237,600	237,600	360	660	44.00	42.17	68.83	14,000
		2	5.20	18,720	18,720	360	52	44.00	42.17	116.30	14,000
		3	34.40	123,840	123,840	360	344	44.00	42.17	86.64	14,000
	Sea Surface	4	23.30	83,880	83,880	360	233	44.00	8.53	148.63	159.46
		5	29.00	104,400	104,400	360	290	44.00	8.53	68.87	79.70
		6	37.20	133,920	133,920	360	372	44.00	8.53	26.47	37.30
		Rig's Surface Pits	2.50	9,000	9,000	360	25	44.00	8.53	970.80	970.80

Copyright **2014** by Fluid Dynamix. Company Confidential.

The OOC model predictions for the dispersion and deposition of the cements, water based drill cuttings, drill fluids, and water based muds in the near-field and far-field receiving water are presented in this technical report by the following effluent characteristics:

- Trajectory and shape of the discharge plume
- Total suspended solids (TSS) concentrations in milligrams per liter (mg/l) in the water column
- Amount of deposition of the discharged solids in kilograms per square meter (kg/m^2) on the seabed
- Spatial extent of deposition (i.e., solids thickness distribution) in centimeter (cm) of the discharged solids on the seabed

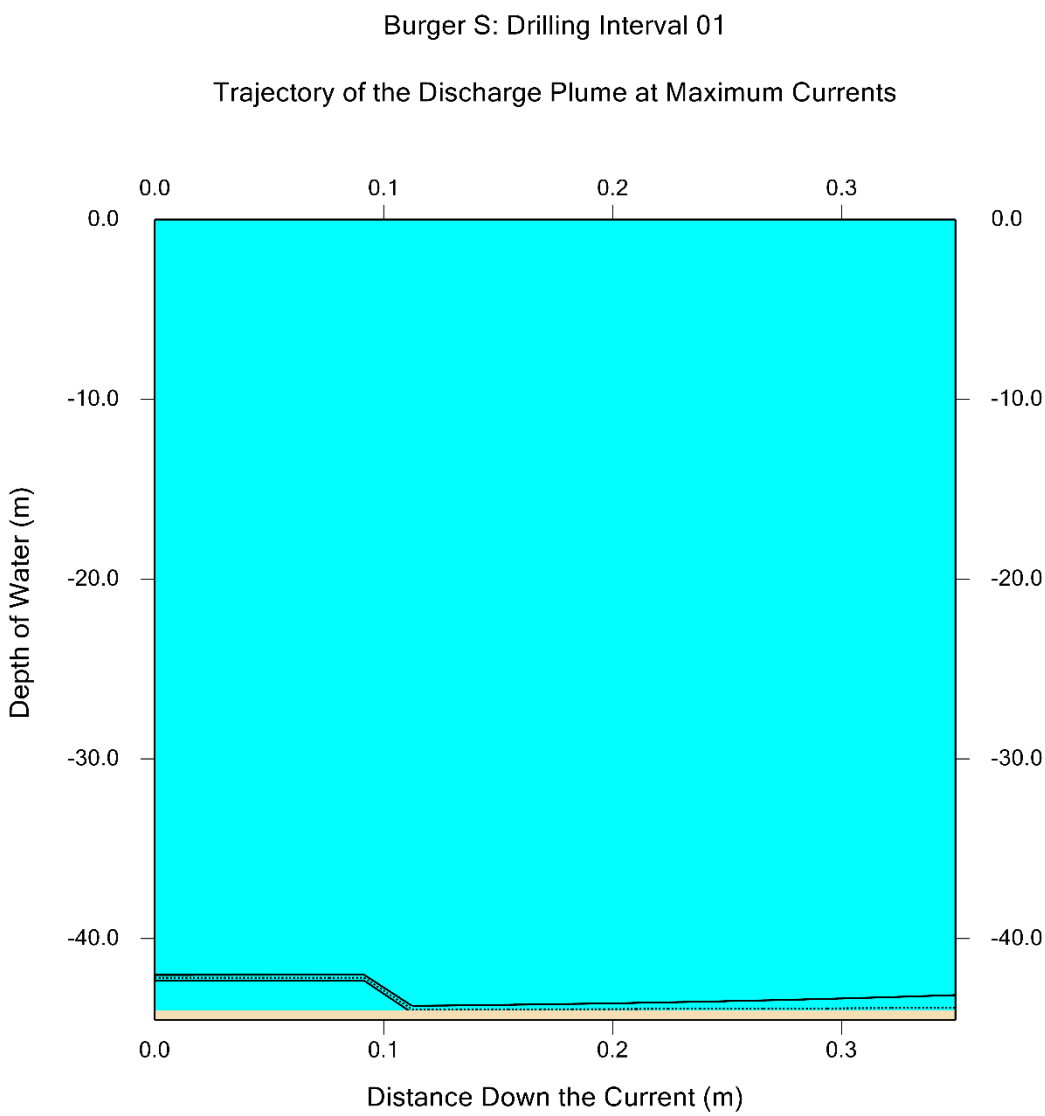
Copyright **2014** by Fluid Dynamix. Company Confidential.

6.1 Model Results for Sea Floor Discharge Scenario – Drilling Interval 01

Trajectory and Shape of the Discharge Plume

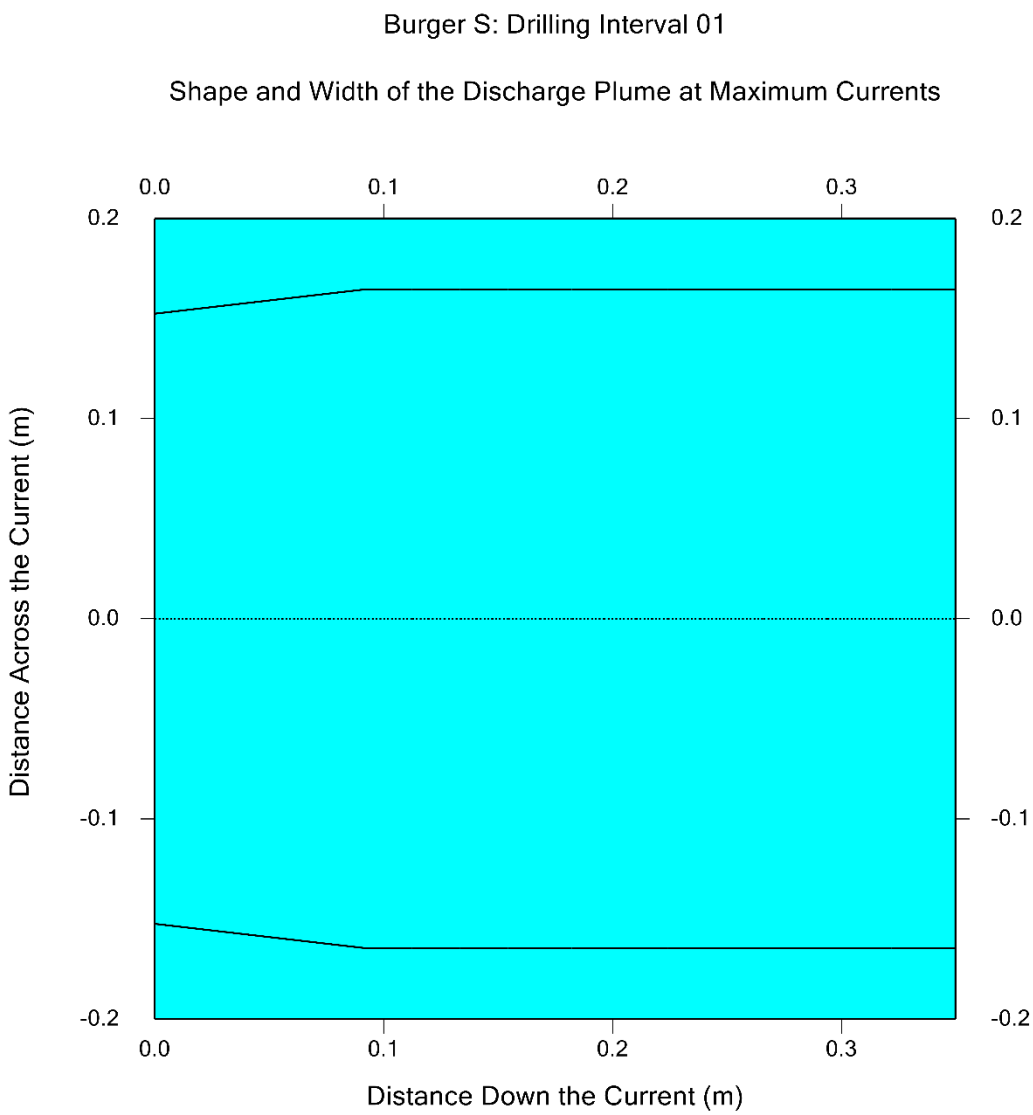
The trajectory of the discharge plume is presented in **Figure 6-1**. The depth of water is **44.0** m and the discharge occurs at a depth of **42.17** m from a **12.0** inches internal diameter discharge pipe of the sea floor pump at **14,000** bbls/hour. A flexible hose suction pipe of this sea floor pump moves the water based drill cuttings and drill fluids from the drill strings and discharges at **1.83** m (or **6** feet) above the seafloor. The discharge pipe is oriented horizontally aligned with the direction of the current, which is to the east. Therefore, the heavier discharge plume attempts to shoot horizontally as seen in Figure **6**-**1** and travels to the east to a distance approximately **0.35** m only from the discharge location before collapsing onto the sea floor due to the proximity of the plume near the sea floor. The shape and width of the discharge plume is presented in **Figure 6-2**. The width of the plume is approximately **0.35** m at a distance **0.35** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **6**-**1** and **6**-**2**.

Figure 6-1: Trajectory of the discharge plume at maximum currents, Drilling Interval 01



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-2: Shape and width of the discharge plume at maximum currents, Drilling Interval 01



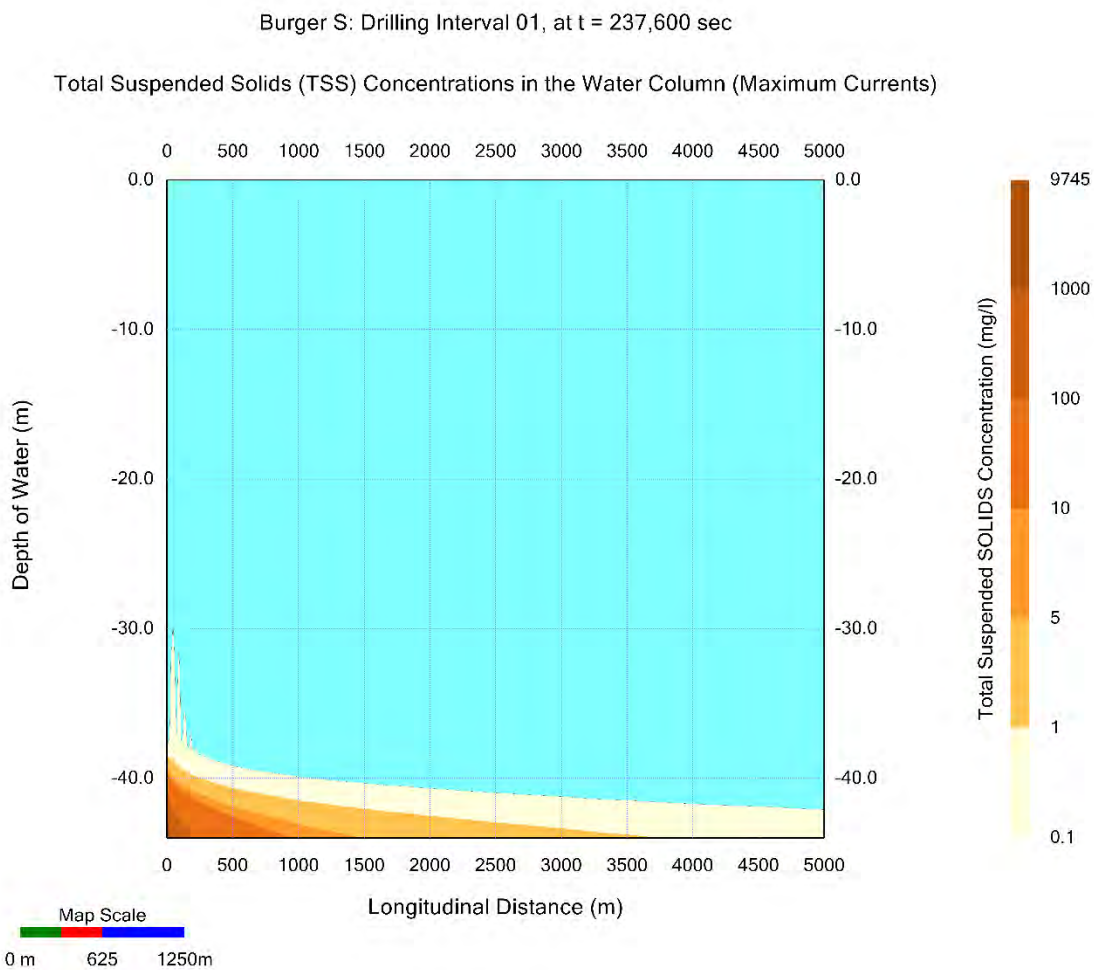
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **237**,**600** sec (or **66.0** hours) which is the discharge duration for this drilling interval is presented in **Figure 6-3a**. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **42**.**17** m from a **12.0** inches internal diameter discharge pipe. Figure 6-**3**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **9**,**745** mg/l occurs at the discharge location. It decreases to a value of **100** mg/l and **10** mg/l at distances approximately **200** m and **950** m, respectively from the discharge location. It varies from **10** to **5** mg/l approximately between **950** and **1**,**450** m distances from the discharge location. It varies from **5** to **1** mg/l between **1**,**450** and **3**,**700** m distances from the source. It is less than **1** mg/l beyond **3**,**700** m from the discharge location. The effect of the sea floor pump is visible in this Figure **6**-**3a**. The discharge plume is spreading farther horizontally to the east along the direction of the current than vertically. The TSS concentration is less than **1** mg/l at a depth approximately **35** m at or near the discharge location. It is less than **1** mg/l at a depth **40** m at **500** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **1,470.2**, **575.3**, **205.0**, **57.8**, and **8.9** mg/l, respectively.

Figure 6-3a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 01

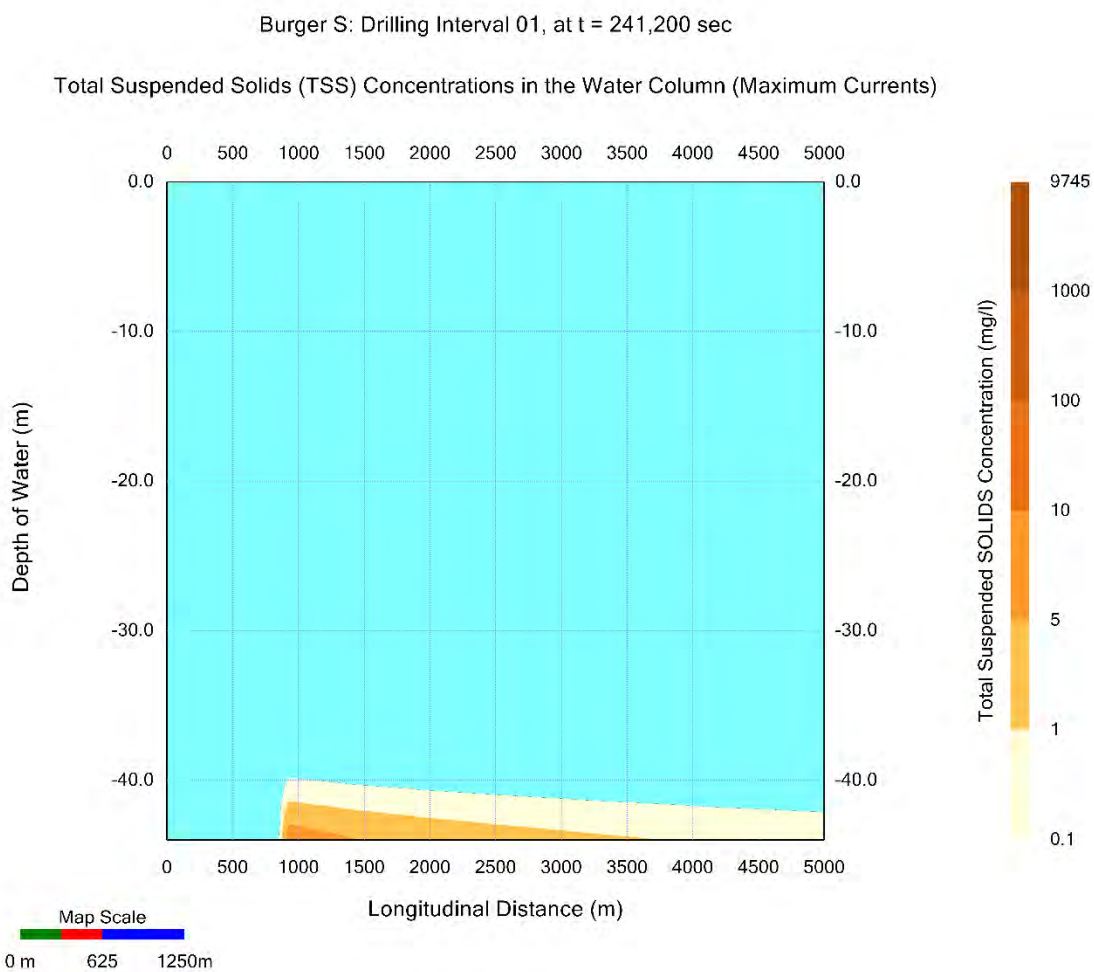


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

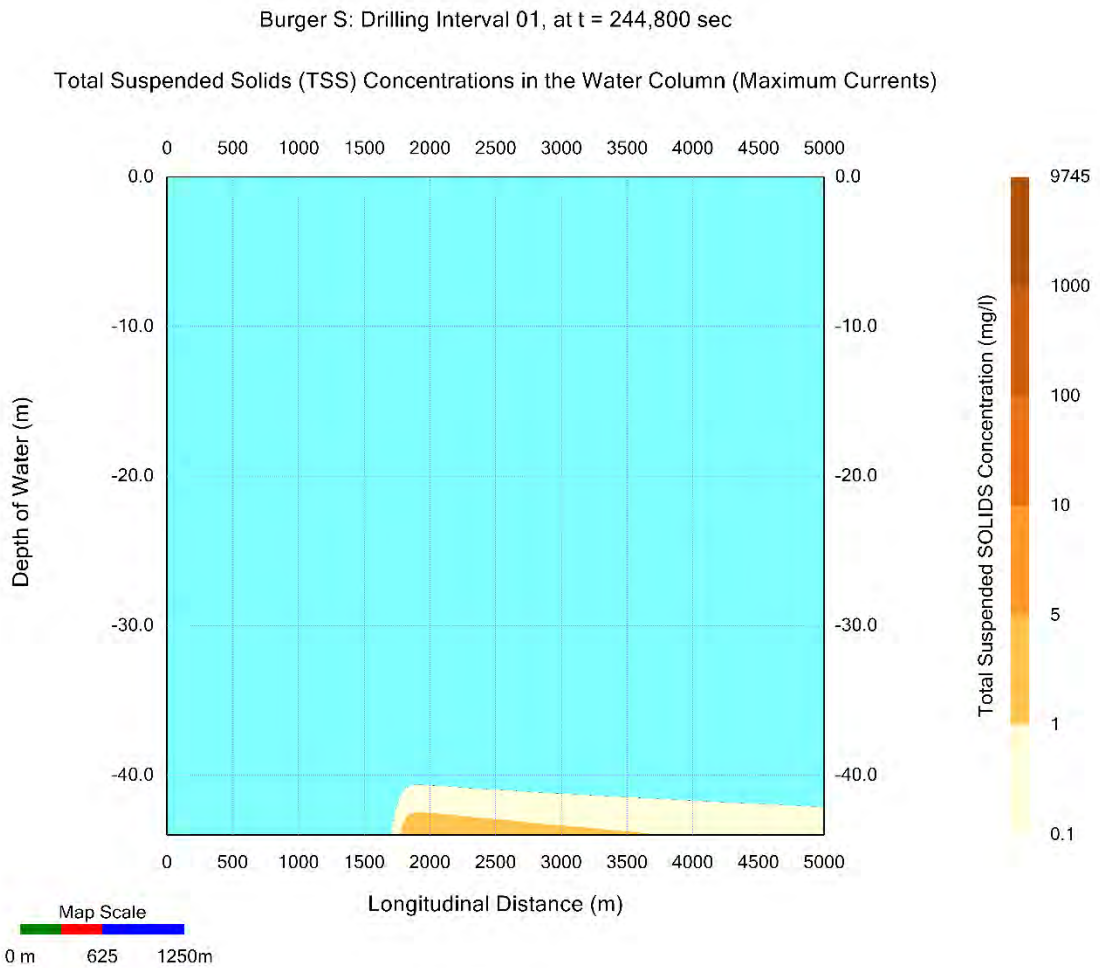
The discharge of the water based drill cuttings and drill fluids ceases at time, t = **237**,**600** sec (or **66**.**0** hours). The fate and transport of the discharged solids at times **1**, **2**, **3**, **4, 5**, and **6** h after the cessation of the discharge are presented by **Figures 6-3**b**, 6-3**c**, 6-3**d**, 6-3**e**, 6-3**f**,** and **6-3**g. These figures show that the TSS concentrations within the **5** km model domain decrease to: **10** mg/l or less at **1** h, **5** mg/l or less at **2** h, **5** mg/l or less at **3** h, **1** mg/l or less at **4** h, **1** mg/l or less at **5** h, and less than **0**.**1** mg/l at **6** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **5** and **6** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 6-3b: TSS concentrations during the maximum currents at 67 h (or 1 h after the cessation of release)



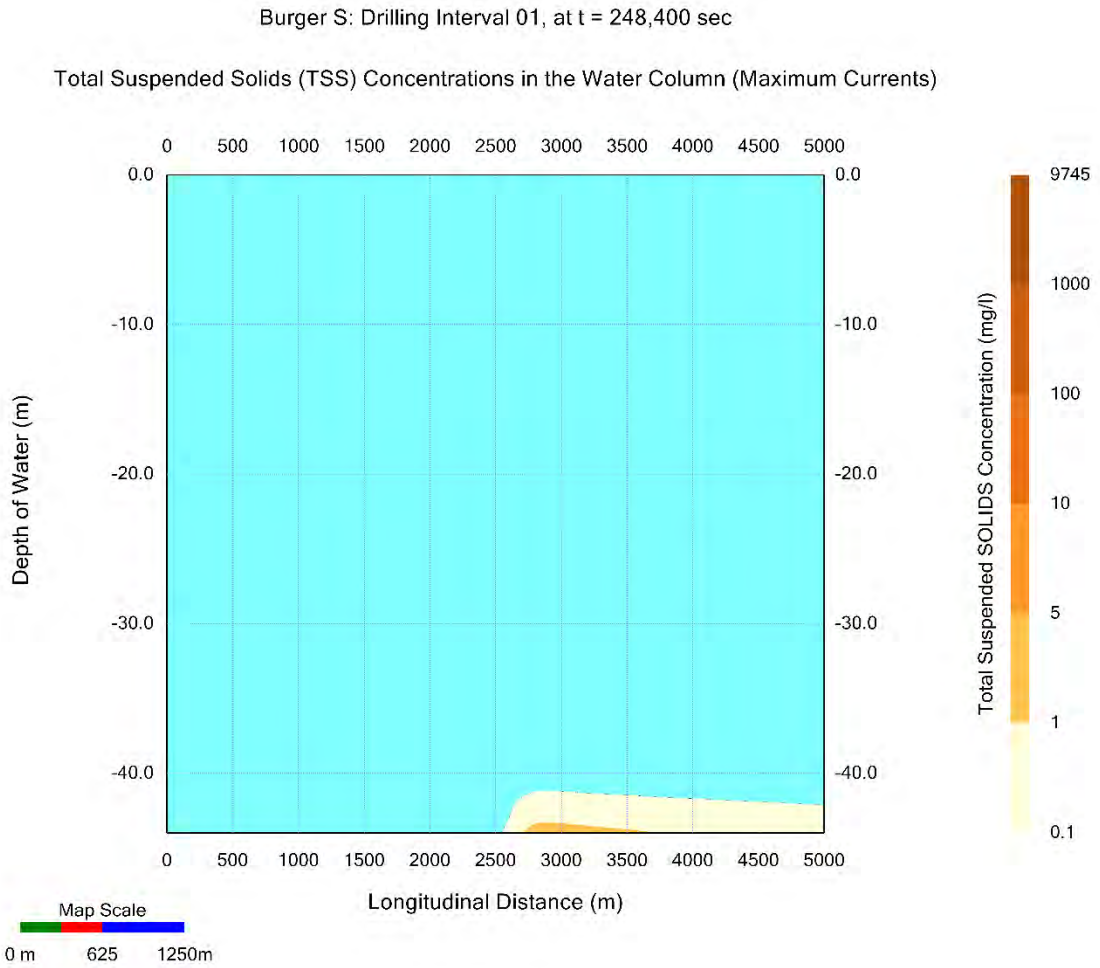
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-3c: TSS concentrations during the maximum currents at 68 h (or 2 h after the cessation of release)



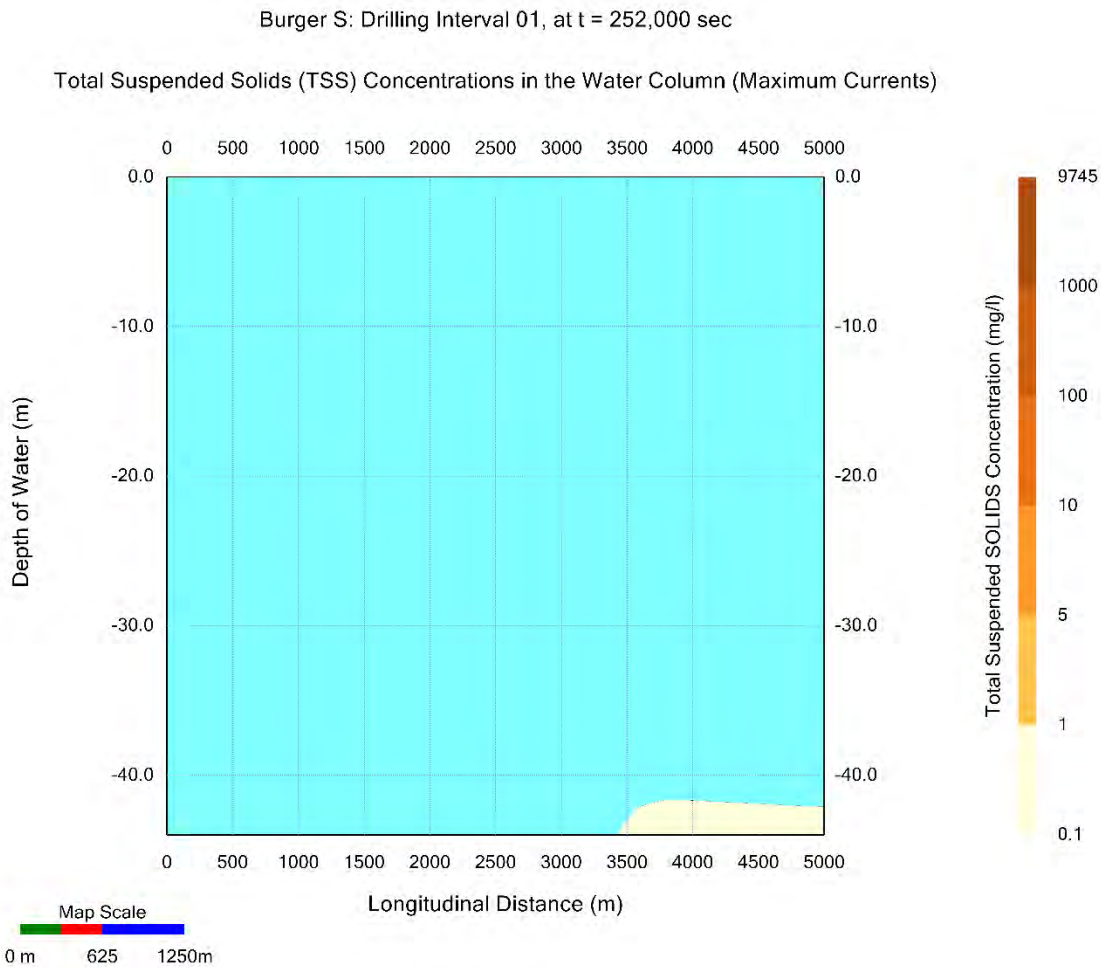
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-3d: TSS concentrations during the maximum currents at 69 h (or 3 h after the cessation of release)



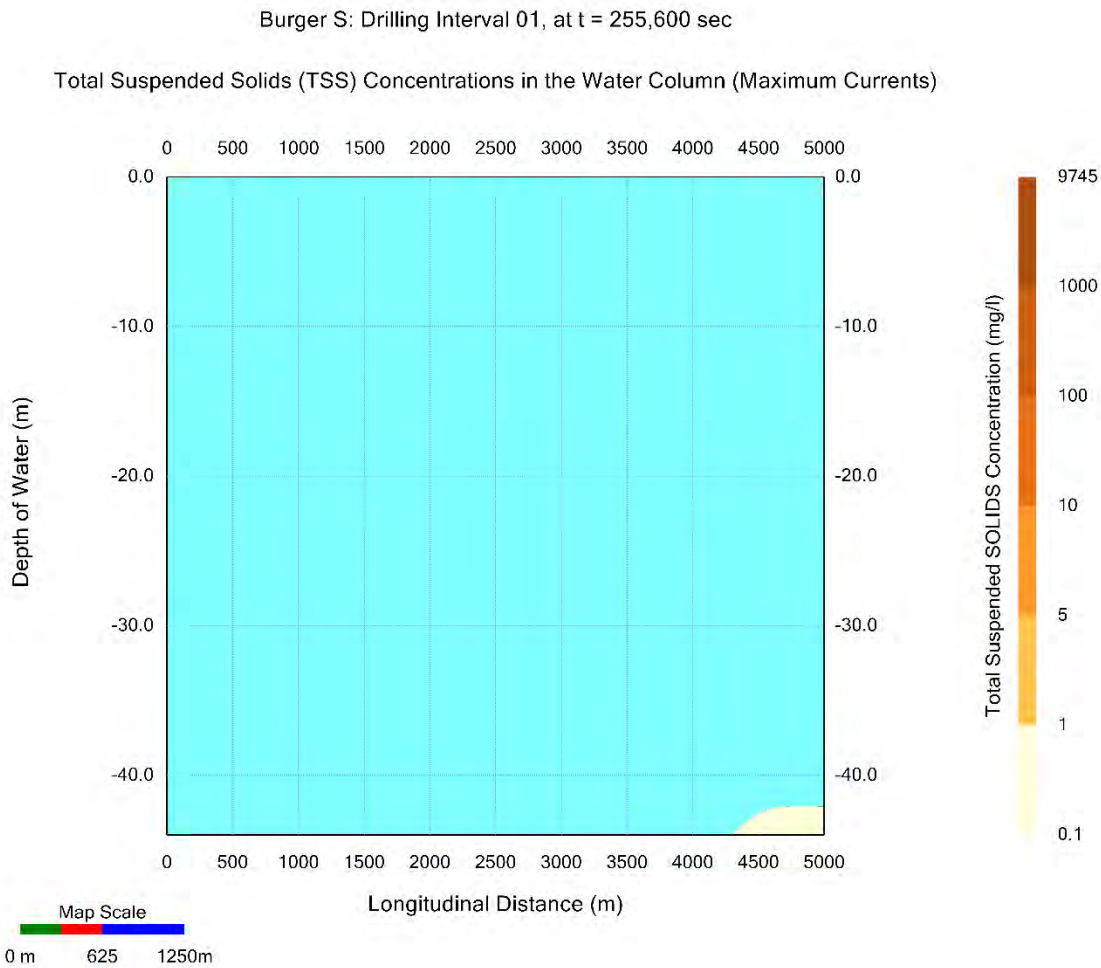
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-3e: TSS concentrations during the maximum currents at 70 h (or 4 h after the cessation of release)



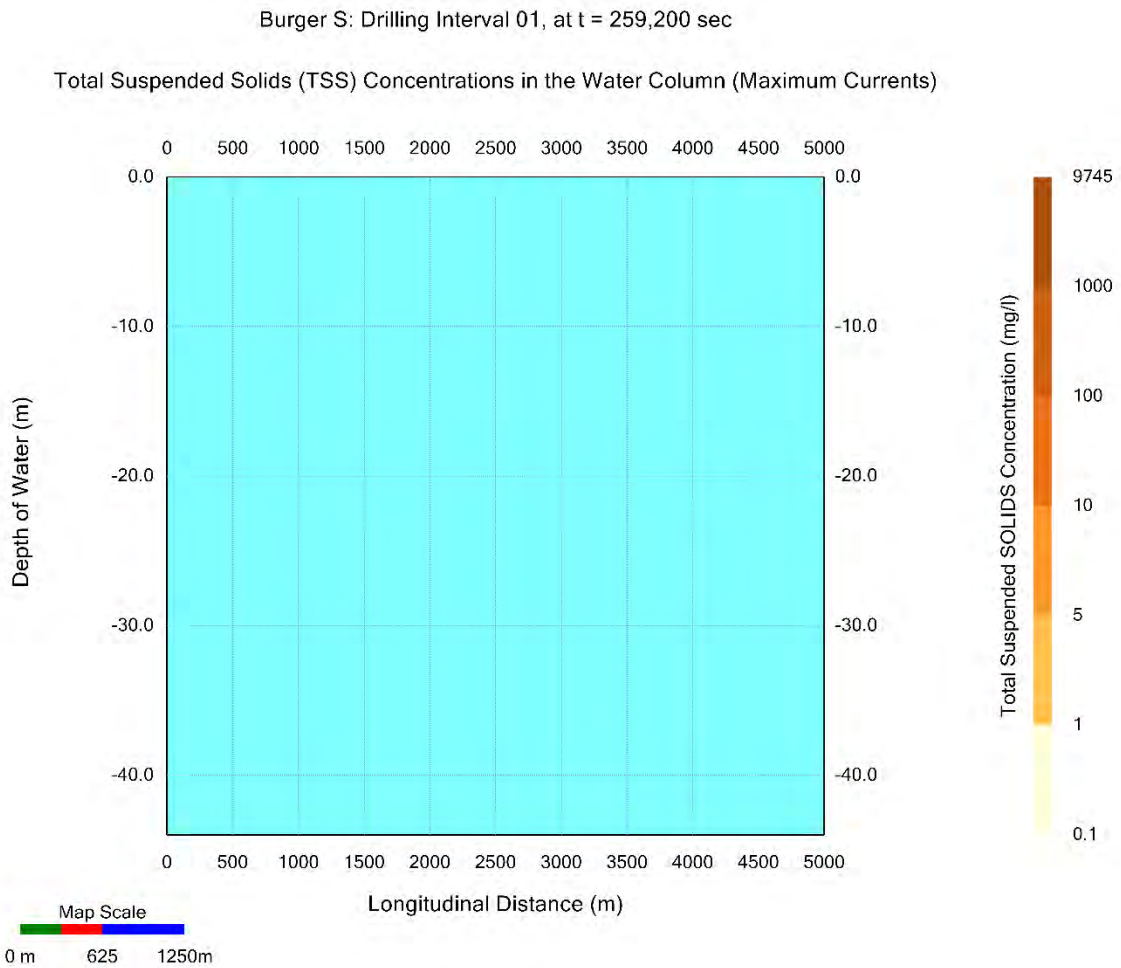
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-3f: TSS concentrations during the maximum currents at 71 h (or 5 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-3g: TSS concentrations during the maximum currents at 72 h (or 6 h after the cessation of release)



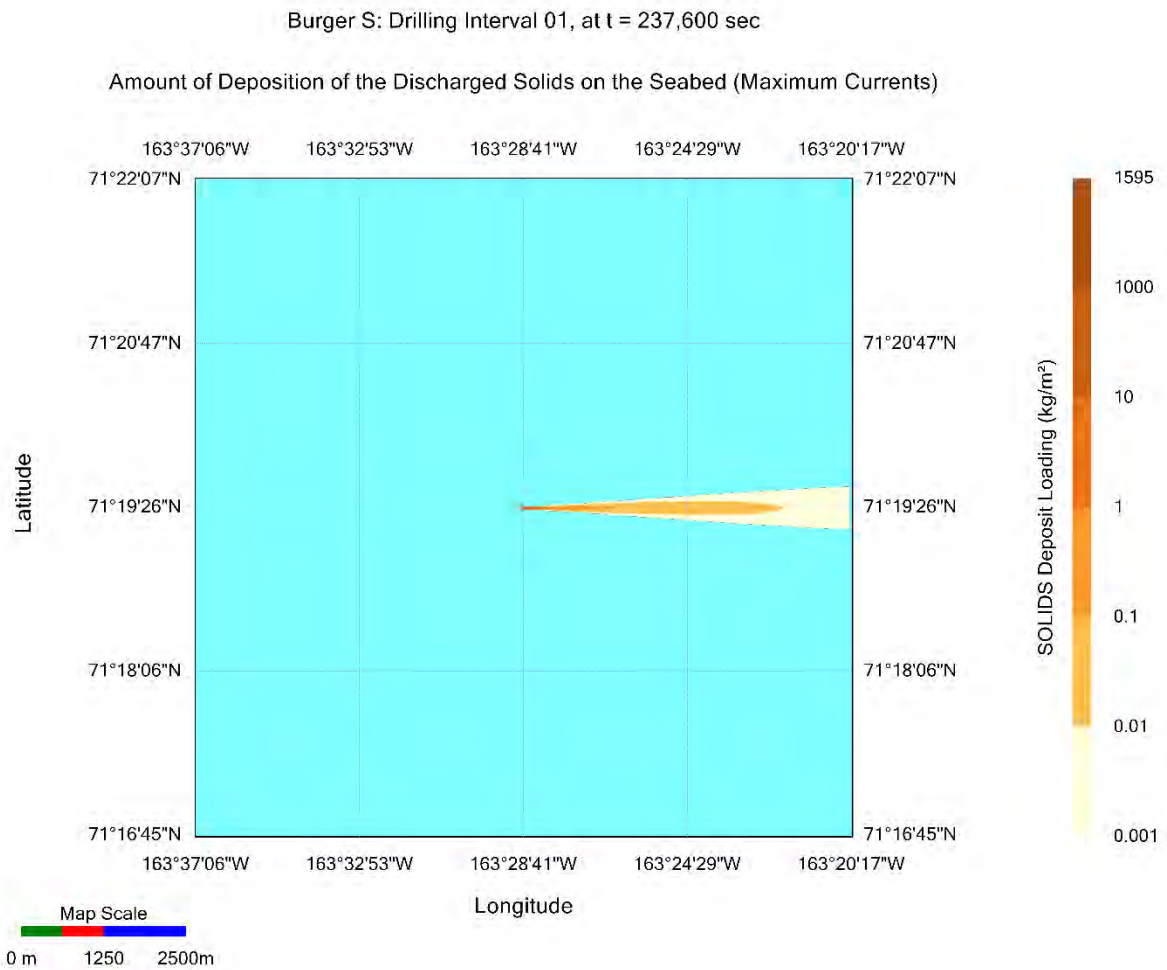
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **237**,**600** sec (or **66**.**0** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figure 6-4**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **6**-**4**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **1**,**594** kg/m^2 occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **85** m and **355** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **355** and **1**,**425** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **1,425** and **4,000** m distances from the discharge location. The loading is less than **0**.**01** kg/m^2 beyond **4,000** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **1000**-, **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**097**, **0**.**185**, **0**.**432**, **1**.528, **5**.**394**, and **56**.**709** ha, respectively.

Figure 6-4: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 01



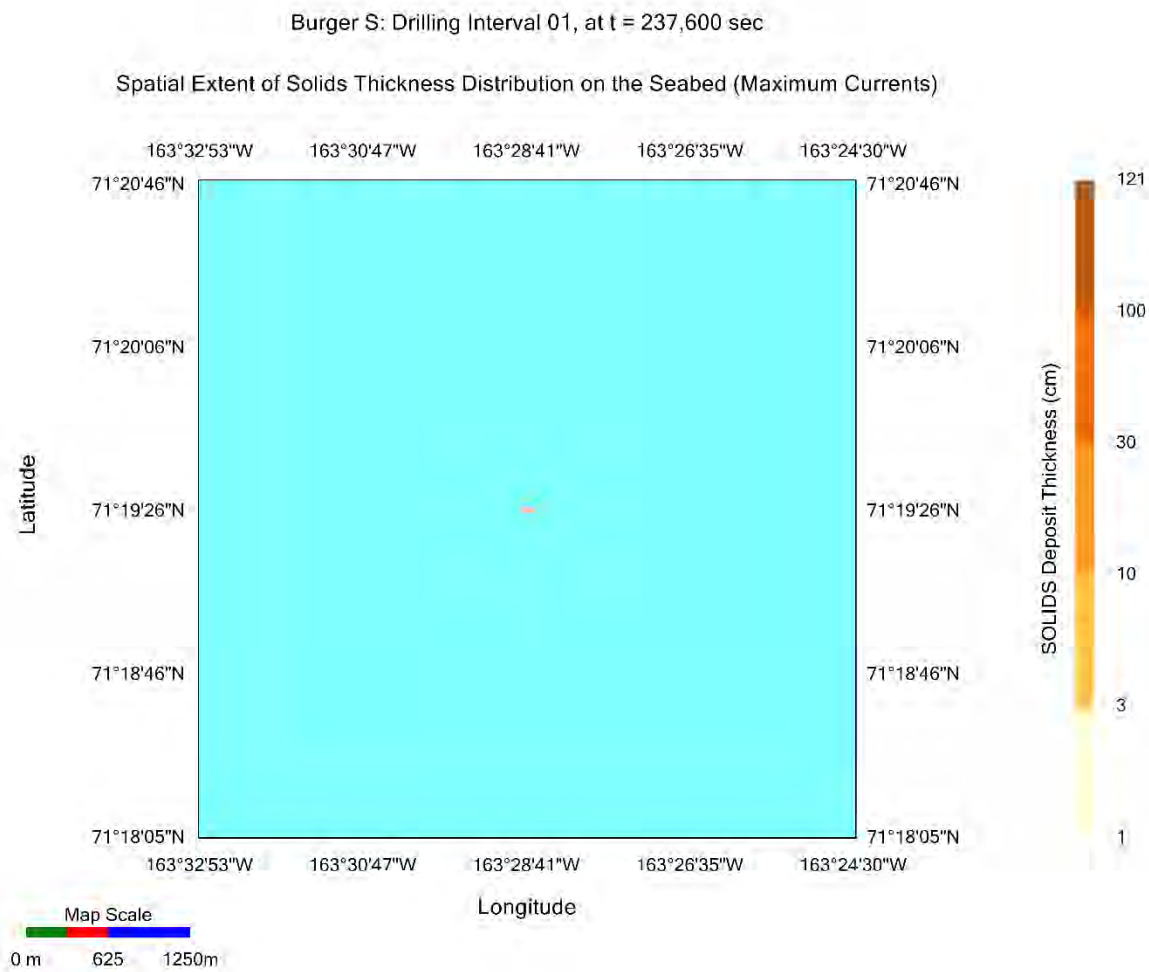
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **237**,**600** sec (or **66**.**0** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 6-5a** and **6-5b.** The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **6**-**5**a. The same result is presented in Figure **6**-**5**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **120.3** cm occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **85** m from the discharge location.

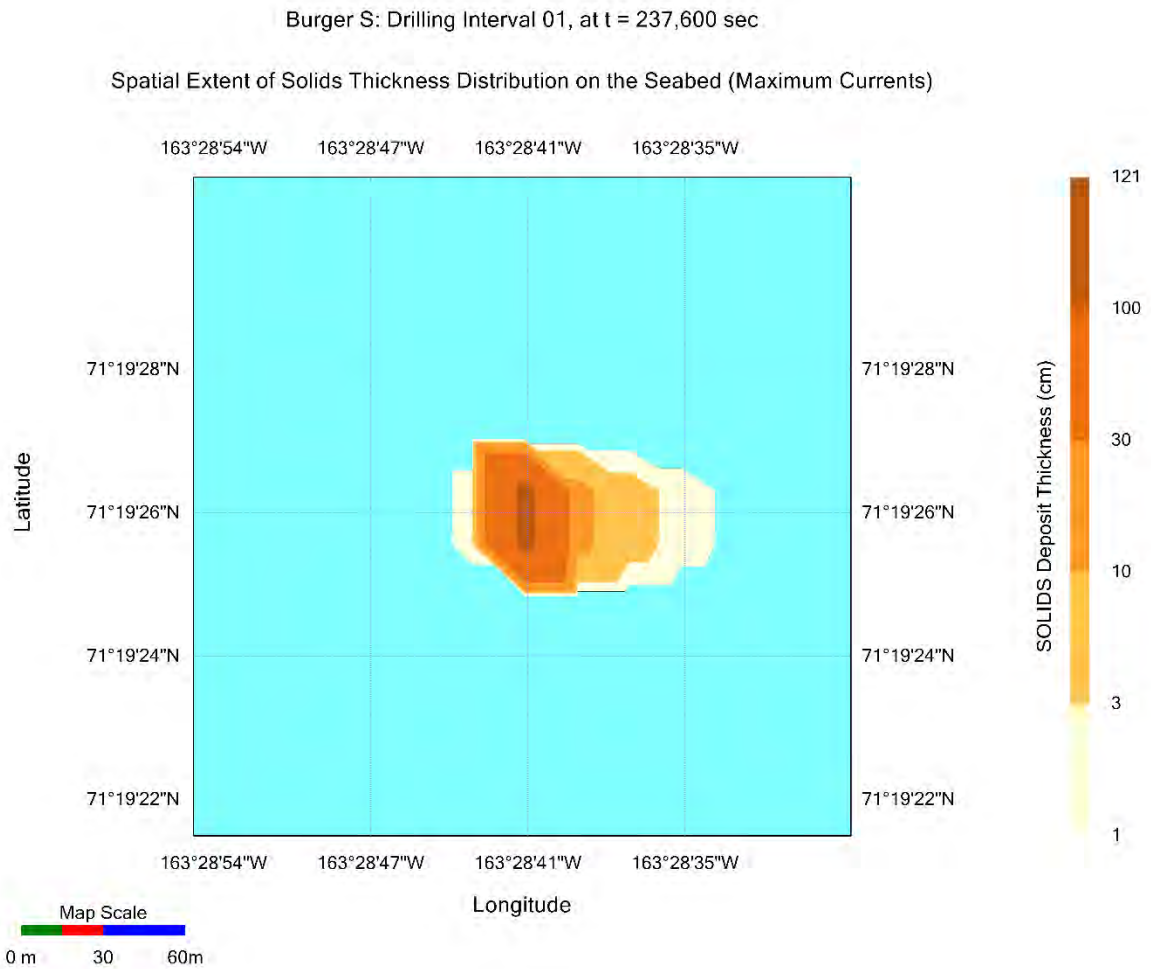
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **100** m x **40** m rectangle area (or **0**.**423** ha) as presented in Figure **6**-**5**b. The sea floor areas affected by deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0**.**088**, **0**.**173**, and **0**.**423** ha, respectively.

Figure 6-5a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 01



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-5b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 01 (Zoom In View)



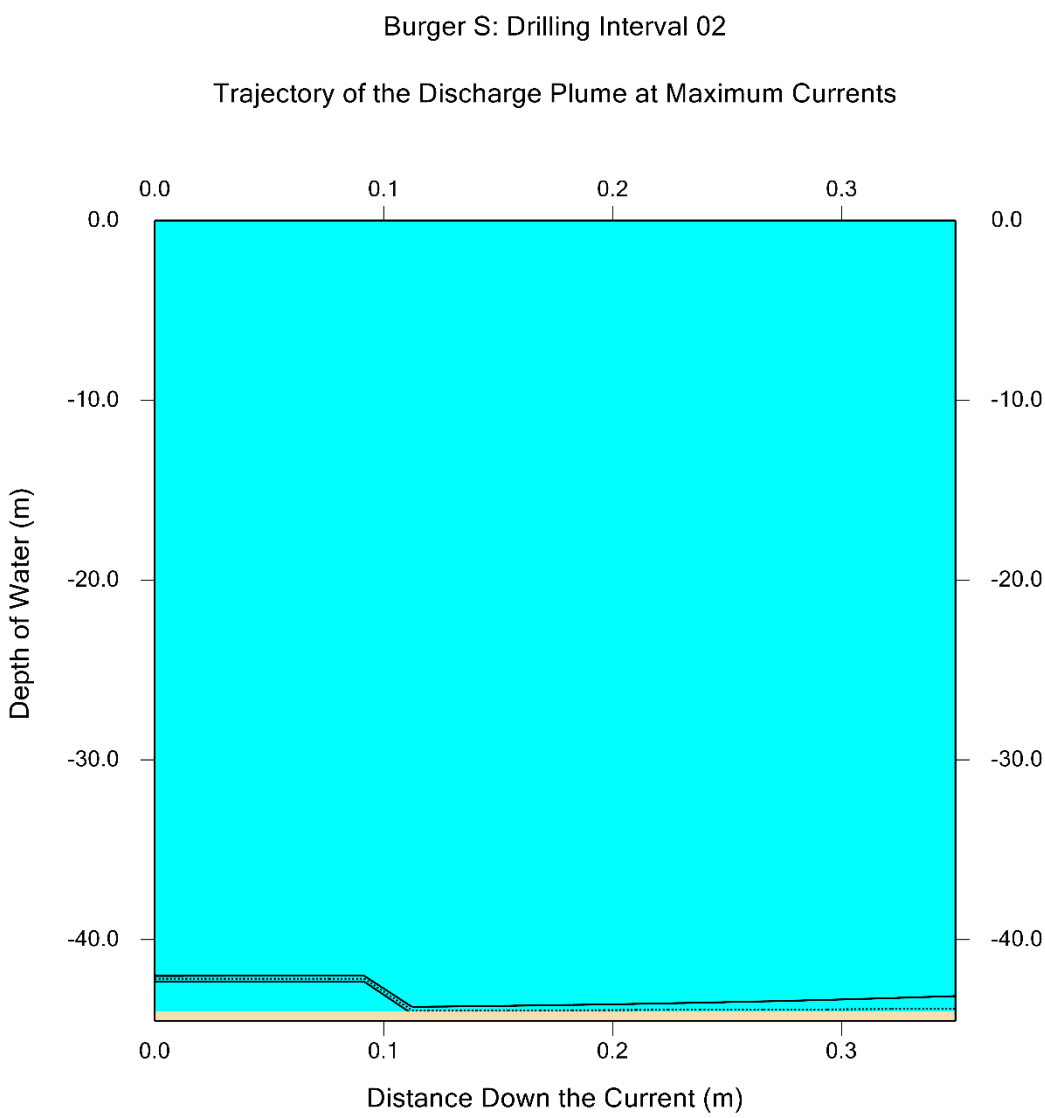
Copyright **2014** by Fluid Dynamix. Company Confidential.

6.2 Model Results for Sea Floor Discharge Scenario – Drilling Interval 02

Trajectory and Shape of the Discharge Plume

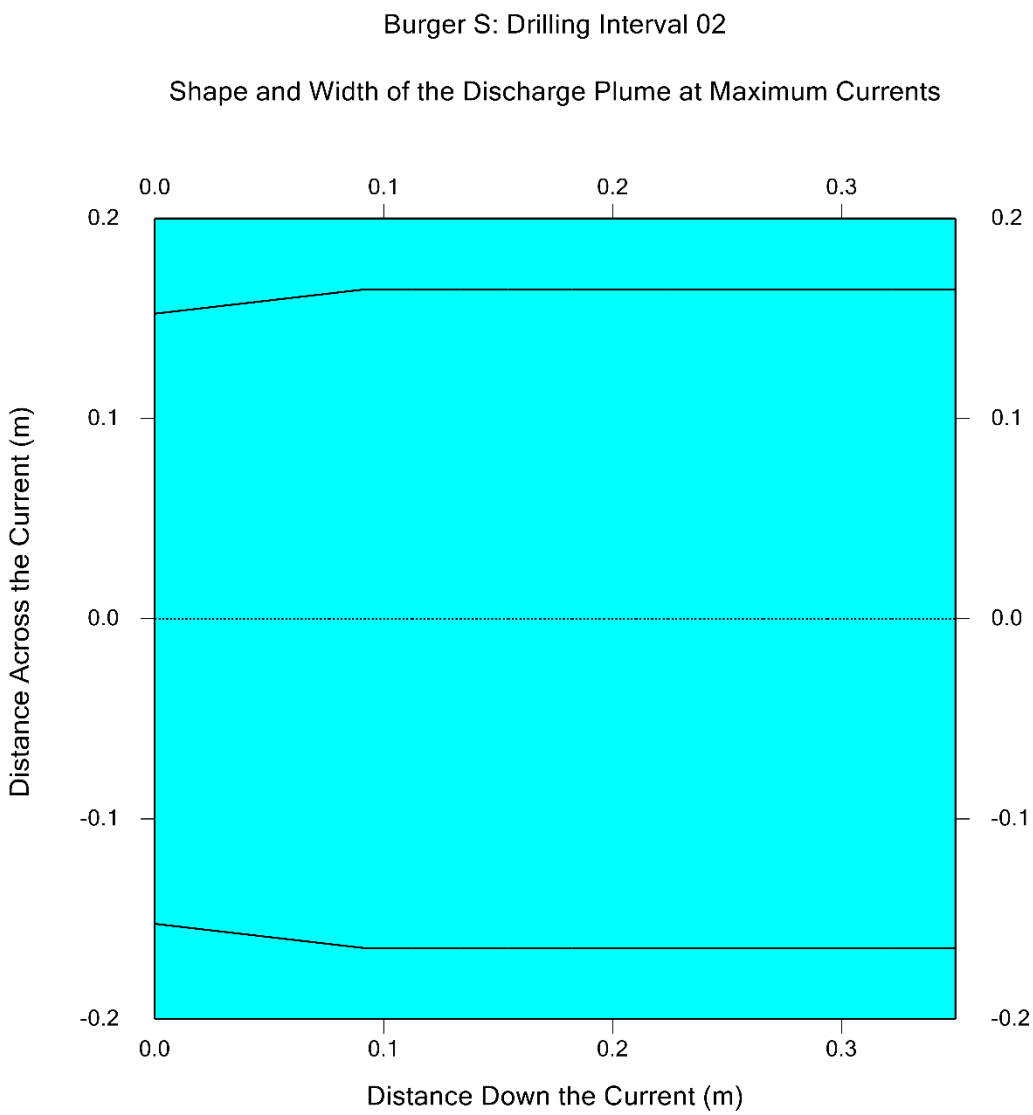
The trajectory of the discharge plume is presented in **Figure 6-6**. The depth of water is **44.0** m and the discharge occurs at a depth of **42.17** m from a **12.0** inches internal diameter discharge pipe of the sea floor pump at **14,000** bbls/hour. A flexible hose suction pipe of this sea floor pump moves the cements, water based drill cuttings, and drill fluids from the drill strings and discharges at **1.83** m (or **6** feet) above the seafloor. The discharge pipe is oriented horizontally aligned with the direction of the current, which is to the east. Therefore, the heavier discharge plume attempts to shoot horizontally as seen in Figure **6-6** and travels to the east to a distance approximately **0.35** m only from the discharge location before collapsing onto the sea floor due to the proximity of the plume near the sea floor. The shape and width of the discharge plume is presented in **Figure 6-7**. The width of the plume is approximately **0.35** m at a distance **0.35** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **6-6** and **6-7**.

Figure 6-6: Trajectory of the discharge plume at maximum currents, Drilling Interval 02



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-7: Shape and width of the discharge plume at maximum currents, Drilling Interval 02



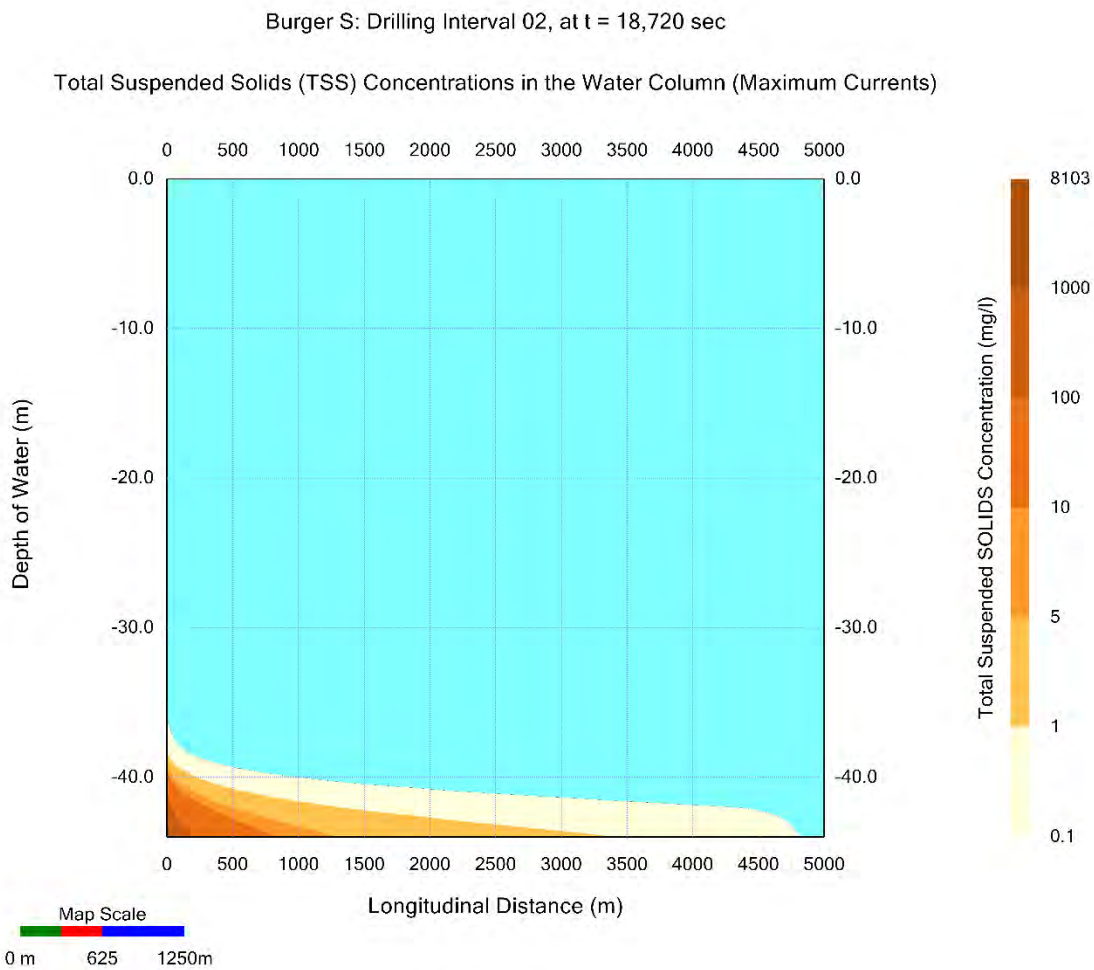
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **18**,**720** sec (or **5**.**2** hours) which is the discharge duration for this drilling interval is presented in **Figure 6-8a**. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **42**.**17** m from a **12.0** inches internal diameter discharge pipe. Figure 6-**8**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **8,103** mg/l occurs at the discharge location. It decreases to a value of **100** mg/l and **10** mg/l at distances approximately **175** m and **825** m, respectively from the discharge location. It varies from **10** to **5** mg/l approximately between **825** and **1**,**300** m distances from the discharge location. It varies from **5** to **1** mg/l between **1**,**300** and **3**,**400** m distances from the discharge location. It is less than **1** mg/l beyond **3**,**400** m from the discharge location. The effect of the sea floor pump is visible in this Figure **6**-**8a**. The discharge plume is spreading farther horizontally to the east along the direction of the current than vertically. The TSS concentration is less than **0**.**1** mg/l at a depth approximately **35** m at or near the discharge location. It is less than **1** mg/l at a depth approximately **40** m at **500** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **1,546.6**, **487.4**, **173.9**, **47.1**, and **7.4** mg/l, respectively.

Figure 6-8a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 02

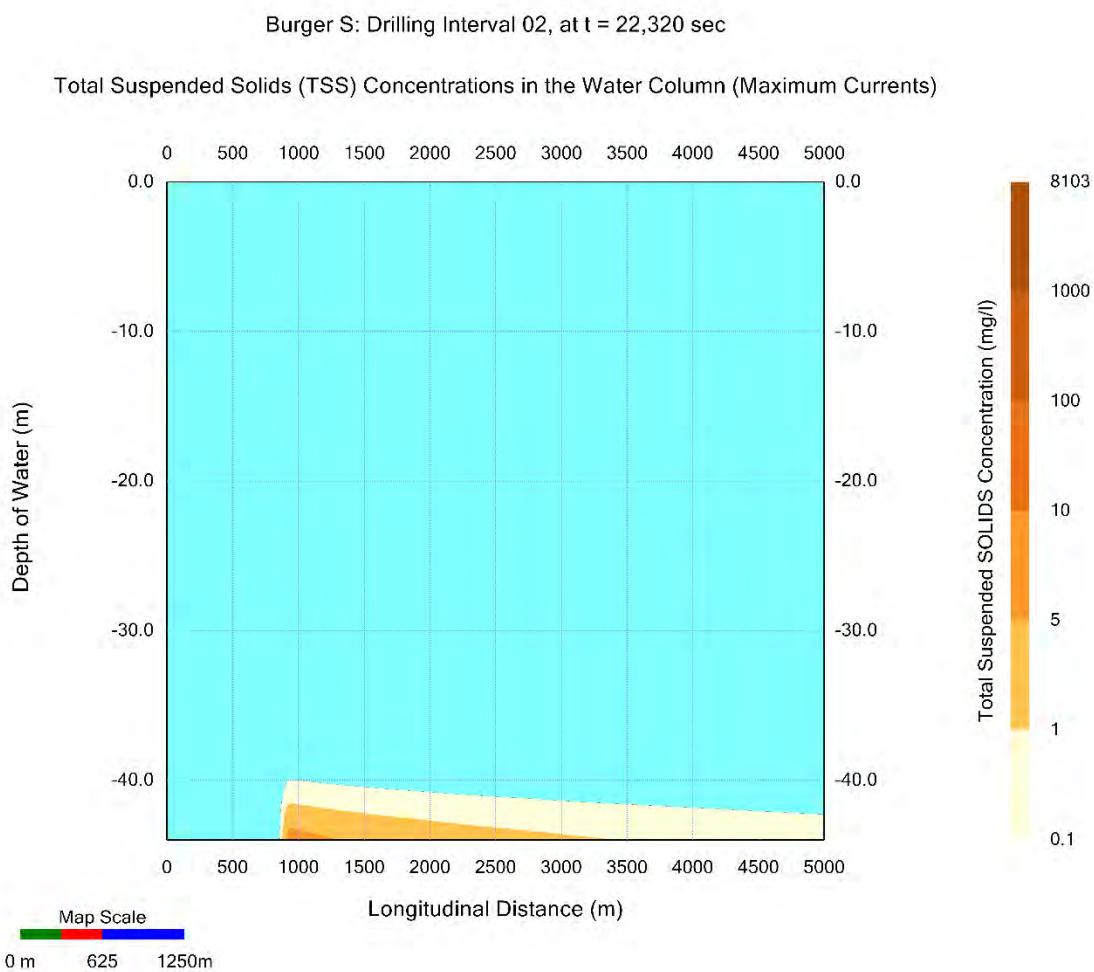


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

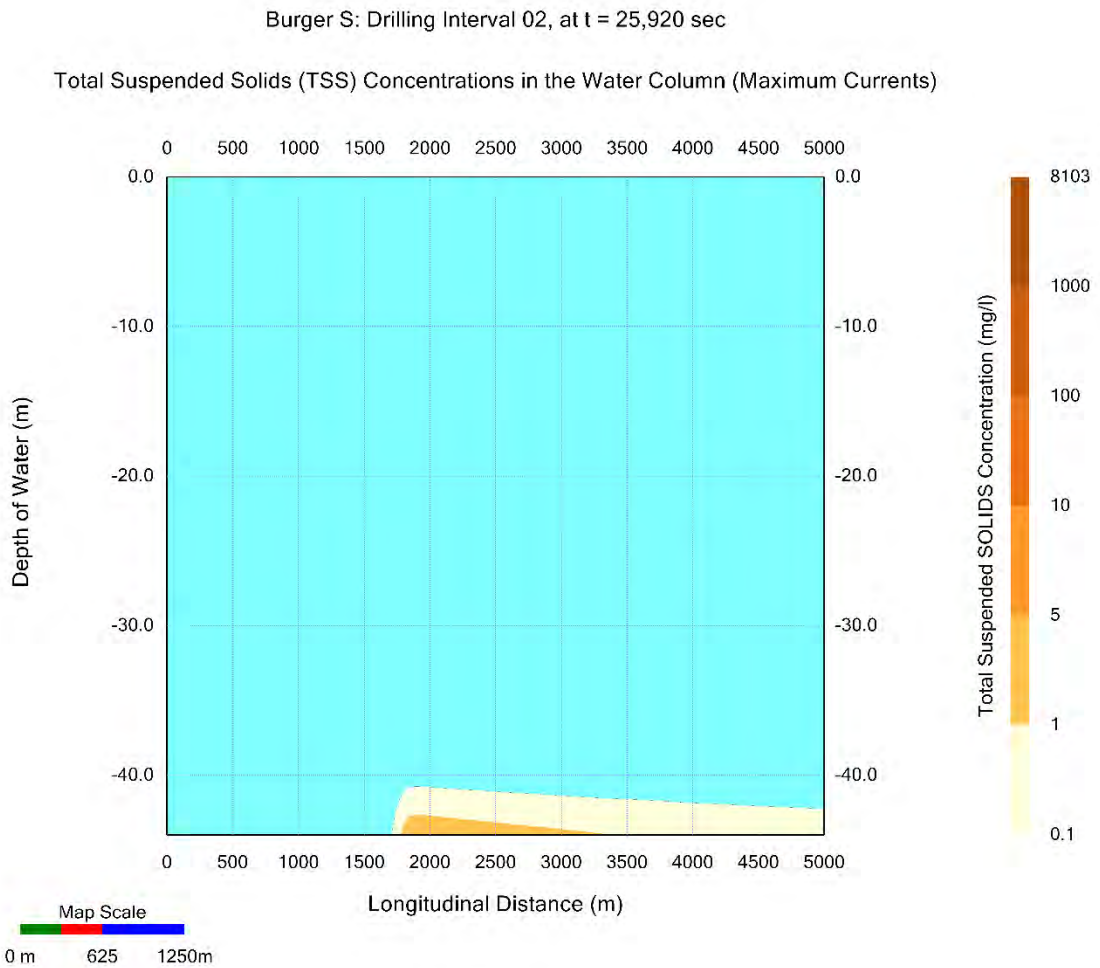
The discharge of the cements, water based drill cuttings, and drill fluids ceases at time, t = **18**,**720** sec (or **5**.**2** hours). The fate and transport of the discharged solids at times **1**, **2**, **3**, **4, 5**, and **6** h after the cessation of the discharge are presented by **Figures 6-8**b**, 6-8**c**, 6-8**d**, 6-8**e, **6-8f**, and **6-8g**. These figures show that the TSS concentrations within the **5** km model domain decrease to: **10** mg/l or less at **1** h, **5** mg/l or less at **2** h, **5** mg/l or less at **3** h, **1** mg/l or less at **4** h, **1** mg/l or less at **5** h, and less than **0**.**1** mg/l at **6** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **5** and **6** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 6-8b: TSS concentrations during the maximum currents at 6.2 h (or 1 h after the cessation of release)



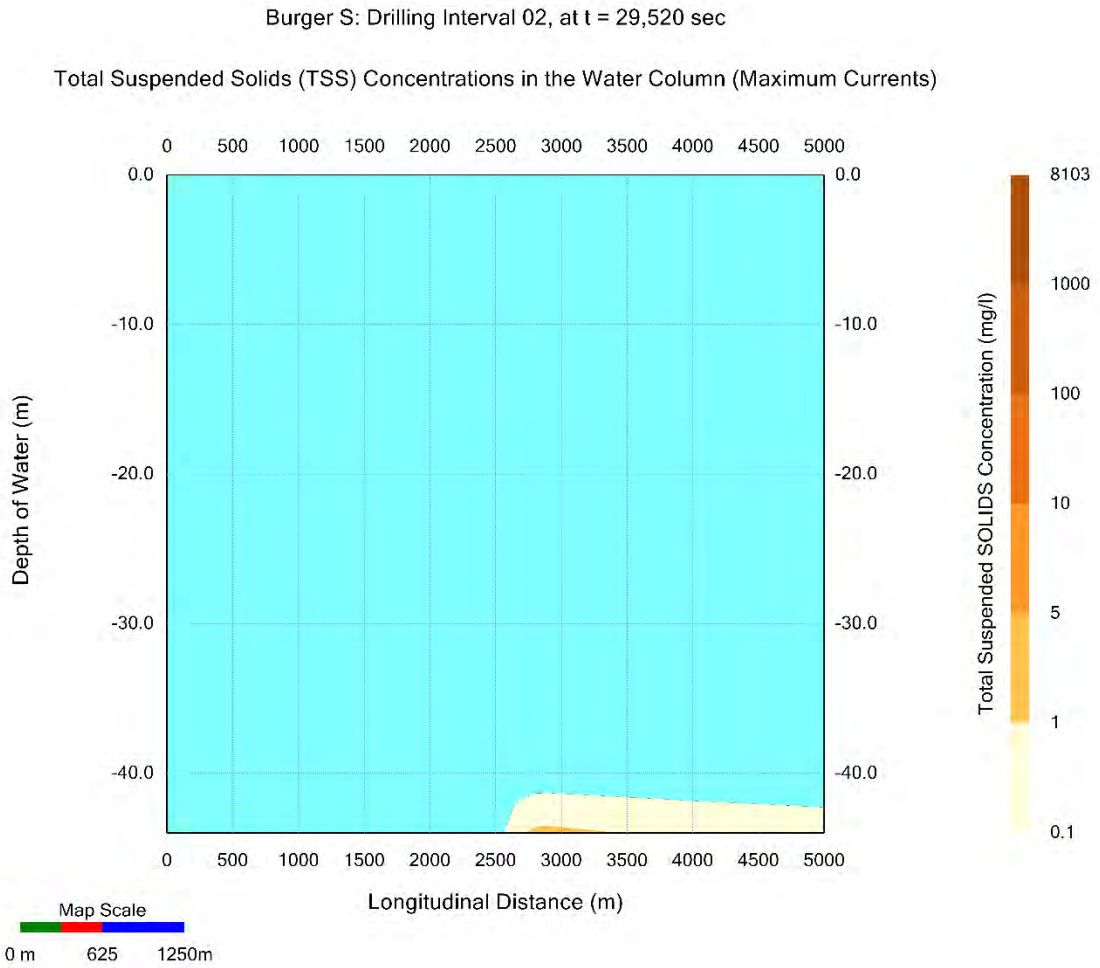
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-8c: TSS concentrations during the maximum currents at 7.2 h (or 2 h after the cessation of release)



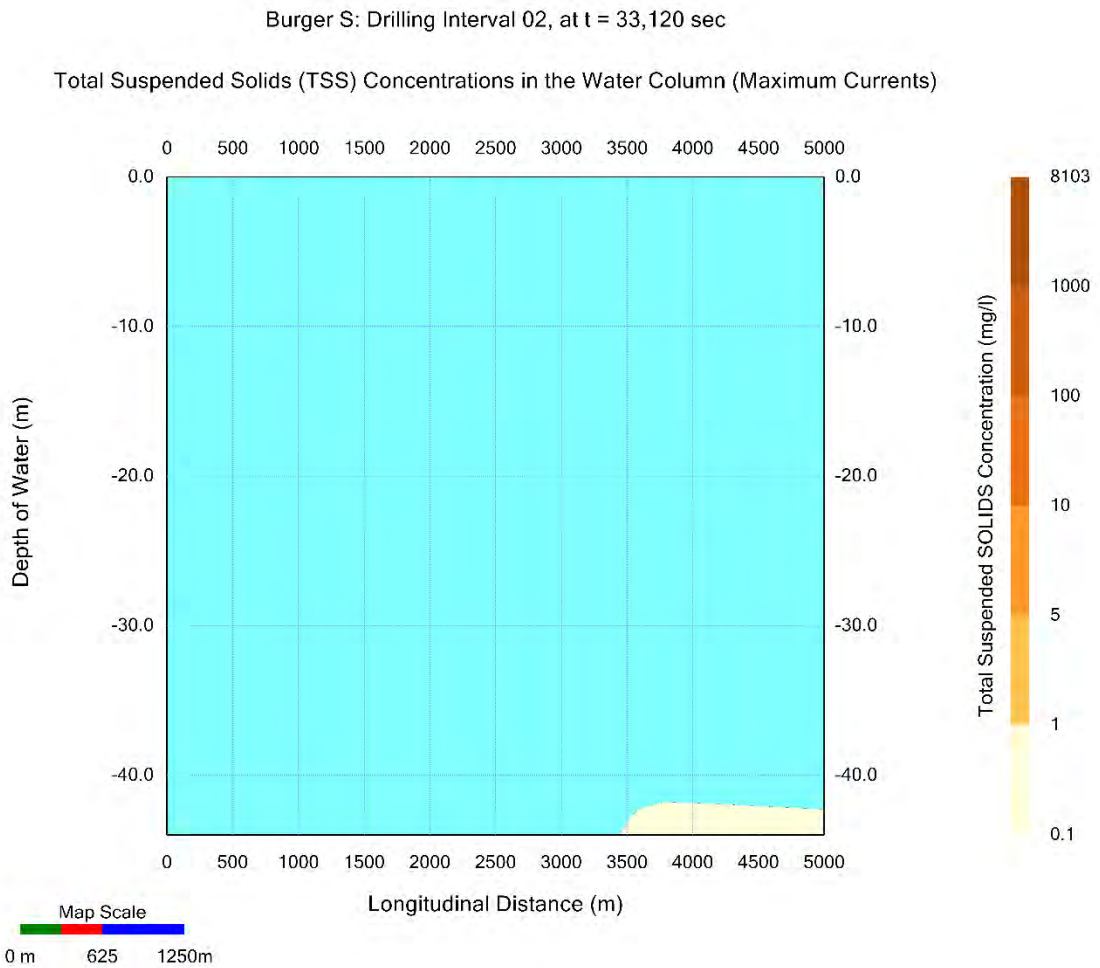
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-8d: TSS concentrations during the maximum currents at 8.2 h (or 3 h after the cessation of release)



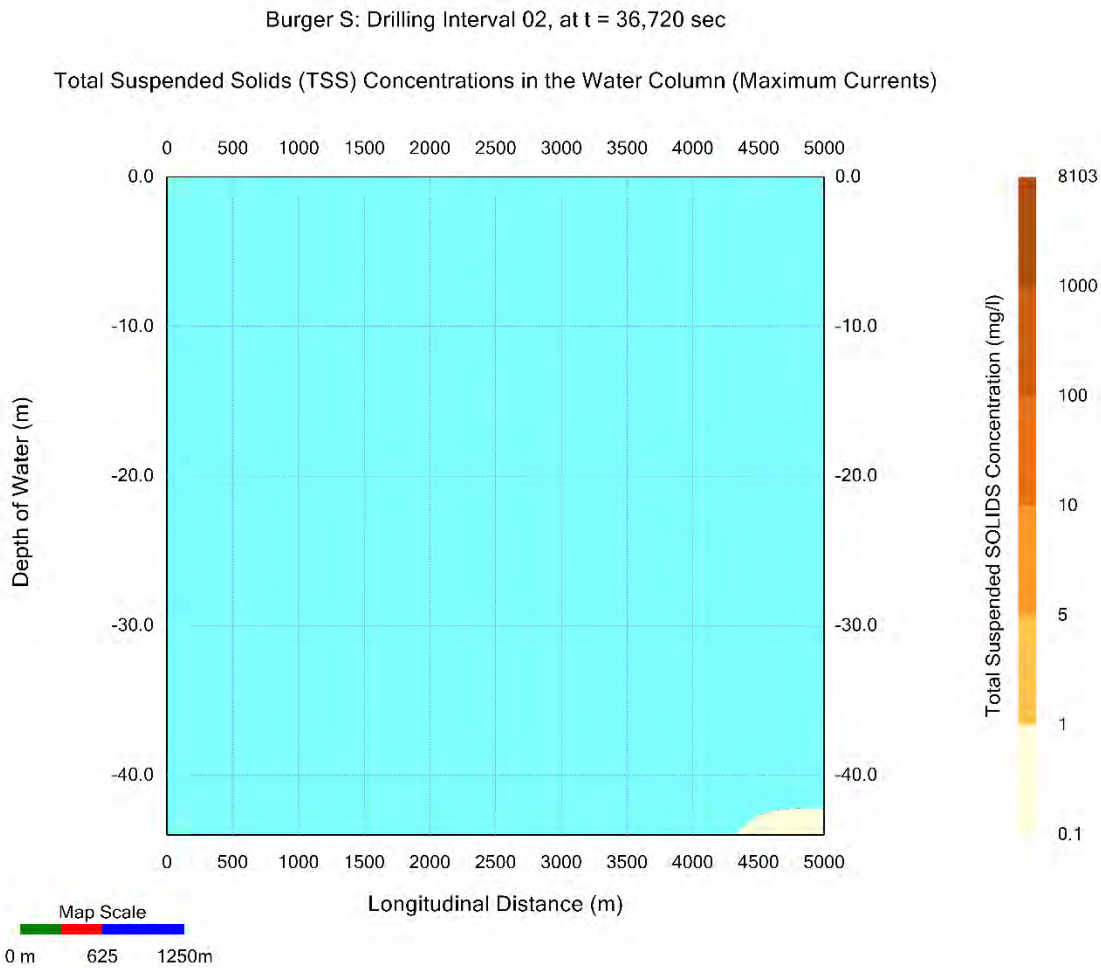
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-8e: TSS concentrations during the maximum currents at 9.2 h (or 4 h after the cessation of release)



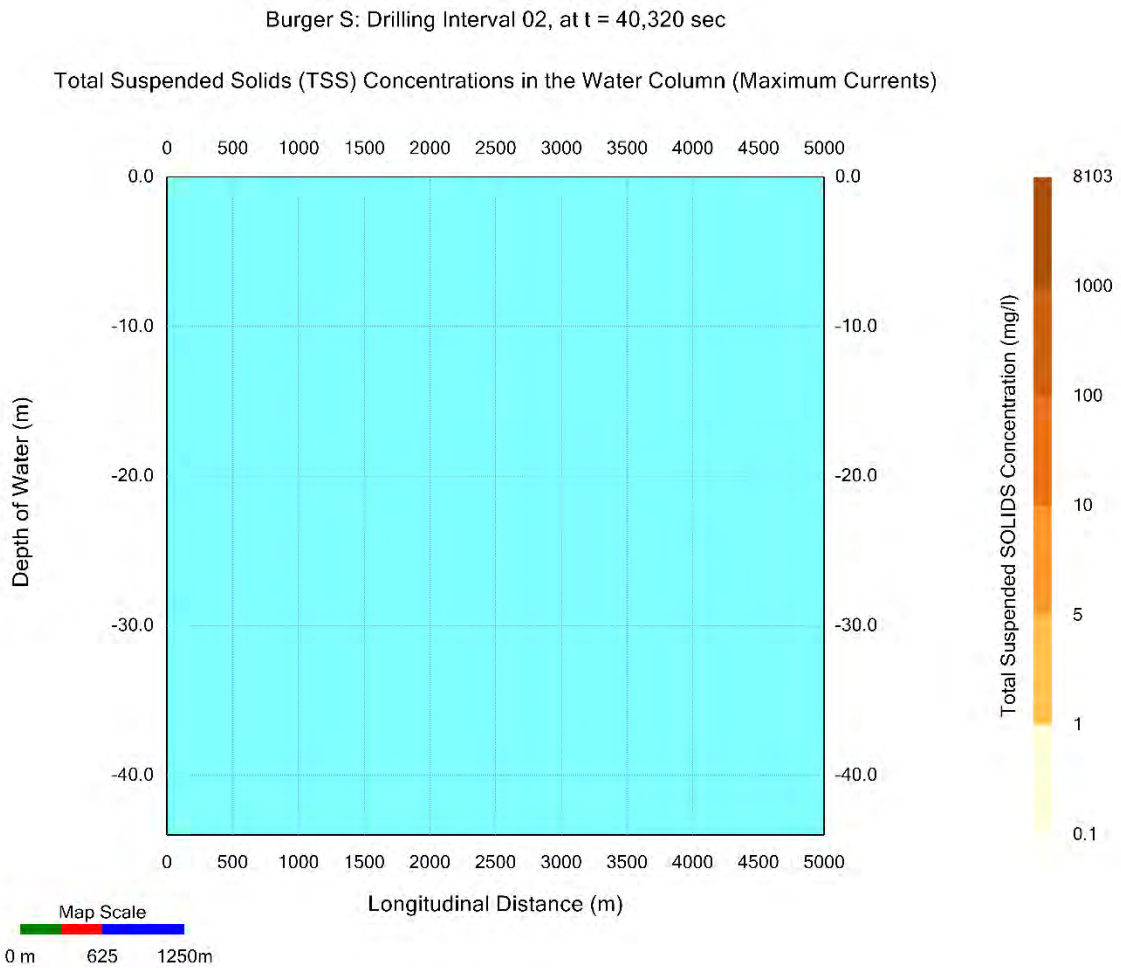
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-8f: TSS concentrations during the maximum currents at 10.2 h (or 5 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-8g: TSS concentrations during the maximum currents at 11.2 h (or 6 h after the cessation of release)



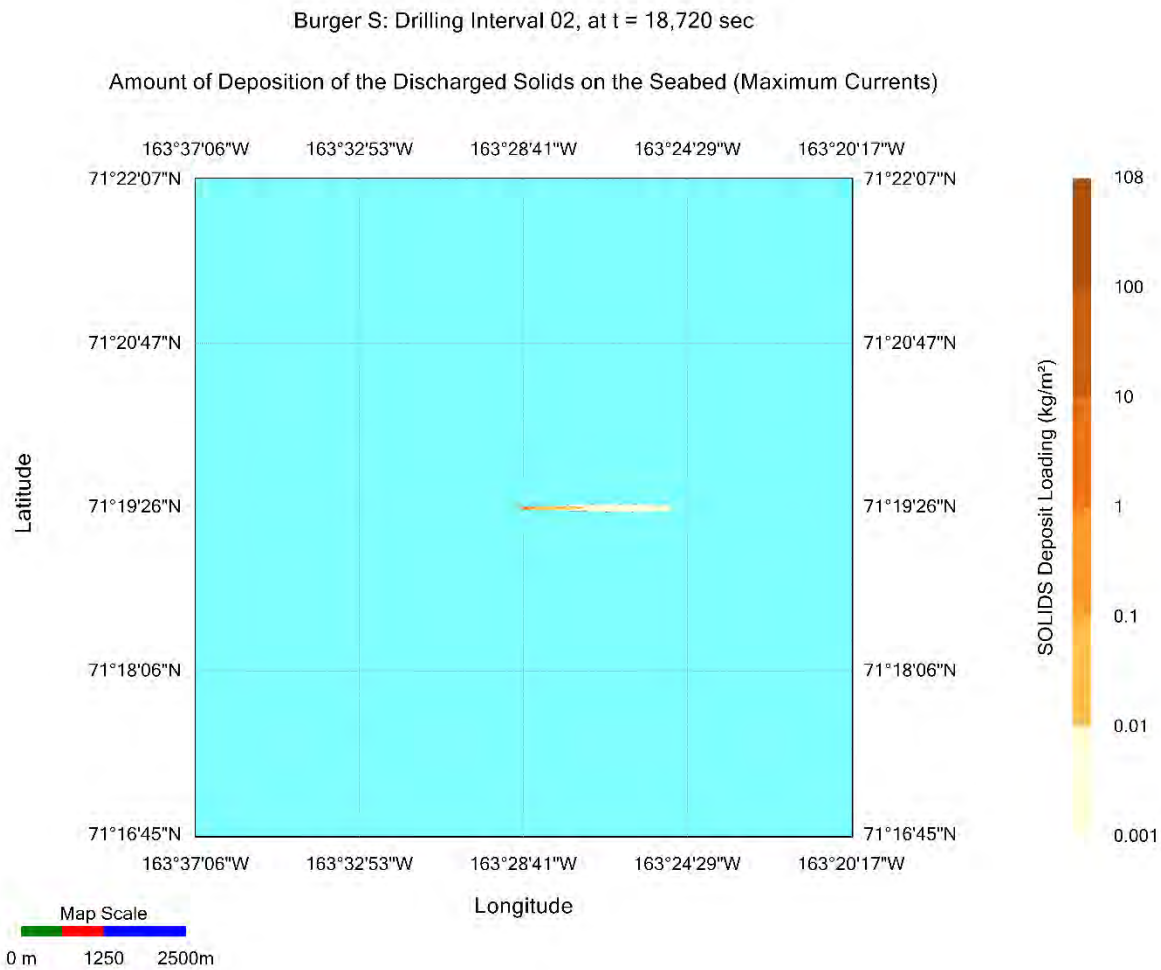
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **18**,**720** sec (or **5**.**2** hours) as a result of the discharge of the cements, water based drill cuttings, and drill fluids on a plan view is presented in **Figure 6-9**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **6**-**9**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading of **108** kg/m^2 occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **30** m and **75** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **75** and **190** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **190** and **950** m distances from the discharge location. It is less than **0**.**01** kg/m^2 beyond **950** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**083**, **0**.**119**, **0**.**410**, **0**.**845**, and **4**.**092** ha, respectively.

Figure 6-9: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 02



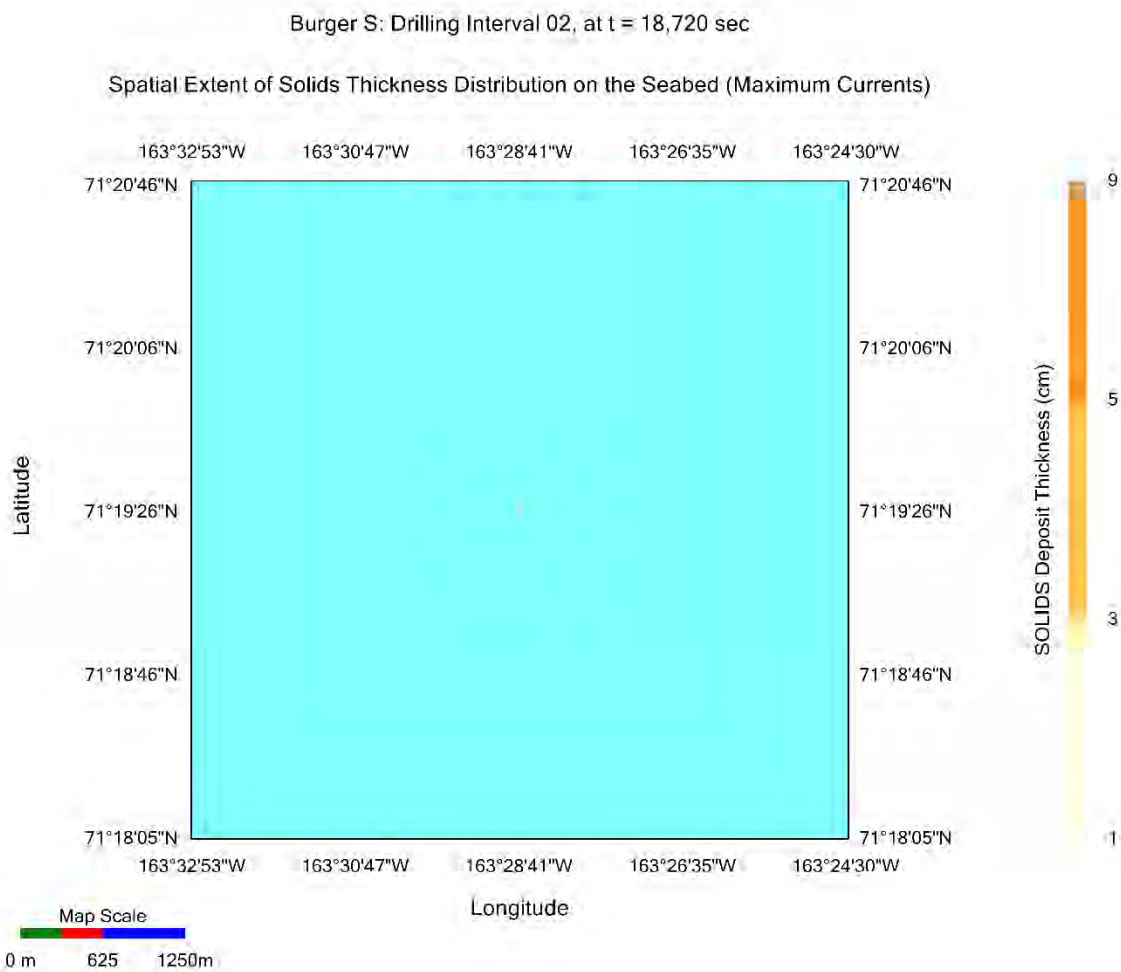
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **18**,**720** sec (or **5**.**2** hours) as a result of the discharge of the cements, water based drill cuttings, and drill fluids on a plan view is presented in **Figures 6-10a** and **6-10b.** The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. But the solids deposit on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **6**-**10**a. The same result is presented in Figure **6**-**10**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **8.2** cm occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **30** m from the discharge location.

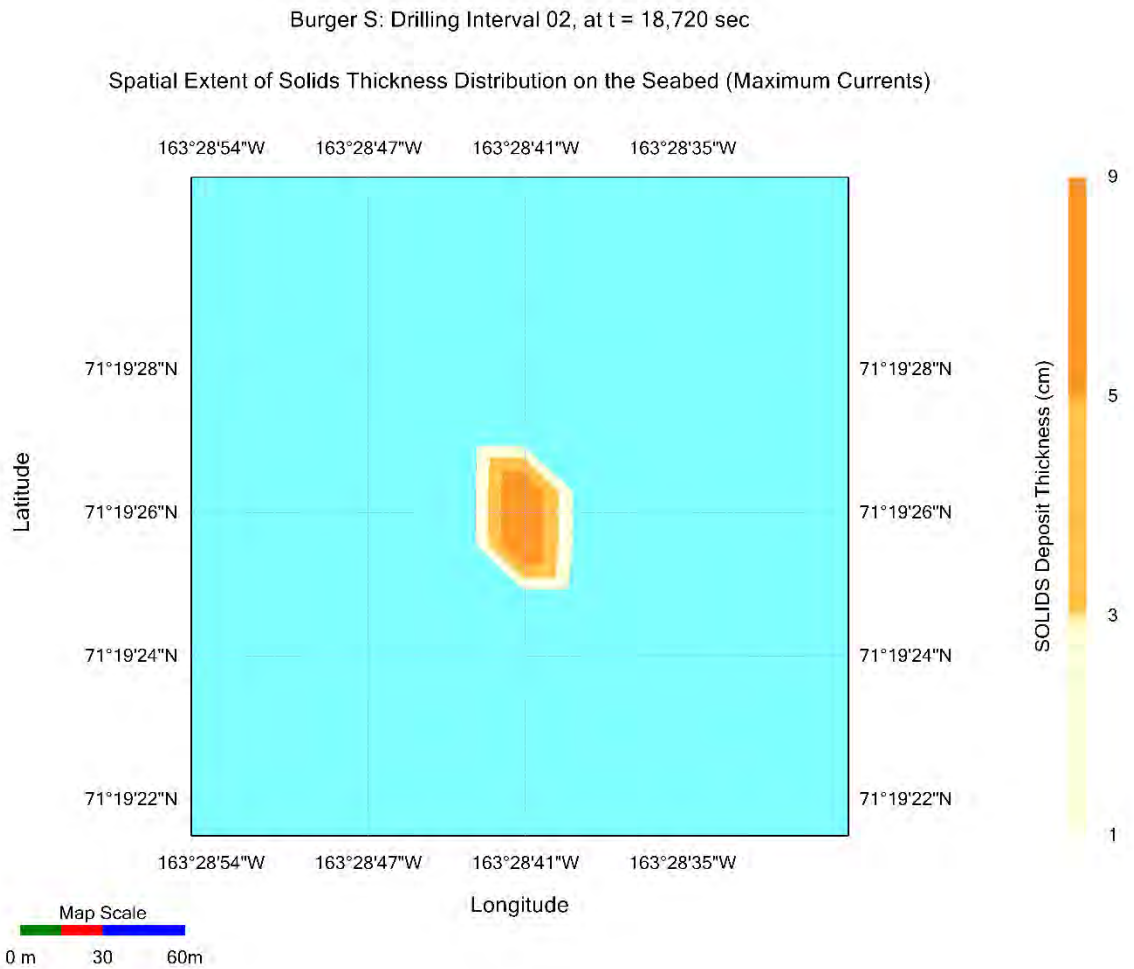
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **35** m x **40** m square area (or **0**.**118** ha) as presented in Figure **6**-**10**b. The sea floor areas affected by deposit thickness larger than **1**-cm is: **0**.**118** ha, respectively.

Figure 6-10a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 02



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-10b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 02 (Zoom In View)



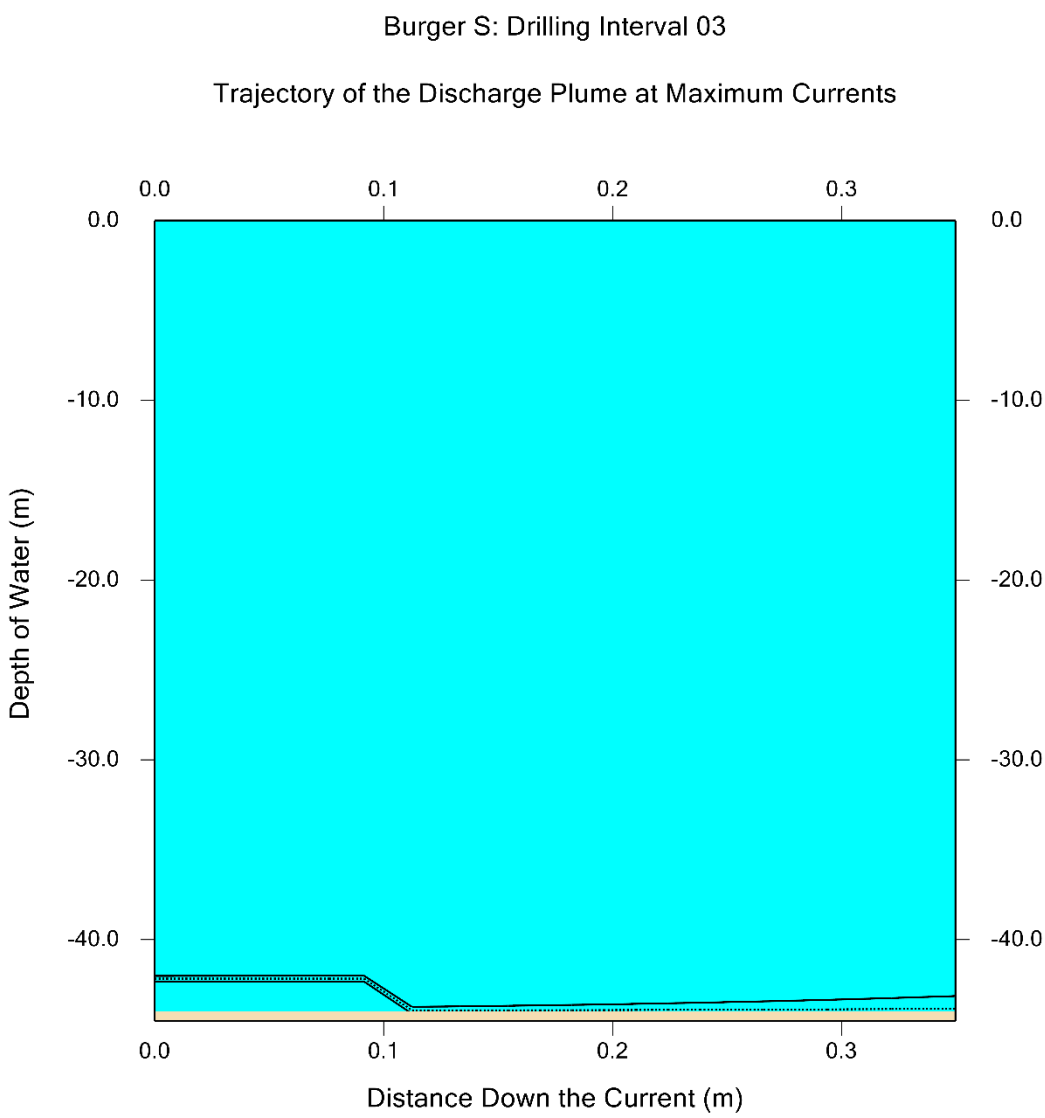
Copyright **2014** by Fluid Dynamix. Company Confidential.

6.3 Model Results for Sea Floor Discharge Scenario – Drilling Interval 03

Trajectory and Shape of the Discharge Plume

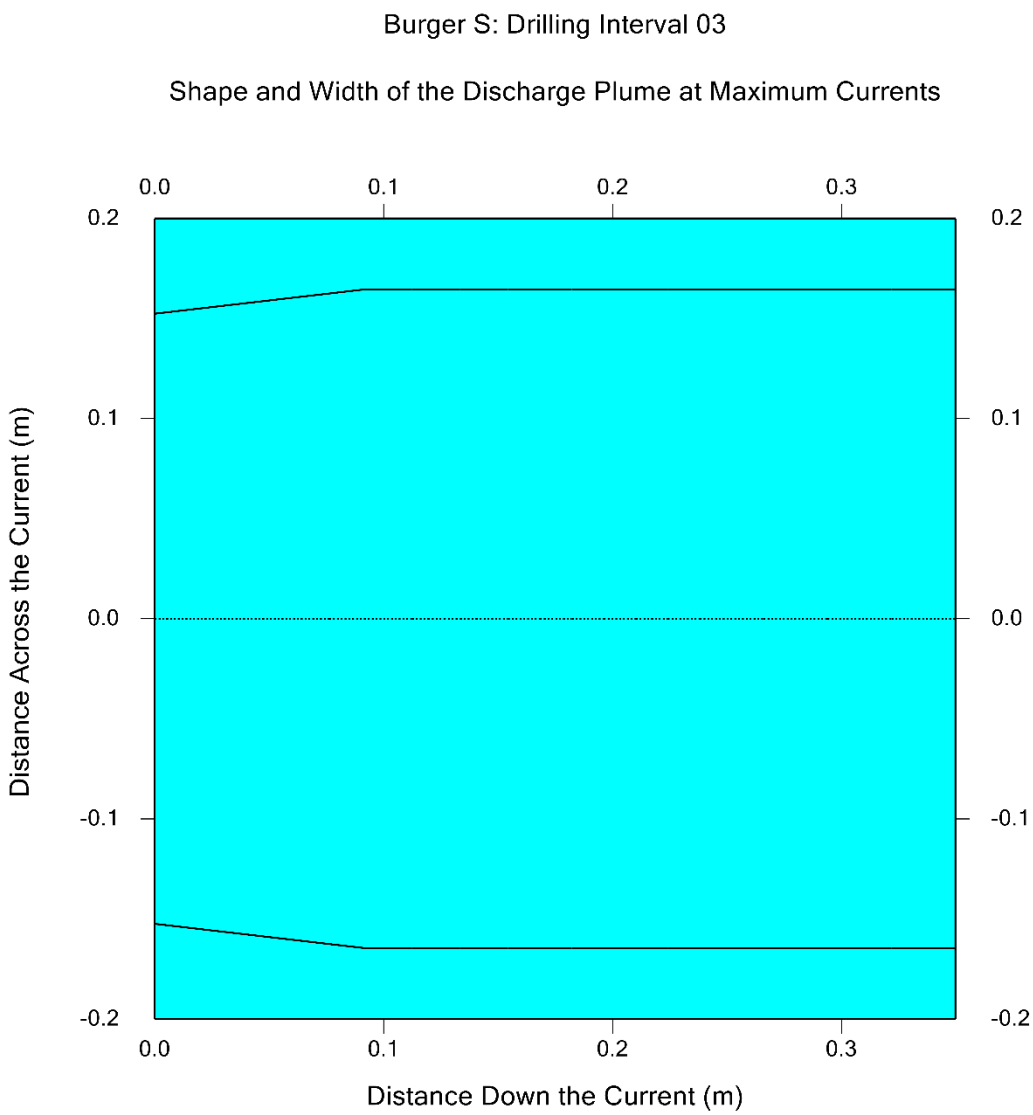
The trajectory of the discharge plume is presented in **Figure 6-11**. The depth of water is **44.0** m and the discharge occurs at a depth of **42.17** m from a **12.0** inches internal diameter discharge pipe of the sea floor pump at **14,000** bbls/hour. A flexible hose suction pipe of this sea floor pump moves the cements, water based drill cuttings, and drill fluids from the drill strings and discharges at **1.83** m (or **6** feet) above the seafloor. The discharge pipe is oriented horizontally aligned with the direction of the current, which is to the east. Therefore, the heavier discharge plume attempts to shoot horizontally as seen in figure below and travels to the east to a distance approximately **0.35** m only from the discharge location before collapsing onto the sea floor due to the proximity of the plume near the sea floor. The shape and width of the discharge plume is presented in **Figure 6-12**. The width of the plume is approximately **0.35** m at a distance **0.35** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **6-11** and **6-12**.

Figure 6-11: Trajectory of the discharge plume at maximum currents, Drilling Interval 03



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-12: Shape and width of the discharge plume at maximum currents, Drilling Interval 03



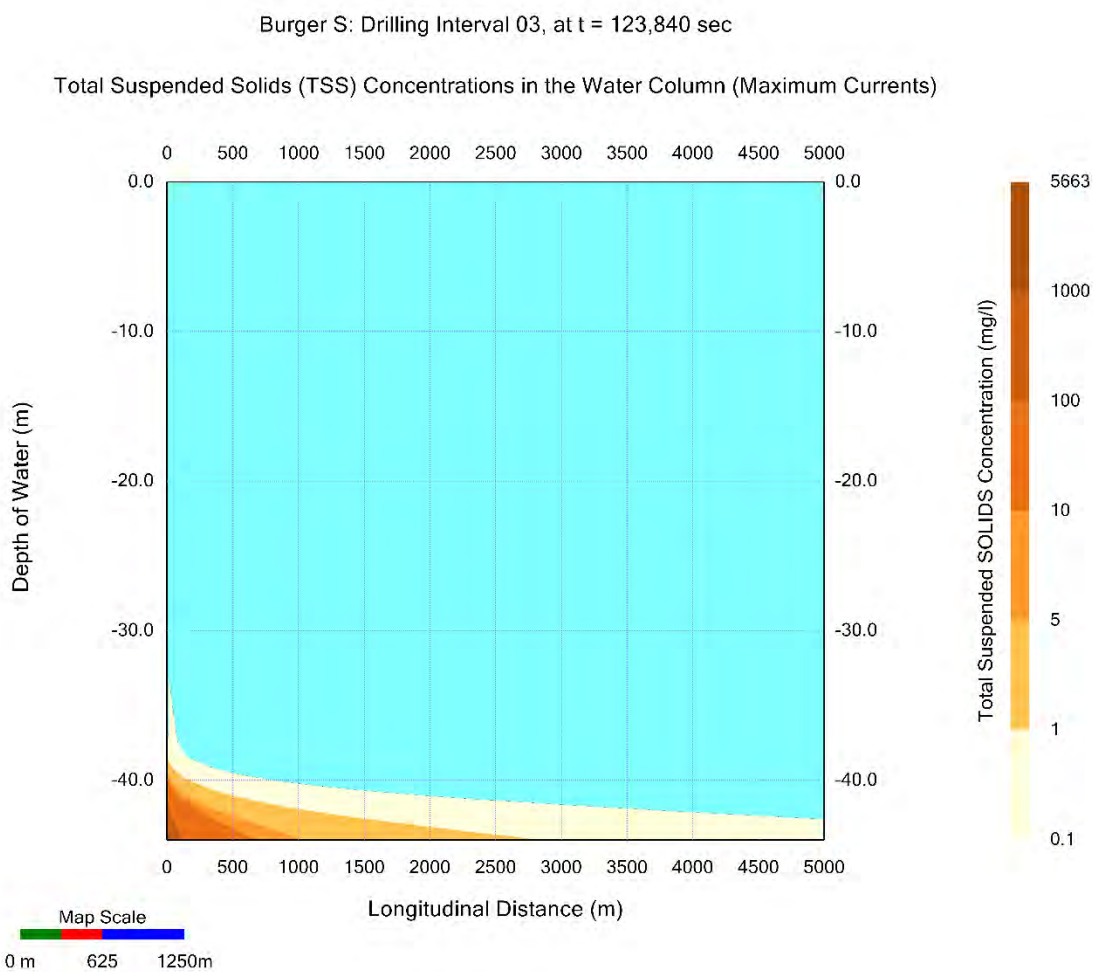
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **123**,**840** sec (or **34**.**4** hours) which is the discharge duration for this drilling interval is presented in **Figure 6-13a**. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **42**.**17** m from a **12.0** inches internal diameter discharge pipe. Figure **6-13**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **5**,**662** mg/l occurs at the source. It decreases to a value of **100** mg/l at a distance approximately **125** m from the discharge location. It varies from **100** to **10** mg/l between **125** and **650** m distances from the discharge location. It varies from **10** to **5** mg/l between **650** and **1**,**000** m distances from the discharge location. It varies from **5** to **1** mg/l between **1**,**000** and **2**,**800** m distances from the discharge location. It is less than **1** mg/l beyond **2**,**800** m from the discharge location. The effect of the sea floor pump is visible in this Figure **6**-**13a**. The discharge plume is spreading farther horizontally to the east along the direction of the current than vertically. The TSS concentration is less than **0.1** mg/l at a depth approximately **30** m at or near the discharge location. It is less than **1** mg/l at a depth approximately **40** m at **500** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **988.6, 353.4**, **121.6**, **33.9**, and **5.2** mg/l, respectively.

Figure 6-13a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 03

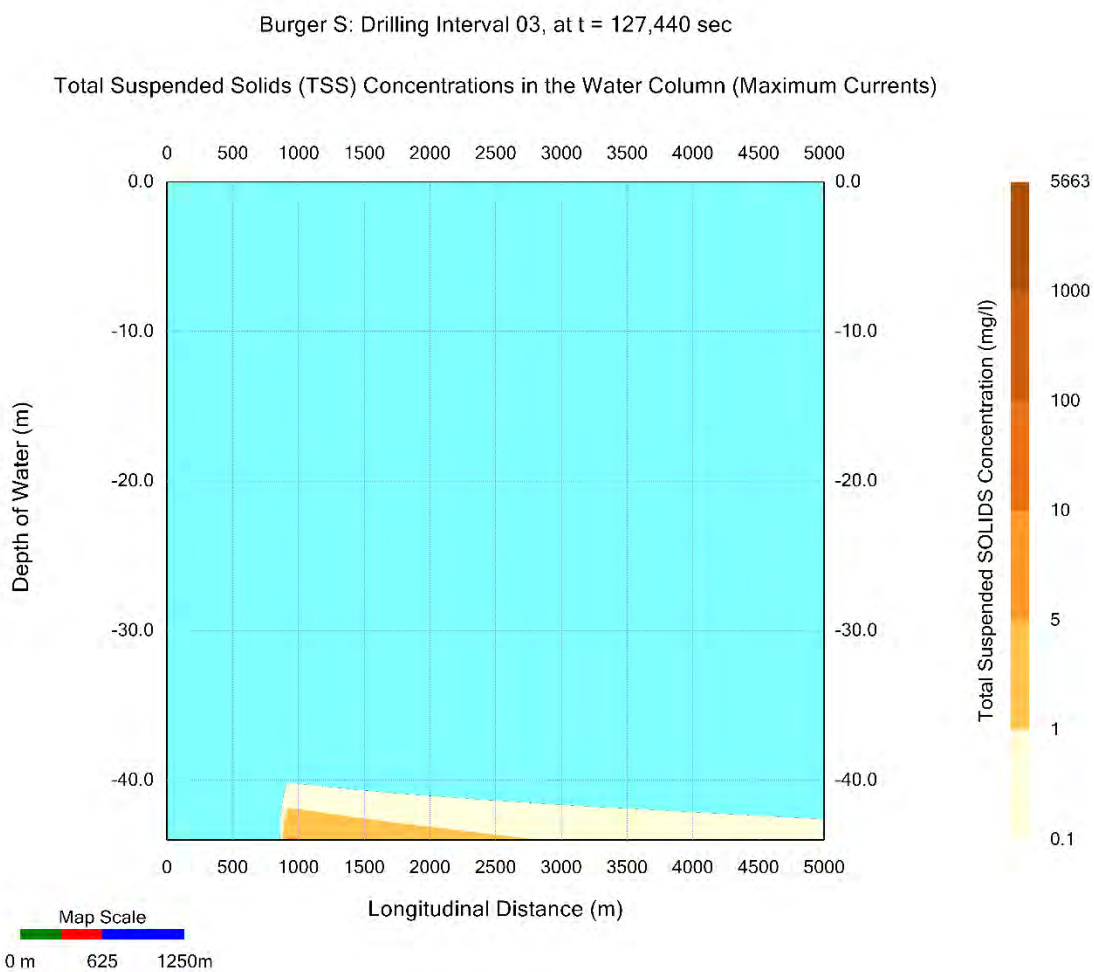


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

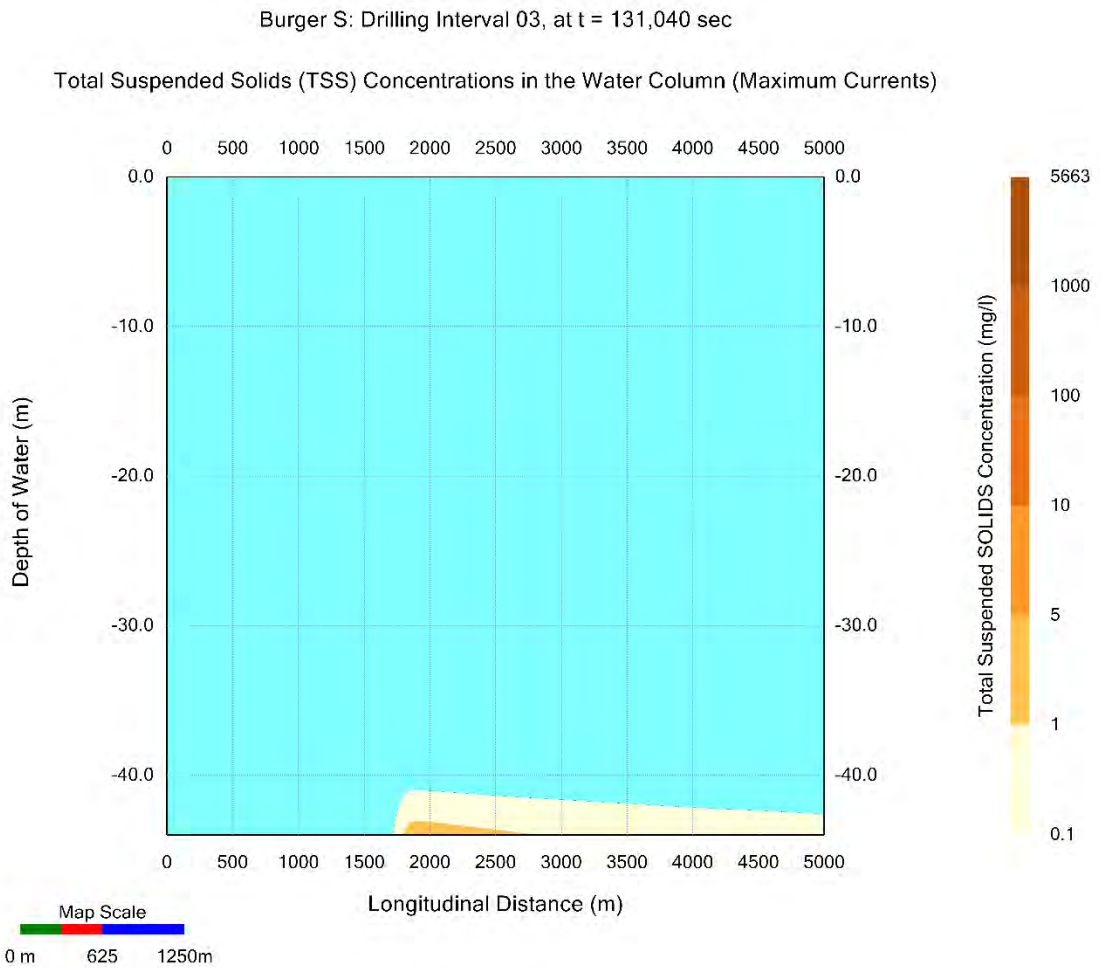
The discharge of the cements, water based drill cuttings, and drill fluids ceases at time, t = **123**,**840** sec (or **34**.**4** hours). The fate and transport of the discharged solids at times **1**, **2**, **3**, **4, 5**, and **6** h after the cessation of the discharge are presented by **Figures 6-13**b**, 6-13**c**, 6-13**d**, 6-13**e**, 6-13**f**,** and **6-13**g. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **5** mg/l or less at **1** h, **5** mg/l or less at **2** h, **1** mg/l or less at **3** h, **1** mg/l or less at **4** h, **1** mg/l or less at **5** h, and less than **0**.**1** mg/l at **6** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **5** and **6** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 6-13b: TSS concentrations during the maximum currents at 35.4 h (or 1 h after the cessation of release)



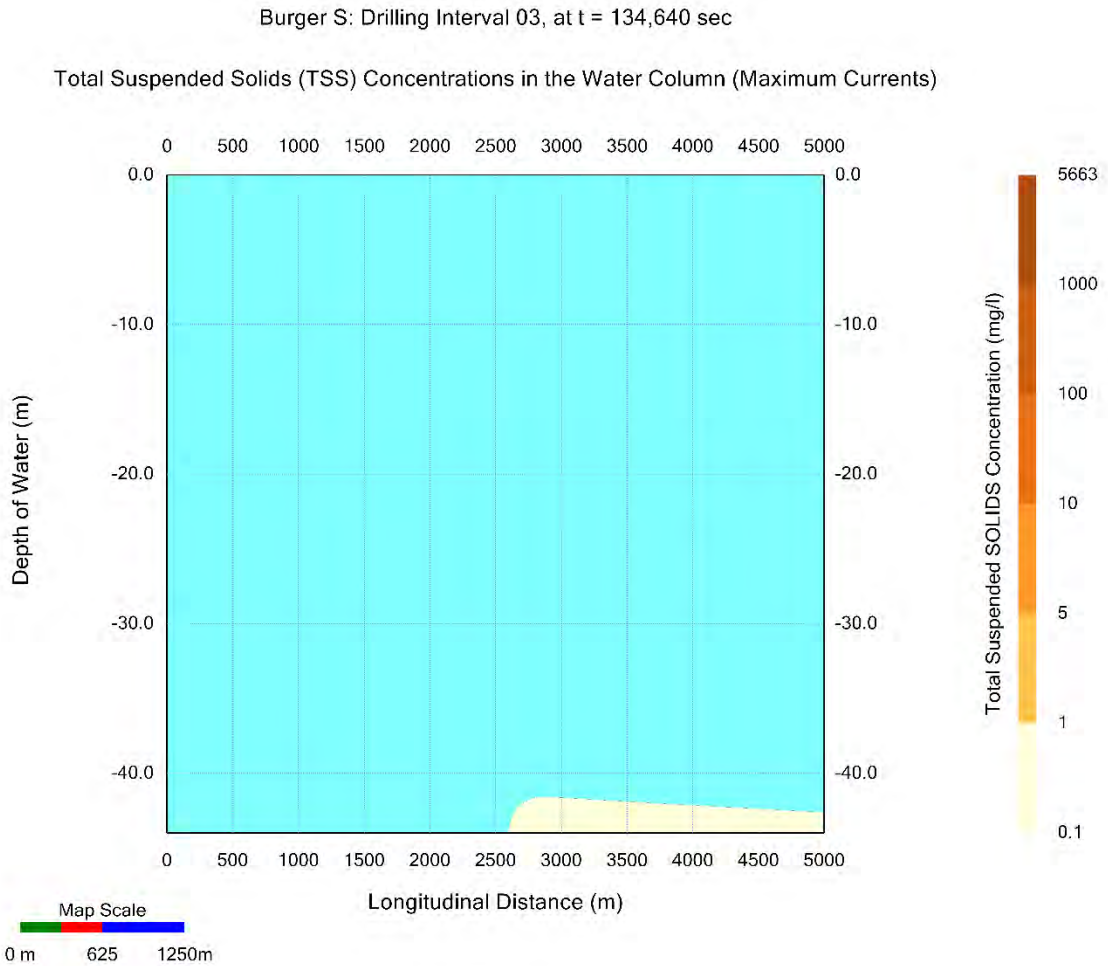
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-13c: TSS concentrations during the maximum currents at 36.4 h (or 2 h after the cessation of release)



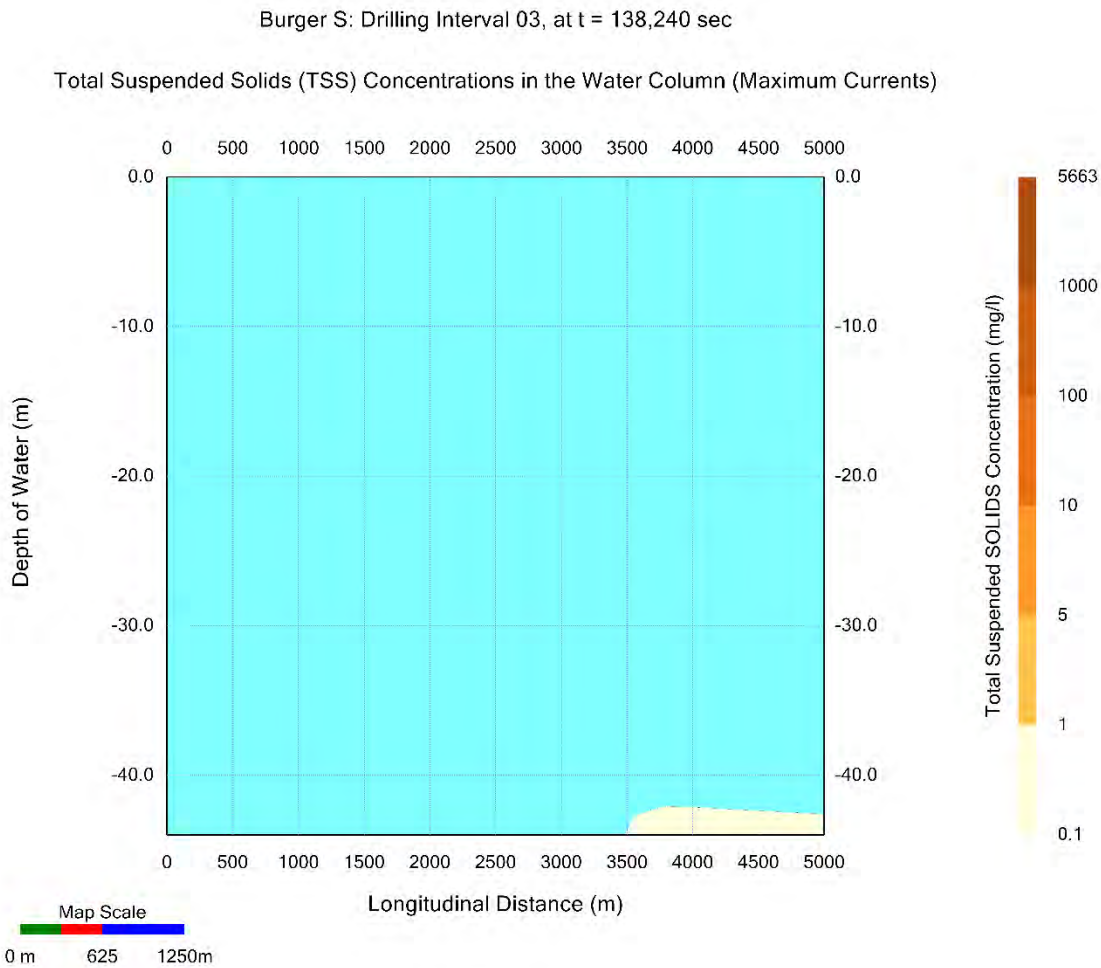
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-13d: TSS concentrations during the maximum currents at 37.4 h (or 3 h after the cessation of release)



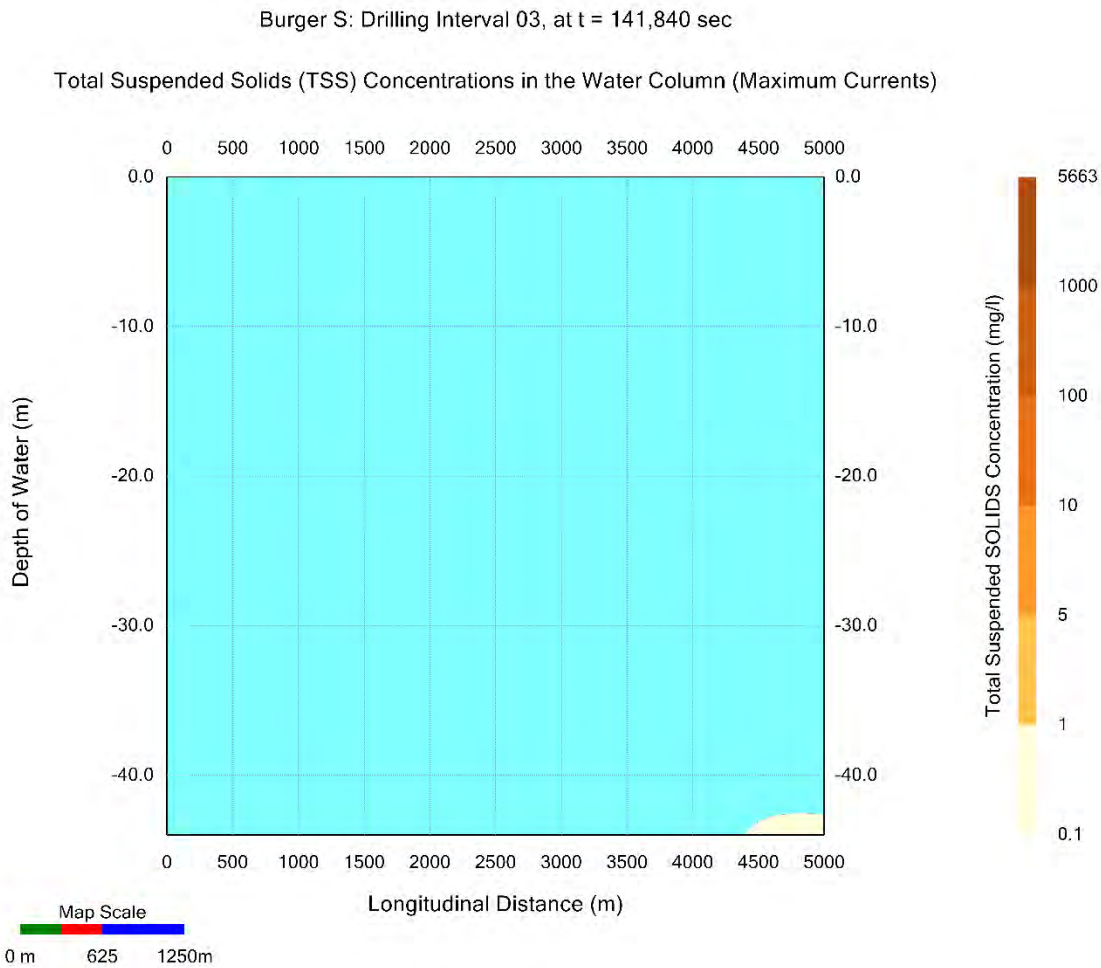
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-13e: TSS concentrations during the maximum currents at 38.4 h (or 4 h after the cessation of release)



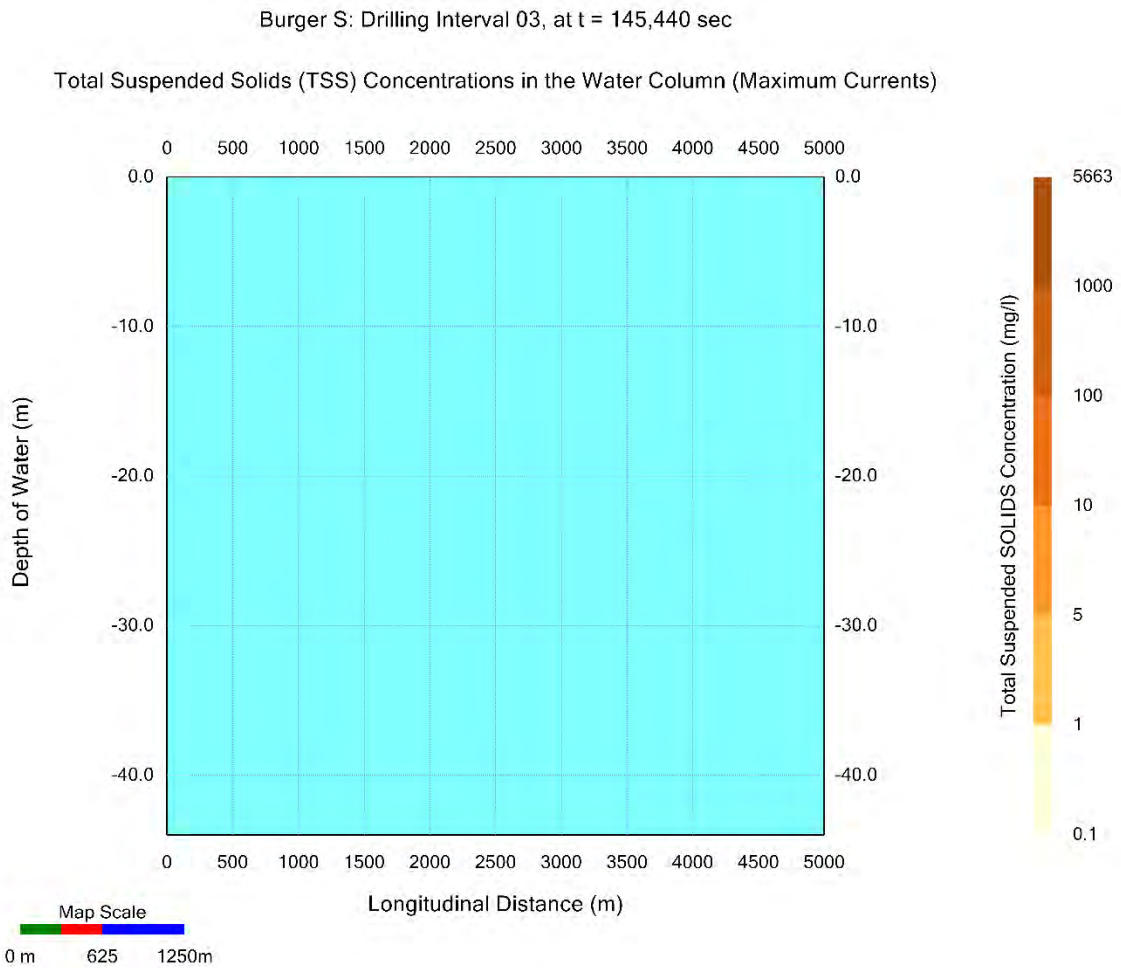
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-13f: TSS concentrations during the maximum currents at 39.4 h (or 5 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-13g: TSS concentrations during the maximum currents at 40.4 h (or 6 h after the cessation of release)



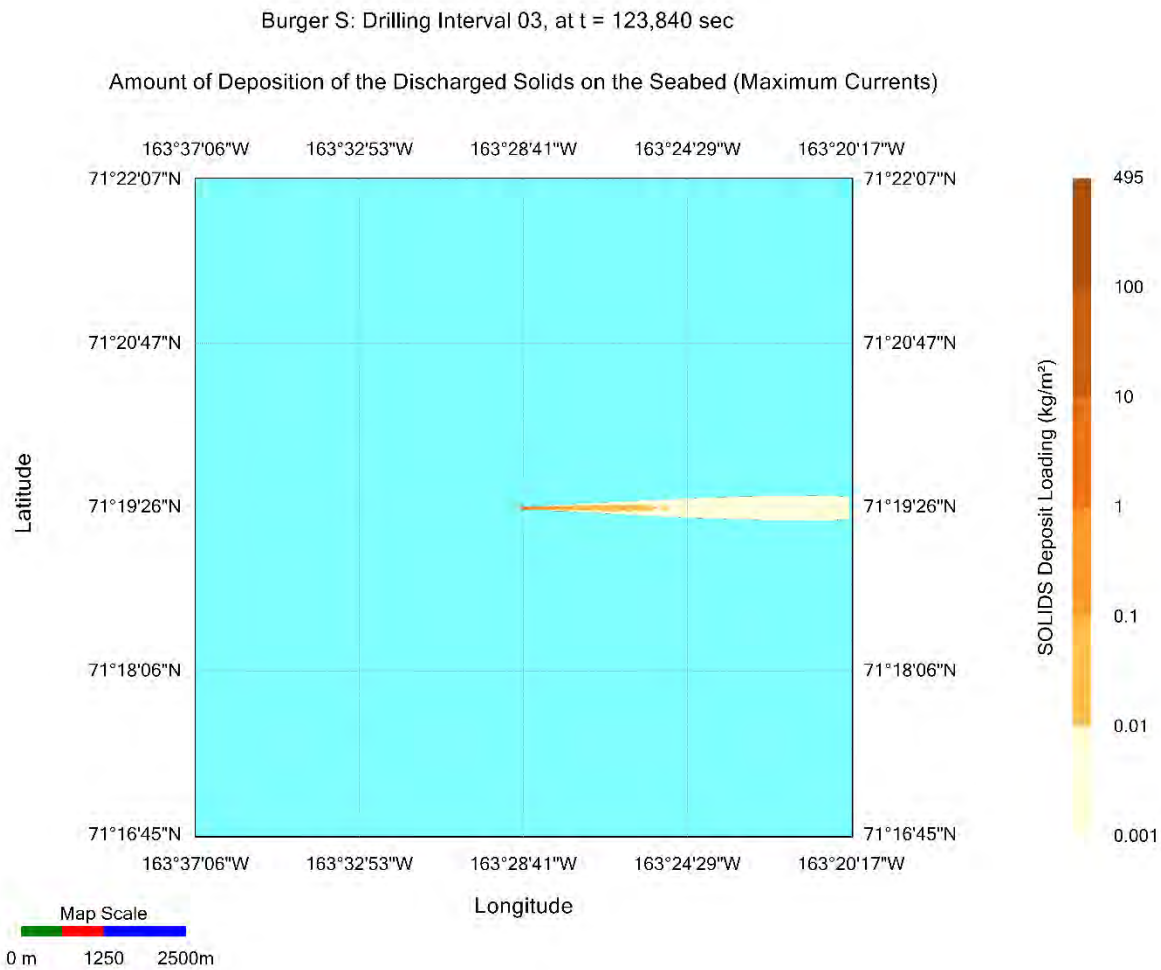
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **123**,**840** sec (or **34**.**4** hours) as a result of the discharge of the cements, water based drill cuttings, and drill fluids on a plan view is presented in **Figure 6-14**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **6**-**14**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **494** kg/m^2 occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **60** m and **105** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **105** and **775** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **775** and **2,250** m distances from the discharge location. The loading is less than **0**.**01** kg/m^2 beyond **2,250** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**115**, **0**.**264**, **0**.**512**, **3**.**165**, and **15**.**919** ha, respectively.

Figure 6-14: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 03



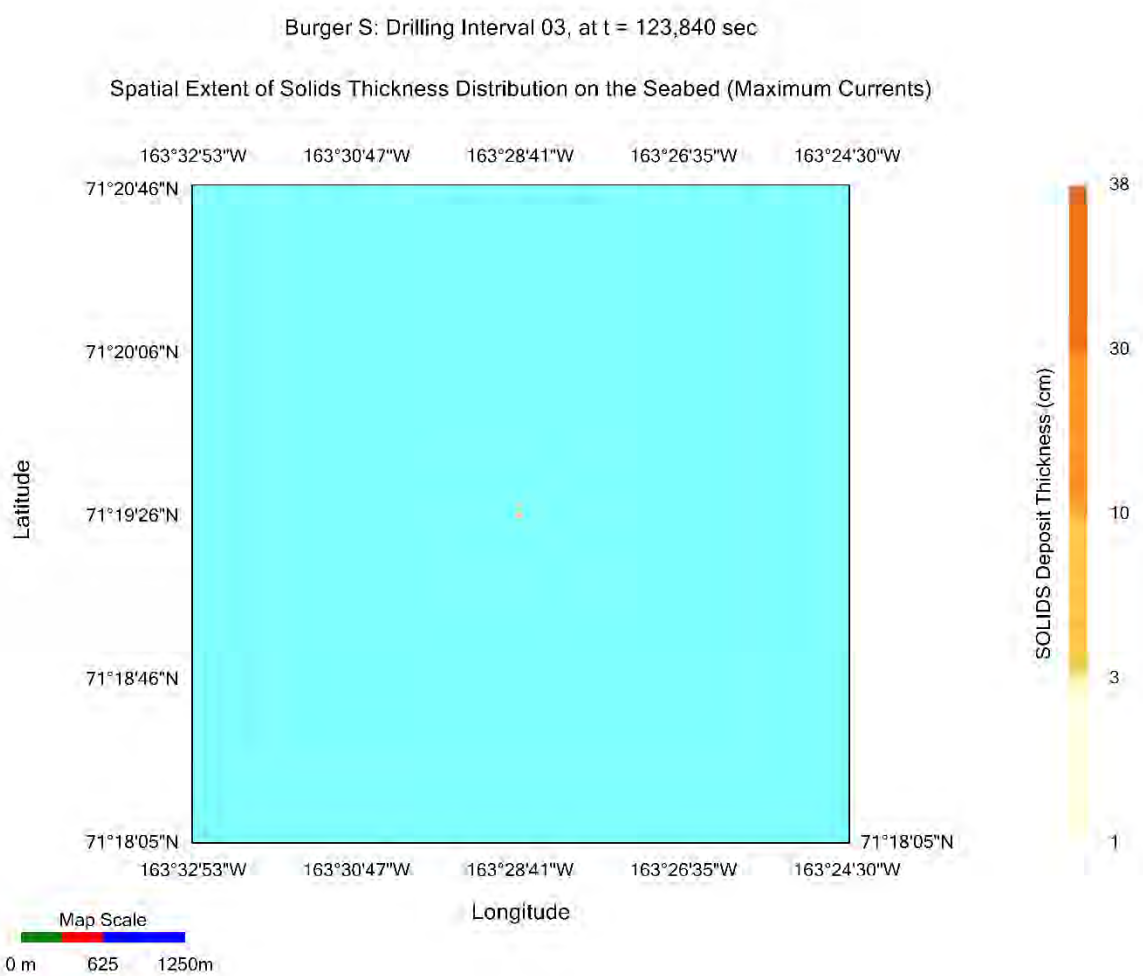
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **123,840** sec (or **34.4** hours) as a result of the discharge of the cements, water based drill cuttings, and drill fluids on a plan view is presented in **Figures 6-15a** and **6-15b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5.0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **6-15**a. The same result is presented in Figure **6-15**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **37.3** cm occurs at **10** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **55** m from the discharge location.

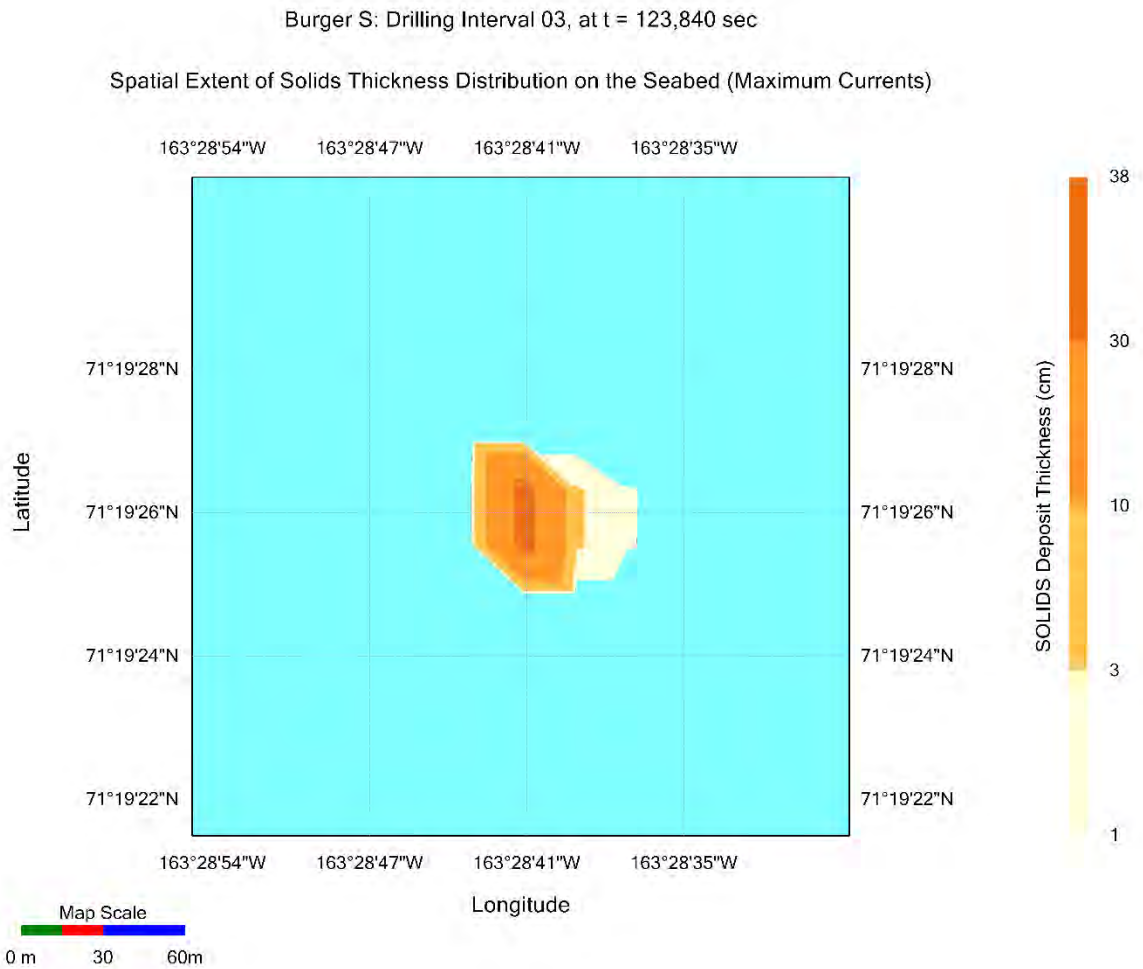
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **60** m x **40** m rectangle area (or **0.248** ha) as presented in Figure **6-15**b. The sea floor areas affected by deposit thickness larger than **10**- and **1**-cm are: **0.112** and **0.248** ha, respectively.

Figure 6-15a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 03



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-15b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 03 (Zoom In View)



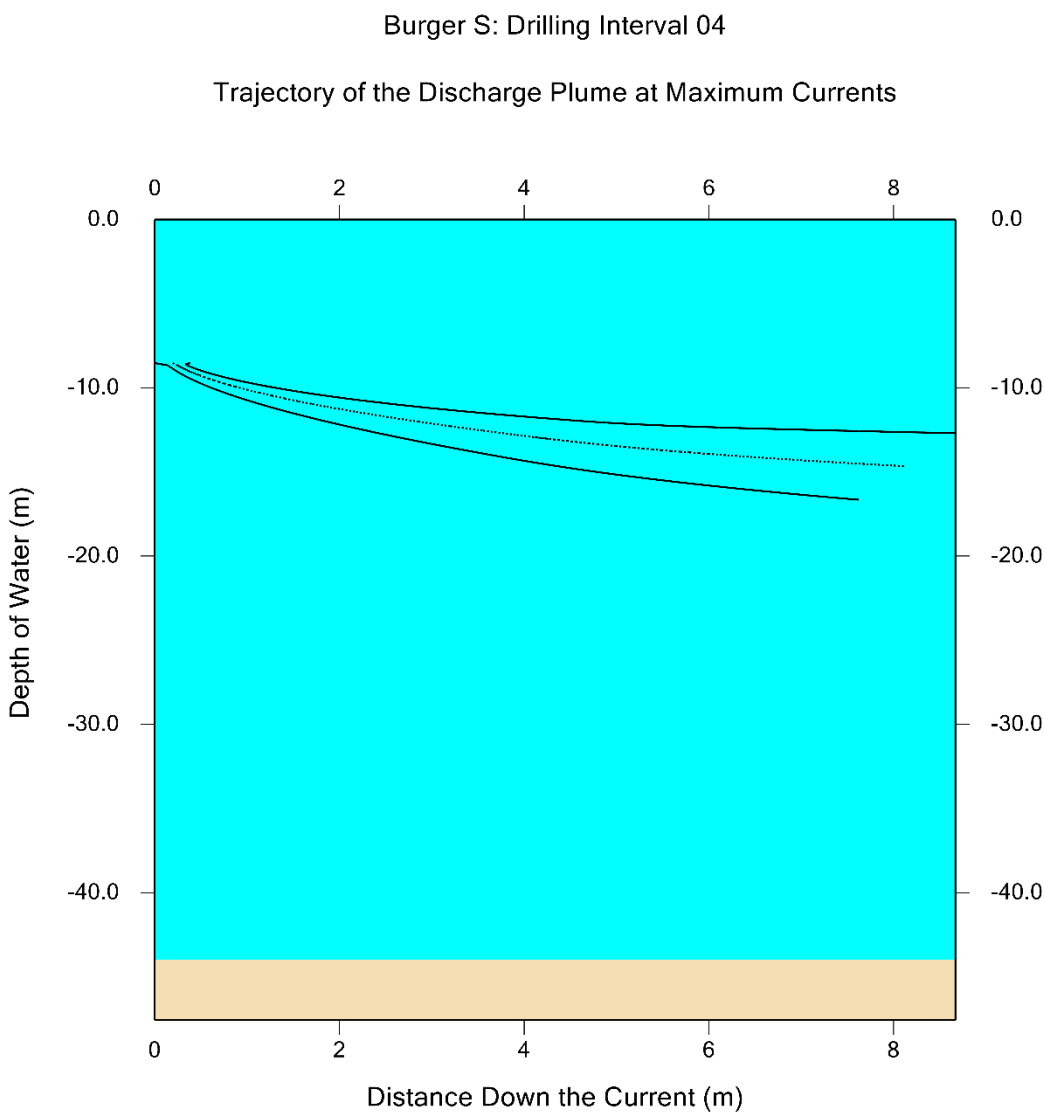
Copyright **2014** by Fluid Dynamix. Company Confidential.

6.4 Model Results for Sea Surface Discharge Scenario – Drilling Interval 04

Trajectory and Shape of the Discharge Plume

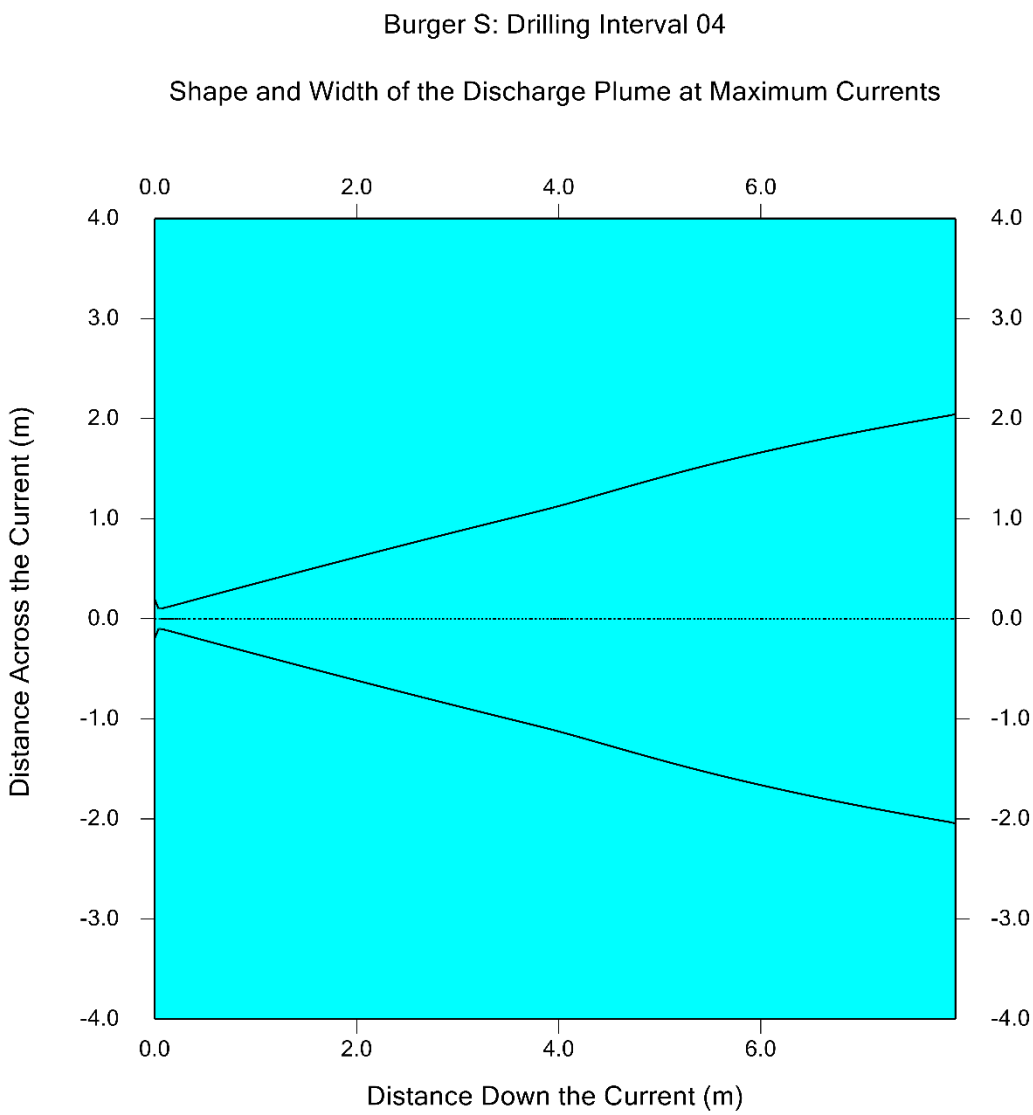
The trajectory of the discharge plume is presented in **Figure 6-16**. The depth of water is **44.0** m and the discharge occurs at a depth of **8.53** m below the sea surface. The heavier plume travels approximately **8.0** m from the discharge location before collapsing into the ambient sea water due to the higher density of the discharge plume. The shape and width of the discharge plume is presented in **Figure 6-17**. The width of the plume is approximately **4.1** m at a distance **8.0** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **6-16** and **6-17**.

Figure 6-16: Trajectory of the discharge plume at maximum currents, Drilling Interval 04



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-17: Shape and width of the discharge plume at maximum currents, Drilling Interval 04



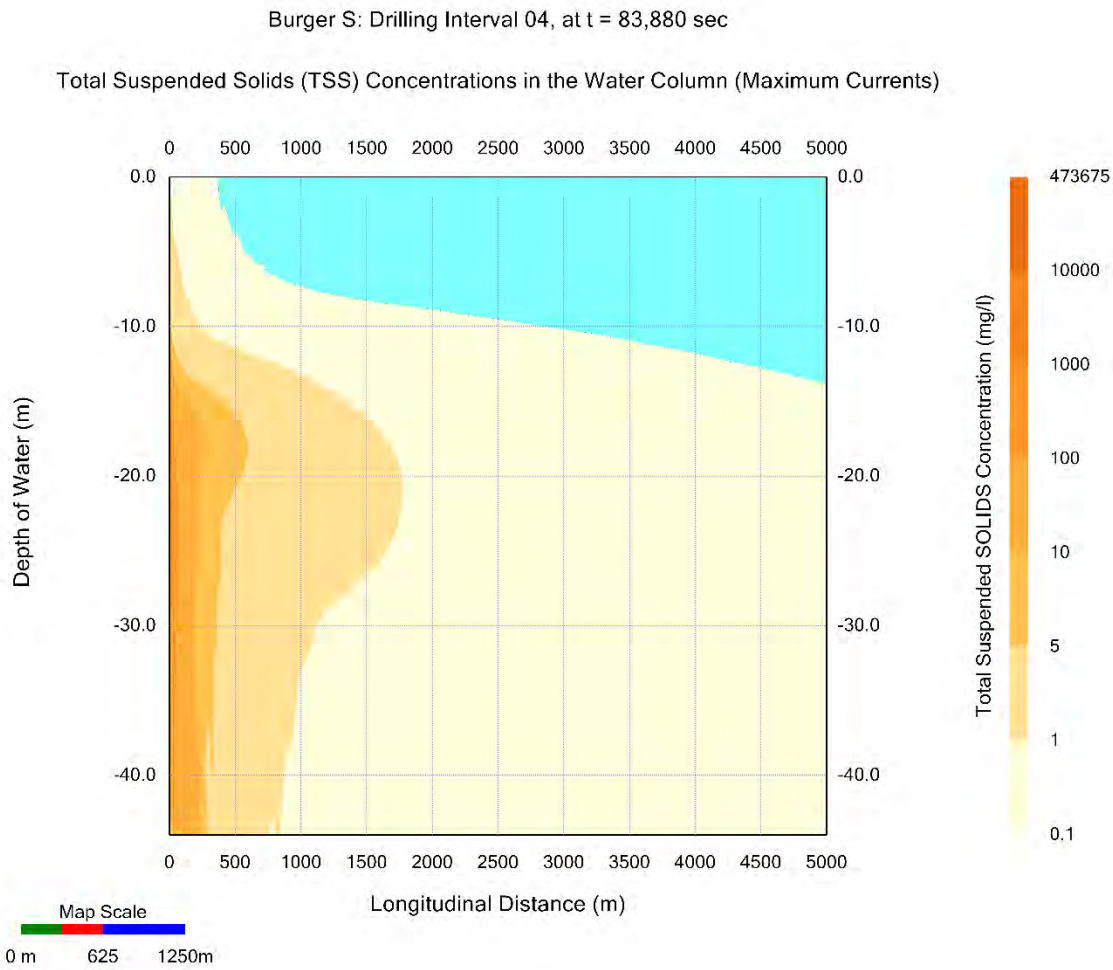
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **83**,**880** sec (or **23**.**3** hours) which is the discharge duration for this drilling interval is presented in **Figure 6-18a**. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **8.53** m from a **15.25** inches internal diameter discharge pipe. Figure **6-18**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **473,675** mg/l occurs at the discharge location. It decreases to a value of **100** and **10** mg/l at distances approximately: **90** and **275** m, respectively from the discharge location. It varies from **10** to **5** mg/l between **275** and **600** m distances from the discharge location. It varies from **5** to **1** mg/l between **600** and **1**,**800** m distances from the source. It is less than **1** mg/l beyond **1**,**800** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **1,045.9**, **335**.**4**, **90.1**, **9.3**, and **2.5** mg/l, respectively.

Figure 6-18a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 04

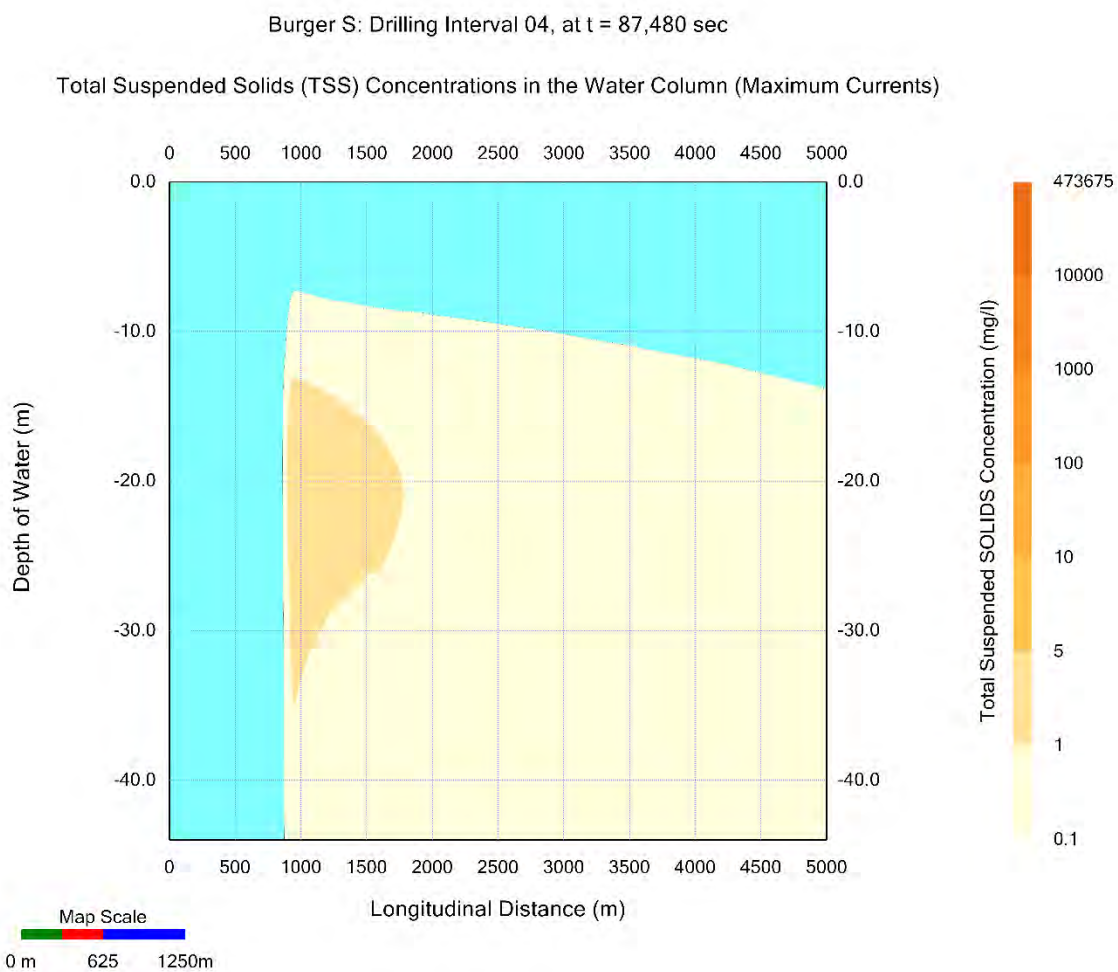


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

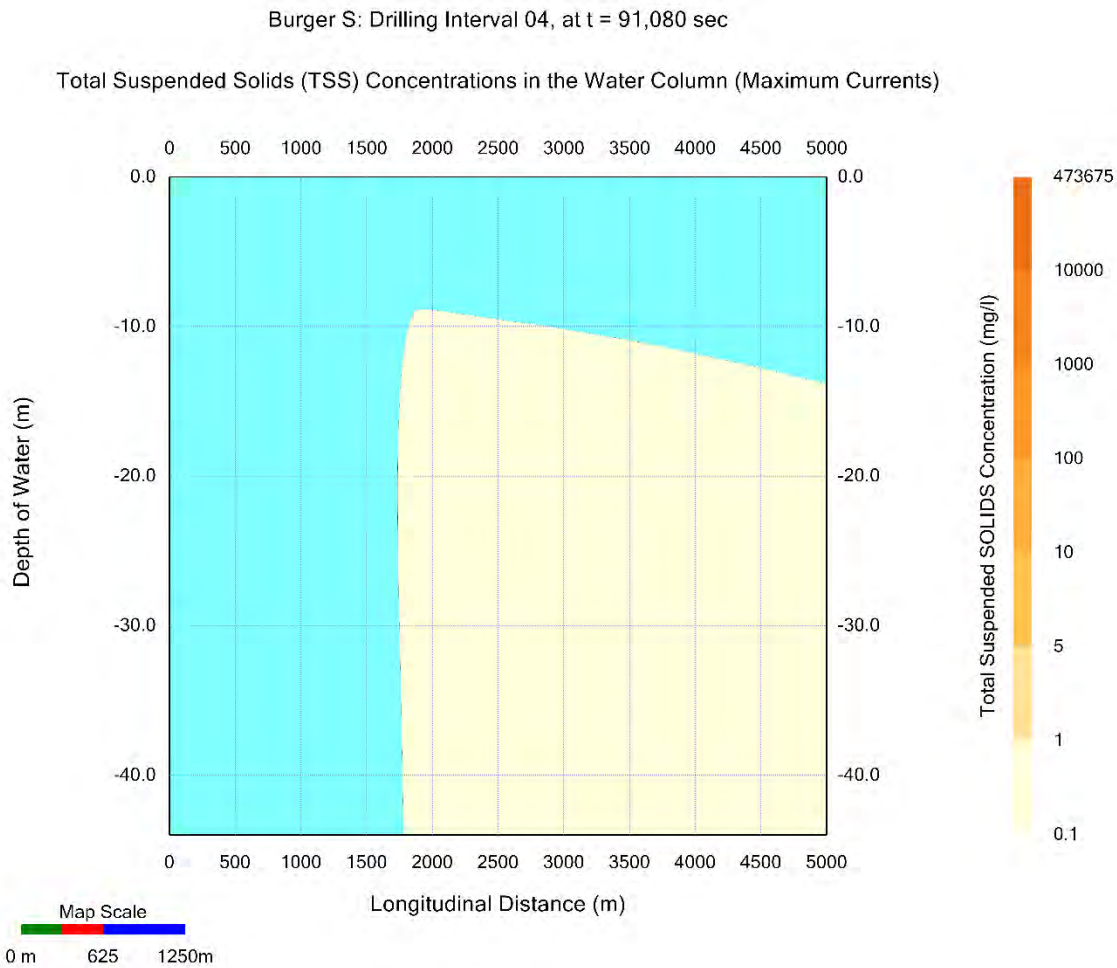
The discharge of the water based drill cuttings and drill fluids ceases at time, t = **83**,**880** sec (or **23**.**3** hours). The fate and transport of the discharged solids at times **1**, **2**, **3**, **4, 5**, and **6** h after the cessation of the discharge are presented by **Figures 6-18**b**, 6-18**c**, 6-18**d**, 6-18**e**, 6-18**f**,** and **6-18**g. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **5** mg/l or less at **1** h, **1** mg/l or less at **2** h, **1** mg/l or less at **3** h, **1** mg/l or less at **4** h, **1** mg/l or less at **5** h, and less than **0**.**1** mg/l at **6** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **5** and **6** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 6-18b: TSS concentrations during the mean currents at 24.3 h (or 1 h after the cessation of release)



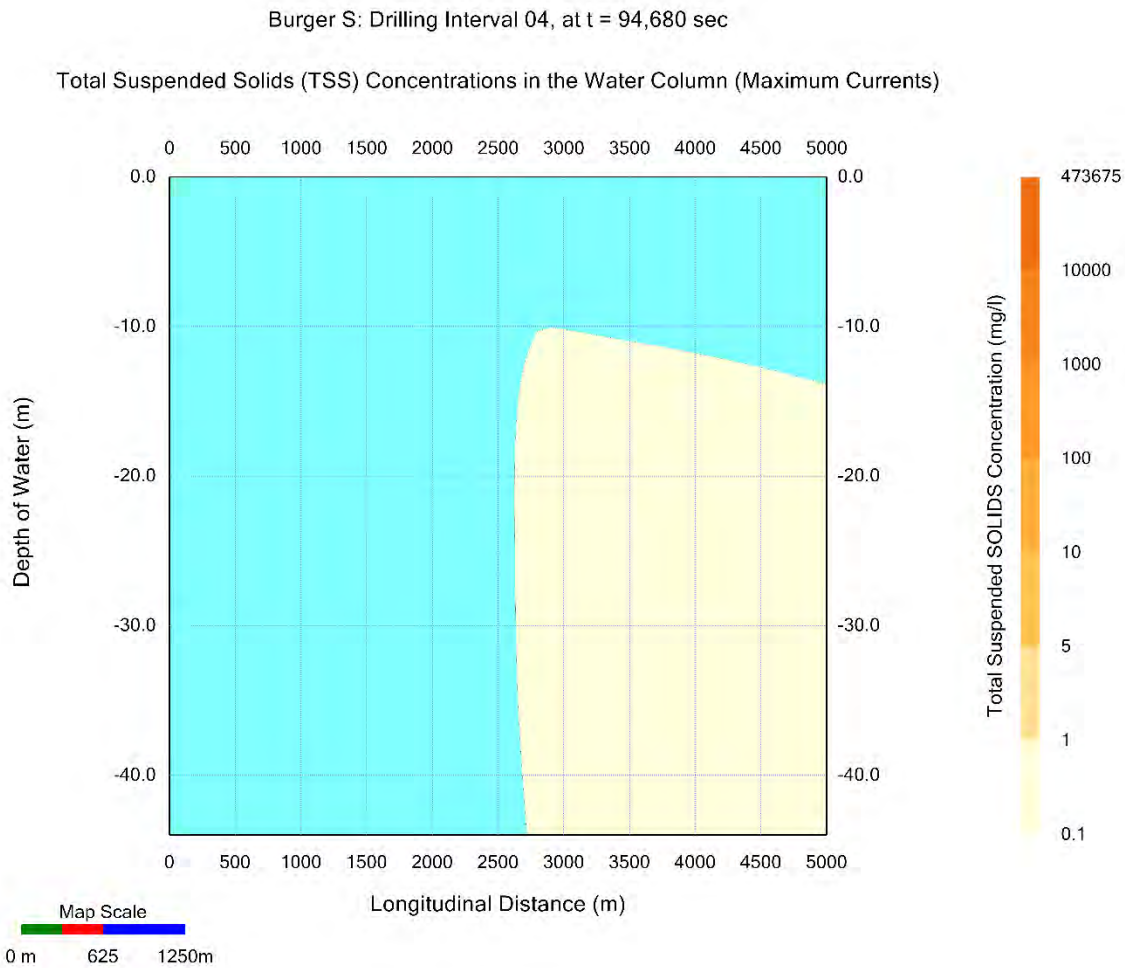
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-18c: TSS concentrations during the mean currents at 25.3 h (or 2 h after the cessation of release)



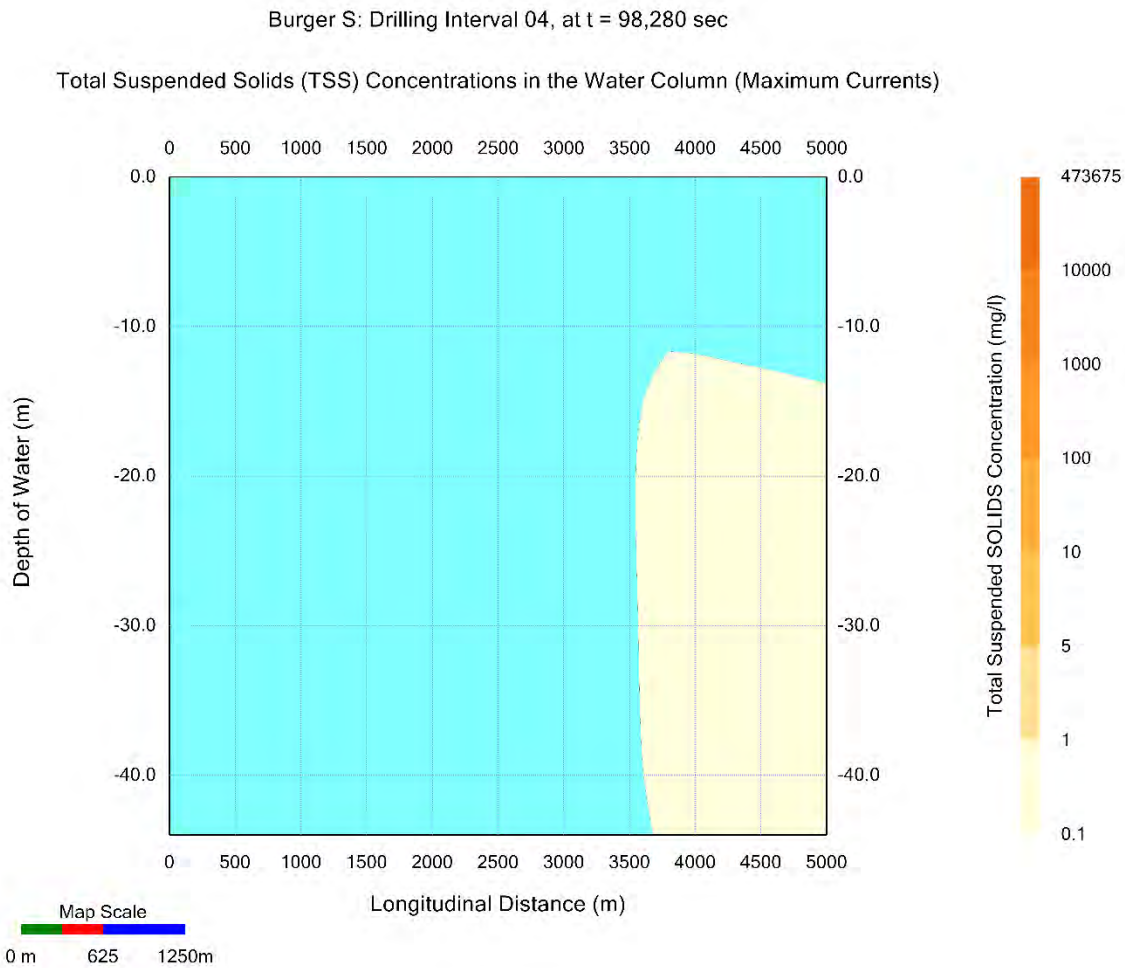
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-18d: TSS concentrations during the mean currents at 26.3 h (or 3 h after the cessation of release)



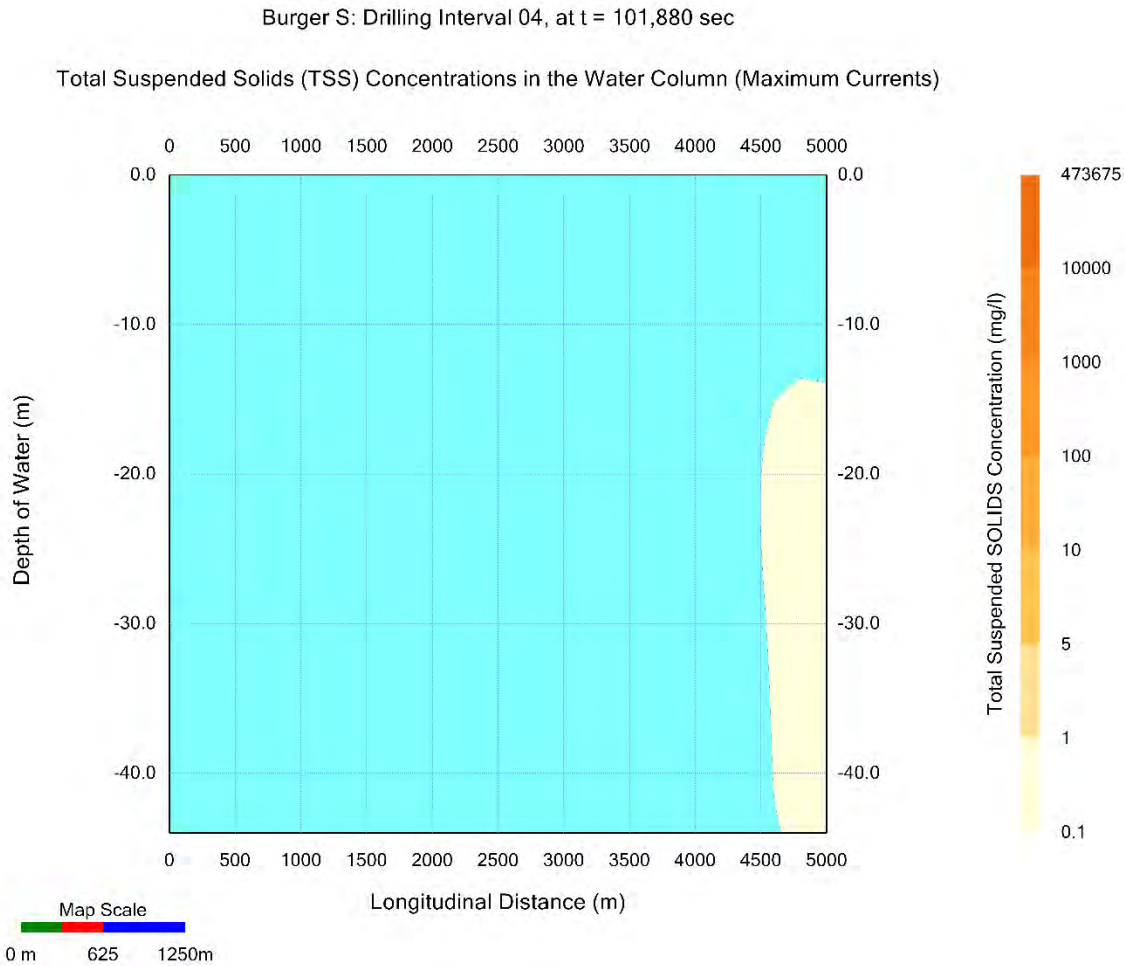
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-18e: TSS concentrations during the mean currents at 27.3 h (or 4 h after the cessation of release)



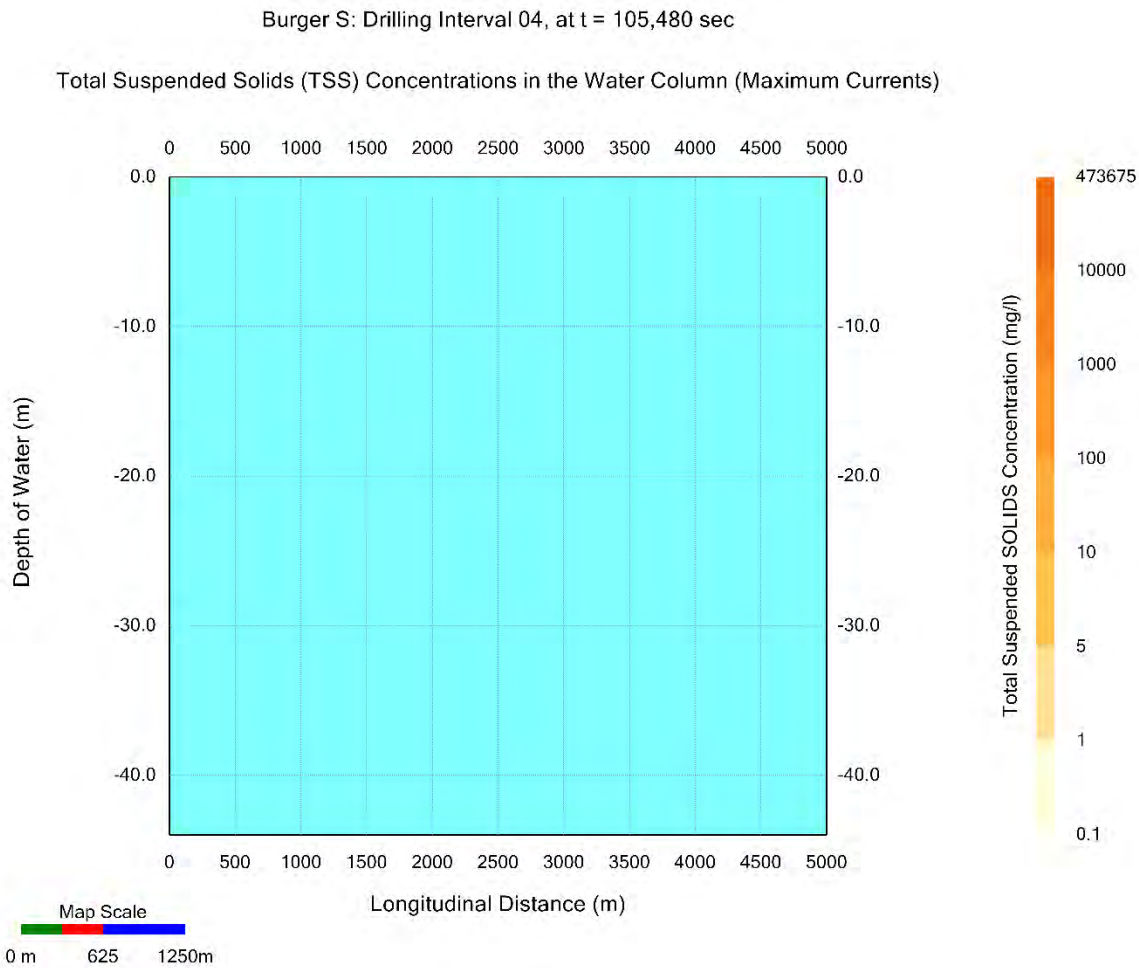
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-18f: TSS concentrations during the mean currents at 28.3 h (or 5 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-18g: TSS concentrations during the mean currents at 29.3 h (or 6 h after the cessation of release)



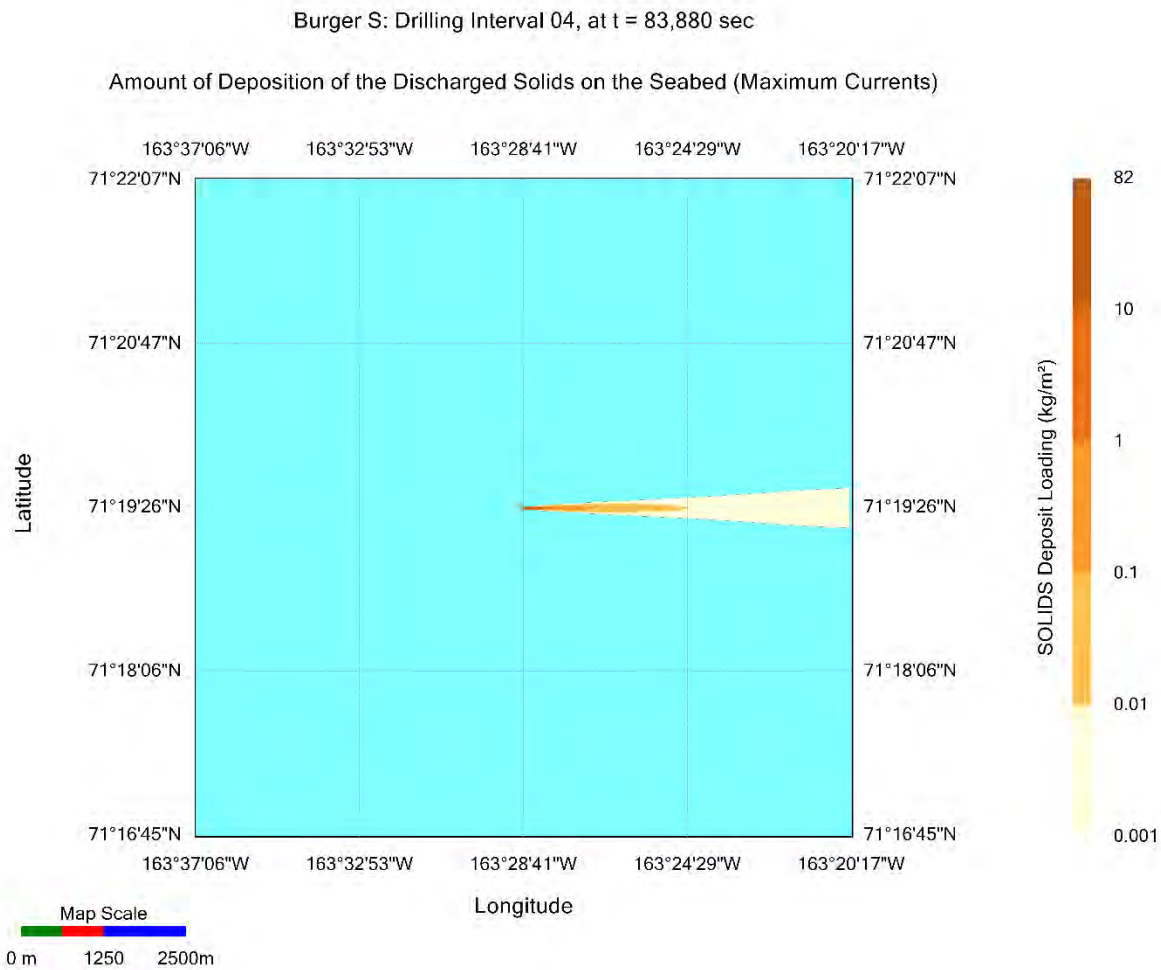
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **83,880** sec (or **23.3** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented **in Figure 6-19.** The model domain extends to **5.0** km in all directions from the discharge location as shown in Figure **6-19**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **81** kg/m^2 occurs at **30** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **175** m and **460** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0.1** kg/m^2 approximately between **460** and **1,120** m distances from the discharge location. It varies from **1** kg/m^2 to **0.1** kg/m^2 approximately between **1,120** and **2,500** m distances from the discharge location. It is less than **0.01** kg/m^2 beyond **2,500** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **10**-, **1**-, **0.1**-, and **0.01**-kg/m^2 are: **0.650**, **1.920**, **4.710**, and **23.951** ha, respectively.

Figure 6-19: Amount of deposition of the solids on the seabed at maximum currents, Drilling Interval 04



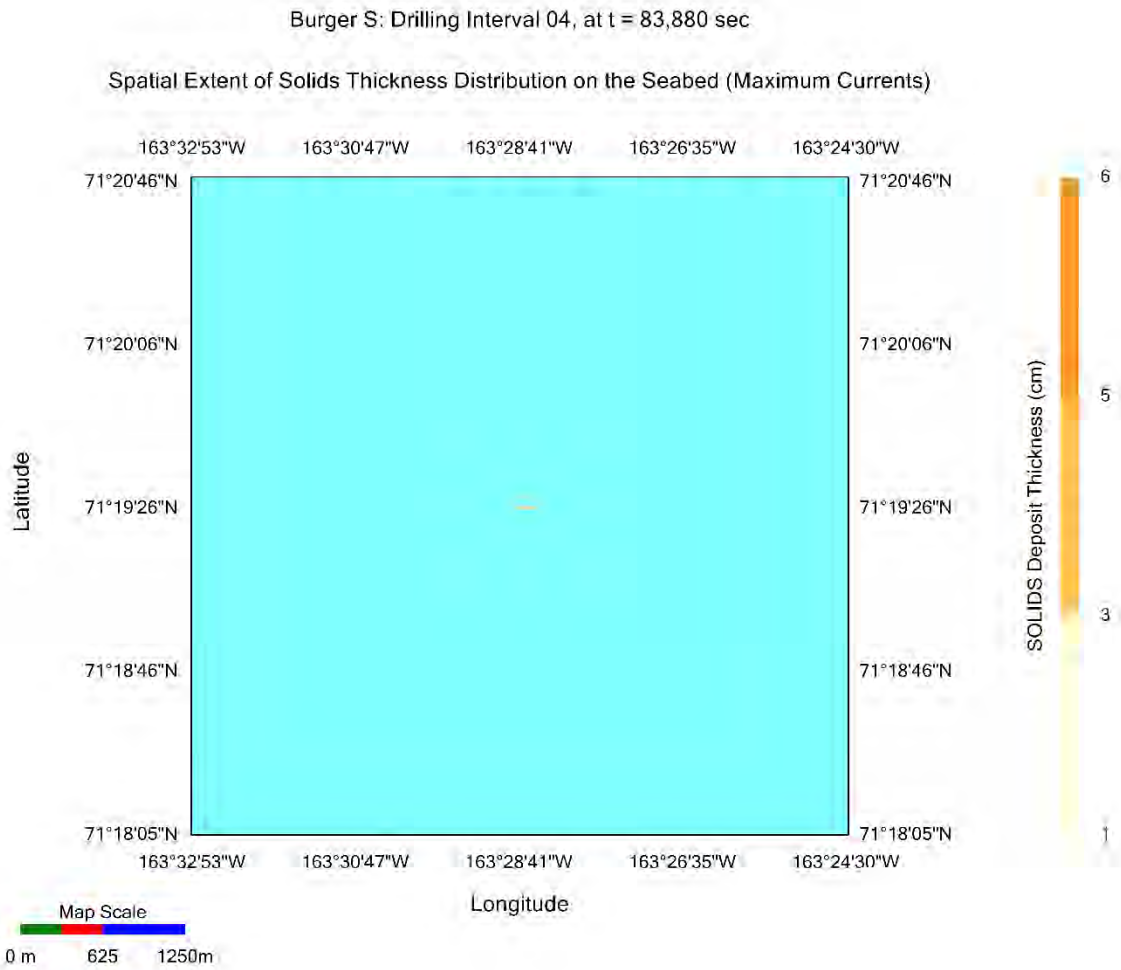
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **83,880** sec (or **23.3** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 6-20a** and **6-20b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5.0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **6-20**a. The same result is presented in Figure **6-20**b but shows only **480** m x **480** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **5.6** cm occurs at **30** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **150** m from the discharge location.

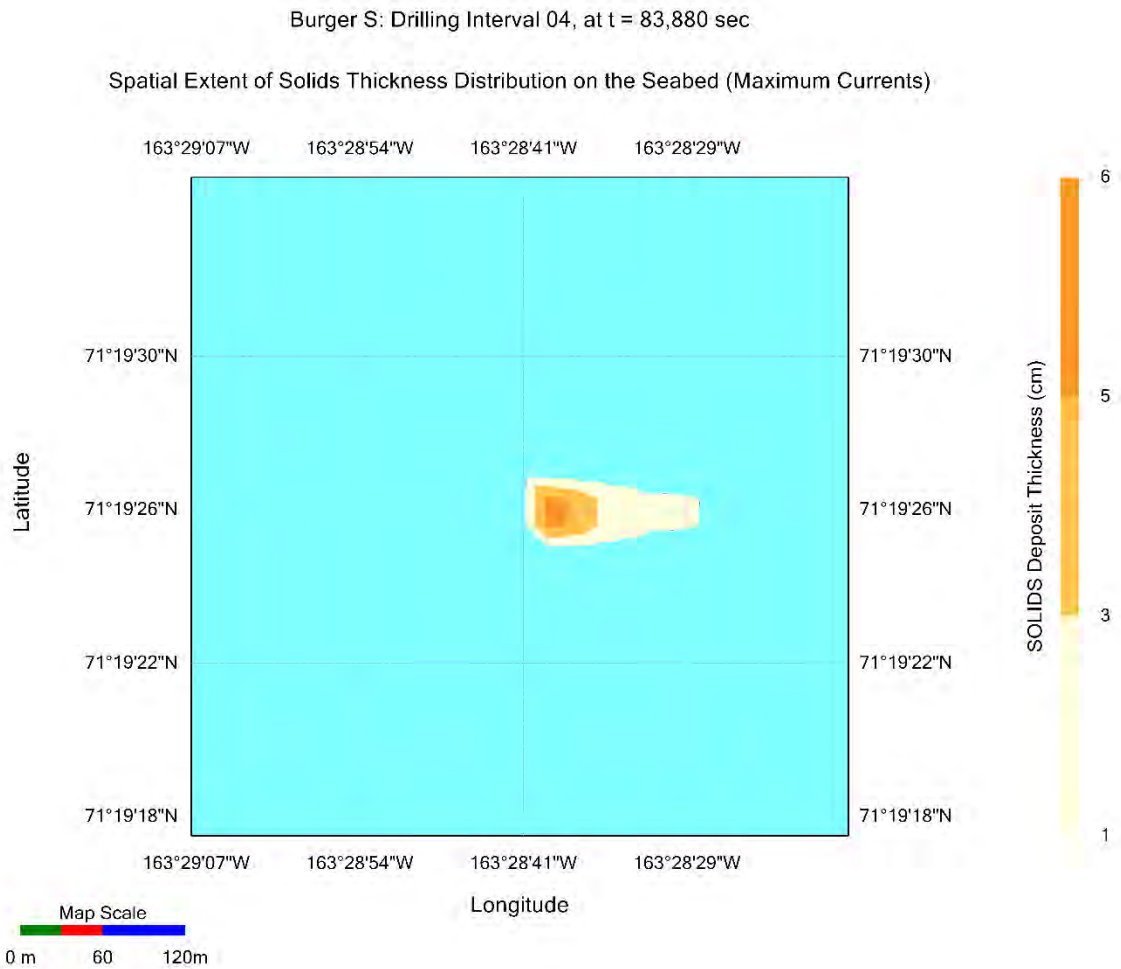
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **130** m x **40** m rectangle area (or **0.512** ha) as presented in Figure **6-20**b.

Figure 6-20a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 04



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-20b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 04 (Zoom In View)



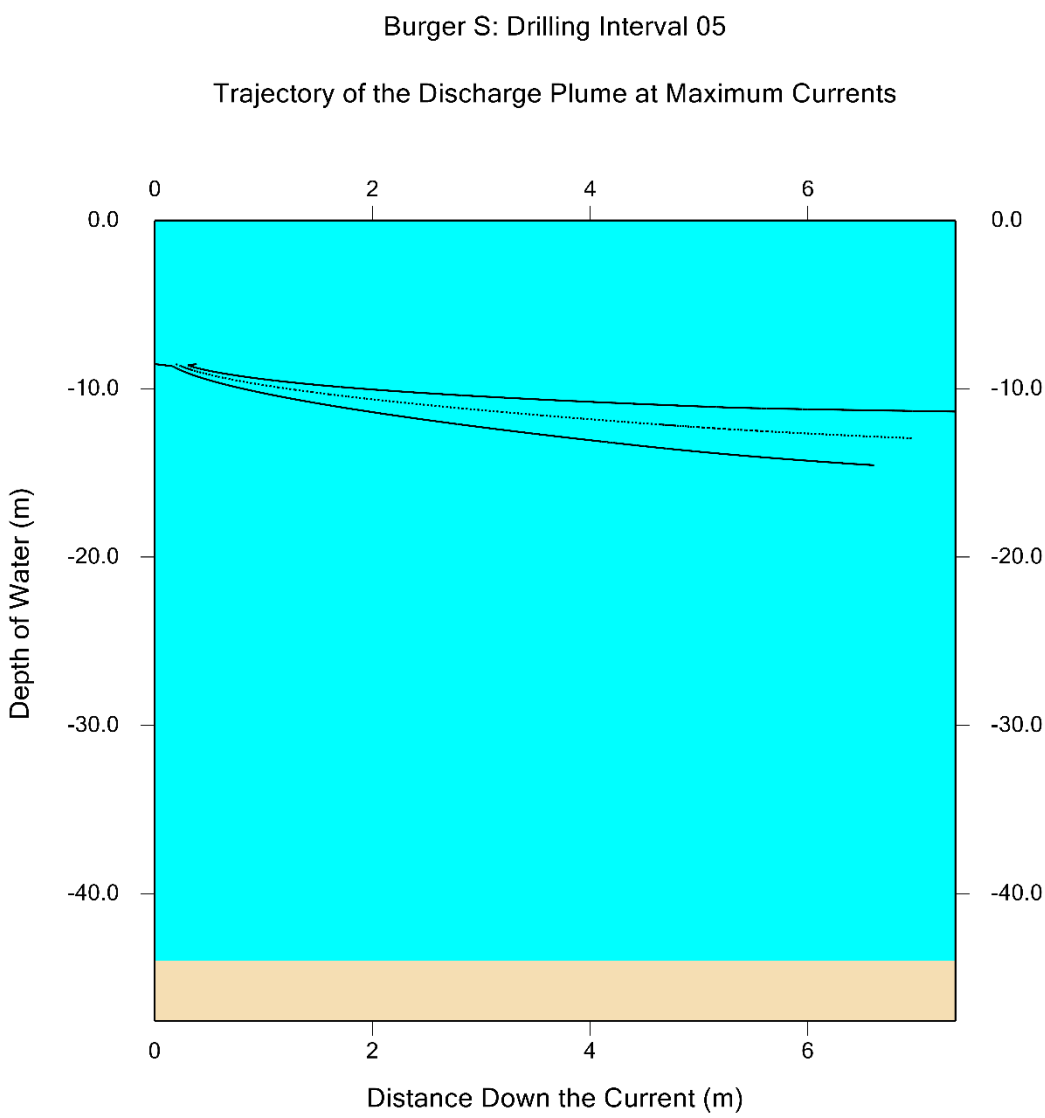
Copyright **2014** by Fluid Dynamix. Company Confidential.

6.5 Model Results for Sea Surface Discharge Scenario – Drilling Interval 05

Trajectory and Shape of the Discharge Plume

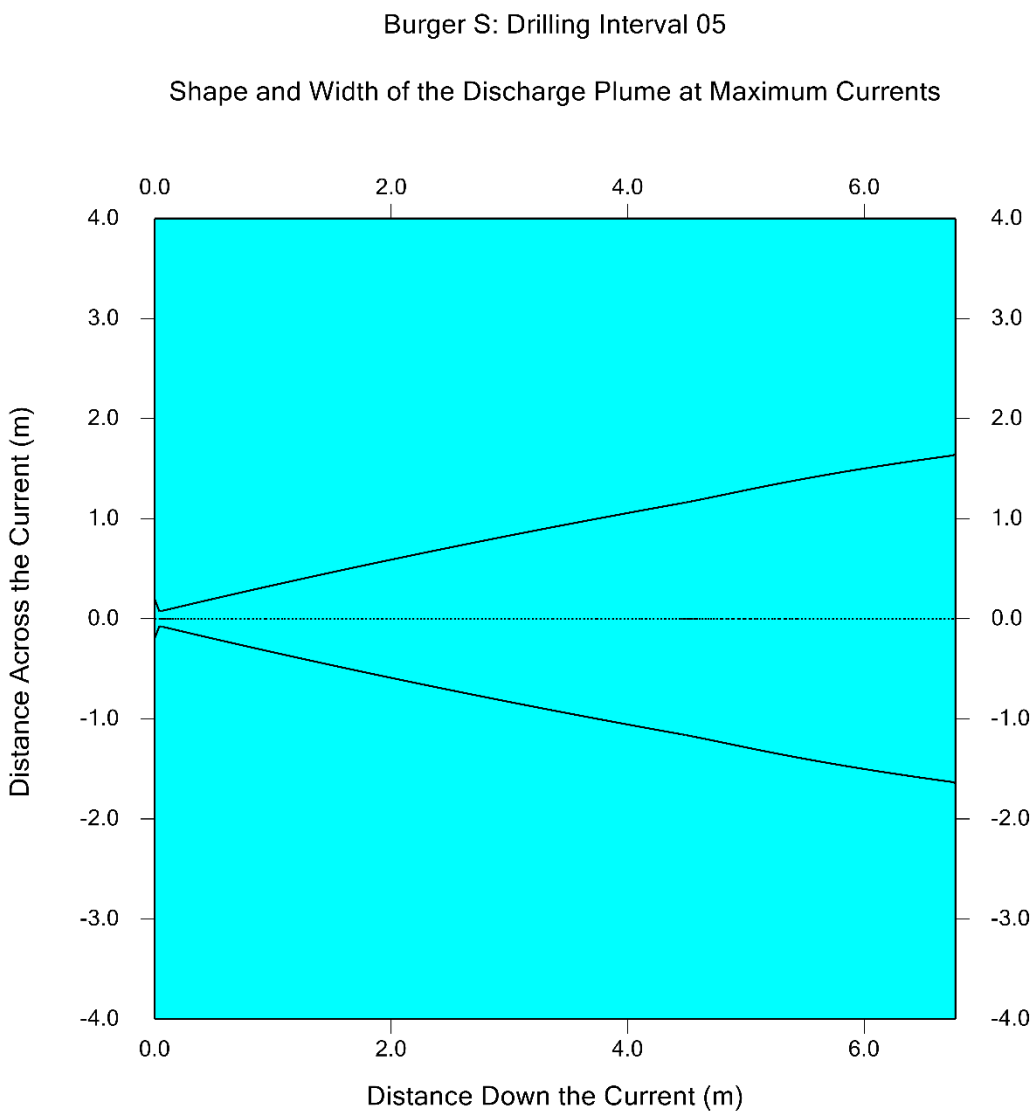
The trajectory of the discharge plume is presented in **Figure 6-21**. The depth of water is **44.0** m and the discharge occurs at a depth of **8.53** m below the sea surface. The heavier plume travels approximately **6.8** m from the discharge location before collapsing into the ambient sea water due to the higher density of the discharge plume. The shape and width of the discharge plume is presented in **Figure 6-22**. The width of the plume is approximately **3.25** m at a distance **6.8** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **6-21** and **6-22**.

Figure 6-21: Trajectory of the discharge plume at maximum currents, Drilling Interval 05



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-22: Shape and width of the discharge plume at maximum currents, Drilling Interval 05



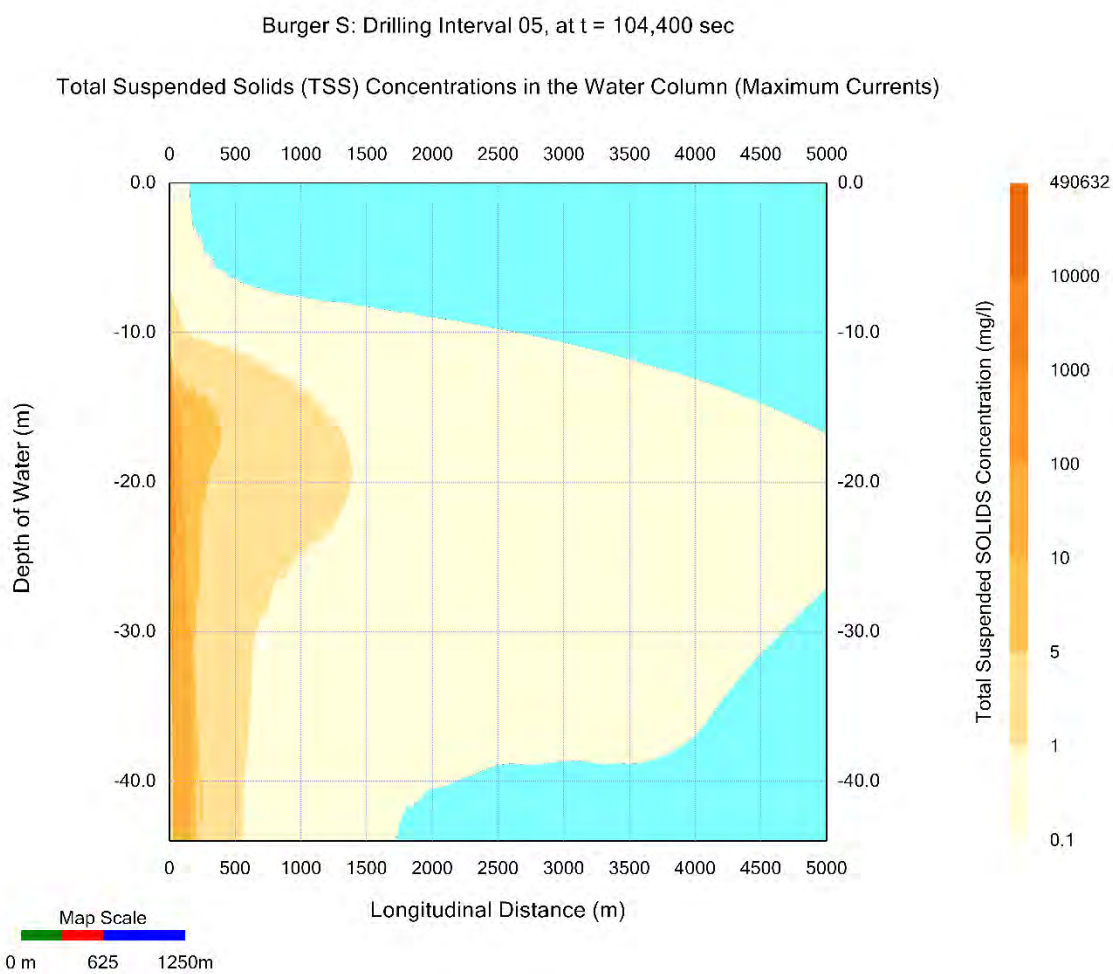
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **104**,**400** sec (or **29**.**0** hours) which is the discharge duration for this drilling interval is presented in **Figure 6-23a**. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **8.53** m from a **15.25** inches internal diameter discharge pipe. Figure **6-23**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **490,632** mg/l occurs at the discharge location. It decreases to a value of **100** and **10** mg/l at distances approximately: **50** and **185** m, respectively from the discharge location. It varies from **10** to **5** mg/l between **185** and **400** m distances from the discharge location. It varies from **5** to **1** mg/l between **400** and **1**,**400** m distances from the source. It is less than **1** mg/l beyond **1**,**400** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **538.6**, **153.1**, **35.6**, **6.0**, and **1.7** mg/l, respectively.

Figure 6-23a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 05

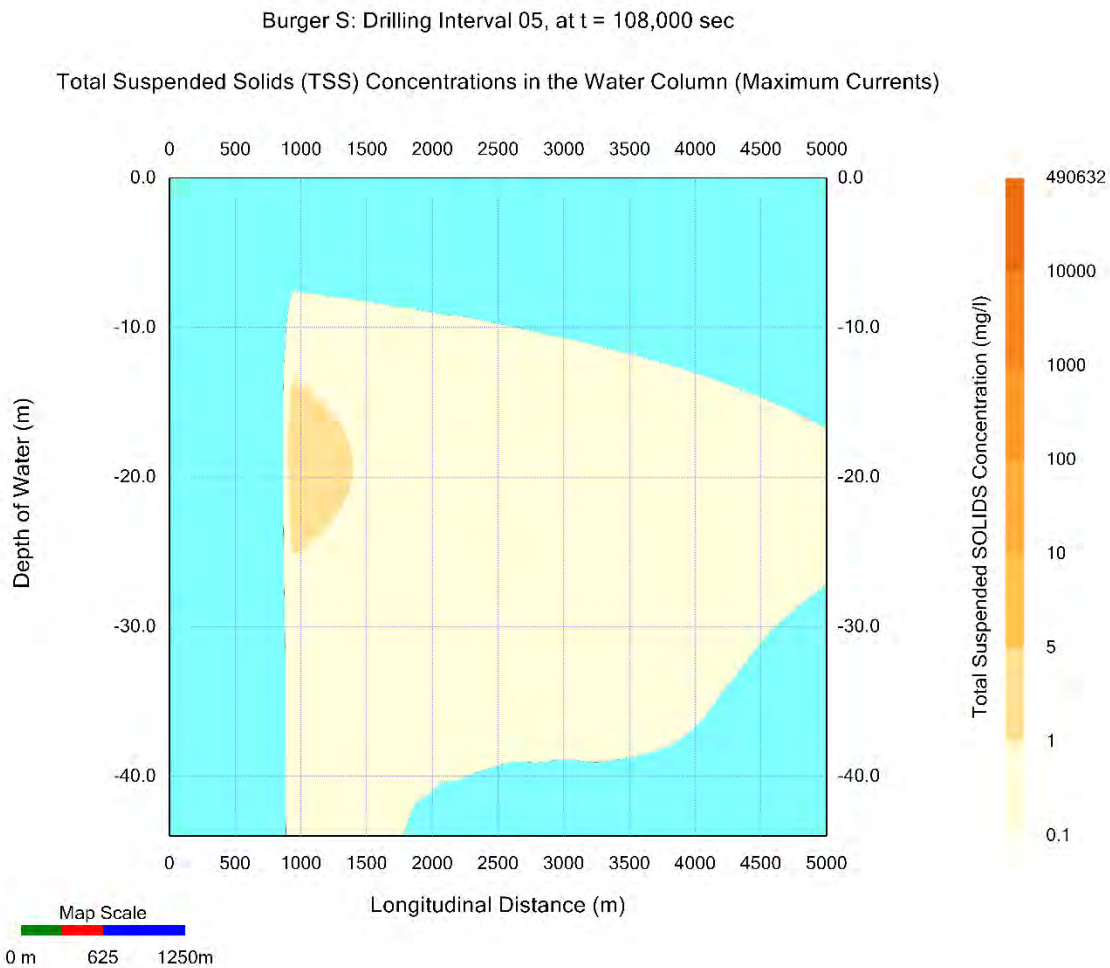


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

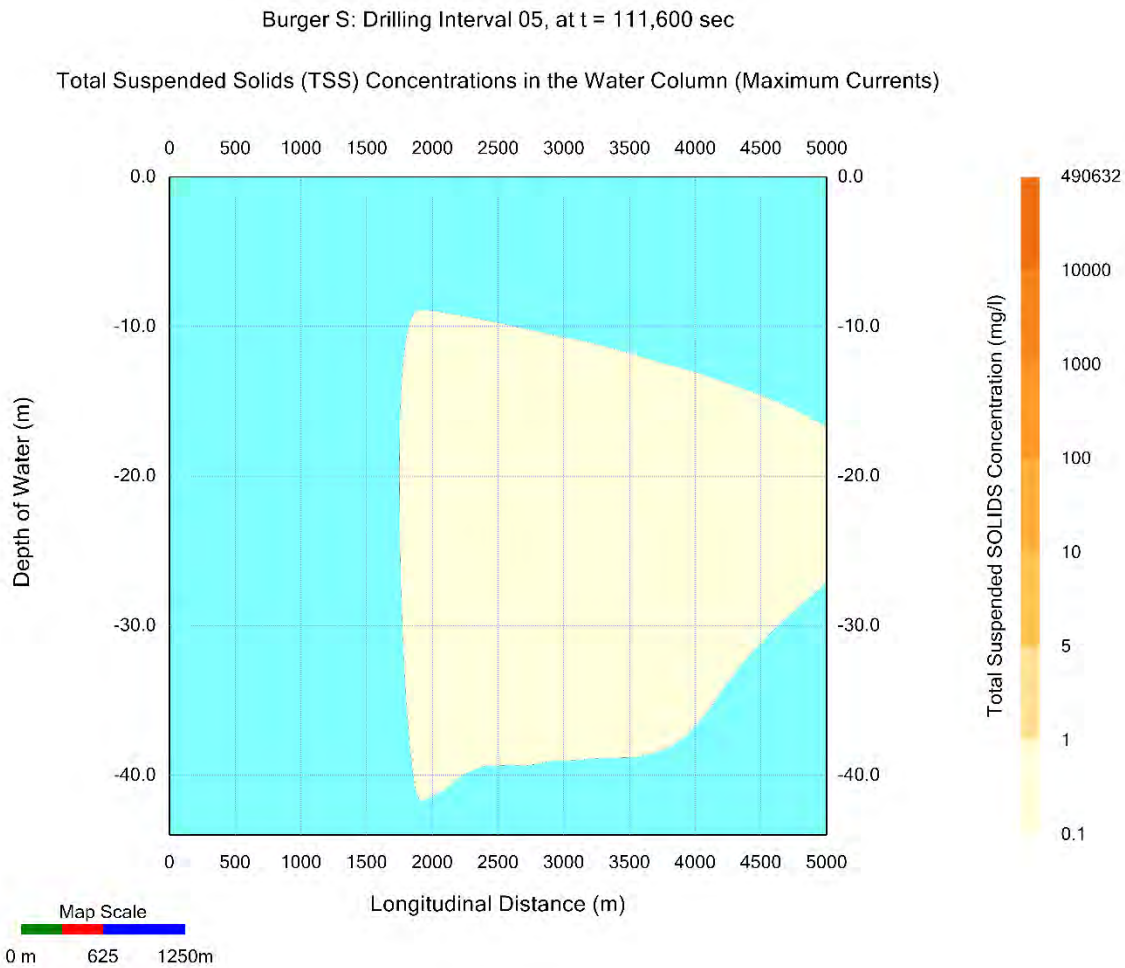
The discharge of the water based drill cuttings and drill fluids ceases at time, t = **104**,**400** sec (or **29**.**0** hours). The fate and transport of the discharged solids at times **1**, **2**, **3**, **4, 5**, and **6** h after the cessation of the discharge are presented by **Figures 6-23**b**, 6-23**c**, 6-23**d**, 6-23**e**, 6-**23f**,** and **6-23**g. These figures show that the TSS concentrations within the **5** km model domain decrease to: **5** mg/l or less at **1** h, **1** mg/l or less at **2** h, **1** mg/l or less at **3** h, **1** mg/l or less at **4** h, **1** mg/l or less at **5** h, and less than **0**.**1** mg/l at **6** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **5** and **6** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 6-23b: TSS concentrations during the maximum currents at 30 h (or 1 h after the cessation of release)



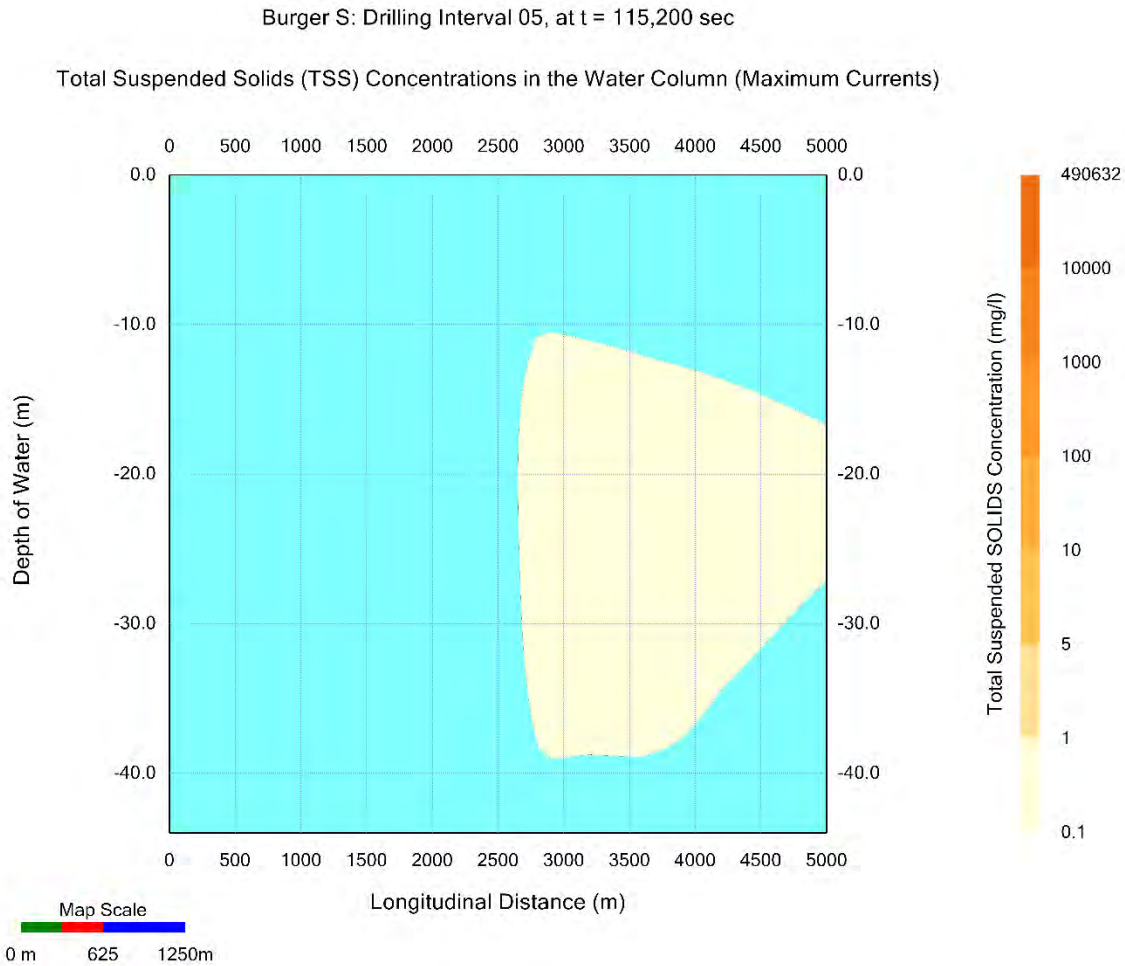
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-23c: TSS concentrations during the maximum currents at 31 h (or 2 h after the cessation of release)



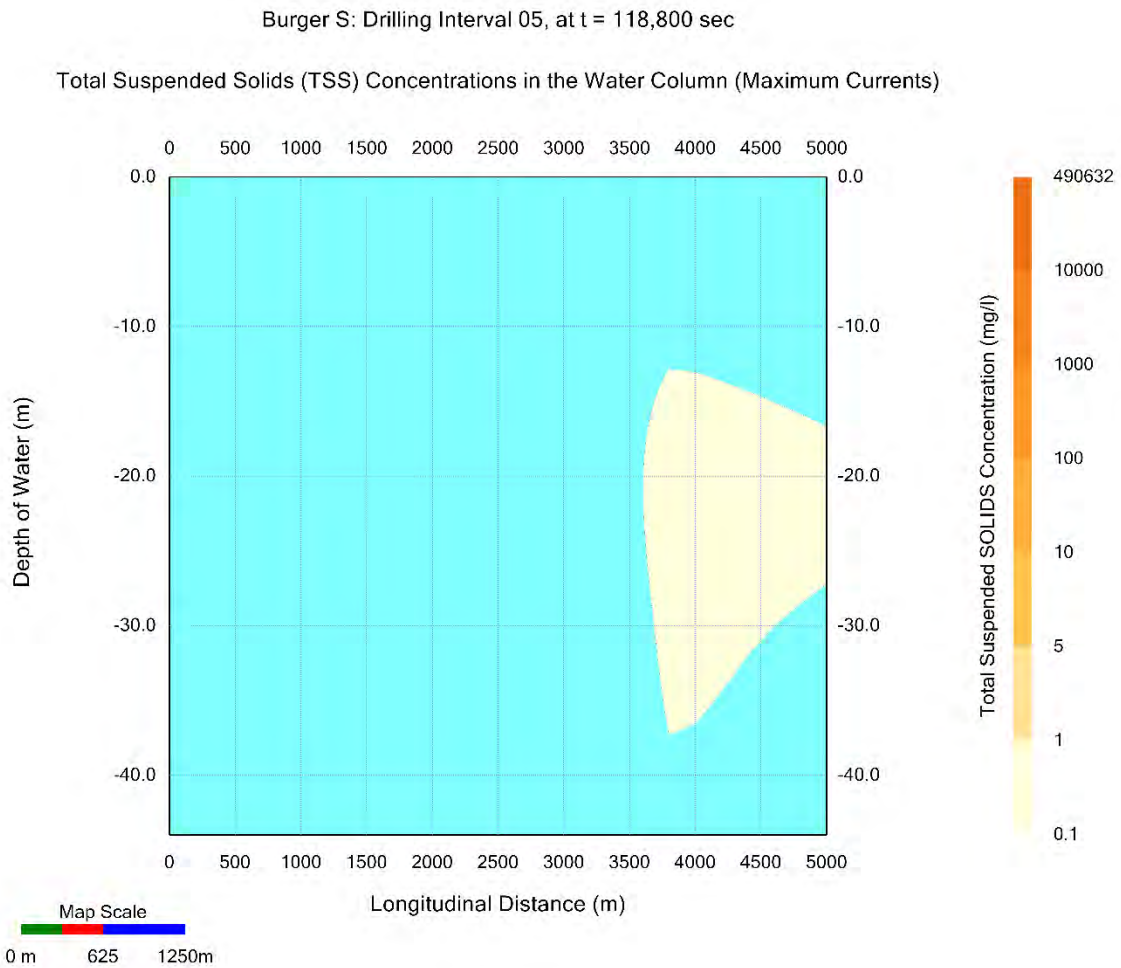
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-23d: TSS concentrations during the maximum currents at 32 h (or 3 h after the cessation of release)



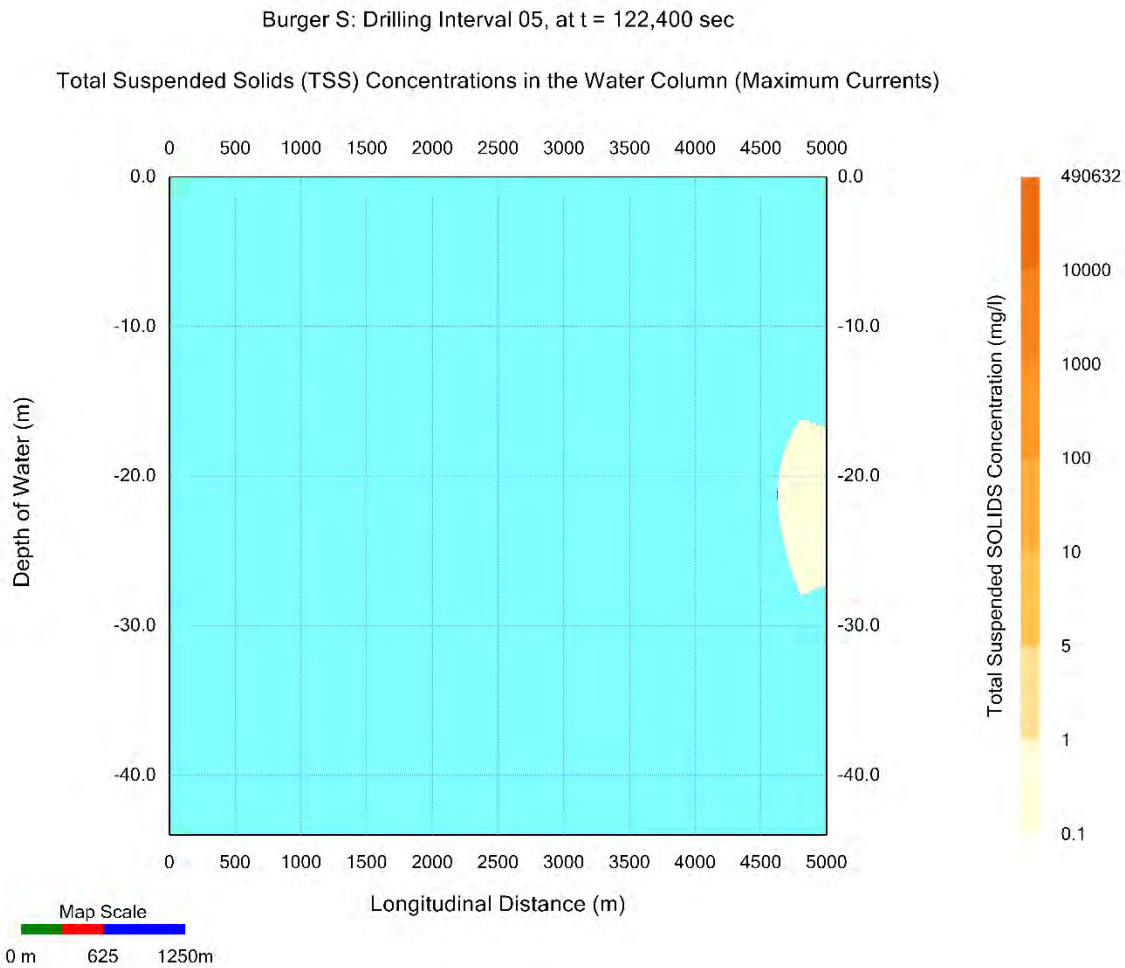
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-23e: TSS concentrations during the maximum currents at 33 h (or 4 h after the cessation of release)



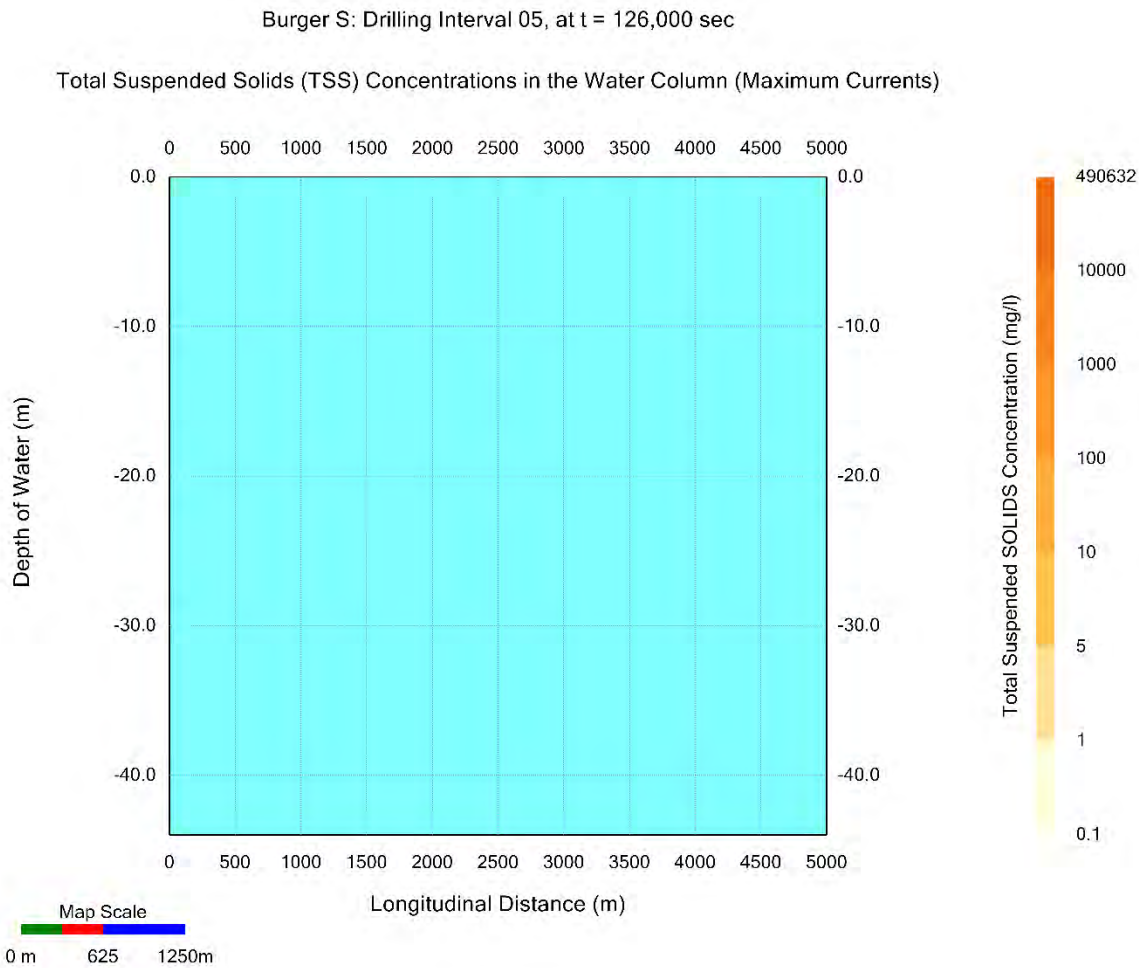
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-23f: TSS concentrations during the maximum currents at 34 h (or 5 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-23g: TSS concentrations during the maximum currents at 35 h (or 6 h after the cessation of release)



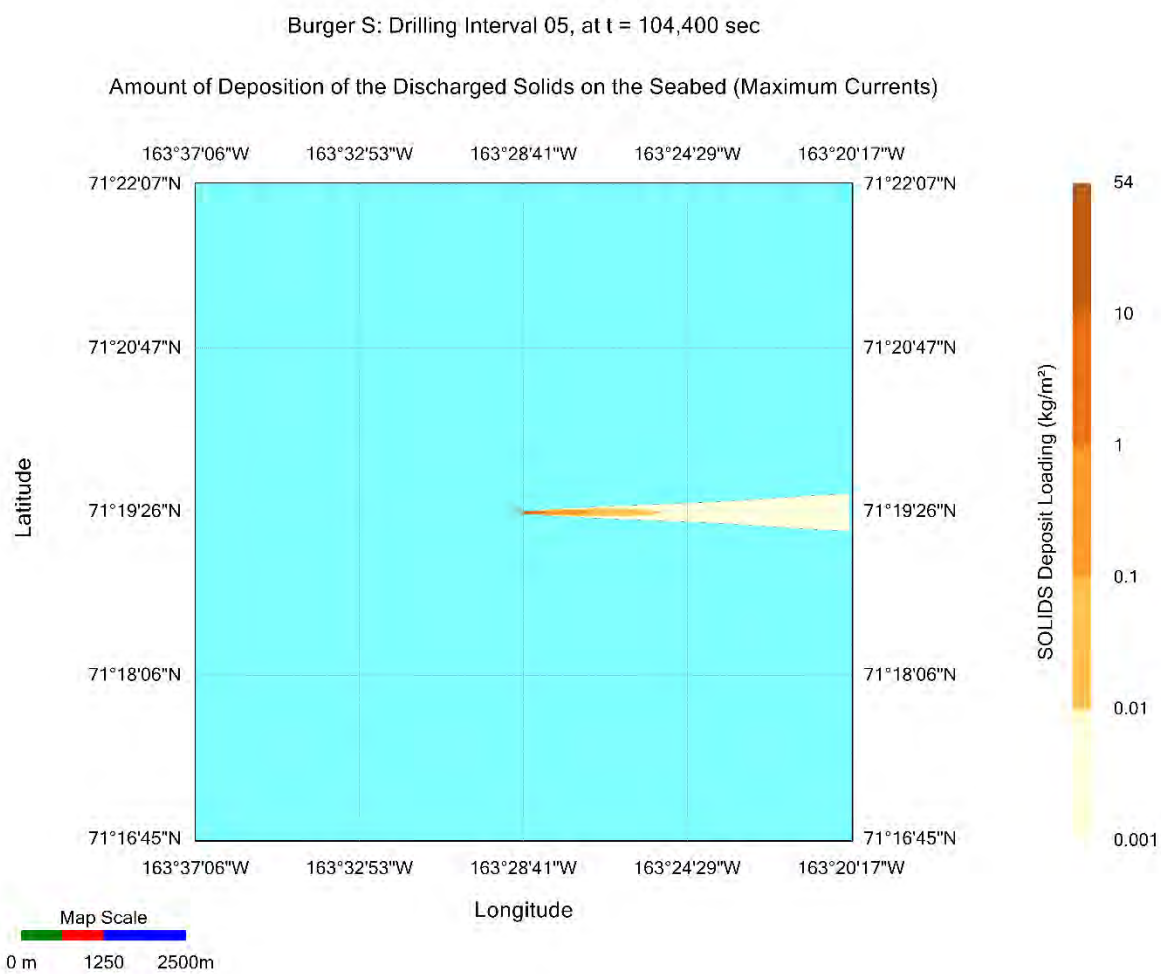
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **104**,**400** sec (or **29**.**0** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figure 6-24**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **6**-**24**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **53** kg/m^2 occurs at **50** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **150**m and **400** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **400** and **1**,**025** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **1,025** and **2,100** m distances from the discharge location. The loading is less than **0**.**01** kg/m^2 beyond **2,100** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **10**-, **1**-, **0**.**1**- and **0**.**01**-kg/m^2 are: **0**.**519**, **1**.**346**, **4**.**102**, and **18**.**245** ha, respectively.

Figure 6-24: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 05



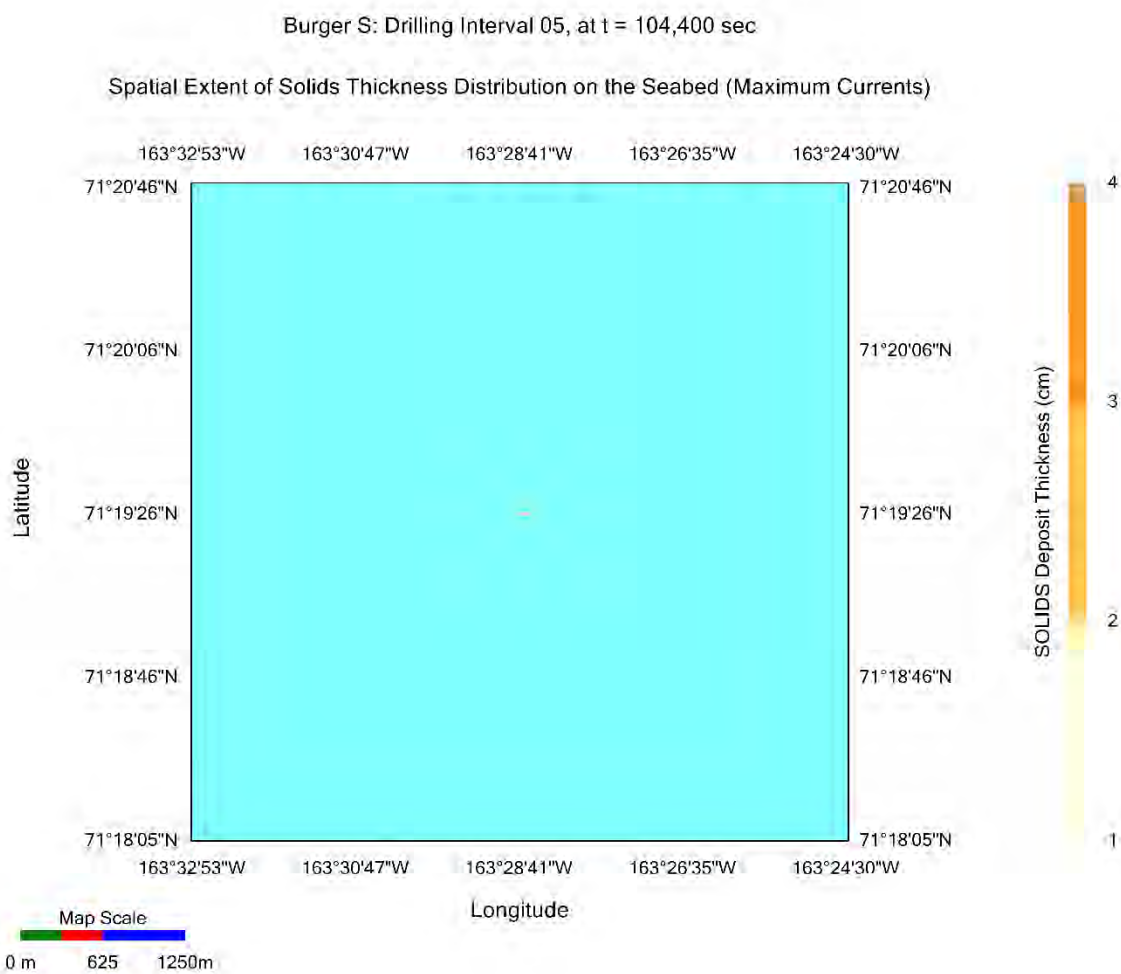
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **104**,**400** sec (or **29**.**0** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 6-25a** and **6-25b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **6**-**25**a. The same result is presented in Figure **6**-**25**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **3**.**5** cm occurs at **50** m to the east and **10** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **105** m from the discharge location.

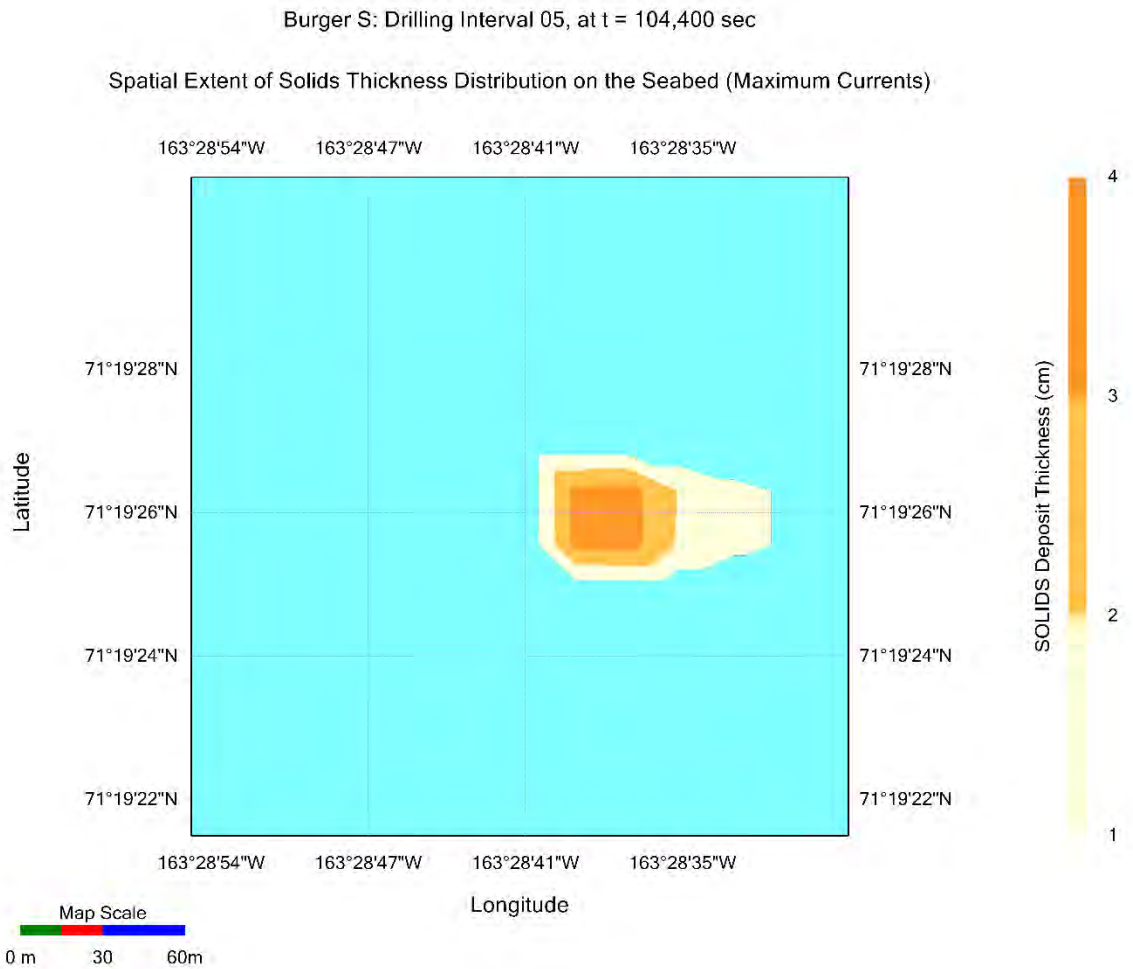
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **90** m x **40** m rectangle area (or **0**.**349** ha) as presented in Figure **6**-**25**b.

Figure 6-25a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 05



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-25b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 05 (Zoom In View)



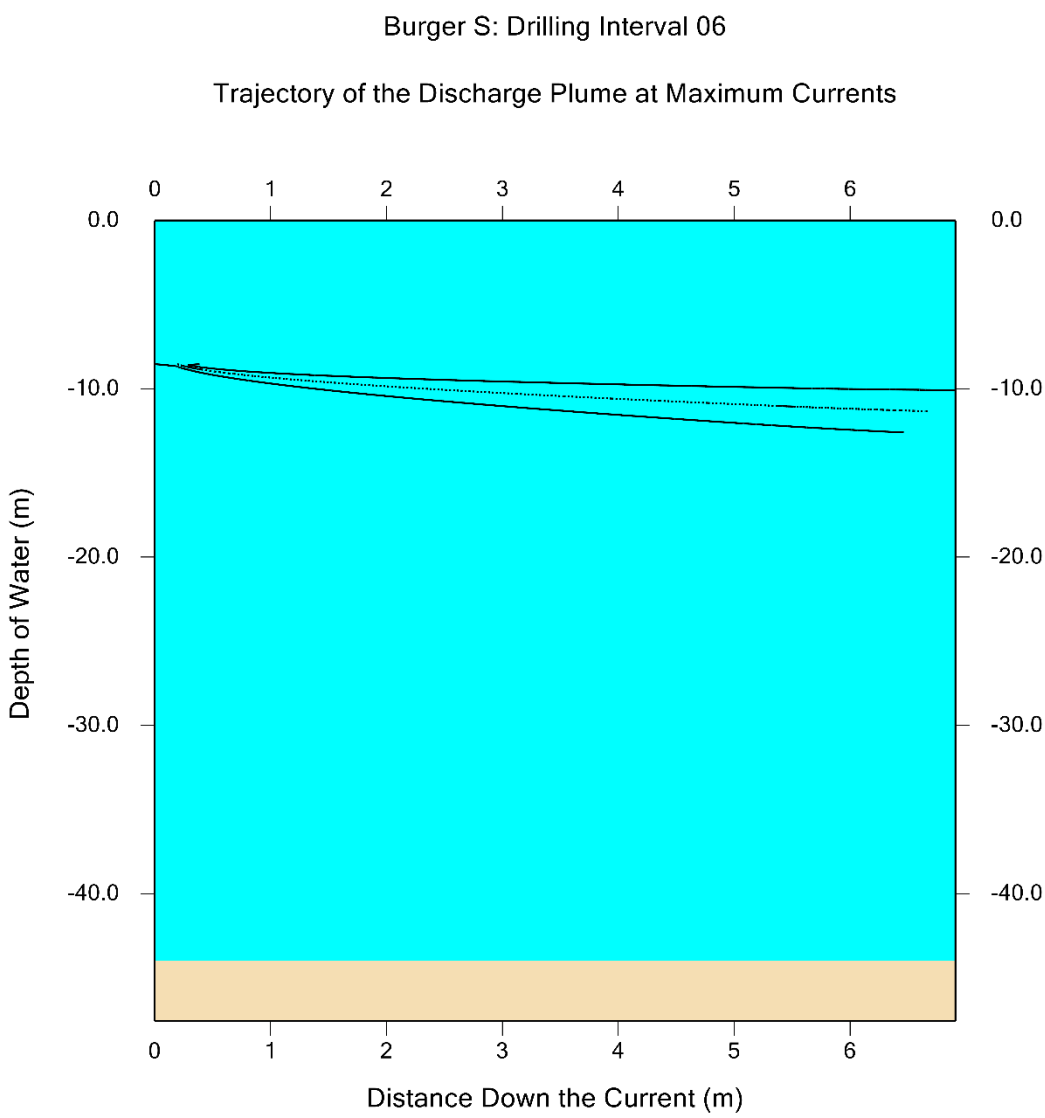
Copyright **2014** by Fluid Dynamix. Company Confidential.

6.6 Model Results for Sea Surface Discharge Scenario – Drilling Interval 06

Trajectory and Shape of the Discharge Plume

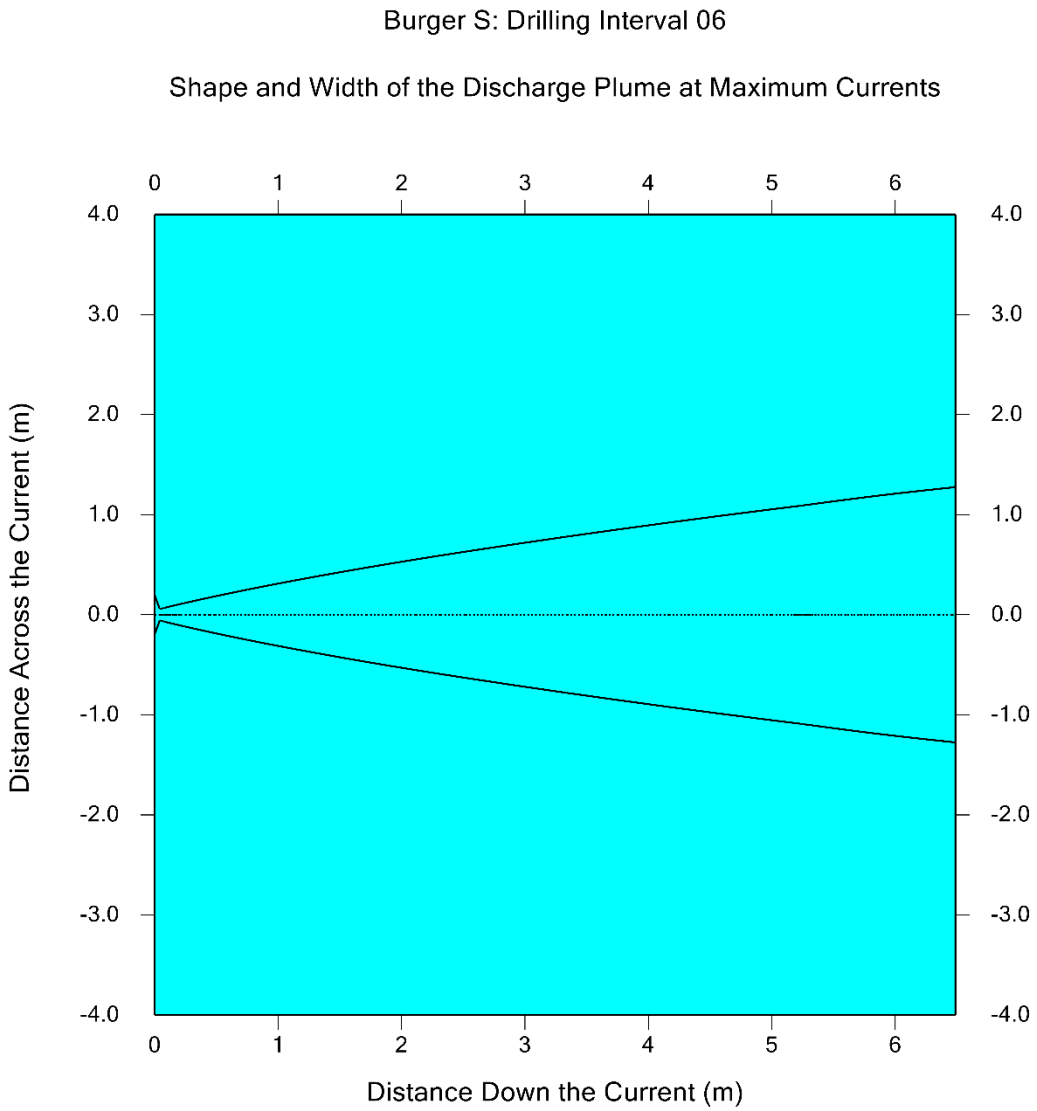
The trajectory of the discharge plume is presented in **Figure 6-26**. The depth of water is **44.0** m and the discharge occurs at a depth of **8.53** m below the sea surface. The heavier plume travels approximately **6.5** m from the discharge location before collapsing into the ambient sea water due to the higher density of the discharge plume. The shape and width of the discharge plume is presented in **Figure 6-27**. The width of the plume is approximately **2.5** m at a distance **6.5** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **6-26** and **6-27**.

Figure 6-26: Trajectory of the discharge plume at maximum currents, Drilling Interval 06



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-27: Shape and width of the discharge plume at maximum currents, Drilling Interval 06



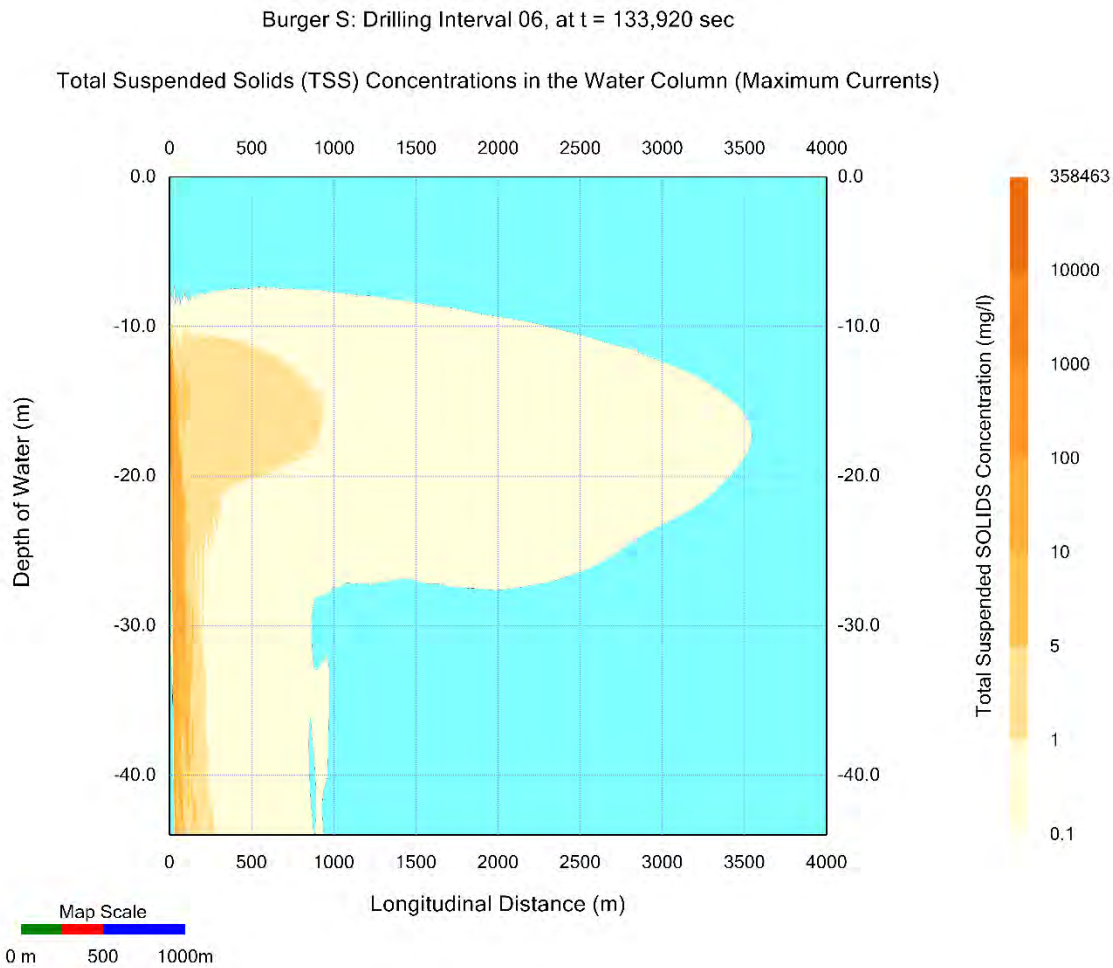
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = **133**,**920** sec (or **37**.**2** hours) which is the discharge duration for this drilling interval is presented in **Figure 6-28**a. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **8.53** m from a **15.25** inches internal diameter discharge pipe. Figure **6-28**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **358,463** mg/l occurs at the discharge location. It decreases to a value of **100** and **10** mg/l at distances approximately: **20** and **125** m, respectively from the discharge location. It varies from **10** to **5** mg/l between **125** m and **175** m distances from the discharge location. It varies from **5** to **1** mg/l between **175** m and **950** m distances from the discharge location. It is less than **1** mg/l beyond **950** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **210.9**, **68.8**, **14.0**, **3.2**, and **0**.**9** mg/l, respectively.

Figure 6-28a: Total suspended solids concentrations in water column at maximum currents, Drilling Interval 06

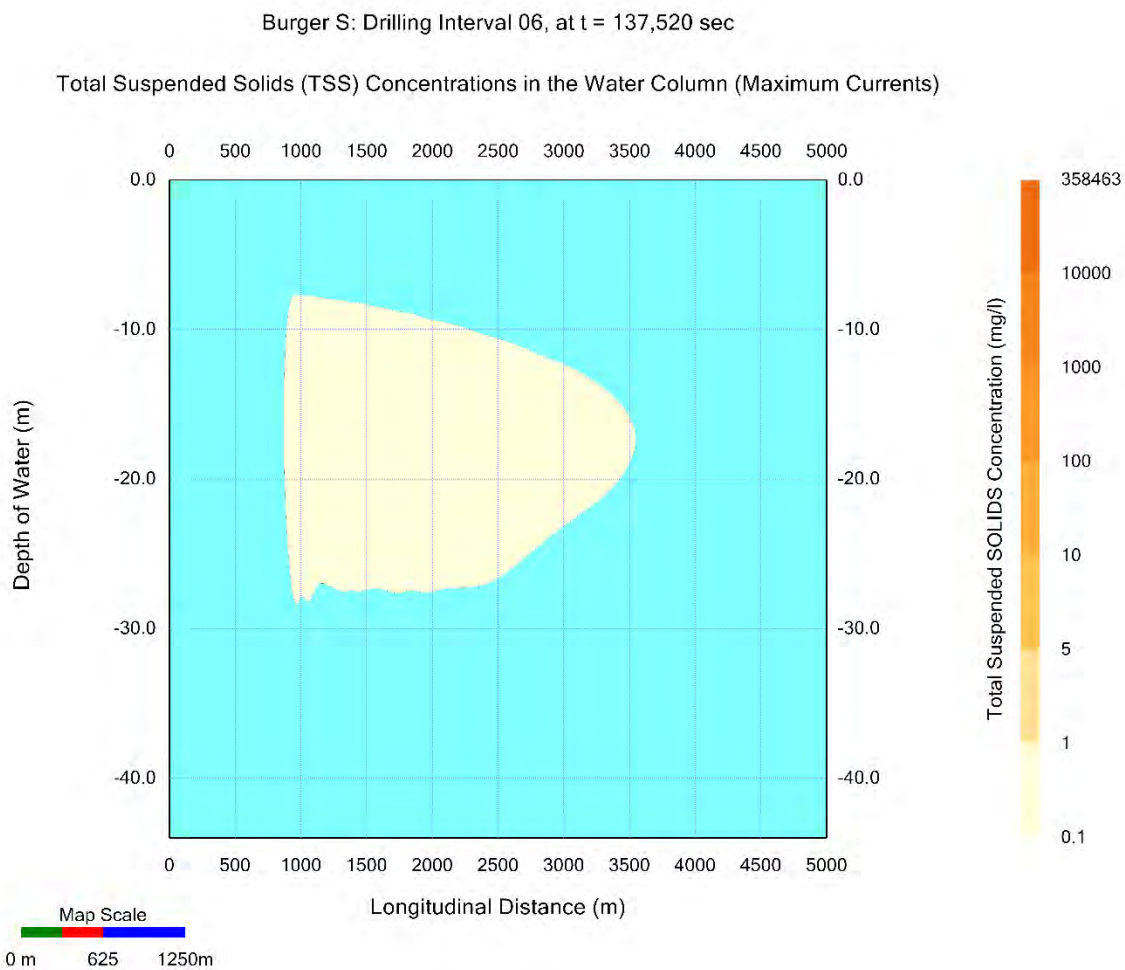


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

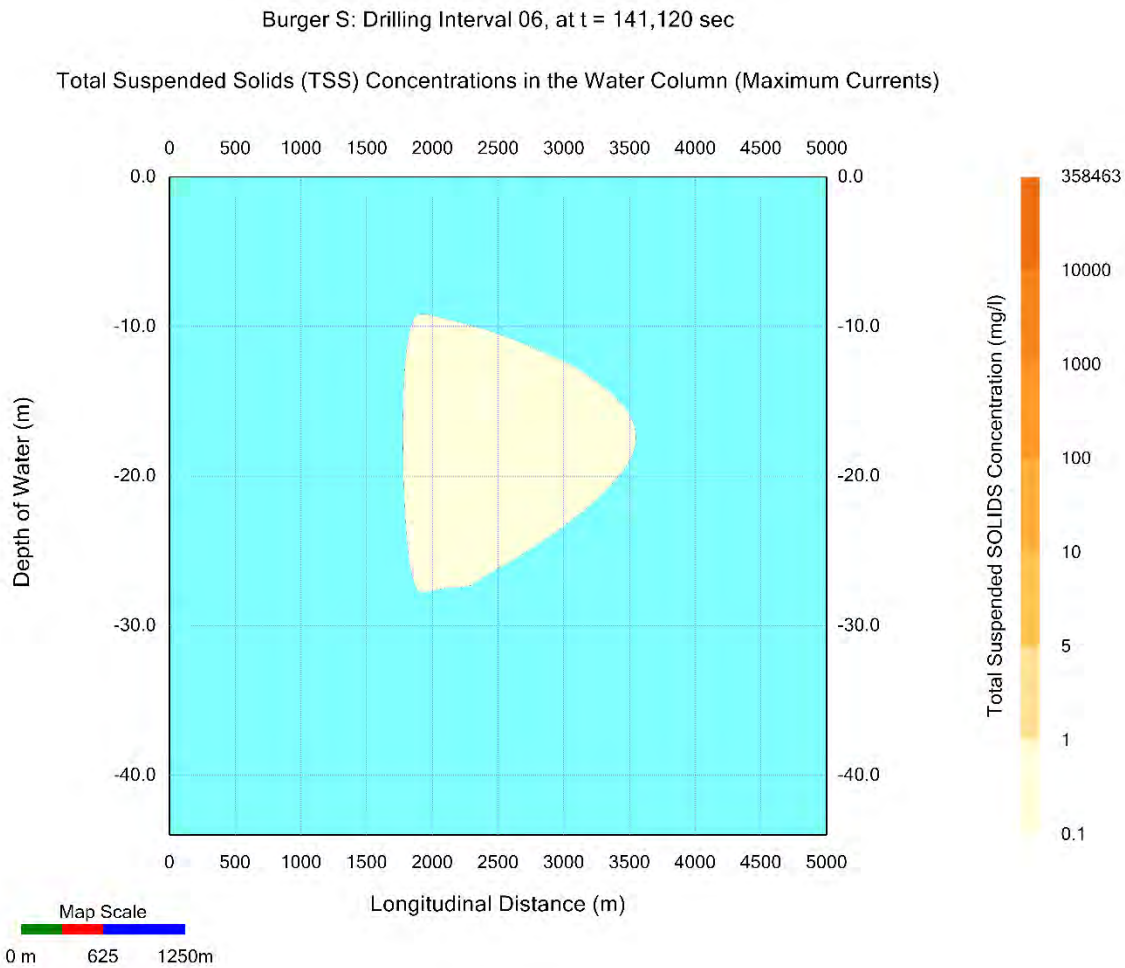
The discharge of the water based drill cuttings and drill fluids ceases at time, t = **133**,**920** sec (or **37**.**2** hours). The fate and transport of the discharged solids at times **1**, **2**, **3**, and **4** h after the cessation of the discharge are presented by **Figures 6-28b, 6-28c, 6-28d,** and **6-28e**. These figures show that the TSS concentrations within the **5** km model domain decrease to: **1** mg/l or less at **1** h, **1** mg/l or less at **2** h, **1** mg/l or less at **3** h and less than **0**.**1** mg/l at **4** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **3** and **4** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 6-28b: TSS concentrations during the maximum currents at 38.2 h (or 1 h after the cessation of release)



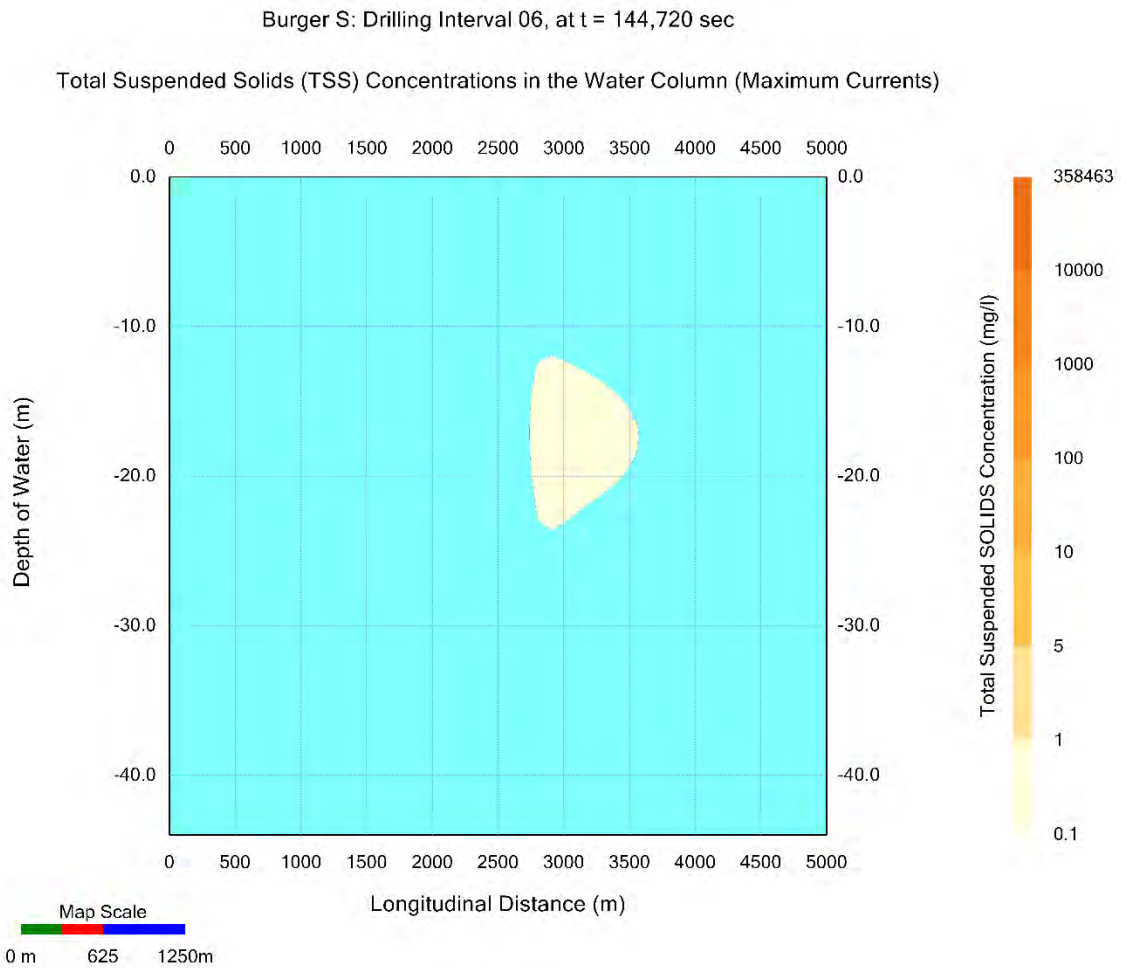
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-28c: TSS concentrations during the maximum currents at 39.2 h (or 2 h after the cessation of release)



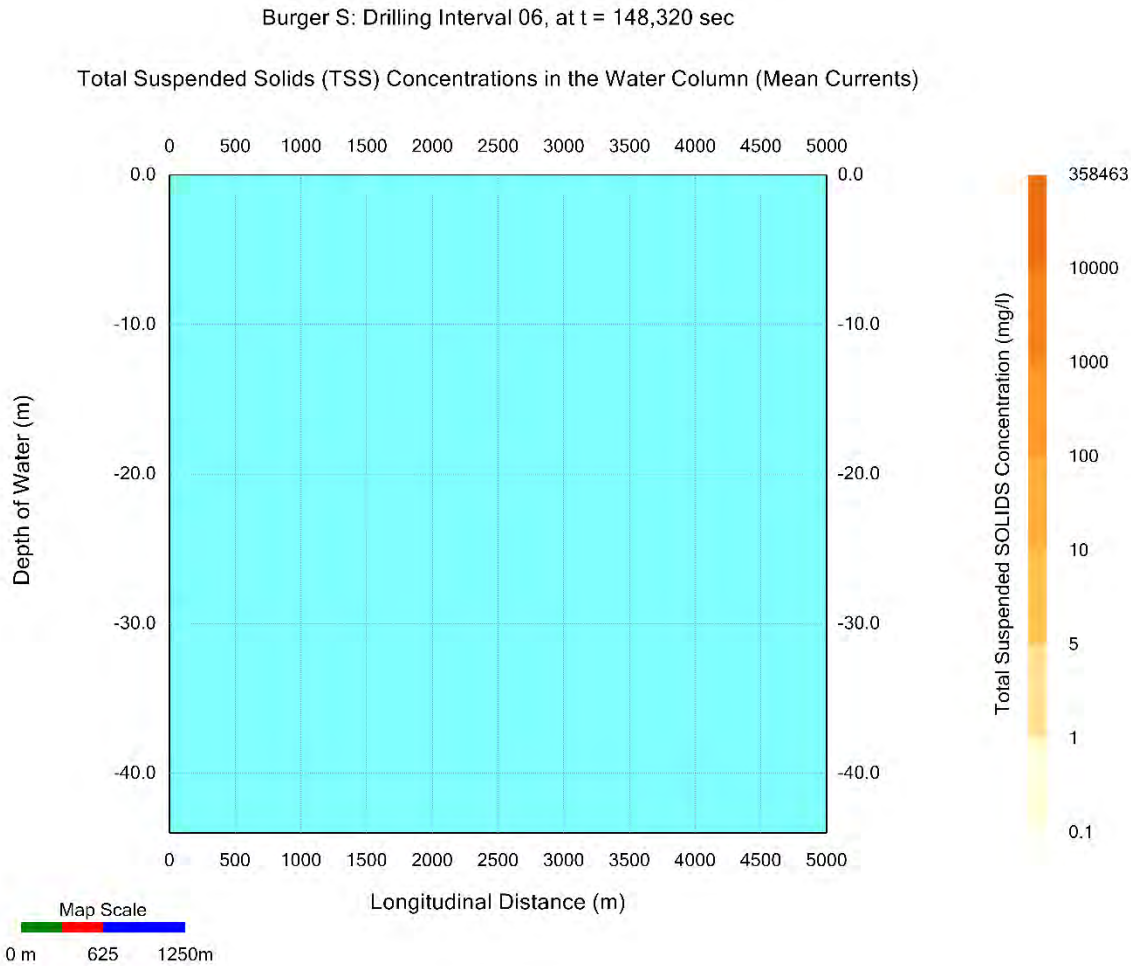
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-28d: TSS concentrations during the maximum currents at 40.2 h (or 3 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-28e: TSS concentrations during the maximum currents at 41.2 h (or 4 h after the cessation of release)



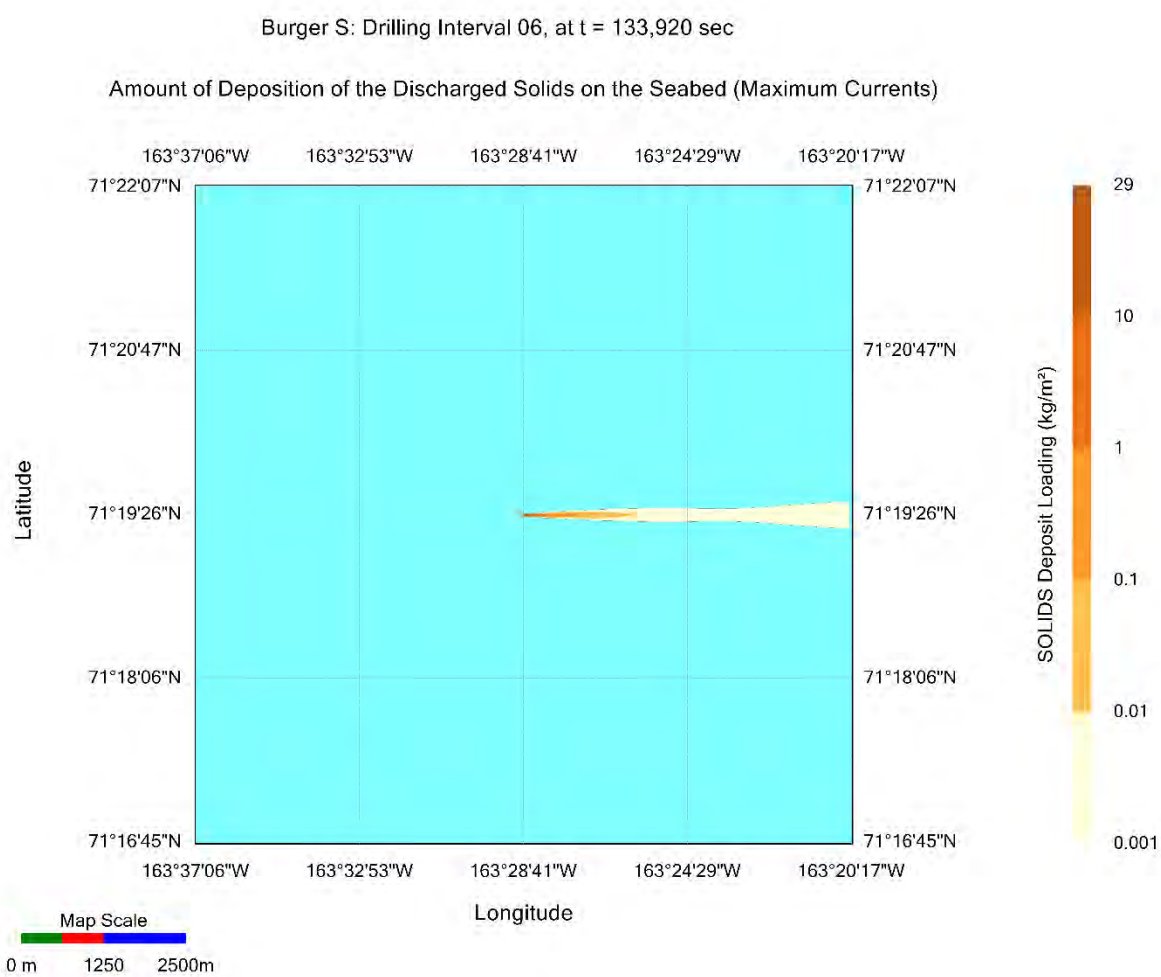
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **133**,**920** sec (or **37**.**2** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figure 6-29**. The model domain extends to **5**.**0** km in all directions from the discharge location as shown in Figure **6**-**29**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **28** kg/m^2 occurs at **50** m to the east and **10** m to the south from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **90** m and **300** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0**.**1** kg/m^2 approximately between **300** and **850** m distances from the discharge location. It varies from **0**.**1** kg/m^2 to **0**.**01** kg/m^2 approximately between **850** and **1,650** m distances from the discharge location. It is less than **0**.**01** kg/m^2 beyond **1,650** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **10**-, **1**-, **0**.**1**- and **0**.**01**-kg/m^2 are: **0**.**324**, **1**.**142**, **3**.**303**, and **11**.**232** ha, respectively.

Figure 6-29: Amount of deposition of the solids on seabed at maximum currents, Drilling Interval 06



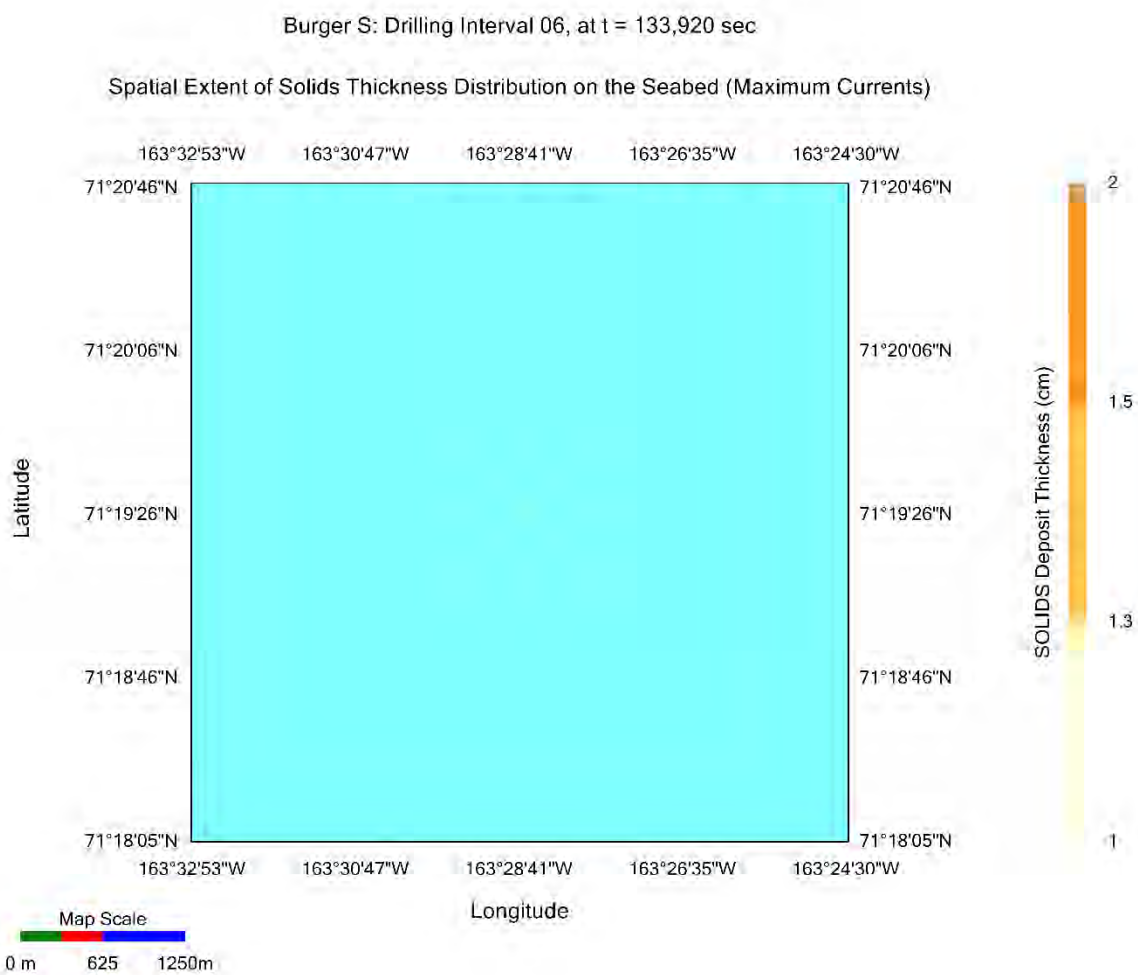
Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of **1** cm or larger deposited on the sea floor at time, t = **133,920** sec (or **37.2** hours) as a result of the discharge of the water based drill cuttings and drill fluids on a plan view is presented in **Figures 6-30a** and **6-30b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5.0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **6-30**a. The same result is presented in Figure **6-30**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation of **1** cm or larger on the seabed. The maximum deposit thickness of **1.8** cm occurs at **50** m to the east and **10** m to the south from the discharge location. It decreases to a value of **1** cm at a distance approximately **70** m from the discharge location.

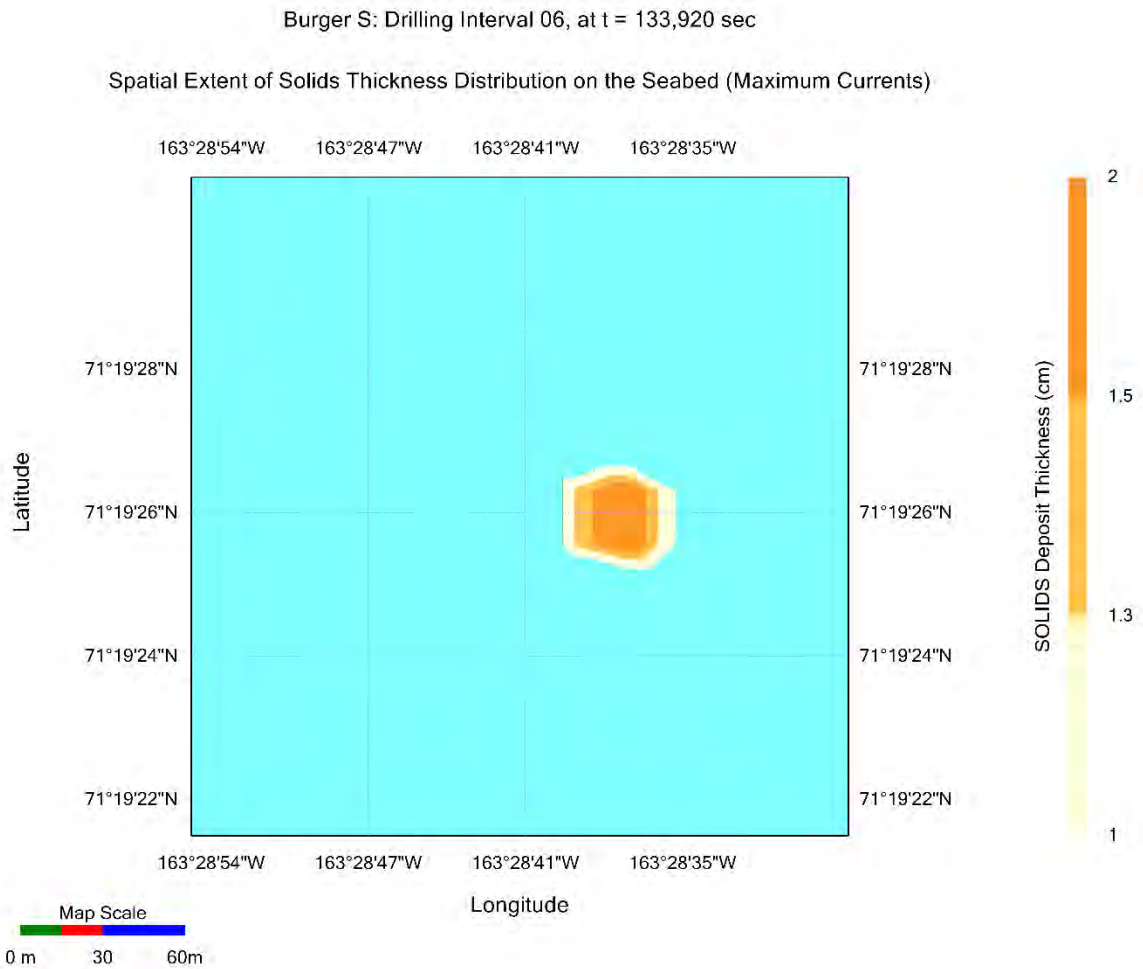
The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **50** m x **40** m square area or **0.193** ha as presented in Figure **6-30**b.

Figure 6-30a: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 06



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-30b: Spatial extent of solids thickness distribution on seabed at maximum currents, Drilling Interval 06 (Zoom In View)



Copyright **2014** by Fluid Dynamix. Company Confidential.

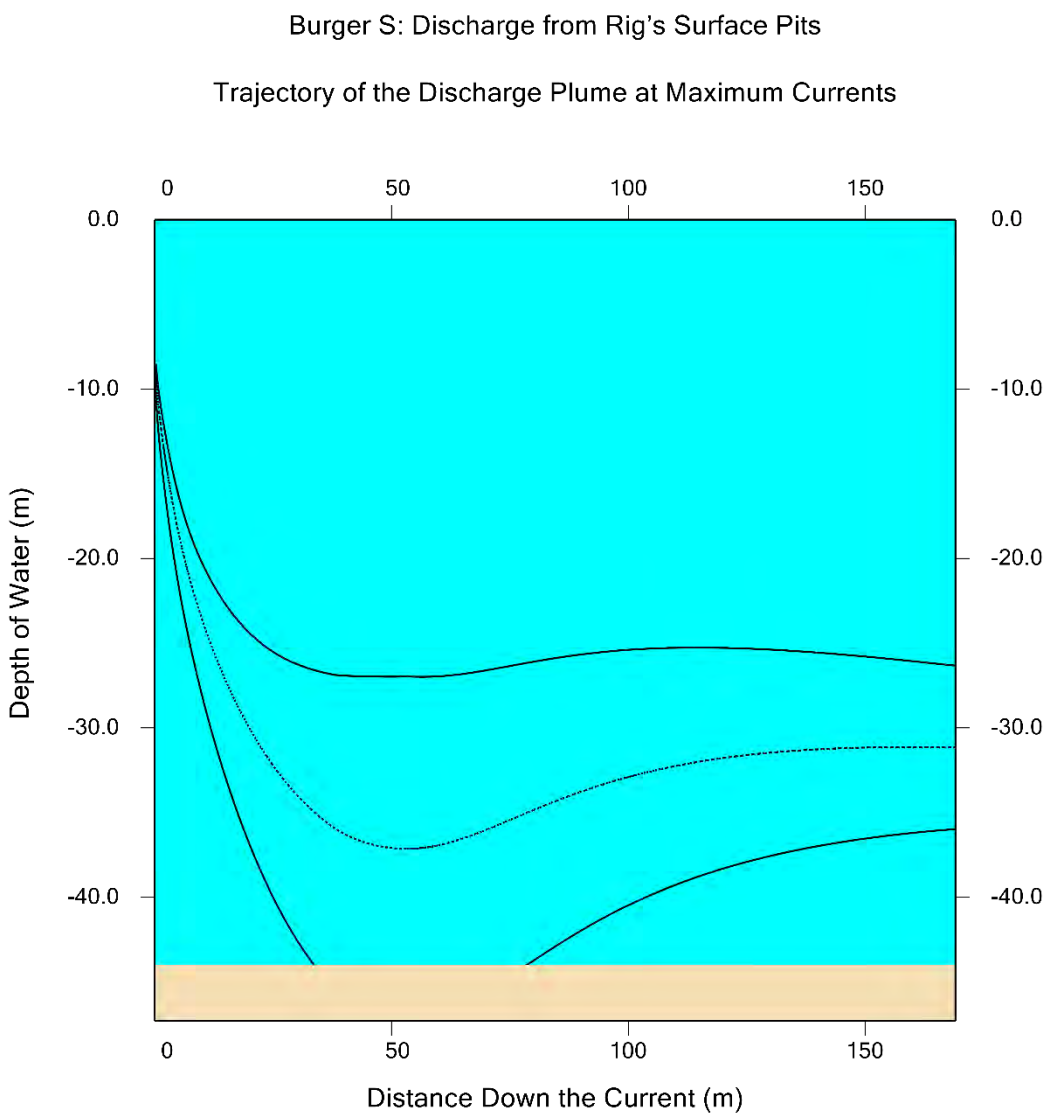
6.7 Model Results for Sea Surface Discharge Scenario – Rigs Surface Pits

Water Based Muds Discharge from Rigs Surface Pits at the end of the Drilling Operation

Trajectory and Shape of the Discharge Plume

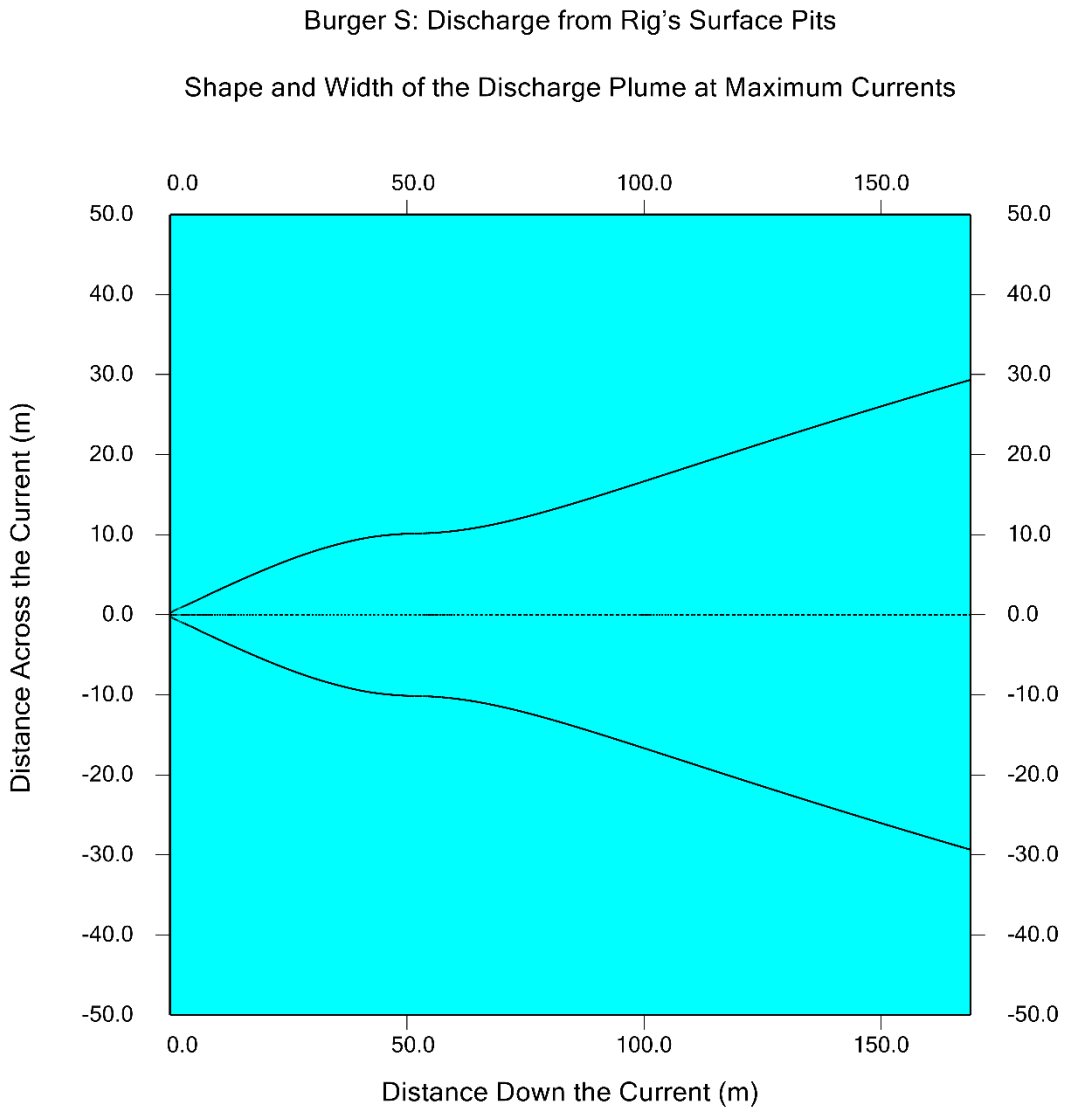
The trajectory of the discharge plume is presented in **Figure 6-31**. The depth of water is **44.0** m and the discharge occurs at a depth of **8.53** m below the sea surface. The heavier plume travels approximately **169.0** m from the discharge location before collapsing into the ambient sea water due to the higher density of the discharge plume. The shape and width of the discharge plume is presented in **Figure 6-32**. The width of the plume is approximately **58.0** m at a distance **169.0** m from the discharge location. The solid lines present the outer boundaries and dotted line presents the center line of the discharge plume in Figures **6-31** and **6-32**. The lower boundary of the plume scours and penetrates the sea floor between **30** and **75** m distances.

Figure 6-31: Trajectory of the discharge plume at maximum currents, Rig's Surface Pits



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-32: Shape and width of the discharge plume at maximum currents, Rig's Surface Pits



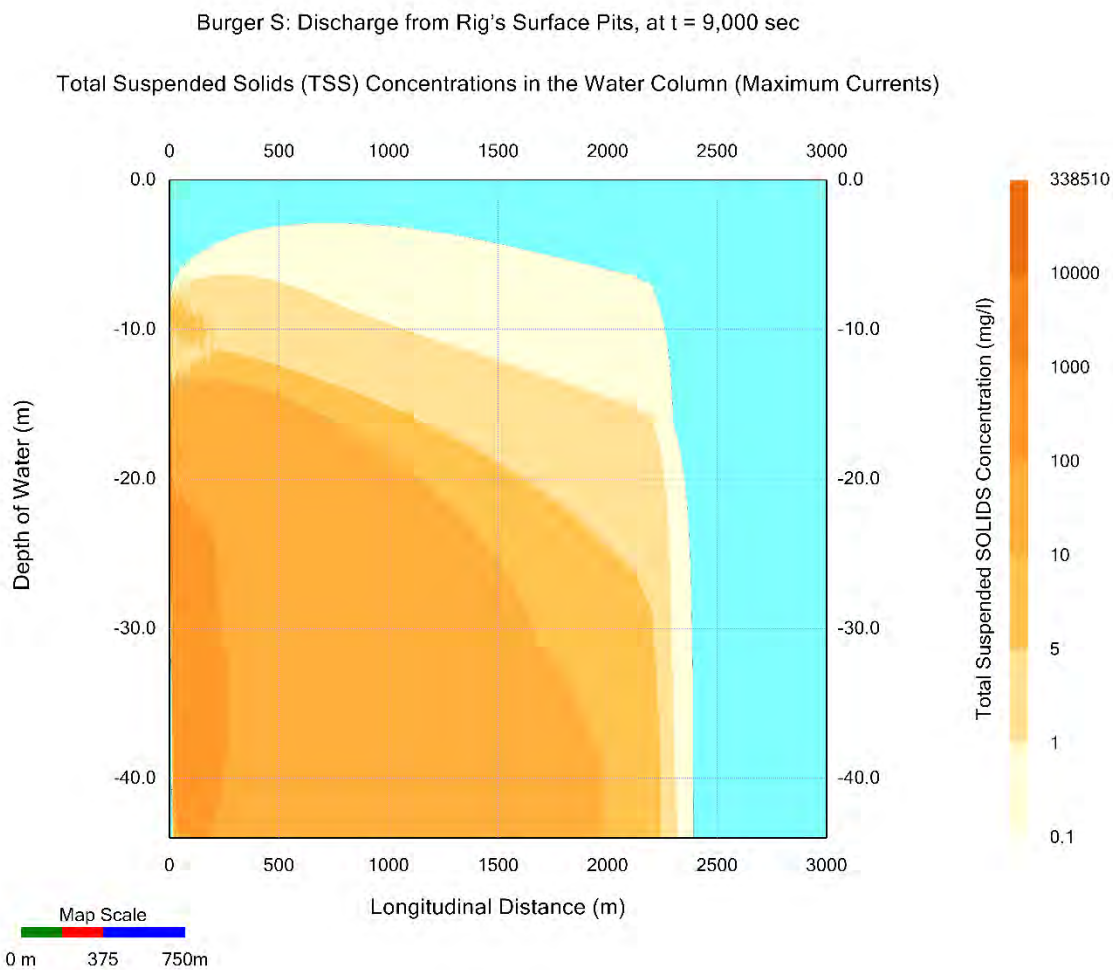
Copyright **2014** by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentration in the water column at time, t = **9,000** sec (or **2.5** hours) which is the discharge duration for the water based muds from the rig's surface pits is presented in **Figure 6-33a**. The depth of water is **44.0** m at the discharge location. The discharge occurs at a depth of **8.53** m from a **15.25** inches internal diameter discharge pipe. Figure **6-33**a presents the maximum TSS concentrations attained during the discharge. The color filled contours present the variations of the TSS concentrations both with respect to the depth from the sea surface and the distance from the source by different color bands. The maximum TSS concentration **338,510** mg/l occurs at the discharge location. It decreases rapidly to a value of **100** mg/l at a distance approximately **250** m from the discharge location. It varies from **100** to **10** mg/l between **250** m and **2,000** m distances from the discharge location. It varies from **10** to **5** mg/l between **2,000** m and **2,250** m distances from the discharge location. It varies from **5** to **1** mg/l between **2,250** m and **2,325** m distances from the source. It is less than **1** mg/l beyond **2,325** m from the discharge location.

The maximum TSS concentrations at **10**-, **30**-, **100**-, **300**-, and **1000**-m from the discharge location are: **1,757.0**, **320.4**, **174.2**, **92.7**, and **29.7** mg/l, respectively.

Figure 6-33a: Total suspended solids concentrations in water column at maximum currents, Rig's Surface Pits

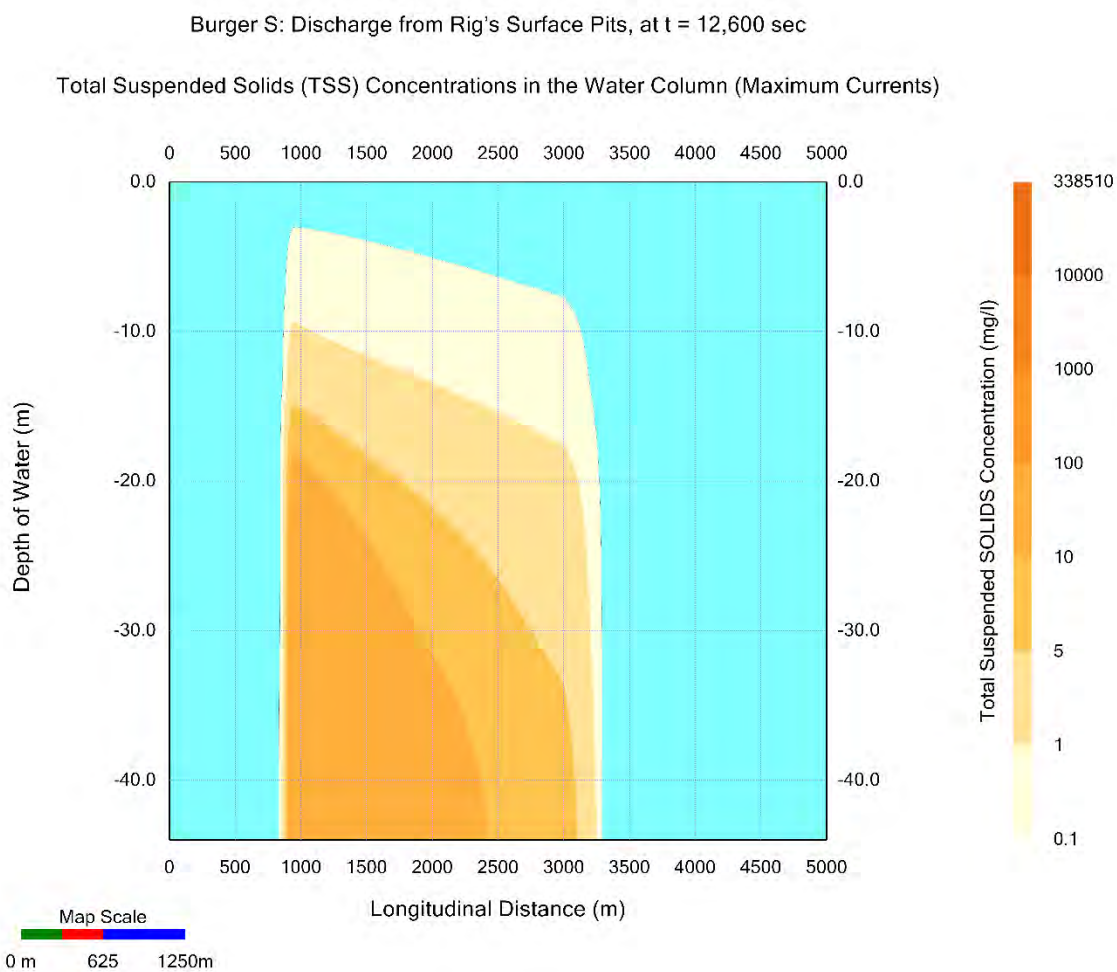


Copyright **2014** by Fluid Dynamix. Company Confidential.

FATE AND TRANSPORT OF THE TSS

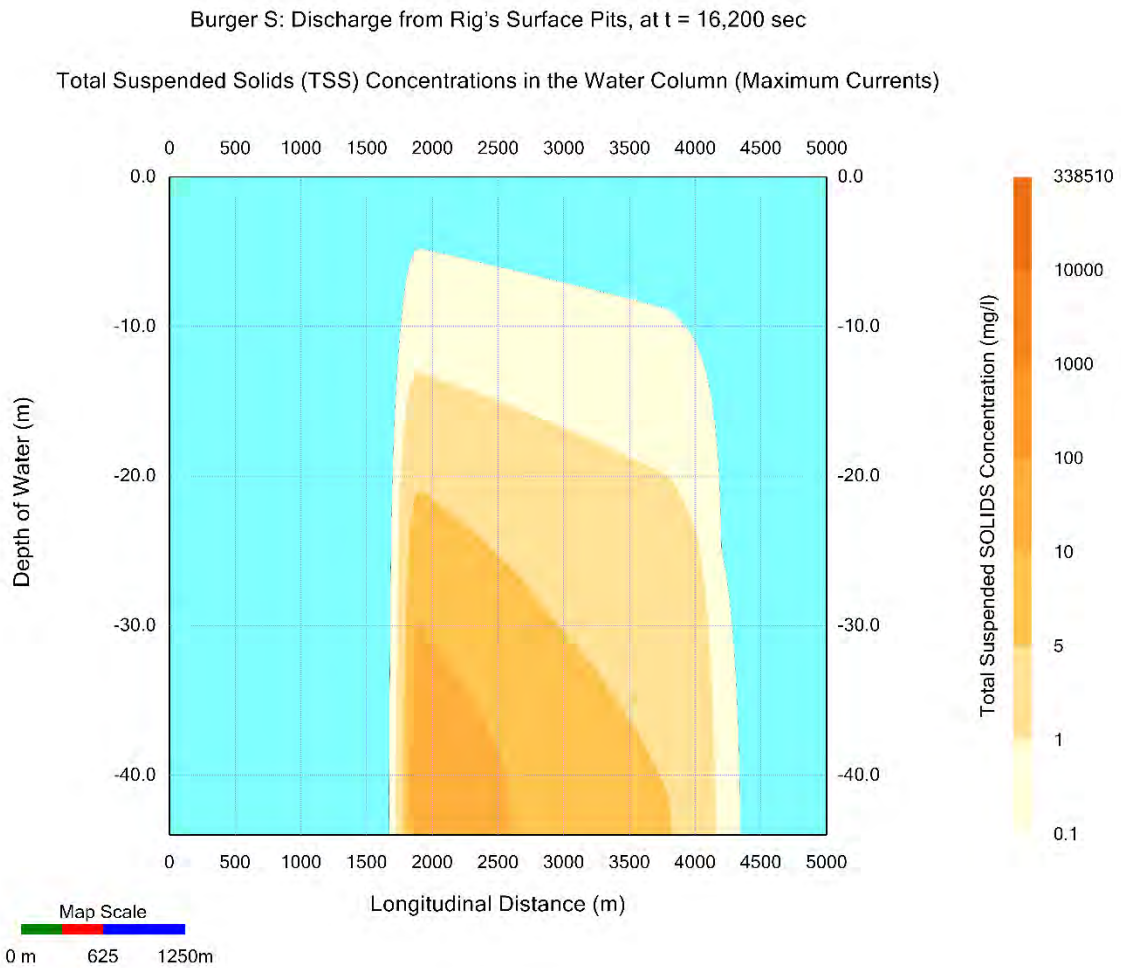
The discharge of the water based muds ceases at time, t = **9**,**000** sec (or **2**.**5** hours). The fate and transport of the discharged solids at times **1**, **2**, **3**, **4**, **5**, and **6** h after the cessation of the discharge are presented by **Figures 6-33**b**, 6-33**c**, 6-33**d **, 6-33**e**, 6-33**f**,** and **6-33**g. These figures show that the TSS concentrations within the **5.0** km model domain decrease to: **100** mg/l or less at **1** h, **100** mg/l or less at **2** h, **10** mg/l or less at **3** h, **10** mg/l or less at **4** h, **5** mg/l or less at **5** h, and less than **0**.**1** mg/l at **6** h after the cessation of the discharge. Therefore, it can be described that the ambient TSS concentrations attains pre-existing conditions between **5** and **6** h after the cessation of the discharge based on the assumption that the ambient TSS value is equal to or more than **0**.**1** mg/l within the model domain.

Figure 6-33b: TSS concentrations during the maximum currents at 3.5 h (or 1 h after the cessation of release)



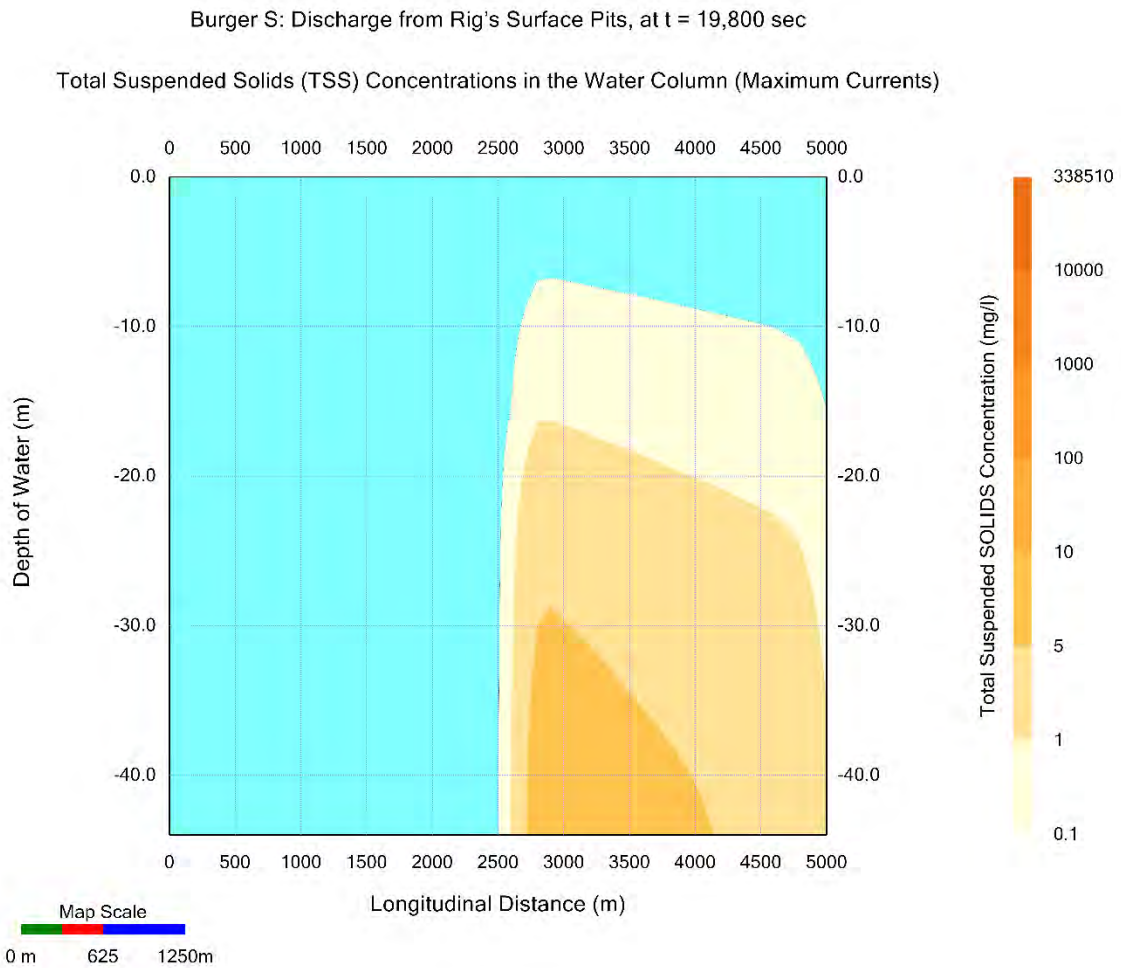
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-33c: TSS concentrations during the maximum currents at 4.5 h (or 2 h after the cessation of release)



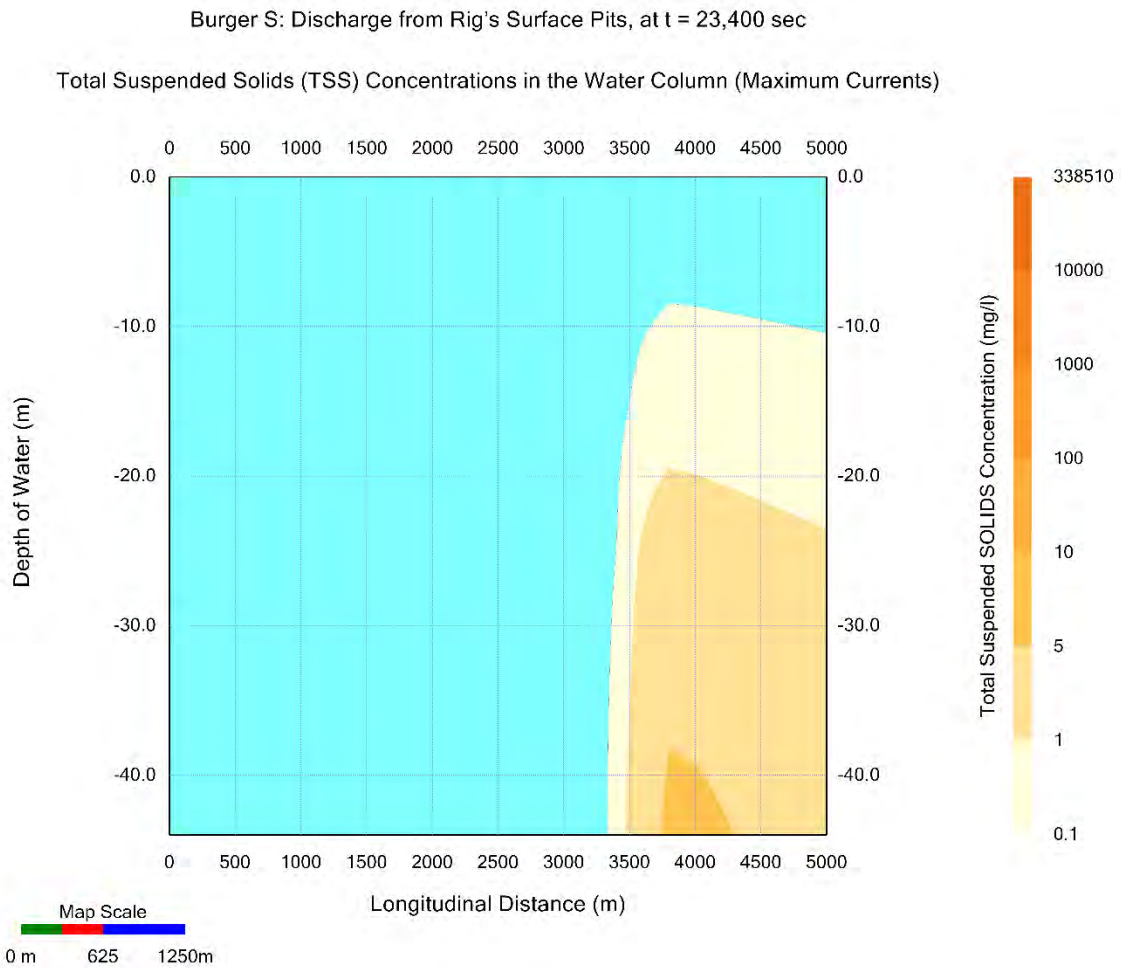
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-33d: TSS concentrations during the maximum currents at 5.5 h (or 3 h after the cessation of release)



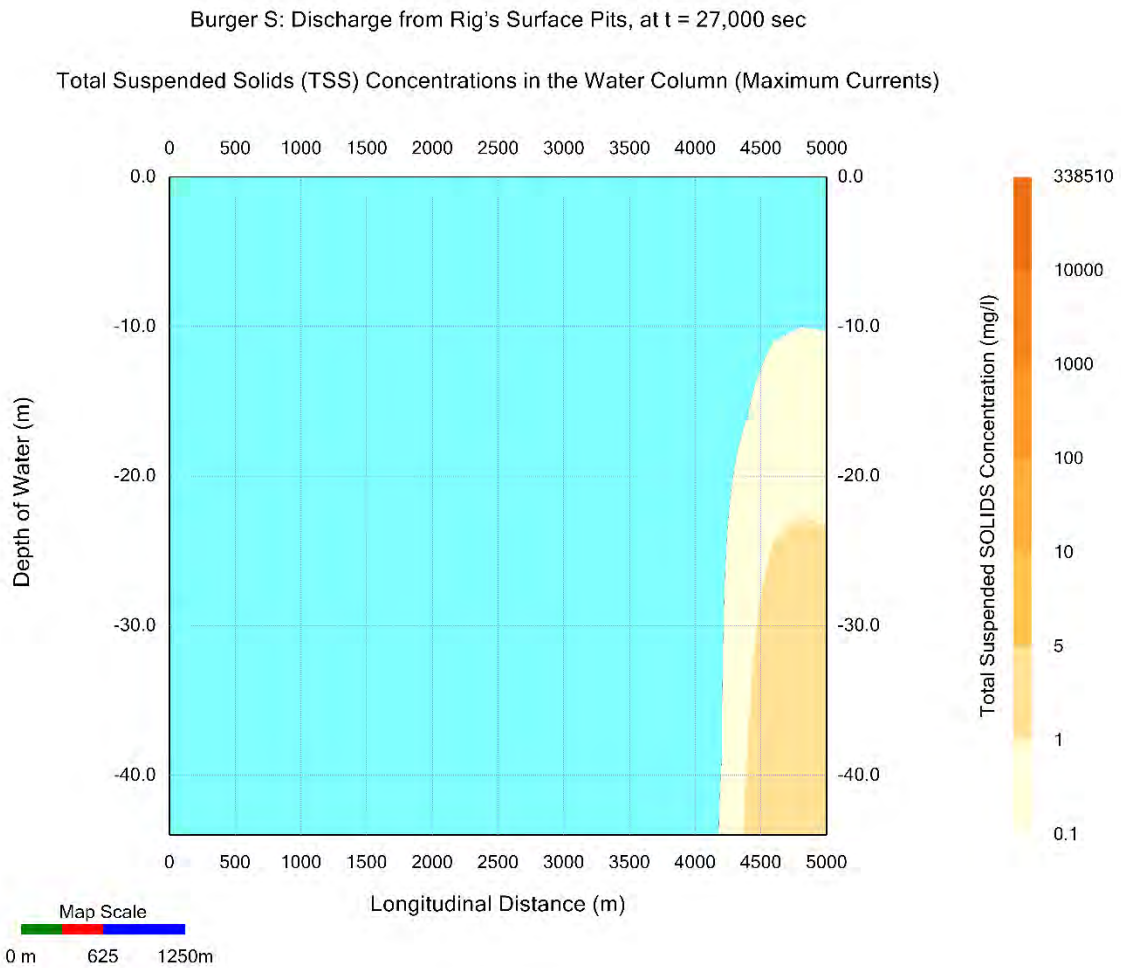
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-33e: TSS concentrations during the maximum currents at 6.5 h (or 4 h after the cessation of release)



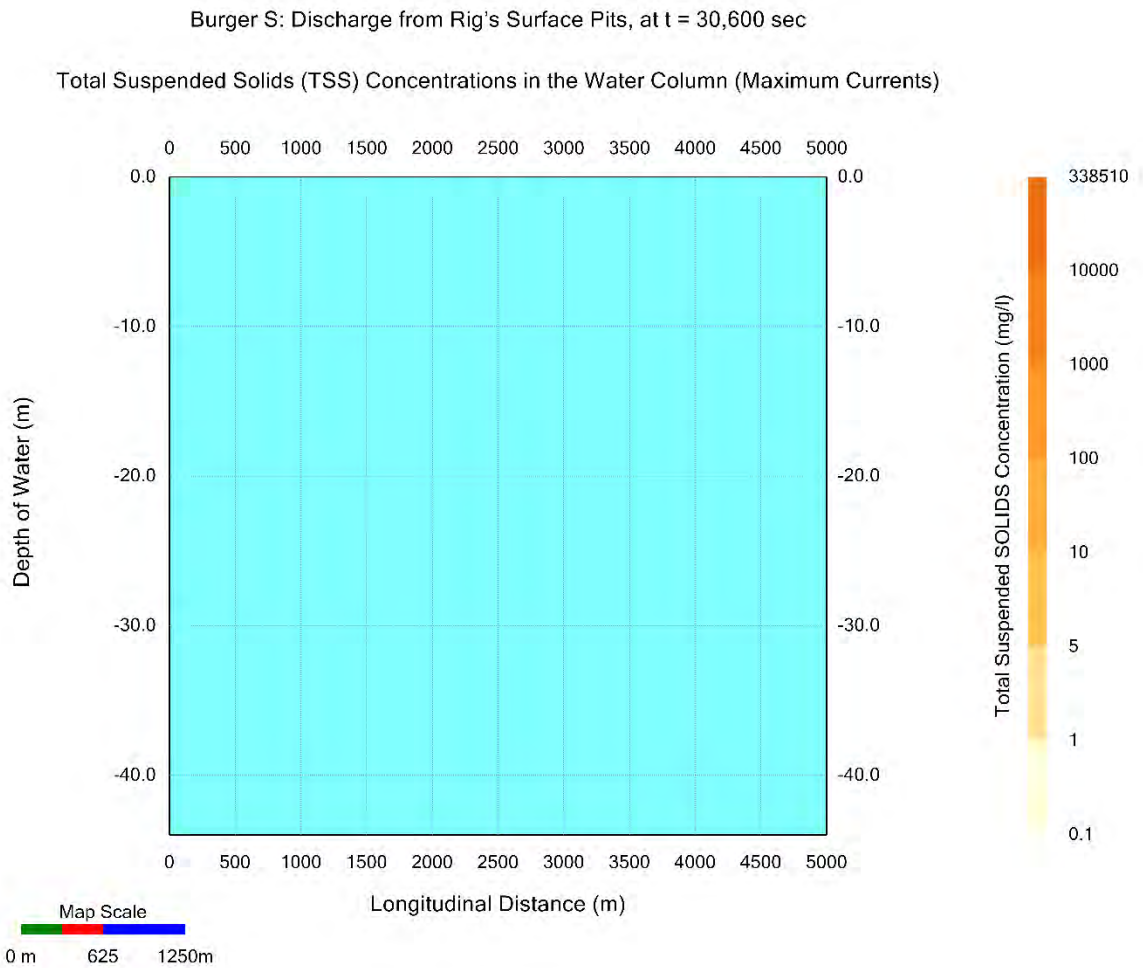
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-33f: TSS concentrations during the maximum currents at 7.5 h (or 5 h after the cessation of release)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-33g: TSS concentrations during the maximum currents at 8.5 h (or 6 h after the cessation of release)



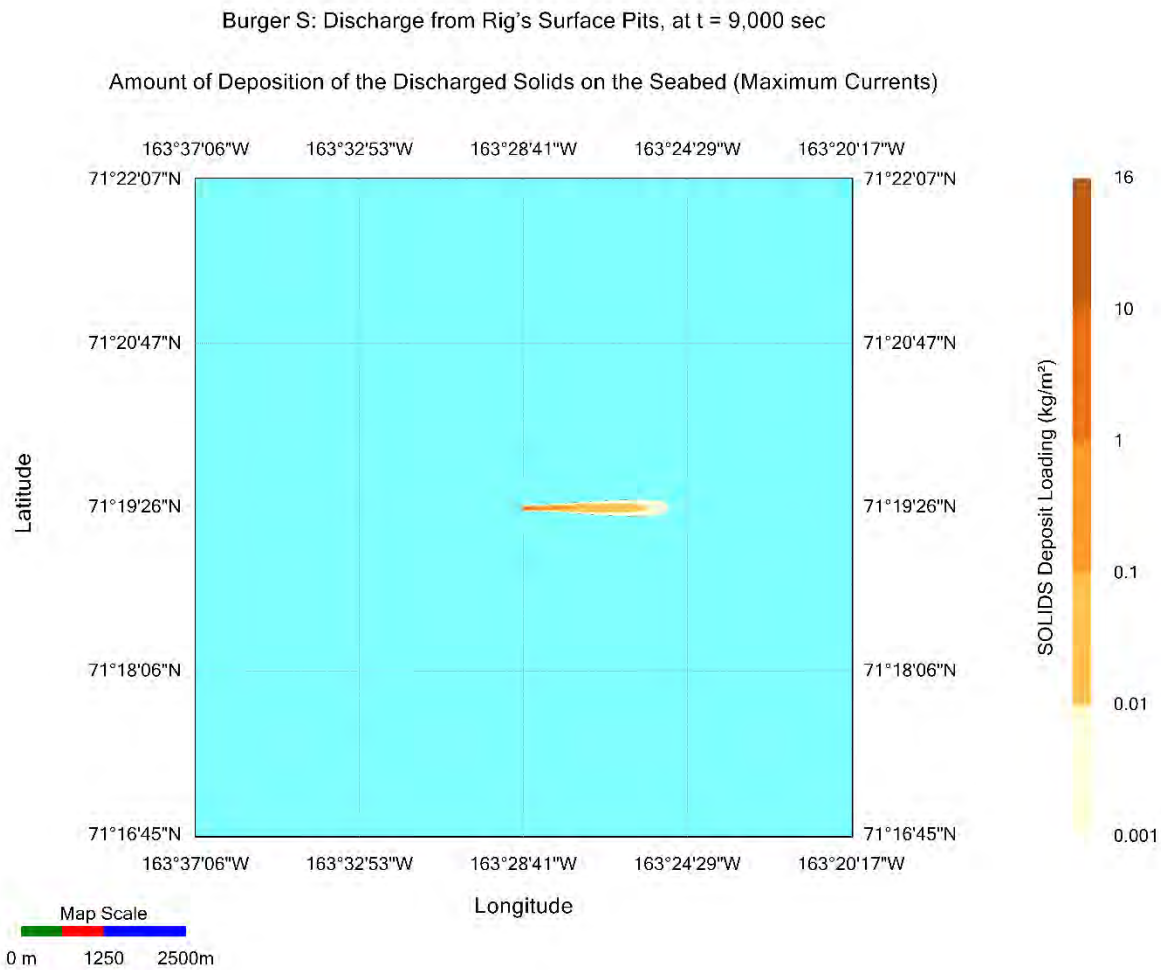
Copyright **2014** by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = **9,000** sec (or **2.5** hours) as a result of the discharge of the water based muds from the rig's surface pits on a plan view is presented in **Figure 6-34**. The model domain extends to **5.0** km in all directions from the discharge location as shown in Figure **6-34**. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading **16** kg/m^2 occurs at **50** m to the east and **10** m to the north from the discharge location. It decreases to a value of **10** kg/m^2 and **1** kg/m^2 at distances approximately **80** m and **135** m, respectively from the discharge location. It varies from **1** kg/m^2 to **0.1** kg/m^2 between distances approximately **135** m and **850** m, respectively from the discharge location. It varies from **0.1** kg/m^2 to **0.01** kg/m^2 between distances approximately **850** m and **1,900** m, respectively from the discharge location. It is less than **0.01** kg/m^2 beyond **1,900** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **10**-, **1**-, **0.1**- and **0.01**-kg/m^2 are: **0.178**, **0.491**, **3.351**, and **19.151** ha, respectively.

Figure 6-34: Amount of deposition of the solids on seabed at maximum currents, Rig's Surface Pits

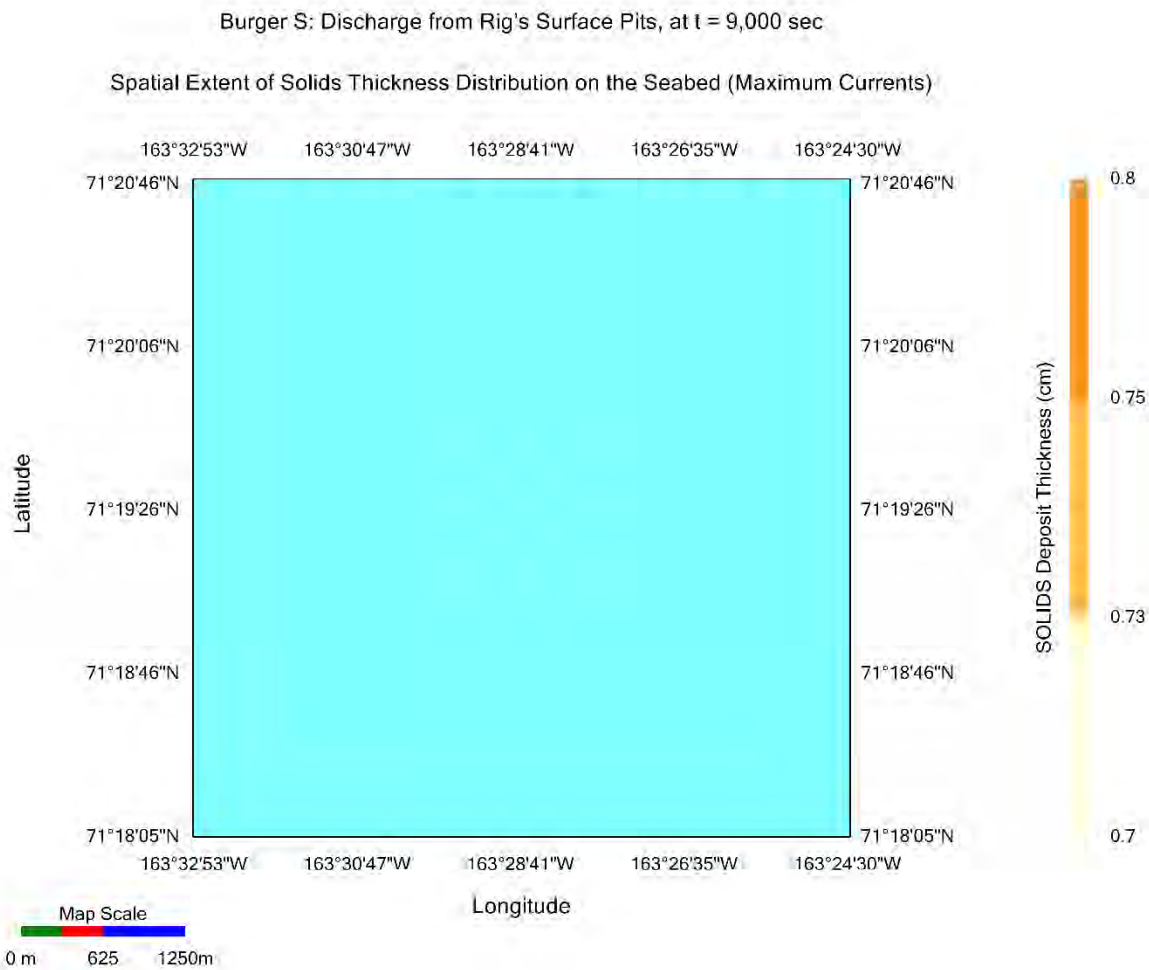


Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

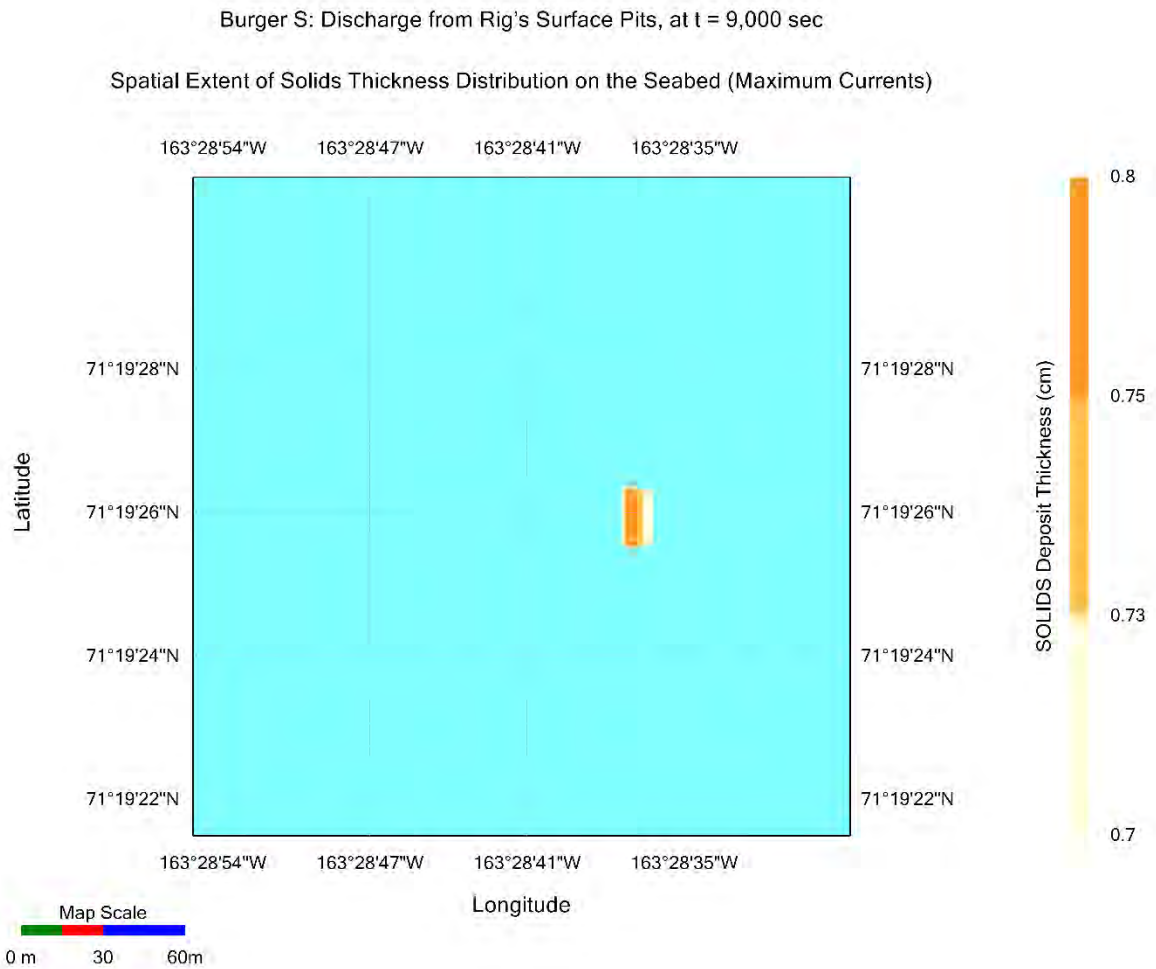
The spatial extent of solids thickness deposited on the sea floor at time, t = **9,000** sec (or **2.5** hours) as a result of the discharge of the water based muds from the rig's surface pits on a plan view is presented in **Figures 6-35a** and **6-35b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5.0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger as shown by a small dot, occurs on a very small surface area compare to the **5** km x **5** km map surface area shown in Figure **6-35**a. The same result is presented in Figure **6-35**b but shows only **240** m x **240** m seabed surface with the well at the center to show the details of the solids accumulation on the seabed. The maximum deposit thickness of **0.8** cm occurs at **50** m to the east and **10** m to the north from the discharge location. **It is less than 1 cm**.

Figure 6-35a: Spatial extent of solids thickness distribution on seabed at maximum currents, Rig's Surface Pits



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-35b: Spatial extent of solids thickness distribution on seabed at maximum currents, Rig's Surface Pits (Zoom In View)



Copyright **2014** by Fluid Dynamix. Company Confidential.

6.8 Combined Model Results - Sea floor and Sea Surface Discharges, Burger S

The spatial extent of the total amount of deposition of the discharged solids on the seabed from the six discrete drilling intervals (**01**, **02**, **03**, **04**, **05**, and **06**) and the rig's surface pits were compiled using the GUIDO **7** (version **7**.**3**) for the OOC model yielding the total solids deposition loading and thickness distribution on the seabed from the drilling operation at the Burger S well site.

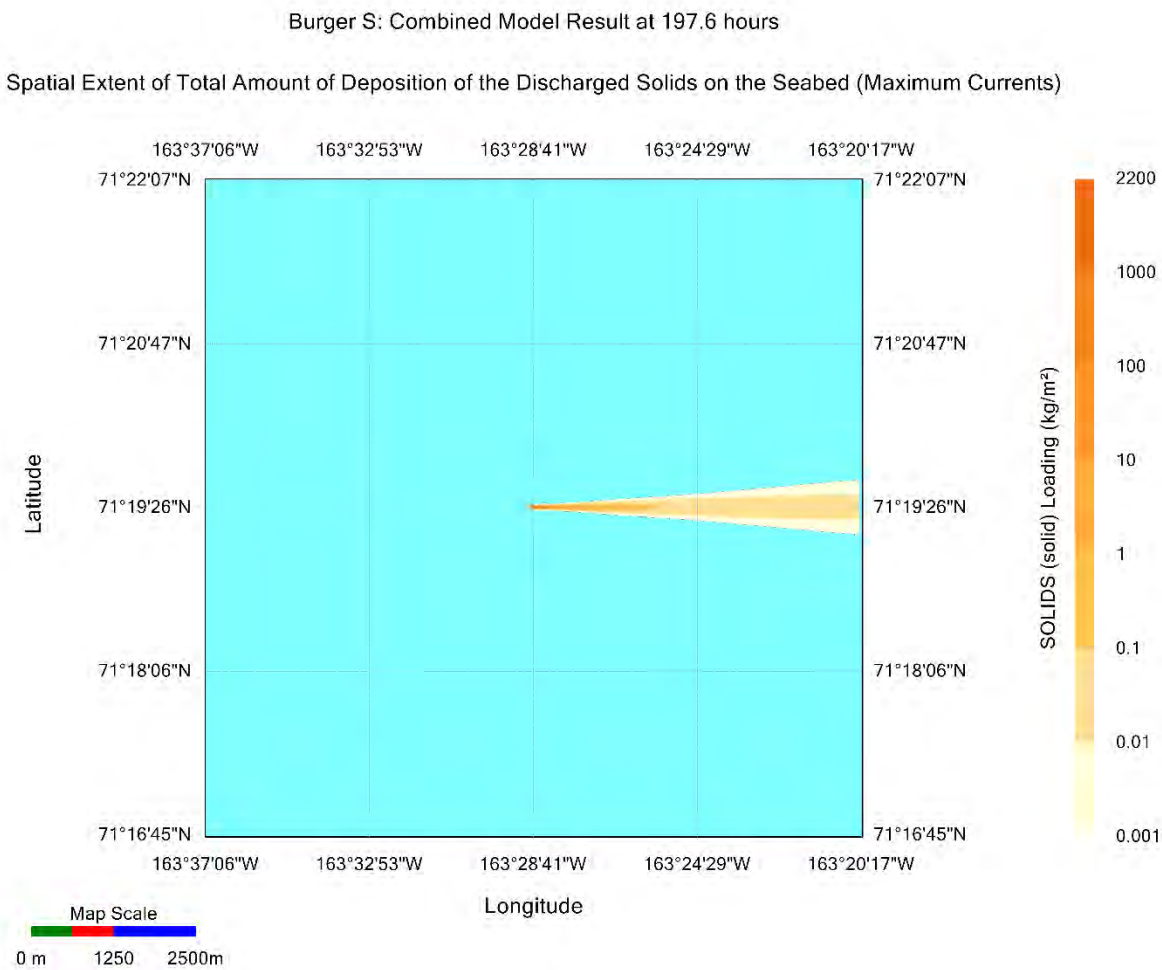
Total Amount of Deposition of the Discharged Solids on the Seabed

The spatial extent of the total amount of solids loading at time t = **197**.**6** hours as a result of the discharge of the cements, water based drill cuttings, drill fluids, and water based muds on a plan view is presented in **Figures 6-36a** and **6-36b**. The model domain extends to **5**.**0** km in all directions from the discharge location as presented in Figure **6**-**36**a. Figure **6**-**36**b presents a zoom in view of the model results, which shows only **2** km x **2** km area of the seabed. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The prevailing current direction is to the east. Therefore, the fate and transport of the discharge plume is towards the east only from the discharge location. The maximum loading of **2,200** kg/m^2 occurs at **10** m to the east and **30** m to the north from the discharge location. It decreases to a value of **100** kg/m^2 at a distance approximately **80** m from the discharge location as shown in Figure **6**-**36**b. It decreases: **100** kg/m^2 to **10** kg/m^2 between **80** m and **275** m; **10** kg/m^2 to **1** kg/m^2 between **275** m and **825** m; and **1** kg/m^2 to **0**.**1** kg/m^2 between **825** m and **1**,**950** m distances approximately from the discharge location. The loading is less than **0**.**1** kg/m^2 beyond **1**,**950** m from the discharge location.

The sea floor areas affected by solids deposit loading of more than **1000**-, **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 are: **0**.**106**, **0**.**340**, **1**.**208**, **3**.**450**, **15**.**080**, and **125**.**133** ha, respectively.

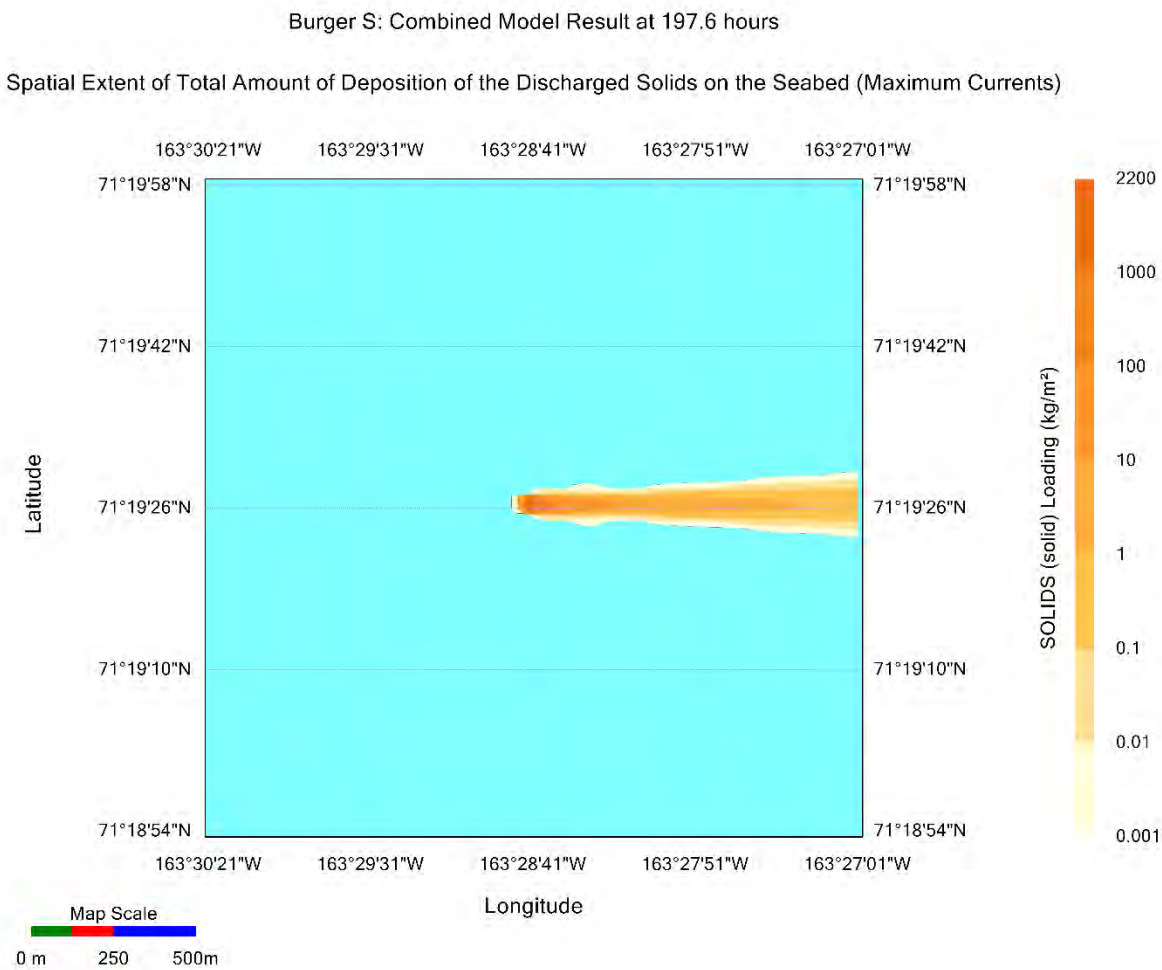
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-36a: Total amount of deposition of the solids on seabed at maximum currents, Burger S



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-36b: Total amount of deposition of the solids on seabed at maximum currents, Burger S (zoom view)



Copyright **2014** by Fluid Dynamix. Company Confidential.

SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

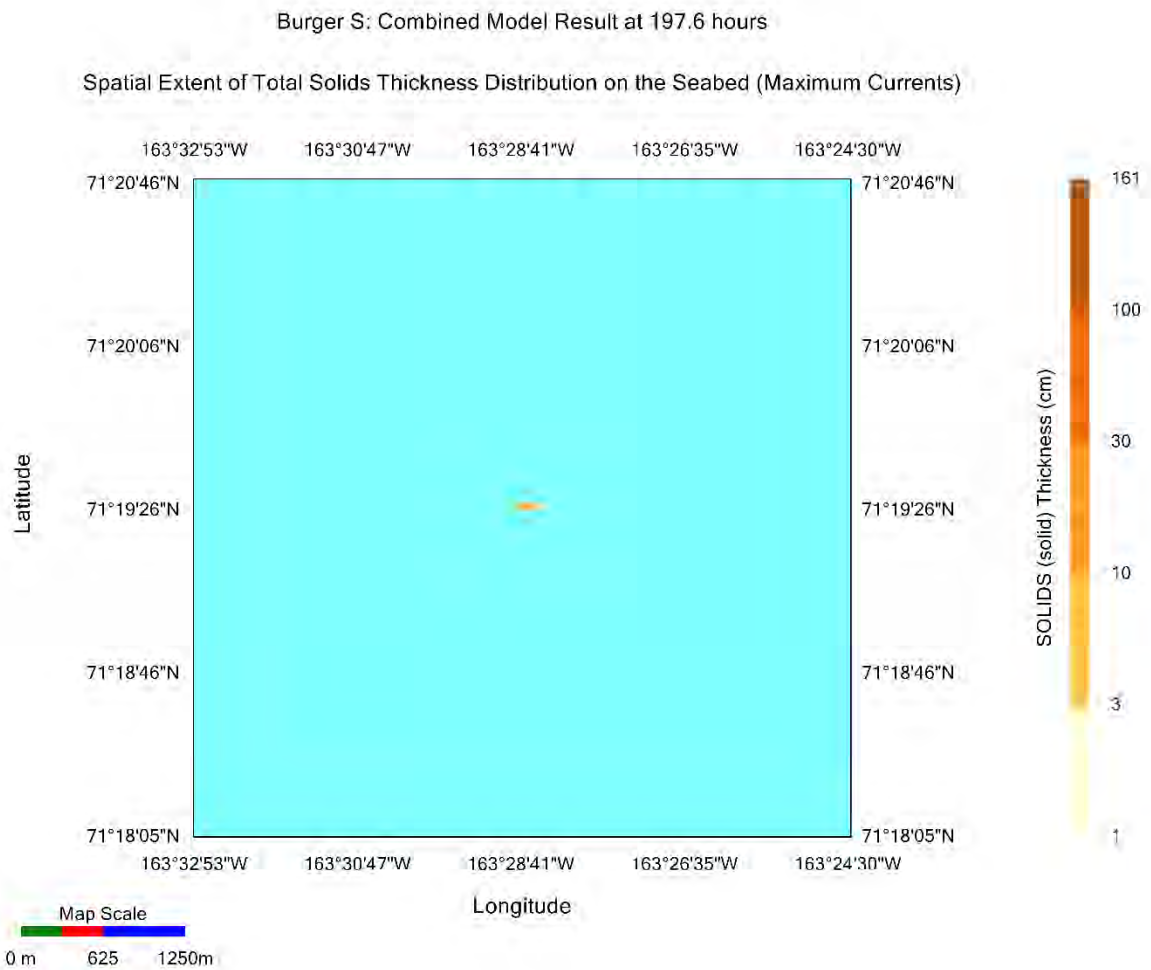
The spatial extent of the total solids thickness of **1** cm or larger deposited on the sea floor at time t = **197**.**6** hours as a result of the discharge of the cements, water based drill cuttings, drill fluids, and water based muds on a plan view is presented in **Figures 6-37a** and **6-37b**. The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to **5**.**0** km in all directions from the discharge location. The solids deposited on the seabed of thickness **1** cm or larger occurs on a small surface area compare to the **5** km x **5** km map surface area shown in Figure **6**-**37**a. The same result is presented in Figure **6**-**37**b but shows only **520** m x **520** m seabed surface to show the details of the solids accumulation of **1** cm or larger on the seabed. The prevailing current direction is to the east. Therefore, the fate and transport of the discharge plume is towards the east only from the discharge location. The maximum deposit thickness of **160**.**2** cm occurs at **10** m to the east and **30** m to the north from the discharge location. It decreases to a value of **100** cm at a distance approximately **20** m from the discharge location as shown in Figure **6**-**37**b. It decreases: **100** cm to **30** cm between **20** m and **30** m; **30** cm to **10** cm between **30** m and **70** m; **10** cm to **3** cm between **70** m and **130** m; and **3** cm to **1** cm between **130** m and **235** m distances approximately from the discharge location. It is less than **1** cm beyond **235** m approximately to the east from the discharge location.

The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **250** m x **40** m rectangle area (or **1**.**048** ha) as presented in Figure **6**-**37**b.

The sea floor areas affected by deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0**.**098**, **0**.**277**, and **1**.**048** ha, respectively. The sea floor areas affected by solids deposit thickness is presented graphically in **Figure 6-38**.

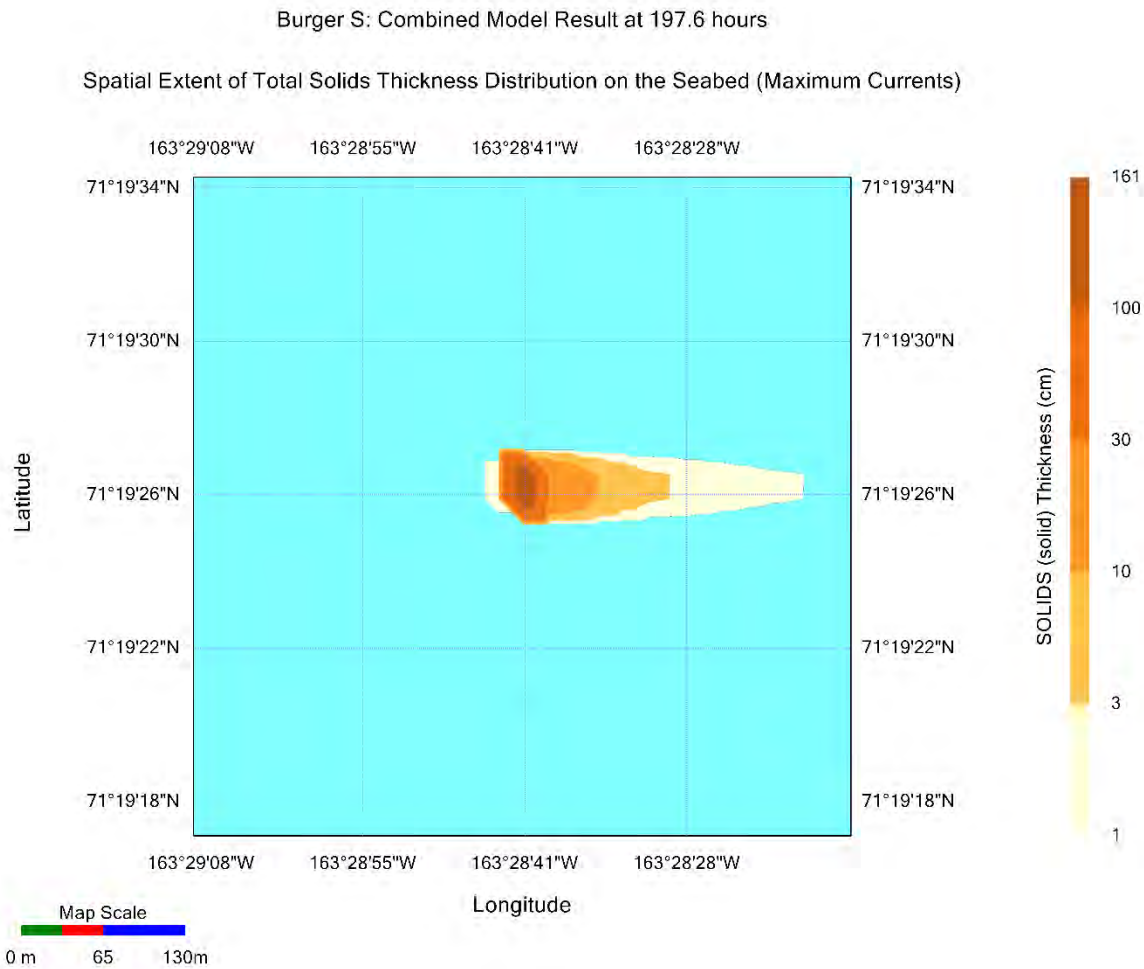
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-37a: Spatial extent of total solids thickness distribution on seabed at maximum currents, Burger S



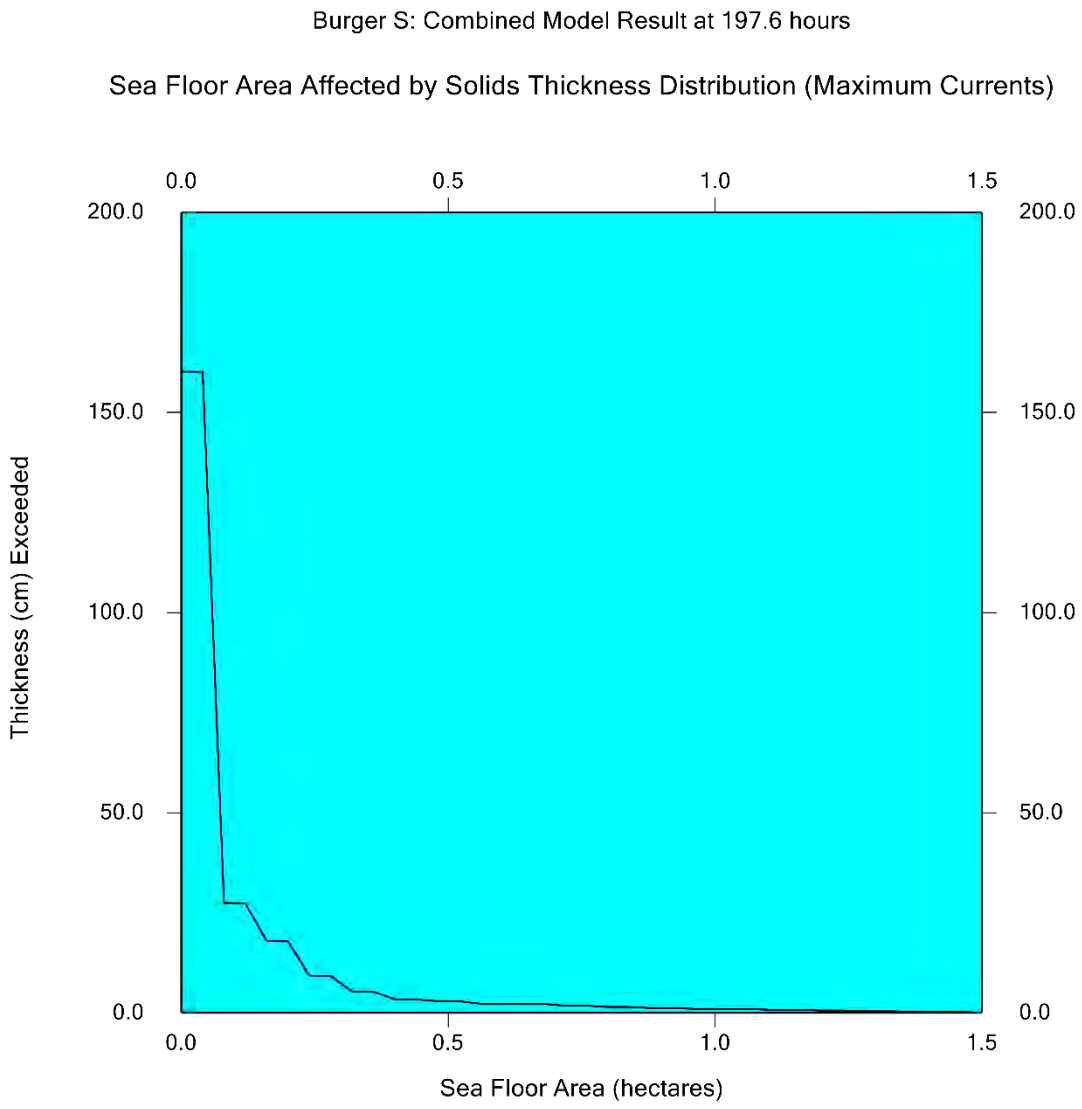
Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-37b: Spatial extent of total solids thickness distribution on seabed at maximum currents, Burger S (Zoom In View)



Copyright **2014** by Fluid Dynamix. Company Confidential.

Figure 6-38: Sea floor area affected by solids thickness distribution at maximum currents, Burger S



Copyright **2014** by Fluid Dynamix. Company Confidential.

The OOC model predictions for the solids deposition on the seabed from the cements, water based drill cuttings, drill fluids, water based muds discharges from the six discrete drilling intervals and the rig's surface pits at the maximum currents speeds were compiled using the GUIDO **7** software yielding the total solids deposition loading and thickness distribution on the seabed from the drilling operation at the Burger S well site and are presented in **Table 6-2**. The sea floor areas affected at the end of the drilling operation at the Burger S well site by the solids deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0.098**, **0.277**, and **1.048** ha, respectively as presented in Table **6-2**.

The total suspended solids (TSS) concentrations in the water column are presented in **Table 6-3**. The TSS concentrations during the drilling operations are: **14.0** to **205.0** mg/l at **100** m; **3.2** to **92.7** mg/l at **300** m; and **0**.9 to **29.7** mg/l at **1000** m distances from the source.

Table 6-2: Total Solids Deposition on the Seabed at Maximum Currents

The OOC Model Predictions at Maximum Currents											
Well ID	Discharge Scenario	Drilling Intervals	Durations of Discharge	Depth of Water	Depth of Discharge	Effluent Discharge Rate	Pre-diluted Effluent Discharge Rate	Solids Deposition on the Seabed			
								Total Area (ha) Covered by Solids Thickness Larger than 100-, 10-, and 1-cm			Maximum Deposit Thickness
			Hours	m	m	bbls/hour	bbls/hour	100 cm	10 cm	1 cm	cm
Burger S	Sea Floor	1	66.00	44.00	42.17	68.83	14,000.00	0.088	0.173	0.423	120.34
		2	5.20	44.00	42.17	116.30	14,000.00	-	-	0.118	8.16
		3	34.40	44.00	42.17	86.64	14,000.00	-	0.112	0.248	37.34
	Sea Surface	4	23.30	44.00	8.53	148.63	159.46	-	-	0.512	5.60
		5	29.00	44.00	8.53	68.87	79.70	-	-	0.349	3.47
		6	37.20	44.00	8.53	26.47	37.30	-	-	0.193	1.84
		Rig's Surface Pits	2.50	44.00	8.53	970.80	970.80	-	-	-	0.78
	At the end of the Drilling Operation							0.098	0.277	1.048	160.20

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 6-3: Total Suspended Solids (TSS) Concentrations in the Water Column at Maximum Currents

The OOC Model Predictions at Maximum Currents												
Well ID	Discharge Scenario	Drilling Intervals	Durations of Discharge	Depth of Water	Depth of Discharge	Effluent Discharge Rate	Pre-diluted Effluent Discharge Rate	Total Suspended Solids (TSS) Concentrations (mg/l) in Water Column at 10-, 30-, 100-, 300-, and 1000-m from the Source				
			Hours	m	m	bbls/hour	bbls/hour	10 m	30 m	100 m	300 m	1000 m
Burger S	Sea Floor	1	66.00	44.00	42.17	68.83	14,000.00	1,470.2	575.3	205.0	57.8	8.9
		2	5.20	44.00	42.17	116.30	14,000.00	1,546.6	487.4	173.9	47.1	7.4
		3	34.40	44.00	42.17	86.64	14,000.00	988.6	353.4	121.6	33.9	5.2
	Sea Surface	4	23.30	44.00	8.53	148.63	159.46	1,045.9	335.4	90.1	9.3	2.5
		5	29.00	44.00	8.53	68.87	79.70	538.6	153.1	35.6	6.0	1.7
		6	37.20	44.00	8.53	26.47	37.30	210.9	68.8	14.0	3.2	0.9
		Rig's Surface Pits	2.50	44.00	8.53	970.80	970.80	1,757.0	320.4	174.2	92.7	29.7

Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 7.0 SENSITIVITY ANALYSIS

The dispersion and deposition numeric simulations were performed both for the sea floor and sea surface discharge scenarios for two sets of currents speed: mean currents speed and maximum currents speed as listed in **Table 7-1**. This provides a sensitivity analysis of the model results: solids deposition presented in **Table 7-2** and total suspended solids (TSS) concentrations in the water column presented in **Table 7-3** to the model input parameter currents speed. It is evidenced from Table **7-2** that the maximum currents speed carries the discharged solids farther from the source and deposits over a larger sea floor area with a smaller peak value compared to those at the mean currents speed. The sea floor area covered by **1** cm or larger solids deposit at the mean and the maximum currents are: **0.510** and **1.048** ha, respectively. Whereas, the maximum deposit thickness at mean and maximum currents are: **201.7** and **160.2** cm, respectively. Therefore, the discharged solids at the maximum currents are deposited approximately over twice the sea floor areas compared to the mean currents but have a smaller peak thickness value.

The TSS concentrations at the maximum currents speed are generally significantly higher than those values at the mean currents speed due to the turbulent mixing at a higher ambient velocity as presented in Table **7-3**. For example, the TSS concentrations at the maximum currents are approximately **2.1** times higher than those values at the mean currents for the sea floor discharge scenario at **100** m from the source. It is more than **2.4** times higher than those values at the mean currents for the sea surface discharge scenario at **100** m from the source except for the water based muds discharge from the rig's surface pits.

The OOC model predicted fate and transport of the TSS concentrations presented in Sections **5** and **6** by a series of plots for each drilling intervals and the discharge from the rig's surface pits show that the TSS concentrations attain a value of less than **0.1** mg/l at: **6** to **24** hours after the cessation of the discharge during the mean currents and **4** to **6** hours after the cessation of the discharge during the maximum currents. The maximum duration to attain less than **0.1** mg/l of TSS concentration is **24** hours after the cessation of the discharge.

The OOC model predicted water based drill cuttings and drill fluids deposition thickness of each sediment class at the end of the drilling operation at the Burger S well site for both at the mean and maximum currents speeds are presented in **Tables 7-4** and **7-5**, respectively. The drill cutting deposition thickness for all the nine (**9**) sediment classes (Table **3-2**) are presented at: **10**, **30**, **90**, and **110** m from the source of the discharge. These tables also exhibit that the maximum currents speed carries the discharged solids farther from the source: smaller deposition thickness of drill cutting value at **10** m from the source and larger deposition thickness of drill cutting value at **30** m from the source compared to those at the mean currents speed.

Table 7-1: Mean and Maximum Currents Speed for the Burger Field, for July through October

Water Depth	Mean Current		Maximum Current	
	Speed	Direction (from True North)	Speed	Direction (from True North)
m	cm/s	°T	cm/s	°T
0.0	7.0	90	25.0	90
15.0	7.0	90	25.0	90
20.0	7.0	90	25.0	90
44.0	7.0	90	25.0	90

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 7-2: The OOC Model Predicted Solids Deposition at the Mean and the Maximum Currents Speed

The OOC Model Predictions at the Mean and the Maximum Currents Speed												
Well ID	Discharge Scenario	Drilling Intervals	Durations of Discharge	Effluent Discharge Rate	Solids Deposition on the Seabed at Mean Currents				Solids Deposition on the Seabed at Maximum Currents			
					Total Area (ha) Covered by Solids Thickness larger than 100-, 10-, and 1-cm			Maximum Deposit Thickness	Total Area (ha) Covered by Solids Thickness Larger than 100-, 10-, and 1-cm			Maximum Deposit Thickness
			Hours	bbls/hour	100 cm	10 cm	1 cm	cm	100 cm	10 cm	1 cm	cm
Burger S	Sea Floor	1	66.00	68.83	0.090	0.119	0.271	129.63	0.088	0.173	0.423	120.34
		2	5.20	116.30	-	-	0.117	8.48	-	-	0.118	8.16
		3	34.40	86.64	-	0.112	0.191	39.28	-	0.112	0.248	37.34
	Sea Surface	4	23.30	148.63	-	0.100	0.274	14.71	-	-	0.512	5.60
		5	29.00	68.87	-	-	0.261	9.55	-	-	0.349	3.47
		6	37.20	26.47	-	-	0.192	4.30	-	-	0.193	1.84
		Rig's Surface Pits	2.50	970.80	-	-	0.091	1.12	-	-	-	0.78
	At the end of the Drilling Operation				**0.102**	**0.195**	**0.510**	**201.74**	**0.098**	**0.277**	**1.048**	**160.20**

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 7-3: The OOC Model Predicted TSS Concentrations at the Mean and the Maximum Currents Speed

The OOC Model Predictions at the Mean and the Maximum Currents Speed														
Well ID	Discharge Scenario	Drilling Intervals	Durations of Discharge	Effluent Discharge Rate	Total Suspended Solids (TSS) Concentrations (mg/l) in Water Column at 10-, 30-, 100-, 300-, and 1000-m from the Source									
					Mean Currents					Maximum Currents				
			Hours	bbls/hour	10 m	30 m	100 m	300 m	1000 m	10 m	30 m	100 m	300 m	1000 m
Burger S	Sea Floor	1	66.00	68.83	1,085.8	383.6	96.1	20.3	3.3	1,470.2	575.3	205.0	57.8	8.9
		2	5.20	116.30	868.5	295.0	81.1	16.9	2.7	1,546.6	487.4	173.9	47.1	7.4
		3	34.40	86.64	556.4	208.0	57.1	11.8	1.9	988.6	353.4	121.6	33.9	5.2
	Sea Surface	4	23.30	148.63	713.3	202.4	23.9	5.5	0.9	1,045.9	335.4	90.1	9.3	2.5
		5	29.00	68.87	443.0	111.7	13.0	3.1	0.5	538.6	153.1	35.6	6.0	1.7
		6	37.20	26.47	185.6	43.3	6.0	1.6	0.2	210.9	68.8	14.0	3.2	0.9
		Rig's Surface Pits	2.50	970.80	608.5	428.3	232.2	109.0	0.0	1,757.0	320.4	174.2	92.7	29.7

Copyright **2014** by Fluid Dynamix. Company Confidential.

Table 7-4: Model Predicted Drill Cutting Deposition Thickness at Mean Currents Speed

The OOC Model Predicted Drill Cutting Deposition Thickness of Each Sediment Class Discharge at the End of the Drilling Operation									
Well ID	Discharge Height Above Bottom Depth		Current Speed		Estimated Particle Diameter	Deposition Thickness of Drill Cutting (m)			
	Sea Floor	Sea Surface				At 10, 30, 90, and 110 meters			
	m	m	m/s		µm	10 m	30 m	90 m	110 m
Burger S	1.83	35.47	Mean Currents	0.07	1	0.089	0.003	0.000	0.000
					4	0.073	0.005	0.002	0.002
					15	0.113	0.017	0.005	0.004
					50	0.062	0.007	0.000	0.000
					125	0.032	0.004	0.002	0.002
					250	0.332	0.051	0.001	0.000
					500	0.328	0.056	0.000	0.000
					1000	0.352	0.002	0.000	0.000
					3600	0.579	0.000	0.000	0.000

Table 7-5: Model Predicted Drill Cutting Deposition Thickness at Maximum Currents Speed

The OOC Model Predicted Drill Cutting Deposition Thickness of Each Sediment Class Discharge at the End of the Drilling Operation									
Well ID	Discharge Height Above Bottom Depth		Current Speed		Estimated Particle Diameter	Deposition Thickness of Drill Cutting (m)			
	Sea Floor	Sea Surface				At 10, 30, 90, and 110 meters			
	m	m	m/s		µm	10 m	30 m	90 m	110 m
Burger S	1.83	35.47	Maximum Currents	0.25	1	0.053	0.027	0.001	0.000
					4	0.043	0.022	0.002	0.001
					15	0.072	0.034	0.003	0.002
					50	0.052	0.003	0.003	0.002
					125	0.023	0.009	0.000	0.000
					250	0.295	0.038	0.001	0.005
					500	0.291	0.007	0.037	0.021
					1000	0.273	0.007	0.000	0.000
					3600	0.451	0.116	0.000	0.000

Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 8.0 SUMMARY AND CONCLUSION

The primary goal of this environmental numeric modeling was to simulate the dispersion and deposition of the cements, water based drill cuttings, drill fluids, and water based muds discharges from the drilling operation by the drill ship Polar Pioneer at the prospect well site Burger S located offshore Chukchi Sea using the Offshore Operators Committee Mud and Produced Water Discharge Model (OOC Model). The prospect well Burger S is located in block **6762** area of Posey. The depth of water is **44.0** m. The dispersion and deposition numeric simulations were performed for the six discrete drilling intervals divided into two discharge scenarios: sea floor (**013**) and sea surface (**001**). The sea floor discharges occur from the drilling intervals **1**, **2**, and **3** and the sea surface discharges occur from the drilling intervals **4**, **5**, and **6**. The sea floor discharges occur at **1.83** m (or **6** feet) above the sea floor and the sea surface discharges occur at **8.53** m (or **28** feet) below the sea surface. Moreover, approximately **2**,**427** bbls of the water based muds will be discharged at the end of the drilling of the well from the rig's surface pits at a rate of **970**.**80** bbls/hour for **2**.**5** hours. These constitute discharges described in Permit no.: **AKG-28-8100** as discharge **013** (Muds, Cuttings, and Cements at the Seafloor) and discharge **001** (Water-Based Drilling Fluids and Drill Cuttings).

The cements, water based dill cuttings, and drill fluids mass discharge rate (effluent) for drilling intervals **1**, **2**, and **3** for the sea floor (**013**) discharges are: **68**.**83**, **116**.**30**, and **86**.**64** bbls/hour, respectively. These sediments will be pumped away via use of a pump at the sea floor. A flexible hose suction pipe will intake a large volume of sea water to move the cements, water based drill cuttings, and drill fluids from the seafloor and will discharge from a **12**.**0** inch internal diameter discharge pipe at **14**,**000** bbls/hour. This yields into **203**.**4**, **120.4**, and **161**.**6** pre-dilution factors before discharging into the ambient for the drilling intervals **1**, **2**, and **3**, respectively. The discharge pipe of the seafloor pump is located at **1**.**83** m (or **6** feet) above the seafloor and oriented horizontally aligned with the direction of the current, which is to the east.

The water based dill cuttings and drill fluids mass discharge rate (effluent) for drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharges are: **148**.**63**, **68**.**87**, and **26**.**47** bbls/hour, respectively. Sea water at a rate of **10**.**83** bbls/hour will be added to the drill cuttings and drill fluids before discharging into the ambient during the drilling of the bottom hole section i.e., the drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharge scenario. This yields into **1**.**1**, **1**.**2**, and **1**.**4** pre-dilution factors before discharging into the ambient for the drilling intervals **4**, **5**, and **6**, respectively. The pre-diluted water based dill cuttings and drill fluids discharge rate (effluent) for drilling intervals **4**, **5**, and **6** for the sea surface (**001**) discharges are: **159**.**46**, **79**.**70**, and **37**.**30** bbls/hour, respectively.

The outer diameter of the pipe for the sea surface discharge is **16**.**0** inches. It runs through the main deck of the drill rig Polar Pioneer and comes out on the bottom of the ship. The discharge pipe is located approximately **8**.**53** m below the water line. Therefore, the surface discharges occur at a depth of approximately **8**.**53** m from the sea surface. The internal pipe diameter of **15**.**25** inches was used for modeling the sea surface discharge scenario based on a **0**.**75** inches of total pipe wall thickness. The discharge pipe is oriented vertically downward with respect to the sea surface and discharges at approximately **8.53** m below the sea surface for modeling the sea surface discharge scenario.

The water based drill fluids for the top hole section i.e., the drilling intervals **1**, **2**, and **3**, for the sea floor (**013**) discharge scenario is composed of primarily sea water, which includes **30** lbs. of bentonite, **0**.**5** lbs. of xanthan gum, and **0**.**03** lbs. of Gelex bentonite extender in each barrel of sea water.

The water based drill fluids for the bottom hole section i.e., the drilling intervals **4**, **5**, and **6**, for the sea surface (**001**) discharge scenario is composed of primarily sodium chloride (NaCl) brine system. Sodium chloride brine systems are single-salt solutions of sodium chloride and water. Saturated sodium chloride brine has a density of **1,198** kg/m^3 or **10** lb/gal and used as a base drill fluids for the bottom hole section. Barite at the rate of **1**.**413** lb/gal is added to the base drill fluids to increase the weight of the drill fluids to **1,318.13** kg/m^3 (or **11** lb/gal**)** for drilling the interval **04** of the bottom hole section. Moreover, barite at the rate of **2**.**83** lb/gal is added to the base

Copyright **2014** by Fluid Dynamix. Company Confidential.

drill fluids to increase the weight of the drill fluids to **1,438** kg/m^3 (or **12** lb/gal) for drilling the intervals **05** and **06** of the bottom hole section.

The dispersion and deposition numeric simulations both for the sea floor (**013**) and the sea surface (**001**) discharge scenarios were performed for two sets of currents speed: mean currents and maximum currents. This provides a sensitivity analysis of the numeric model results to the model input parameter: currents speed. The current speed of **7** cm/sec was used as the mean value and **25** cm/sec was used as the maximum value in the OOC model.

The solids deposition on the seabed from the effluents discharged during the six discrete drilling intervals and the rig's surface pits were compiled using the Graphical User Interface Discharge Offshore (GUIDO, version **7**.**3**) software for the OOC model yielding the total solids deposition loading and total thickness distribution on the seabed from the drilling operation by the drill ship Polar Pioneer at the Burger S well site.

The OOC model predicted total amount of solids loading on the sea floor as a result of the discharge of the cements, water based drill cuttings, drill fluids, and water based muds at the mean currents are: (i) **100** kg/m^2 at **50** m, (ii) **10** kg/m^2 at **130** m, (iii) **1** kg/m^2 at **380** m, (iv) **0.1** kg/m^2 at **1,050** m, and (v) **0.01** kg/m^2 at **2,600** m distances approximately from the source towards the direction of the current.

The sea floor areas affected by solids deposit loading of more than **1000-, 100-, 10-, 1-, 0.1-,** and **0.01-**kg/m^2 at the mean currents are: **0**.**108**, **0**.**268**, **0**.**598**, **4**.**243**, **17**.**429**, **126**.**801**, and **684**.**938** ha, respectively.

The OOC model predicted maximum deposit thickness at the mean currents is **201.7** cm, which occurs at **10** m to the east and **30** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **105** m to the east from the discharge location.

The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **130** m x **40** m rectangle area (or **0**.**510** ha) at the mean currents. The sea floor areas affected by deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0**.**102**, **0**.**195**, and **0**.**510** ha, respectively.

The OOC model predicted total amount of solids loading on the sea floor as a result of the discharge of the cements, water based drill cuttings, drill fluids, and water based muds at the maximum currents are: (i) **100** kg/m^2 at **80** m, (ii) **10** kg/m^2 at **275** m, (iii) **1** kg/m^2 at **825** m, and (iv) **0**.**1** kg/m^2 at **1**,**950** m distances approximately from the source towards the direction of the current.

The sea floor areas affected by solids deposit loading of more than **1000**-, **100**-, **10**-, **1**-, **0**.**1**-, and **0**.**01**-kg/m^2 at the maximum currents are: **0**.**106**, **0**.**340**, **1**.**280**, **3**.**450**, **15**.**080**, and **125**.**133**, ha, respectively.

The OOC model predicted maximum deposit thickness at the maximum currents is **160.2** cm, which occurs at **10** m to the east and **30** m to the north from the discharge location. It decreases to a value of **1** cm at a distance approximately **235** m to the east from the discharge location.

The sea floor area affected by solids deposit thickness of **1** cm or larger is approximately a **250** m x **40** m rectangle area (or **1**.**048** ha) at the maximum currents. The sea floor areas affected by deposit thickness larger than **100**-, **10**-, and **1**-cm are: **0**.**098**, **0**.**277**, and **1**.**048** ha, respectively.

The OOC model predicted fate and transport of the TSS concentrations show that the TSS concentrations attain a value of less than **0.1** mg/l at: **6** to **24** hours after the cessation of the discharge during the mean currents and **4** to **6** hours after the cessation of the discharge during the maximum currents. The maximum duration to attain less than **0.1** mg/l of TSS concentration is **24** hours after the cessation of the discharge.

The impacts on the ambient from the drilling operations at the Burger S well in terms of solids deposit thickness of **1** cm or larger is limited to an area: **0.510** ha at the mean currents and **1.048** ha at the maximum currents. The impacts at **100** m from the discharge source are: solids deposit thickness in the range of **1** to **3** cm at the mean

Copyright **2014** by Fluid Dynamix. Company Confidential.

currents and **3** to **10** cm at the maximum currents on the seabed. The impacts on the ambient water in terms of the TSS concentrations at **100** m from the discharge source are: **6.0** to **233.2** mg/l at the mean currents and **14.0** to **205.0** mg/l at the maximum currents. The impacts at **300** m from the source are: solids deposit thickness of less than **1** cm on the seabed both for the mean and maximum currents. The impacts on the ambient water in terms of the TSS concentrations at **300** m from the discharge source are: **1.6** to **109.0** mg/l at the mean currents and **3.2** to **92.7** mg/l at the maximum currents. The overall impacts on the ambient from the drilling operations at the Burger S well by the drill ship Polar Pioneer can be classified as low.

Copyright **2014** by Fluid Dynamix. Company Confidential.

SECTION 9.0 REFERENCES

Alam, M. and Brandsma, M.G. “GUIDO – Graphical User Interface for the OOC Model for Offshore Discharges, User Guide, Version **7**.**0**”, April **2013**.

Brandsma, M.G. and Smith J.P. “Offshore Operators Committee Mud and Produced Water Discharge Model – Report and Users Guide”, December **1999**.

Brandsma, M.G. Automated Validation of the Offshore Operators Committee Discharge Model and application to predicting drilling solids accumulation on the sea floor. Environmental Modeling and Software. V **19**. No **7**-**8**. **2004**. pp **617**-**628**.

Crowley, W. P., **1968**. A Global Numerical Ocean Model: Part **1**, Journal of Computational Physics. Volume **3**, Page **111**-**147**.

Keith Dyer, **1986**. Coastal and Estuarine Sediment Dynamics published by John Wiley & Sons.

O'Reilly, J., Sauer, Jr. T.C., Ayers, Jr. R.C., Meek, R.P., and Brandsma, M.G. "OOC mud discharge model: field verification study", In: Drilling Wastes. Engelhardt, F.R., Ray, J.P., Gillam, A.H., Eds. Elsevier Applied Science. New York, **1989**.

Smith, J.P., Mairs, H.L., Brandsma, M.G., Meek, R.P., and Ayers, R.C. Jr. **1994**. Field Validation of the Offshore Operators Committee (OOC) Produced Water Discharge Model, SPE Paper **28350**. Presented at the SPE **69**th Annual Technical Conference Exhibition, New Orleans, LA, September **25**-**28**, **1994**.

Smith, J.P., Brandsma, M.G., and Nedwed, T.J.: Field verification of the Offshore Operators Committee (OOC) Mud and Produced Water Discharge Model. Environmental Modelling and Software, **2004**. pp. **739**-**749**.

Weingartner, T. and S. Danielson. **2010**. Physical oceanographic measurements in the Klondike and Burger prospects of the Chukchi Sea: **2008** and **2009**.

This is the last page of this document.

Copyright **2014** by Fluid Dynamix. Company Confidential.