Trinity Consultants

trinityconsultants.com

Kitimat Airshed Emissions Effects Assessment and CALPUFF Modelling

EMA of BC - May 2016 Session - Regional Air Topics

Anna Henolson

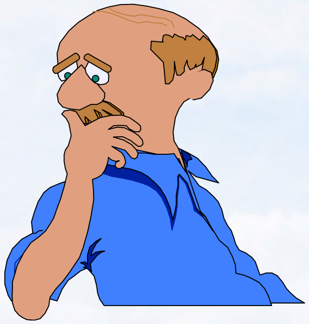
Topics to Cover

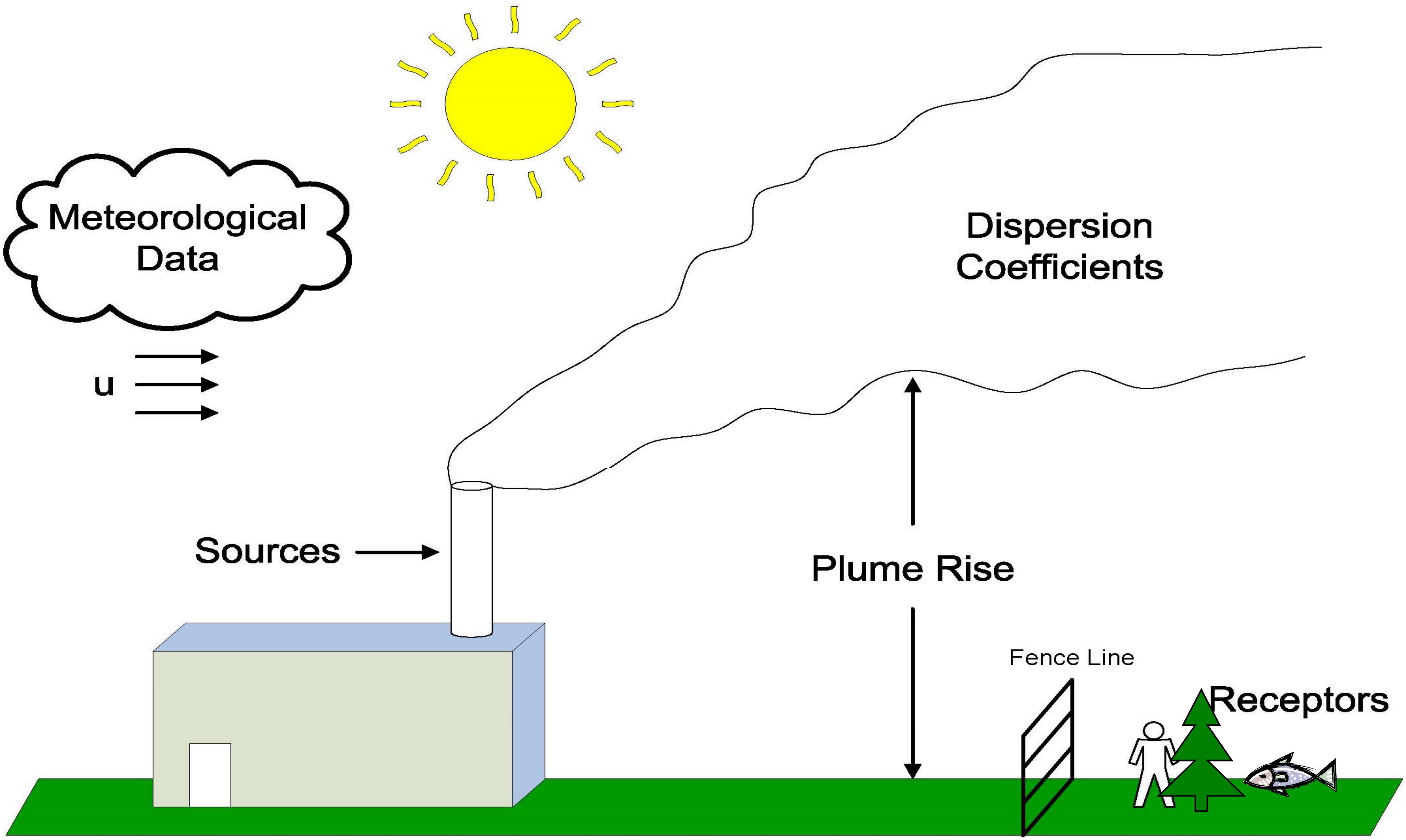
- What is Air Dispersion Modelling?
  - Types of Models
  - CALPUFF Overview
- Kitimat Emissions Effects Assessment Example
  - CALPUFF Concentration Results
  - CALPUFF Deposition Results
- Translating lessons learned to permit modelling

What is Modeling?

Modeling - a definition

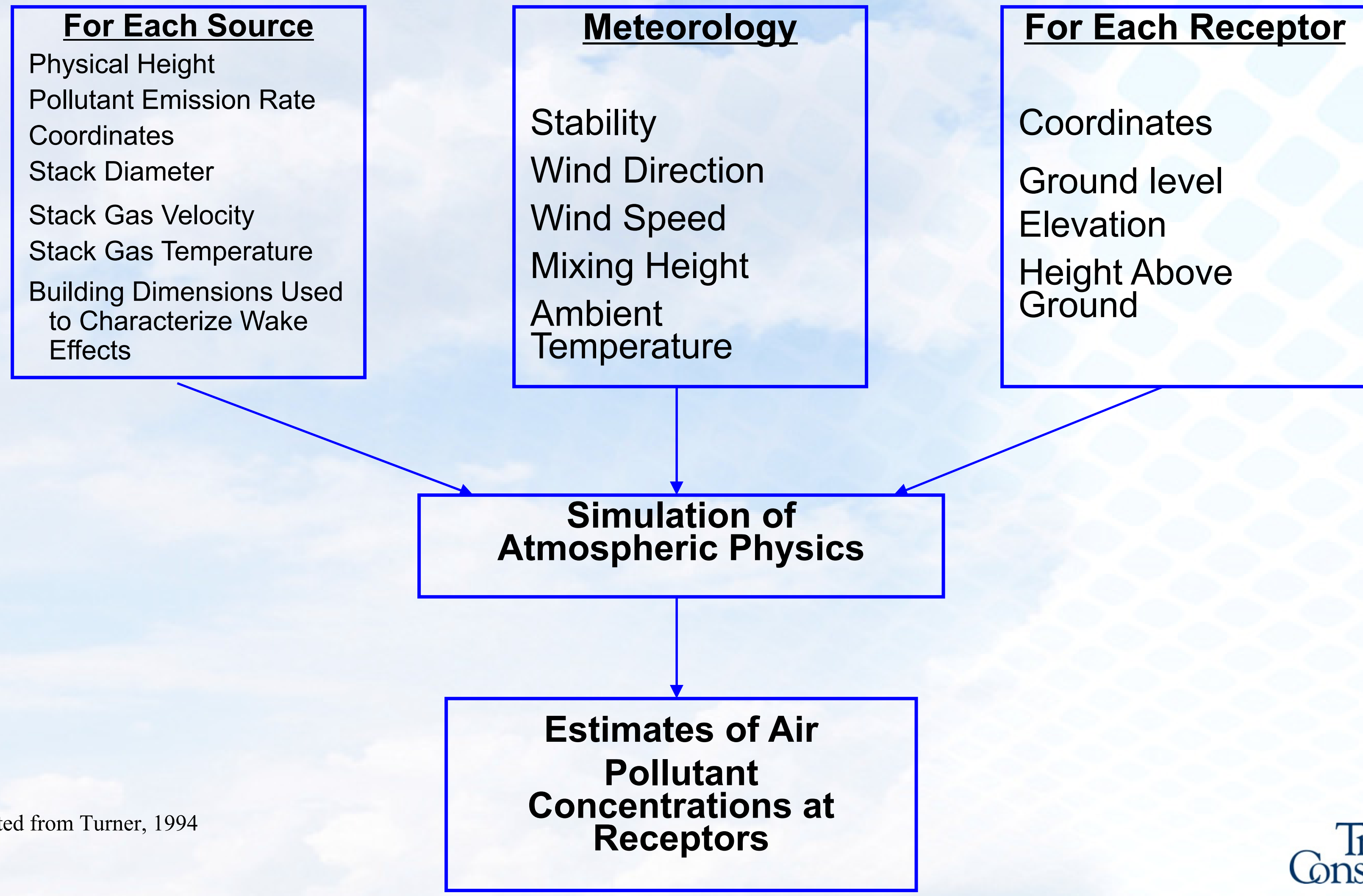
“ Modeling is the combined mathematical simulation of atmospheric processes which gives a convenient and physically meaningful way of relating sources/emissions to ambient air impacts”





Trinity Consultants

Structure of a Dispersion Model



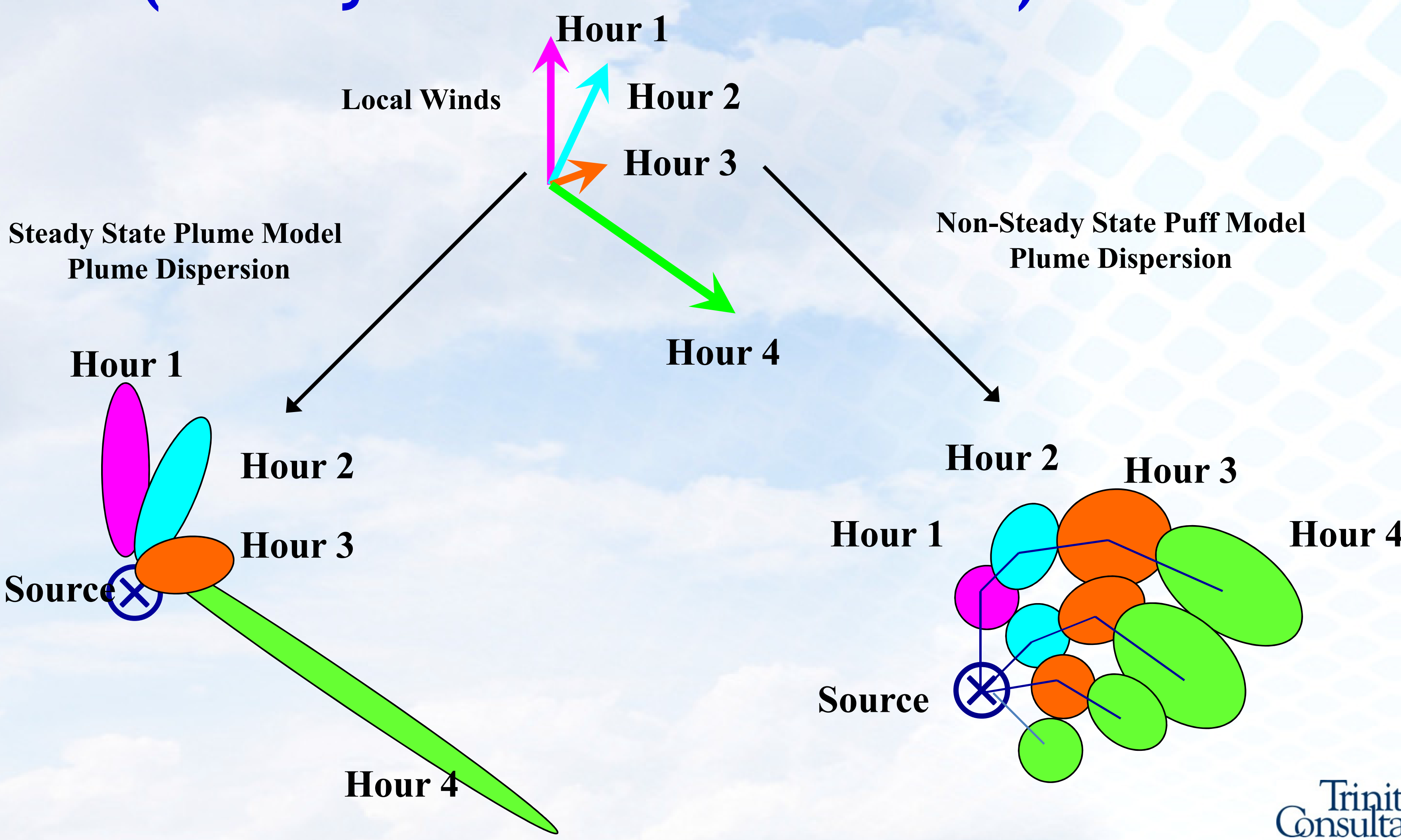
Adapted from Turner, 1994

Dispersion Models

- SCREEN Models
  - SCREEN3, AERSCREEN, CALPUFF Screen
  - Models that give worst-case first-cut concentration.
- Refined Models
  - ISC / AERMOD (<50 km)
  - CALPUFF (>50 km and complex winds)
- Special Case Models
  - CMAQ – Community Mulitscale Air Quality (ozone)
  - CAMx – Comprehensive Air quality Model with extensions (ozone)
  - CTDM – Complex Terrain Dispersion Model
  - RPM – Reactive Plume Model
  - SDM – shoreline fumigation
  - DEGADIS – dense gas model

Trinity Consultants

ISC / AERMOD vs CALPUFF Models (Steady State Plume vs Puff)



Trinity Consultants

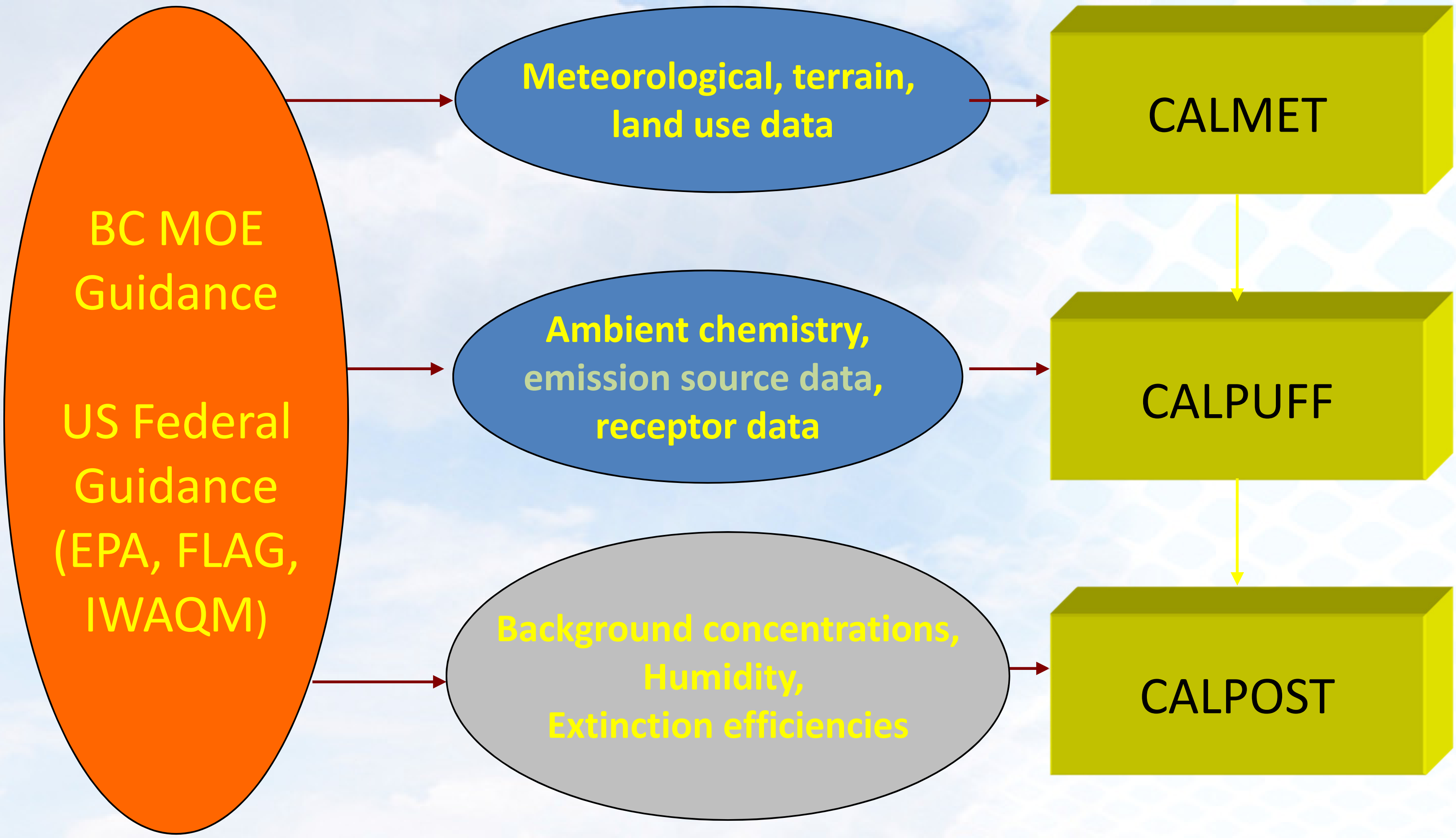
CALPUFF used for Kitimat Emissions Effect Assessment

Because:

> Complex Terrain
> Stagnation Conditions
> Long-range transport
> Deposition
> Buoyant Line Source (KMP aluminum smelter potlines)

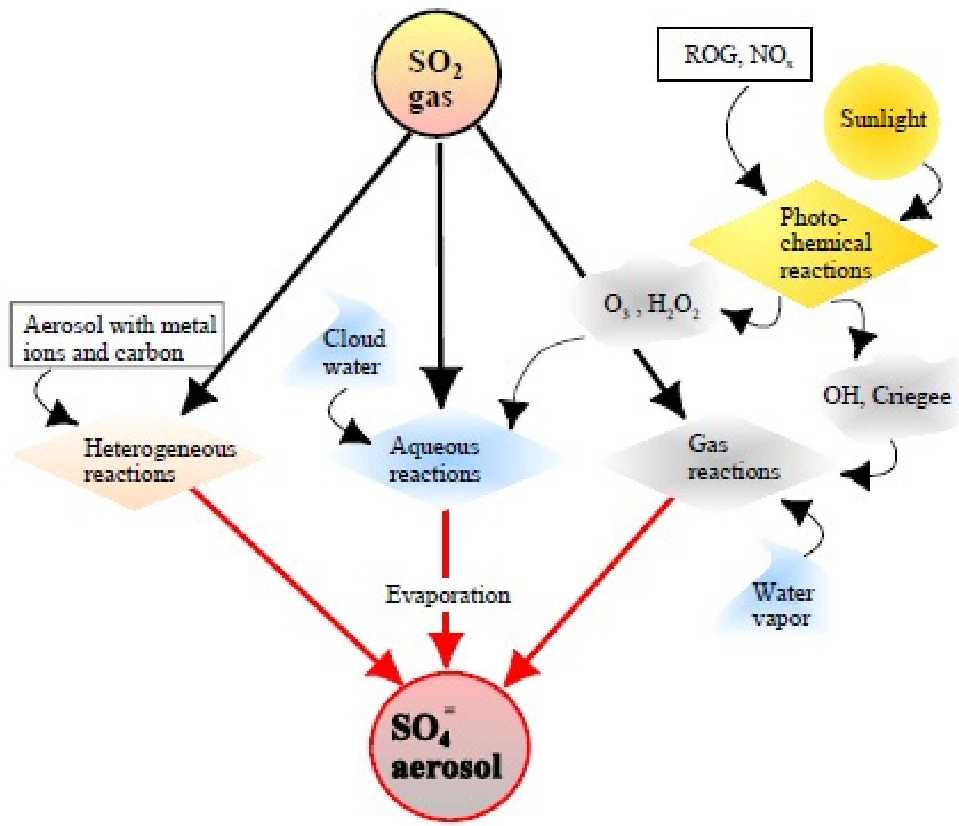
Trinity Consultants

CALPUFF Modelling System



Only one meteorological year (2008) was simulated (highest S deposition)

CALPUFF Chemical Transformation and Deposition Mechanisms



Trinity Consultants

Chemical Transformation: MESOPUFF II Scheme

> Simulates the conversion of
  - $SO_2 \rightarrow SO_4$
  - $NO_X \rightarrow HNO_3 : NO_3$
> Conversion of both is dependant on
  - Relative Humidity,
  - Background ozone, and
  - Background ammonia
> Does not include aqueous phase transformation
> Does not treat NO and NO_2 separately (assumes immediate conversion to NO_2)

Trinity Consultants

Ozone and NH_3 Data

- Background concentrations affect chemical transformation of primary into secondary pollutants

$$SO_2(g) \xrightarrow[\text{photochemical oxidants}]{\text{cloud droplets}} SO_4(s)$$

$$NO(g) + NO_2(g) \xrightarrow[\text{photochemical oxidants}]{} HNO_3 \underset{NH_3}{\Leftrightarrow} NO_3(s)$$

Data options

- Constant background based on land use type
- Monitored background (rural only?)
- Photochemical model output

Data used:

- 80 ppb constant ozone (default)
- 0.5 ppb constant ammonia (forest landuse)

Trinity Consultants

Deposition Mechanisms

Dry Deposition

- Resistance deposition model. For gases (SO_2) applies:
  - Pollutant diffusivity (cm/s)
  - Aqueous phase dissociation constant, α
  - Pollutant reactivity
  - Mesophyll resistance, r_m (s/cm)
  - Henry's Law coefficient, H (dimensionless)

  For particles (SO_4), applies:
  - Diameter mean and Standard Deviation

Wet Deposition

- Scavenging Coefficients

  Liquid:
  - 3.0E-5 for SO_2
  - 10.0E-5 for SO_4

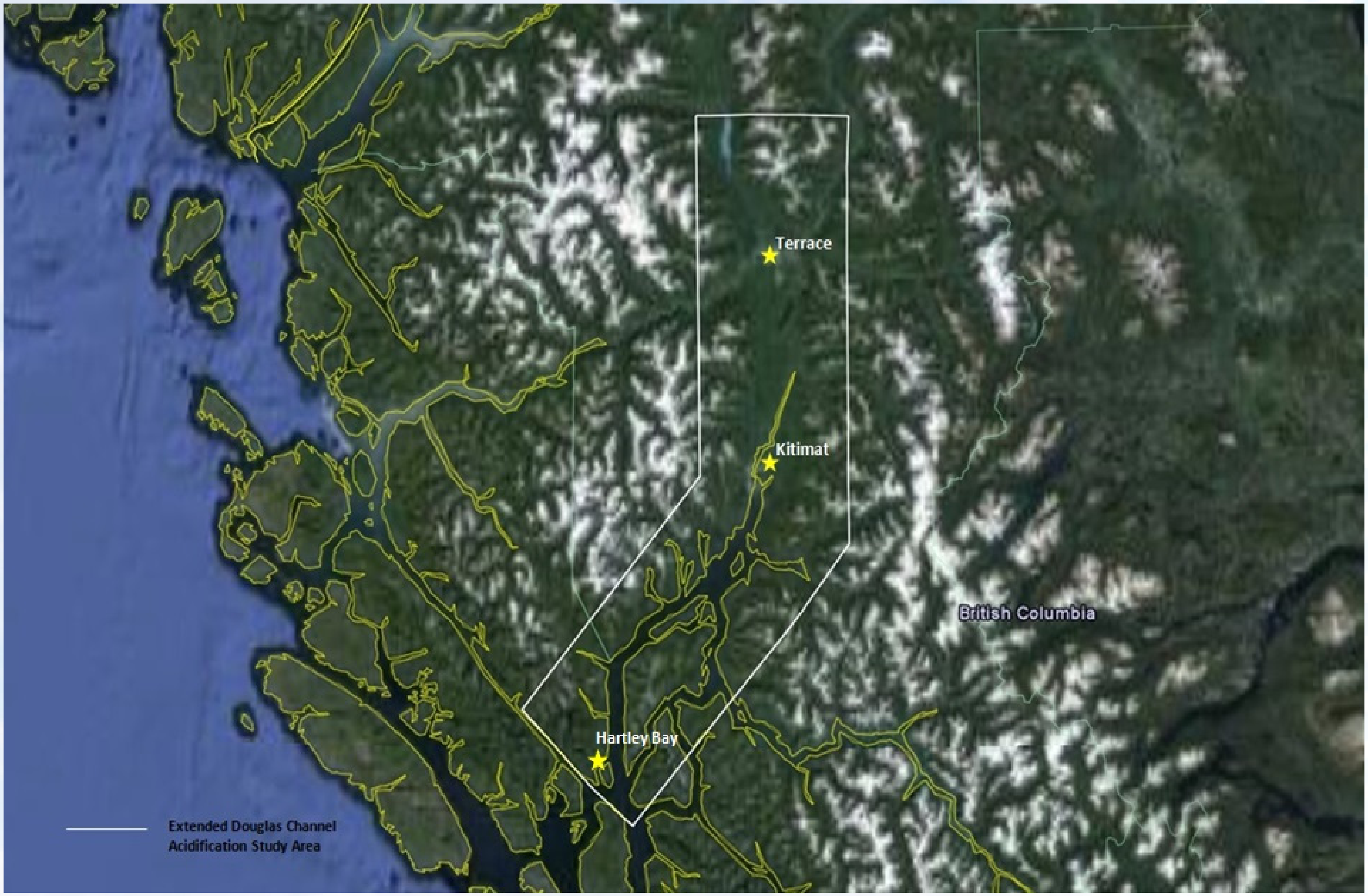
  Frozen:
  - 0.0 for SO_2
  - 3.0E-5 for SO_4

Trinity Consultants

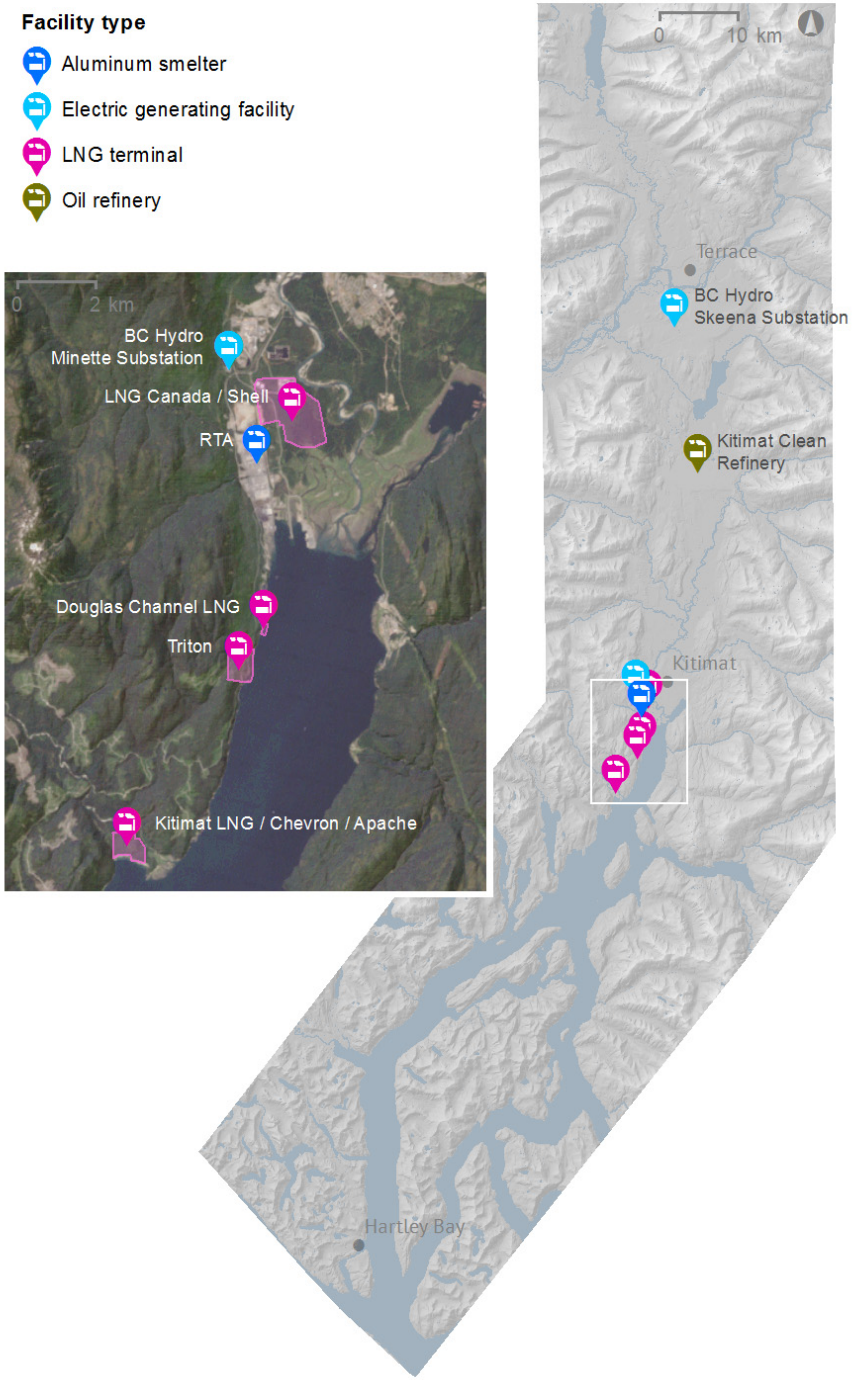
Kitimat Airshed Effects Assessment Example

Trinity Consultants

Study Area


Terrace
Kitimat
Hartley Bay
British Columbia
Extended Douglas Channel
Acidification Study Area

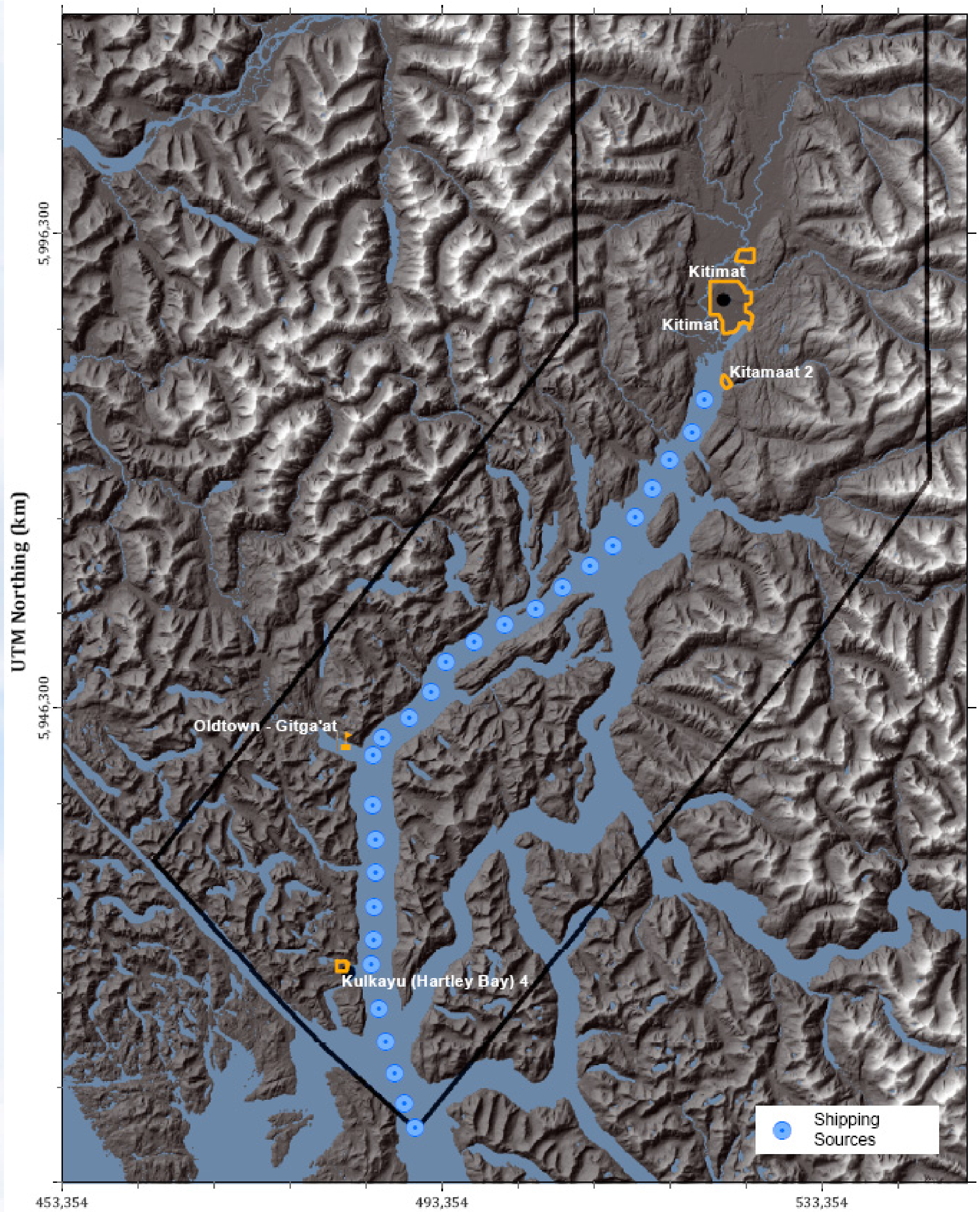
Stationary Emission Sources Assessed



ESSA 35 YEARS

Trinity Consultants

Marine Transport Model Sources



UTM Easting (km)
All Coordinates shown in UTM Coordinates, Zone 9N, NAD 27 Datum

Trinity Consultants

Risk Framework

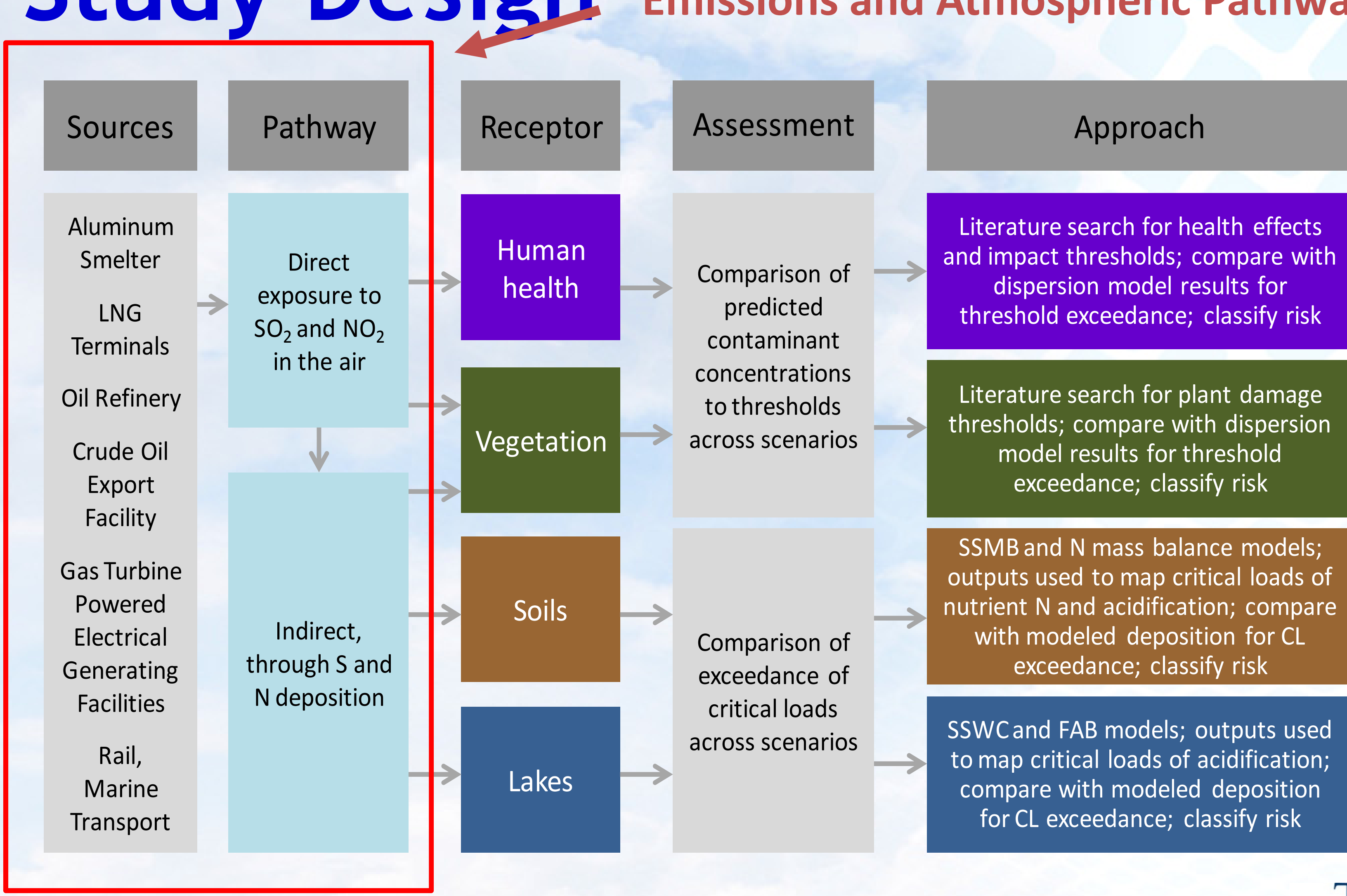
Low	• No, or negligible, impact
Moderate	• Impact expected, but of a magnitude, frequency, or spatial extent, or in locations, considered to be acceptable*
High	• Impact of a magnitude, frequency or spatial extent, or in locations, considered to be not acceptable*; • further investigation needed of assessment assumptions to determine if reducing uncertainties / refining inputs lowers impact category
Critical	• Impact of a magnitude, frequency or spatial extent, or in locations, considered to be extremely unacceptable*; • further investigation could be made into assumptions (as above) but unlikely to reduce impact sufficiently to be considered acceptable.

*** "acceptability", based on QP's best professional judgement and on conventions followed elsewhere.** Acceptability depends on values, and is ultimately a policy decision *informed* by this assessment.

Trinity Consultants

Study Design

Emissions and Atmospheric Pathways

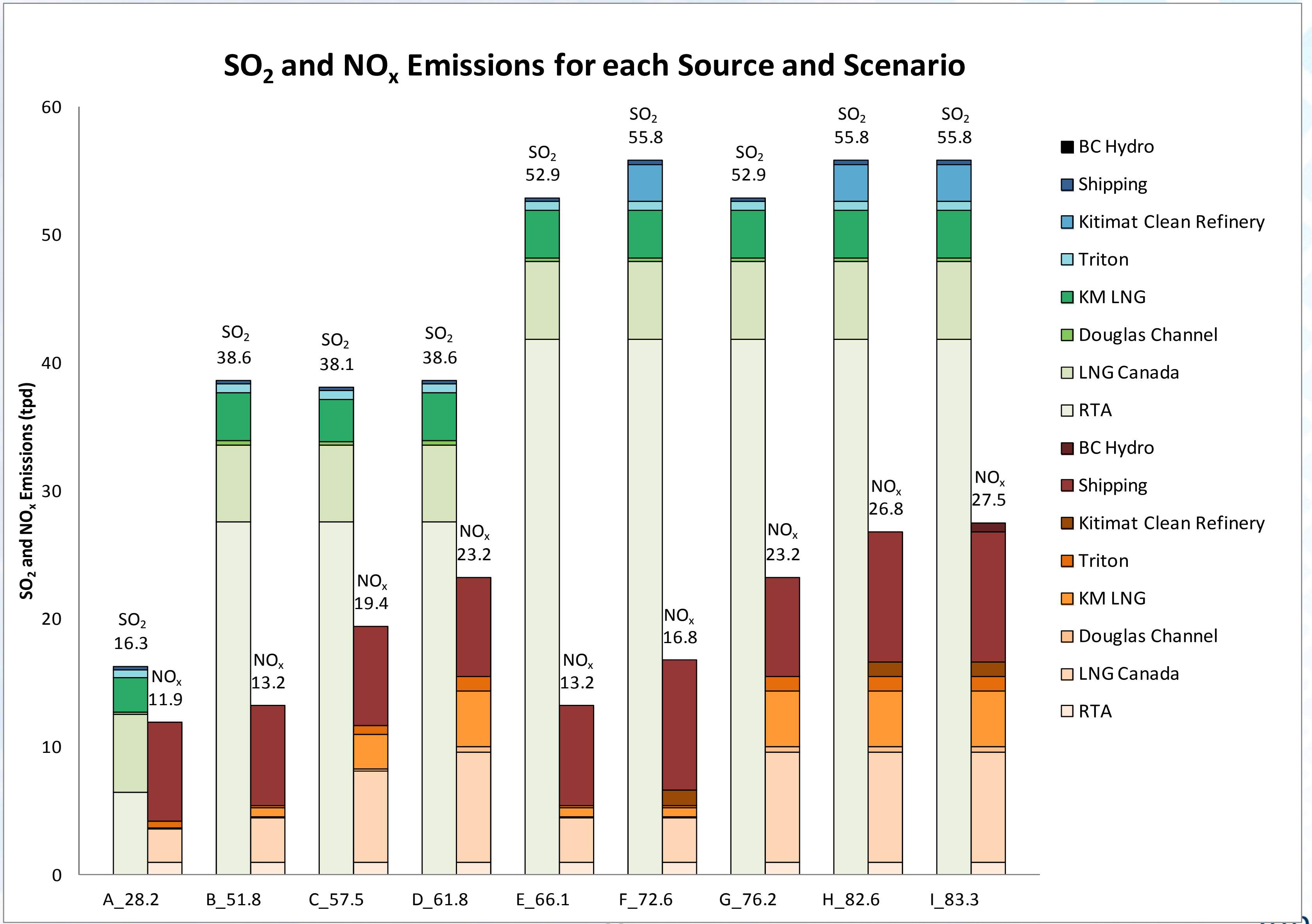


Scenarios

Scenario	Smelter	SO_2 t/d	NO_x t/d	LNG	SO_2 t/d	NO_x t/d	Refinery	SO_2 t/d	NO_x t/d	Shipping	SO_2 t/d	NO_x t/d	Total SO_2 t/d	Total NO_x t/d
A_28.2	Full Treatment	6.5	1.0	All Electric Drive	9.6	3.2	Off	-	-	Smelter +LNG	0.2	7.8	16.3	11.9
B_51.8	Partial Treatment	27.5	1.0	Base Case- NO_x treatment	10.8	4.4	Off	-	-	Smelter +LNG	0.2	7.8	38.6	13.2
C_57.5	Partial Treatment	27.5	1.0	Mixed 60/40	10.3	10.7	Off	-	-	Smelter +LNG	0.2	7.8	38.1	19.4
D_61.8	Partial Treatment	27.5	1.0	Base Case	10.8	14.5	Off	-	-	Smelter +LNG	0.2	7.8	38.6	23.2
E_66.1	Base Case	41.8	1.0	Base Case- NO_x treatment	10.8	4.4	Off	-	-	Smelter +LNG	0.2	7.8	52.9	13.2
F_72.6	Base Case	41.8	1.0	Base Case- NO_x treatment	10.8	4.4	On	2.9	1.1	Smelter +LNG + Refinery	0.3	10.2	55.8	16.8
G_76.2	Base Case	41.8	1.0	Base Case	10.8	14.5	Off	-	-	Smelter +LNG	0.2	7.8	52.9	23.2
H_82.6	Base Case	41.8	1.0	Base Case	10.8	14.5	On	2.9	1.1	Smelter +LNG + Refinery	0.3	10.2	55.8	26.8

BC Hydro Scenarios

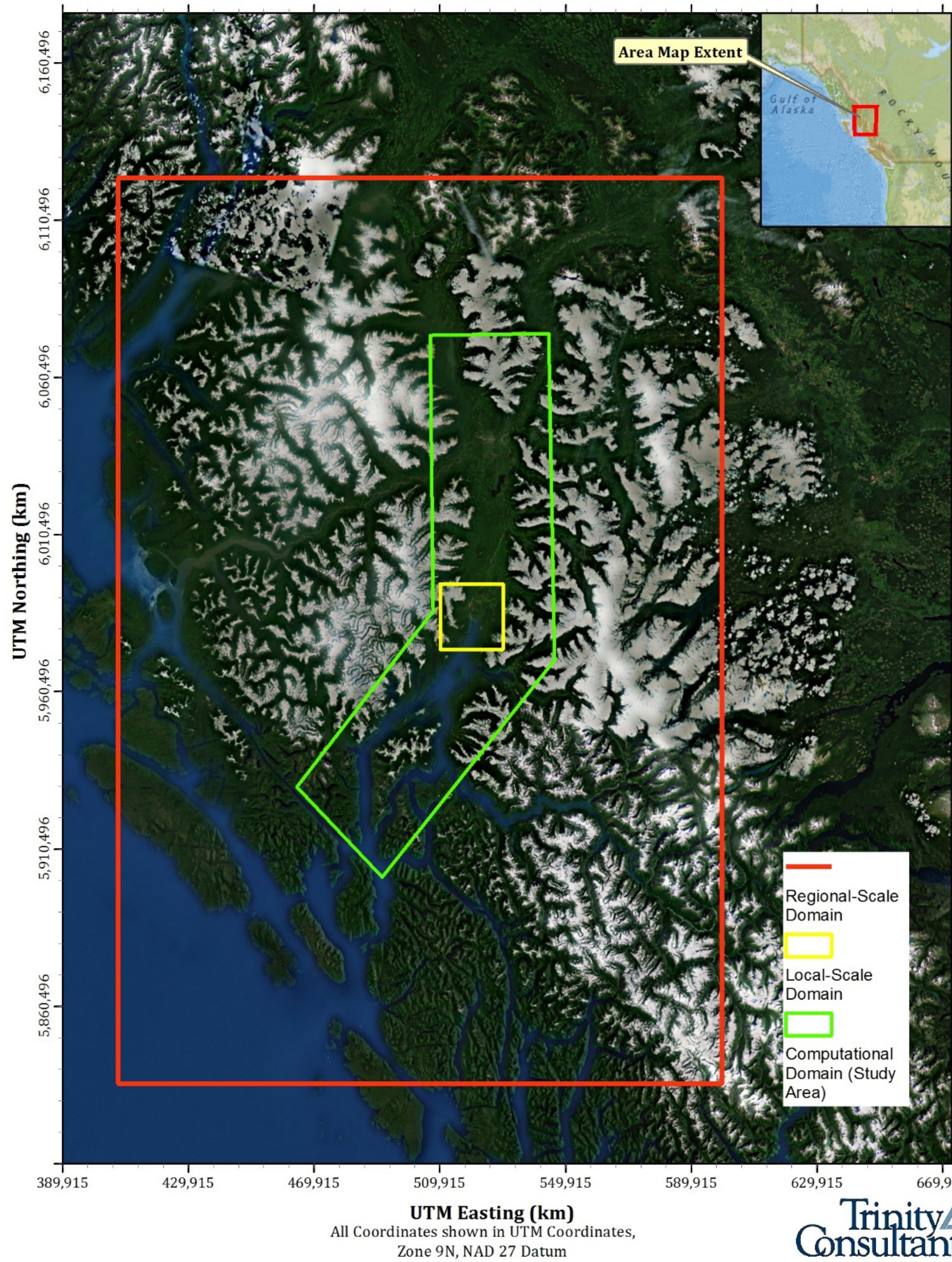
Scenario	Smelter, LNG, Refinery and Shipping	SO_2	NO_X	BC Hydro	SO_2	NO_X	Total SO_2	Total NO_X
		t/d	t/d		t/d	t/d	t/d	t/d
Is_83.3	As for Scenario H_82.6	55.8	26.8	Skeena	3.84E-06	0.69	55.81	27.49
Im_83.3	As for Scenario H_82.6	55.8	26.8	Minette	3.84E-06	0.69	55.81	27.49



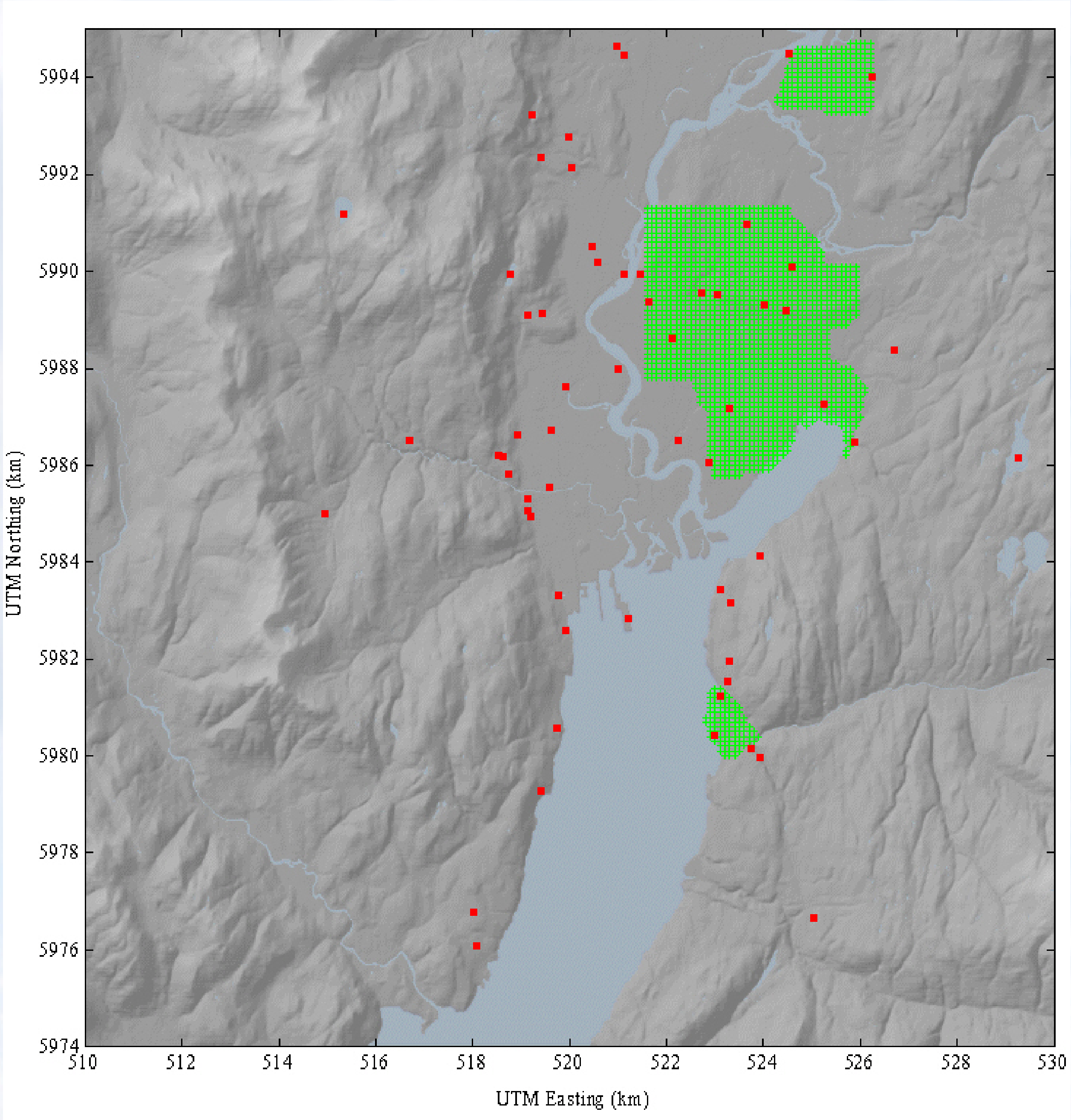
ESSA 35 YEARS

Trinity Consultants

Meteorological and Computational Modeling Domains



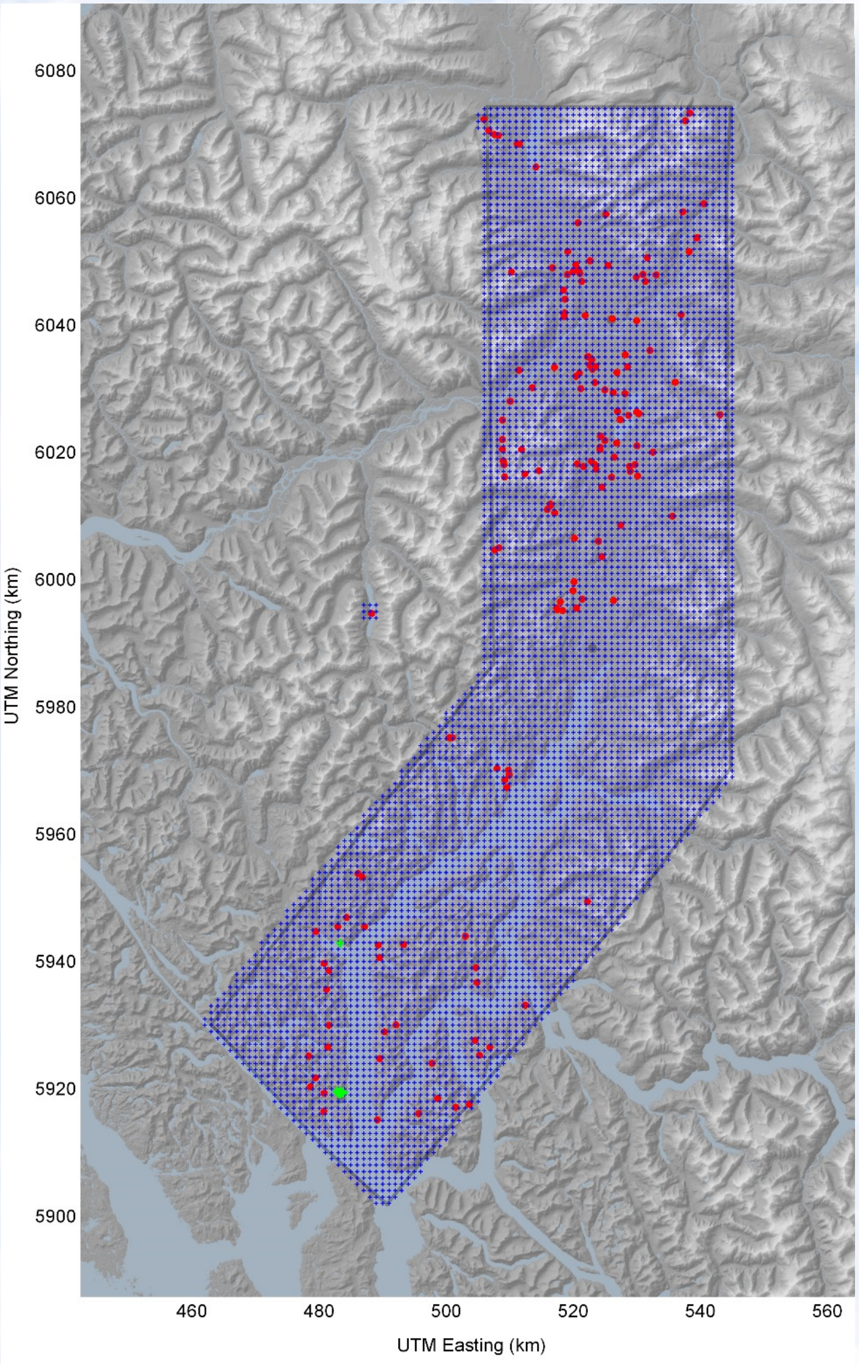
Trinity Consultants



Residential and Individual Receptors in Near Grid

Red = All individual receptors (soils, lakes, and points of interest)

Green =residential receptors



Receptors within Study Area

Red = All individual receptors (soils, lakes, and points of interest)

Green =residential receptors

Blue = grid receptors

Emission Source Data Basis & Uncertainty

- Smelter (RTA): Directly from proponent, final design
- Kitimat LNG: Directly from proponent, preliminary/intermediate design phase
- LNG Canada: Directly from proponent with exception of layout (based on Kitimat LNG), preliminary/intermediate design phase
- Douglas Channel: Directly from proponent, preliminary design phase
- Triton: Estimated based on Douglas Channel and Kitimat LNG
  Refinery: Directly from proponent, preliminary design phase
- Shipping: Calculated by Trinity based on emission factors provided by BCMOE and U.S. EPA calculation procedures
- BC Hydro: Emission rates provided directly by BC Hydro, stack parameters estimated based on similar facility

Uncertainty Legend

Dark green = very low	Light orange = low/moderate	Red = high
Light green = low	Dark orange = moderate	

Trinity Consultants

Key Emission Source Data Assumptions

- Model assumes 24-7 operation at full capacity
- No buildings included for all sources other than RTA
- Sulphur content of feed gas can greatly affect SO_2 emission rates
- Stack parameters based on preliminary estimates for all preliminary/intermediate design

Trinity Consultants

Model Results Processing

NO_2/NO_x Ratio

- Modelled NO_x concentrations scaled based on US EPA guidance:
  - Assume 80% of NO_x is NO_2, for short term averaging periods (1 hour)
  - Assume 75% of NO_x is NO_2, for long term averaging periods (annual)

Trinity Consultants

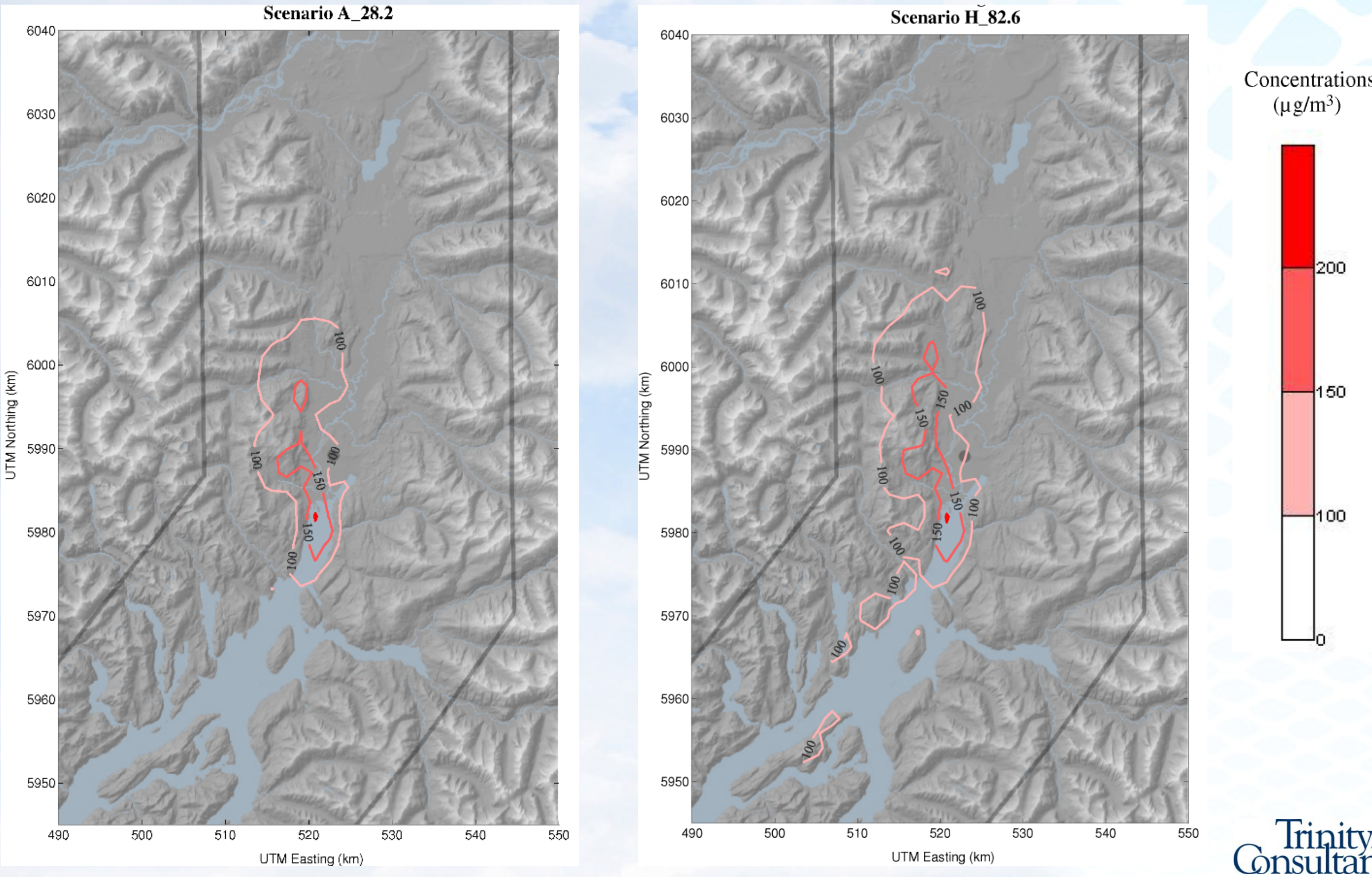
Model Results
Scenario A to H, NO_x Comparison

- Rio Tinto Alcan Full Treatment (1.0 tpd)
- Liquefied Natural Gas Facilities All Electric (3.2 tpd)
- No Refinery (0 tpd)
- Shipping (7.8 tpd)

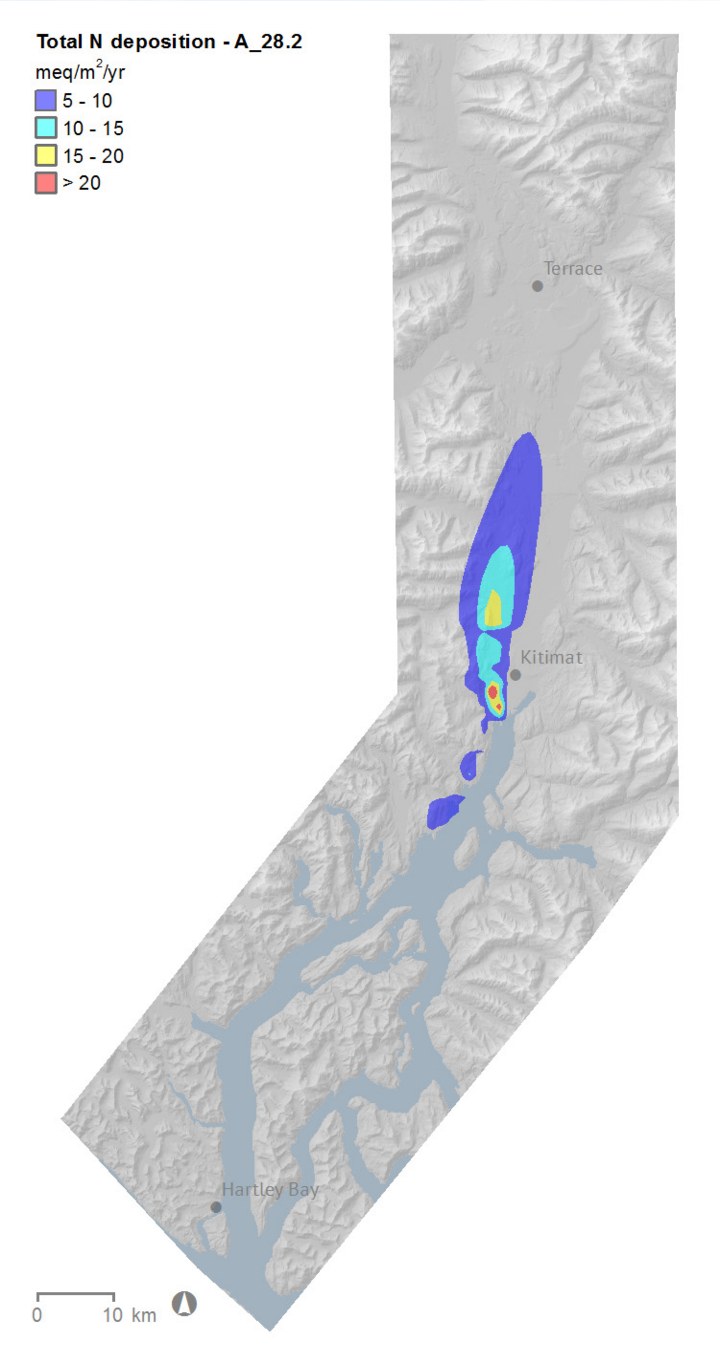
- Rio Tinto Alcan Base Case (1.0 tpd)
- Liquefied Natural Gas Facilities Base Case (14.5 tpd)
- Refinery Included (1.1 tpd)
- Shipping (10.2 tpd)

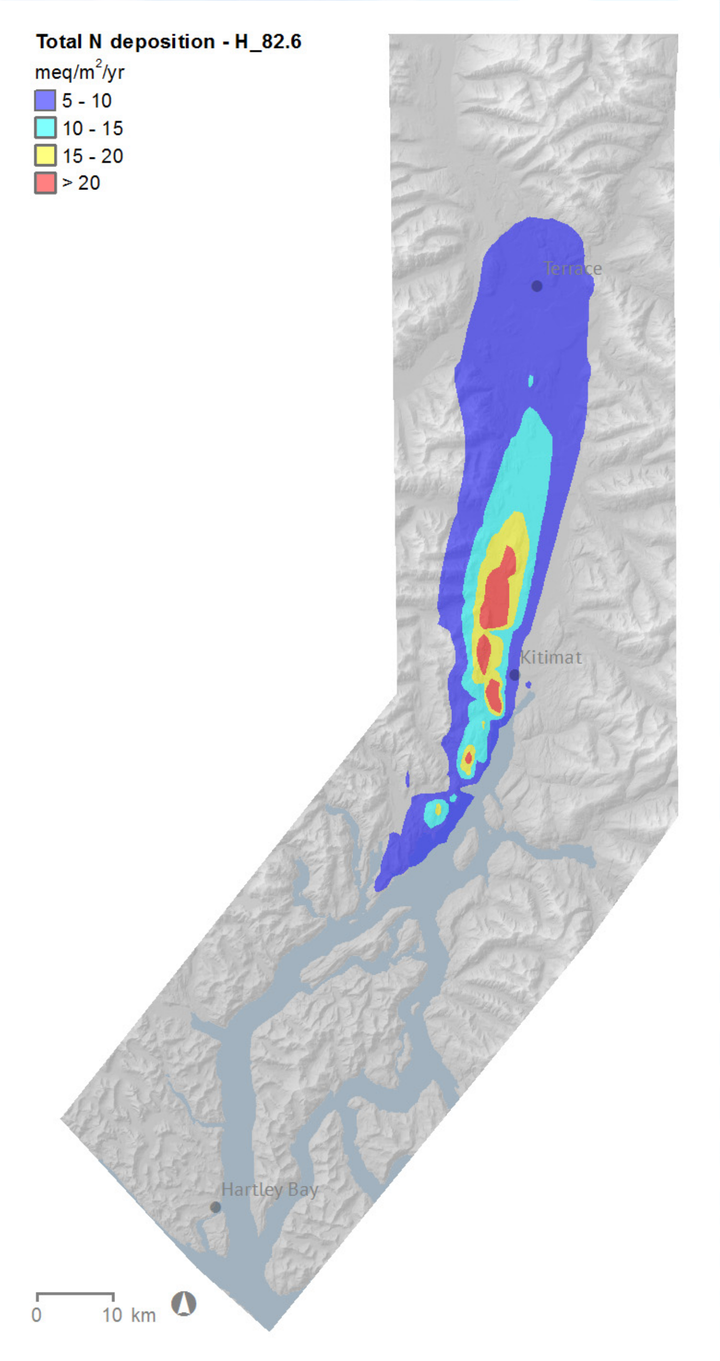
Trinity Consultants

98^{th} Percentile 1 hour NO_2 Concentration Scenario A_28.2 vs Scenario H_82.6



Trinity Consultants





Trinity Consultants

Scenario A to H, SO_2 Comparison

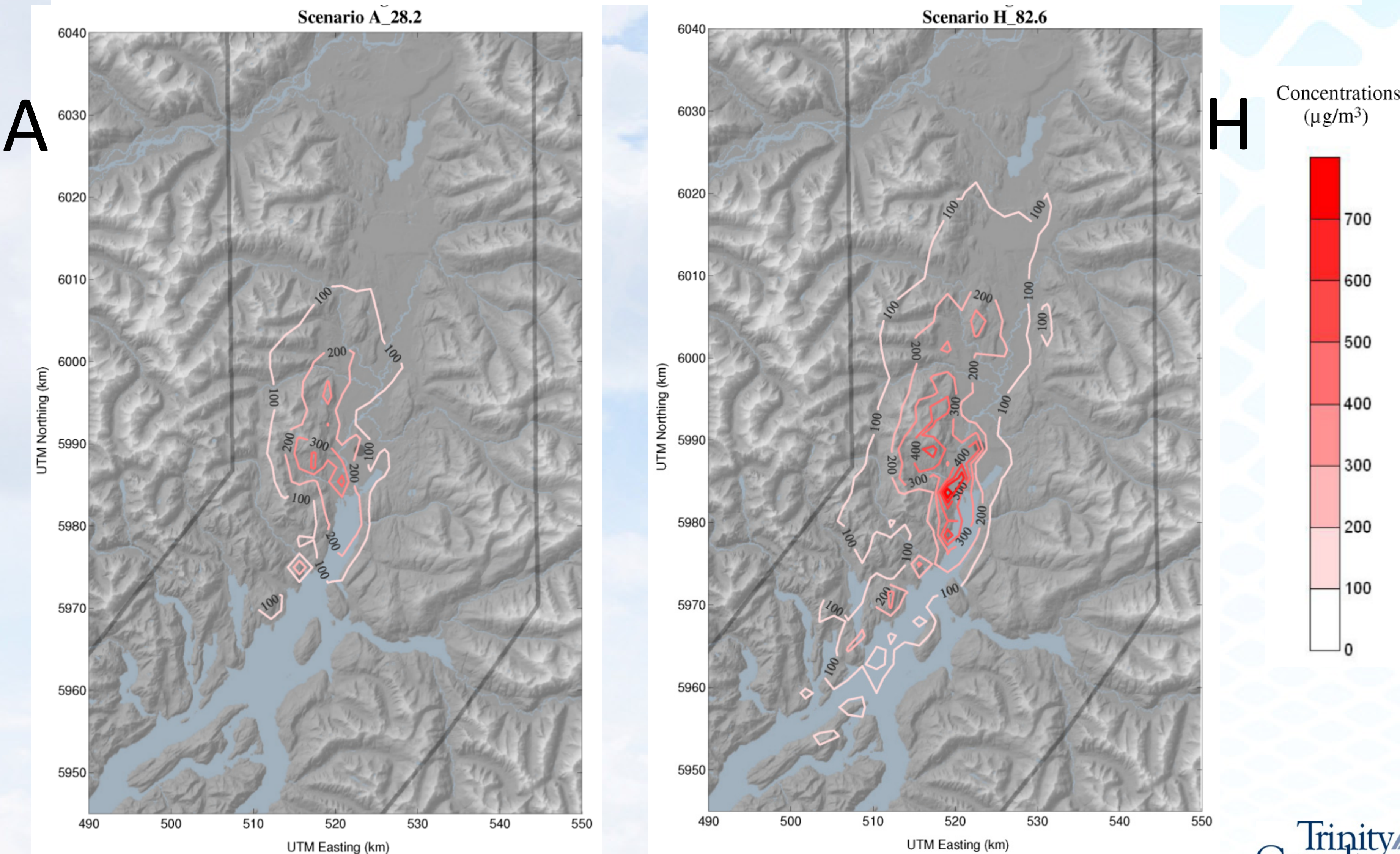
- Rio Tinto Alcan Full Treatment (6.5 tpd)
- Liquefied Natural Gas Facilities All Electric (9.6 tpd)
- No Refinery (0 tpd)
- Shipping (0.2 tpd)

- Rio Tinto Alcan Base Case (41.8 tpd)
- Liquefied Natural Gas Facilities Base Case (10.8 tpd)
- Refinery Included (2.9 tpd)
- Shipping (0.3 tpd)

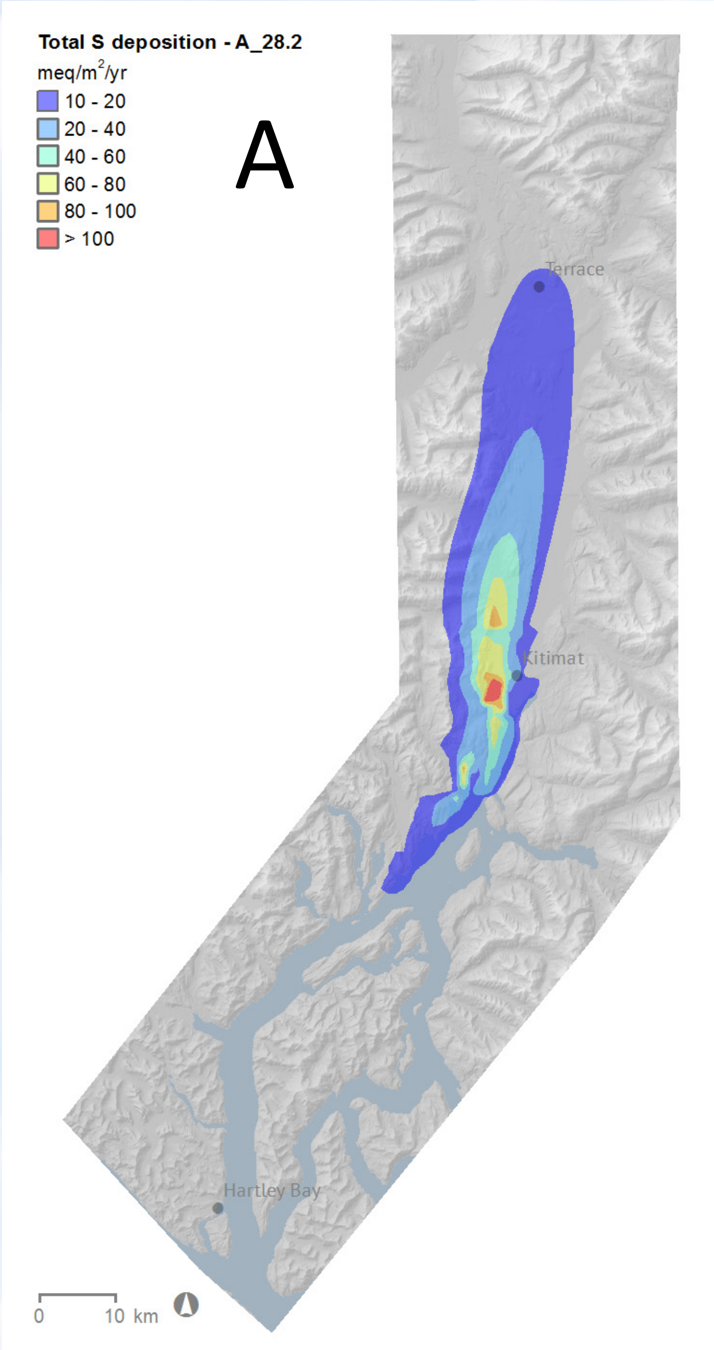
Scenario SO2 concentrations: [A] < [B ≅ C ≅ D] < [E ≅ F ≅ G ≅ H ≅ I]

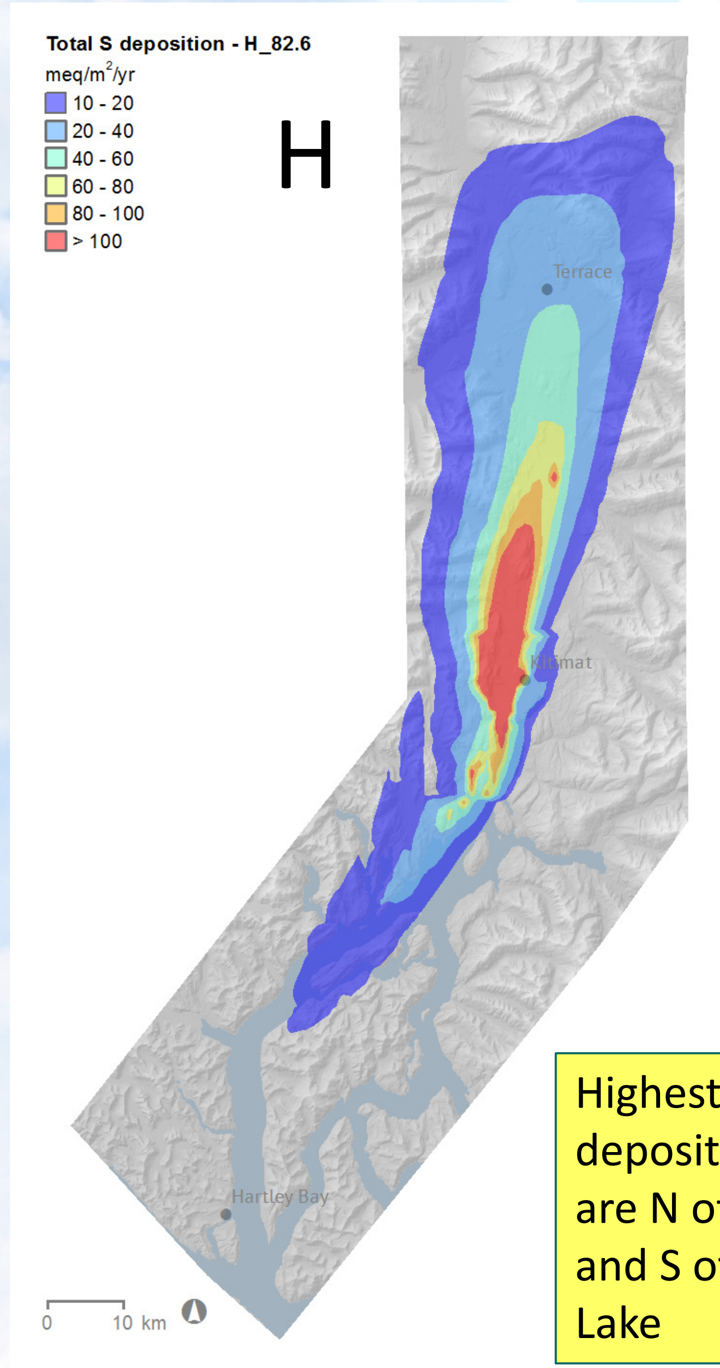
Trinity Consultants

99th Percentile 1 hour SO_2 Concentration Scenario A_28.2 vs Scenario H_82.6



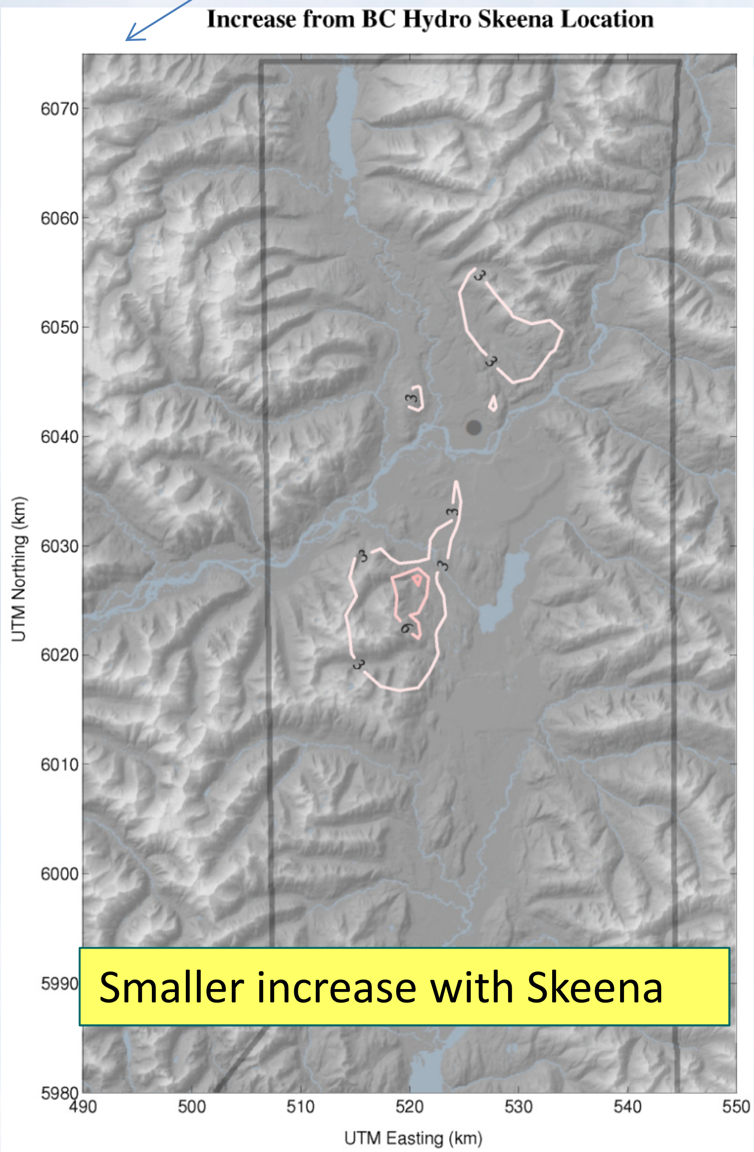
Trinity Consultants

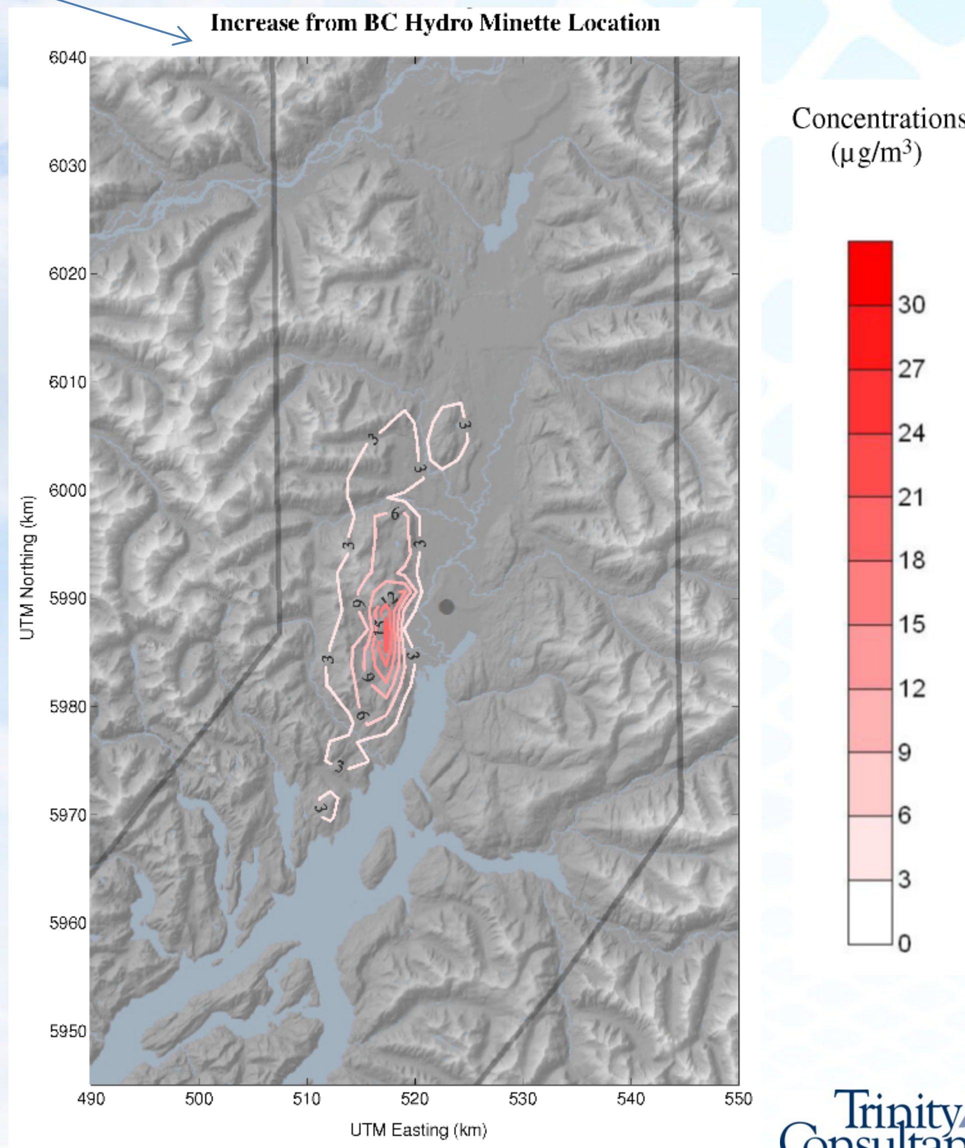




Highest deposition levels are N of Kitimat and S of Lakelse Lake

BC Hydro Siting Exercise with SCR
Skeena vs Minette [Increase in NO2]





Trinity Consultants

Translating lessons learned to permit modelling

Trinity Consultants

Model Results

- Overall changes to emissions ≠ linear changes to modelled concentrations/deposition rates
  - Particularly true for 1-hour
- Need to look at **contribution**
  - Focus on highest contributing sources
- Also review assumptions
  - NO to NO_2 conversion
  - Sulphur content in fuel or feed

Trinity Consultants

Overcoming Challenges for 1-hr SO_2 & NO_2

- Evaluate costs of modeling improvements
  - For example, new stack/ht change, necking stack, emissions controls, multiple scenario modeling, fenceline, property purchase
- For NO_2, implement NO to NO_2 Conversion
  - Nov. 2015 update to BC AQ Modelling Guideline included specific techniques:
    - **100% conversion.** If there are exceedances, use one of three methods described next.
    - If there are adequate (at least one year) hourly NO and NO2 monitoring data, use the **ambient ratio method.**
    - If adequate monitoring data are not available, use the **ozone limited method.**
    - If AERMOD is used, apply the **plume volume molar ratio method.**

Trinity Consultants

Overcoming Challenges for 1-hr SO_2 & NO_2

- Focus on review on handful of exceeding receptors
- Build relationship with agency meteorologist modeller
  - Helpful in getting the benefit of the doubt regarding the many gray areas in modeling
  - Can provide helpful suggestions
- Investigate pairing modeled concentrations & background in time
- Consider operational and scheduling limitations
  - Highest 1-hour concentration often occur at night

Trinity Consultants

Questions

Anna Henolson
ahenolson@trinityconsultants.com
253-867-5600

Trinity Consultants